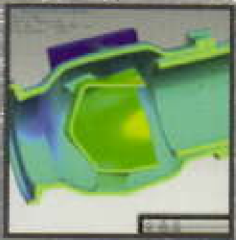

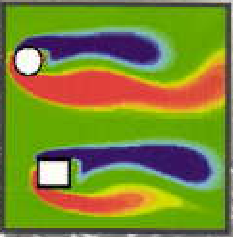

वार्षिक प्रतिवेदन
Annual Report
2010 - 11

सी. एस. आई. आर - केन्द्रीय यान्त्रिक अभियान्त्रिकी अनुसंधान संस्थान, दुर्गापुर
CSIR - Central Mechanical Engineering Research Institute

1. Axial sectional view of deformed valve body
2. CAD Model of Precision Planter Prototype
3. Inside view of 40kW RFQ
4. IPMC strip showing deformation under time-varied voltage
5. A Soleckshaw variant
6. CSIR Centre for Post Harvest Processing and Research, Aizwal
7. Vorticity plot for flow over bluff obstacles
8. Outdoor Mobile Robot

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CSIR - Central Mechanical Engineering Research Institute, Durgapur

About CSIR-CMERI

As a constituent member under the Council of Scientific & Industrial research, the ambit of the CSIR – Central Mechanical Engineering Research Institute, Durgapur – a premier establishment of national standing dedicated to research and development – extends over mechanical engineering and allied and advanced disciplines of science and technology.

The Institute employs over 500 scientific and technical staff with a rich blend of expertise and experience in different disciplines of engineering and science.

Besides conducting frontline research in varied areas, the Institute dedicates its R&D efforts towards different mission mode programmes to disseminate appropriate technological solutions for poverty alleviation, societal improvement, energy security, food security, defence, etc.

CSIR-CMERI has developed as many as 150 products and processes of which 26 have been awarded prestigious national awards. More than 120 licensees have obtained know-how for various products and processes developed for commercial exploitation.

CSIR-CMERI has a dedicated team of highly qualified professionals and support staff well balanced in terms of youth and experience. The manpower available at CSIR-CMERI is comparable to the very best available in India.

CSIR-CMERI is making steady inroads into such areas as Robotics, Mechatronics, Micro Systems Technology, Cybernetics, Manufacturing, Precision Farming, etc. and is assuming leadership in many of these emerging front-end interdisciplinary domains.

Thrust Area

- Underwater Robotics, Surface Robotics & Mechatronics
- Micro Systems Technology, Surface Engineering & Tribology
- Materials, Processes, Chemistry & Synthetic Biology
- Advanced Design, Manufacturing, Foundry
- Design Dynamics, Simulation and Analysis, Immersive Visualization
- Thermal Engineering
- Cybernetics, Electronics & Embedded Systems, Drives & Control
- Precision & Conservation Farm Machinery

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From the Director's Desk

The Institute has witnessed significant growth in its Research and Development activities in diverse fields of Science and Technology during the year 2010-11. The scientists of the institute are engaged in executing a large number of Network, Supra, CSIR-800, Laboratory (CSIR in house) and sponsored (GAP) projects.

CSIR-CMERI has grown even further in Robotics research. The robotics research includes abstraction, integration, and fusion of fundamental functions of robots. It demands autonomously distributed systems for higher intelligence, human-machine interfaces for the symbiosis of humans and robots.

On July 17, 2011, deep into the heart of the Bay of Bengal, buffeted by a choppy sea amidst inclement weather, the AUV-150 – an Autonomous Underwater Vehicle designed and developed by CSIR-CMERI, Durgapur with inputs from the IIT, Kharagpur – literally plumbed a sea depth of 150 m within its estimated mission time. This event marked the end of a protracted effort for obtaining self-sufficiency in the design development underwater robotic systems, for which the country had to depend solely on foreign sources. Courtesy CSIR-CMERI, Durgapur, India now has the wherewithal of manufacturing its own functional Automated Underwater Vehicles. The project is sponsored by Ministry of Earth Sciences, Govt. of India.

A crawl-type Stair Climbing Robot has been developed by the Surface Robotics group. This has shown a clear advantage over the conventional Stair Climbing Robots in which rotary motion of the disk is converted to linear motion by following on a drive guide. The other significant developments are Vision Guided Robots, Flying Robots and Serpentine Robots.

In addition, simulators that are needed for the development of humanoid robots, in terms of dynamics, geometry, actuators, sensors, and controllers are being developed. Various image processing algorithms have been fine tuned. The majority of relevant researches have been conducted in the field of robotics under the broad sub-area of robot path planning. Automatic motion planning is an important problem, not only in autonomous robotics but also in design, CIM, and Artificial Intelligence. Hybrid (position-based and image-based) control system development for visual servo control of robotic manipulators is notable among the vibrant research activities.

The Cybernetics group has been involved in the Applications of Visual Servoing in Robotic surgery. Finding appropriate models which properly describe the physical properties of catheters and endoscope alongside developing the software necessary to obtain the feedback and also implementing the control algorithms are parts of the main objective in this initiative.

The downsizing production system, which we have newly proposed as "microfactory", can help not only in saving energy, spaces and resources but also in improving flexibility for model change and controllability of the atmosphere. Eventually, the microfactory can compose and complete a miniaturized production system. The key to the microfactory is downsizing machine tools and elements and increasing the accuracy of operations. The microfactory development by the Micro-system Technology group is nearing completion fast. This is a Network project steered by CSIR-CMERI with CSIR-CEERI and several other CSIR Laboratories as the partners.

The five axes micro-milling machine developed by the Tribology and Surface Engineering group is capable of creating micro and nano scale fabrications with high level of accuracy. This indigenously developed machine has improved the potential of the microfactory and initiated the development of micro bearings and high precision lubrication technology.

The Materials Science group has been involved in development of dye sensitized solar thin films,advanced structural ceramic composites, multi-ferroics & spintronics, optoelectronics, thermoelectric junction and porous-biomaterials for tissue engineering. The researchers are looking at how disorder and complexity within the unit cell as well as nanostructured materials can lead to enhanced efficiency.

The excellent achievement of the Chemistry and Biomimetics group is centered on Copolymerization followed by metallation leading to development of micro-devices. In another approach, the heteroaromatic triazoles at which metal-ligand coordination is augmented by ester functionalities are engineered to afford metal-incorporated hybrid polymers. Such modified structures have controlled properties and are applicable to functional microdevices.

CSIR-CMERI is engaged in several projects aimed at improving efficiency of energy conversion, energy conservation and developing advanced thermal engineering technology. The activities in the area of solar adsorption refrigeration need special mention.

The Design and Stress Analysis groups are involved in the development of valves and control systems involving valve network for the Saras Aircraft, analyzing landing gears.

The Advanced Design and Optimization group contributed significantly in the development of low horsepower tractors for special usage.

A major project has been initiated in the area of Rheo-pressure die casting. The activities pertaining to Austempered Ductile Iron (ADI) are in the full swing. Several industry partners, including Mcnally Bharat are working in tandem in a number of Foundry related problems.

The partnership with the Variable Energy Cyclotron Centre (VECC) has completed yet another year of successful collaboration in the area of RFQ LINAC. The activities related to development of improved beam bunchers were the focus of last year.

The research focus of Drives and Control embraces development of intelligent power electronic interfaces for designated drives, experimentation with application of different control methodologies including non-linear sliding mode speed control, experimentation with different prime movers with special emphasis on development of BLDC motors, linear motors, reluctance motors, stepper and servo controllers, etc.

The extension centre at Ludhiana has been engaged in the activities related to the Centre of Excellence in Precision Farm Machinery. Development of precision seed planters, novel rotavators and inter-row cultivators have been the major focus.

The Centre Research Facility (CRF) has been formed to facilitate the research activities at CSIR-CMERI. Scanning Electron Microscope with energy dispersive Specography (SEM-EDS) and high temperature (upto 1000°C) rheometer have been inducted at CRF.

CSIR-CMERI has no other option than to establish itself as a technology source or as a national R&D platform in applied science and engineering. The scientists have to perpetually strive for a combination of three elements – namely basic knowledge, innovative applications, and accuracy of results. They have to be emotionally involved and see beyond what is visible.

Gautam Biswas

निदेशक की कलम से

वर्ष 2010-11 के दौरान संस्थान, विज्ञान एवं प्रौद्योगिकी के विविध क्षेत्रों में अपने अनुसंधान एवं विकास की गतिविधियों में हुई महत्वपूर्ण वृद्धि का साक्षी रहा है। संस्थान के वैज्ञानिक एक बड़ी संख्या में नेटवर्क, सुप्रा (Supra), सी. एस. आई. आर. 800, प्रयोगशाला (सी. एस. आई. आर. के अंदर) और प्रायोजित परियोजनाओं को कियान्वित करने में लगे हुए हैं।

सी. एस. आई. आर. – सी. एम. ई. आर. आई. रोबोटिक्स अनुसंधान में पहले से भी अधिक परिपक्व हुआ है। रोबोटिक्स अनुसंधान में रोबोट के मौलिक कार्यों का संलयन, अमूर्तिकरण और एकीकरण शामिल हैं। यह मानव और रोबोट के सहजीवन के लिए मानव मशीन इंटरफेस, उच्च बुद्धिमत्ता के लिए स्वायत्त वितरण प्रणाली (Autonomously Distributed Systems) की मांग करता है।

AUV-150 - एक ऑटोनोमस अंडर वाटर वैहकिल (Autonomous Underwater Vehicle), आई. आई. टी. खड़गपुर के सहयोग से सी. एस. आई. आर. – सी. एम. ई. आर. आई., दुर्गापुर द्वारा डिजायन और विकसित, ने 17 जुलाई, 2011 को बंगाल की खाड़ी के मध्य में प्रतिकूल मौसम में लहरों से लड़ते हुए तरंगित समुद्र के बीच में 150 मीटर सागर की गहराई नापने का कार्य अपने अनुमानित मिशन समय के भीतर पूरा किया। इस घटना को डिजायन एवं विकास में आत्मनिर्भरता प्राप्त करने के लिए विलम्बित प्रयास के अंत के रूप में चिन्हित किया गया जिसके लिए देश पूरी तरह से विदेशी स्त्रोतों पर निर्भर था। सी. एस. आई. आर. – सी. एम. ई. आर. आई., दुर्गापुर के सौजन्य से, भारत अब अपने स्वयं के कार्यात्मक ऑटोनोमस अंडरवाटर वैहकिल के निर्माण के लिए सक्षम है। यह परियोजना पृथ्वी विज्ञान मंत्रालय, भारत सरकार द्वारा प्रायोजित की गयी है।

सरफेस (Surface) रोबोटिक्स विभाग के द्वारा एक धीरे-धीरे रेंगकर सीढ़ी चढ़ने वाले एक विशेष प्रकार के रोबोट को विकसित किया गया है। यह स्पष्ट तरीके से परम्परागत सीढ़ी चढ़ने वाले रोबोट पर लाभ प्रदर्शित करता है जिसमें एक ड्राईव गाइड का पालन करके, डिस्क की घूर्णन गति को रेखीय गति मे परिवर्तित किया जाता है। विजन गाइडेड रोबोट्स (Vision Guided Robots), फ्लाईंग रोबोट्स (Flying Robots) एवं सर्पन्टाइन रोबोटस (Serpentine Robots) अन्य महत्वपूर्ण विकास हैं।

इसके अतिरिक्त कंट्रोलर्स (Controllers), सेंसरस (Sensors), ऐक्ट्यूएटरस (Actuators), ज्यामिति और गतिशीलता (Dynamics) के संदर्भ में सिमुलेटरस (Simulators) जो ह्यूमनोइड (Humonid) रोबोट के विकास के लिए आवश्यक है, विकसित किए जा रहे हैं। विभिन्न इमेज प्रोसेसिंग ऐल्गरिदम (Image Processing Algorithm) को बहुत अच्छे से किया गया है। रोबोट पथ योजना (Robot Path Planning) के व्यापक उपक्षेत्र के अंतर्गत रोबोटिक्स के क्षेत्र में प्रासंगिक शोध बहुतायत में किए गए हैं। स्वाचालित मोशन प्लानिंग (Automatic Motion Planning) केवल स्वचालित रोबोटिक्स में ही नहीं अपितु डिजायन, CIM एवं आर्टिफिशियल इंटेलिजेंस (Artificial Intelligence) में भी एक महत्वपूर्ण समस्या है। हाईब्रिड कंट्रोल सिस्टम (Hybrid Control System) (स्थिति आधारित एवं चित्र आधारित) विजुवल सर्वो कंट्रोल (Visual Servo Control) के लिए हाईब्रिड कंट्रोल सिस्टम का विकास जीवंत अनुसंधान गतिविधियों के बीच उल्लेखनीय है।

साइबरनेटिक्स (Cybernetics) विभाग रोबोट सर्जरी में विजुअल सर्वोइंग (Visual Servoing) के अनुप्रयोगों में लगा हुआ है। एक उपयुक्त मॉडल को ढूंढ़ना जो ठीक प्रकार से इंडोस्कोप (Endoscope) एवं कैथेटर (Catheters) के भौतिक गुणों के वर्णन के साथ प्रतिकिया एवं कंट्रोल ऐल्गरिदम को लागू करने के लिए एक आवश्यक साफ्टवेयर का विकास करना इस प्रस्ताव के मुख्य उद्देश्यों का हिस्सा है।

लघु रूप में उत्पादन प्रणाली, जिसको हमने माइक्रोफैक्टरी (Microfactory) के रूप में प्रस्तावित किया है, न केवल उर्जा, स्थान एवं स्त्रोतों का बचाव करती है अपितु वातावरण के नियंत्रित करने एवं मॉडल परिवर्तन की लचक मे वृद्धि करने में सहायता प्रदान करती है। अंततः माइक्रोफैक्टरी (Microfactory) एक लघु रूप में उत्पादन प्रणाली की रचना को पूर्ण कर सकती है। माइक्रोफैक्टरी में मशीन टूल्स (Machine Tools) एवं तत्वों का आकार घटाना और कार्यों की शुद्धता को बढ़ाना ही मुख्य है। माइक्रो-सिस्टम (Micro-system) प्रौद्योगिकी समूह द्वारा माइक्रोफैक्टरी का विकास तेजी से पूरा होने वाला है। सी. एस. आई. आर. – सी. ई. ई. आर. आई. (CSIR-CEERI) और कई अन्य सी. एस. आई. आर. प्रयोगशालाओं के साथ भागीदार के रूप में सी. एस. आई. आर. – सी. एम. ई. आर. आई. द्वारा इस परियोजना को चलाया जा रहा है।

ट्राईबोलॉजी एवं सरफेस इंजीनियरिंग (Tribology & Surface Engineering) समूह के द्वारा विकसित पंच अक्षीय माइक्रो मिलिंग मशीन (Five Axis Milling Machine) उच्च स्तर की सटीकता के साथ माइक्रो एवं नैनो स्केल पर निर्माण करने में सक्षम है। देश में विकसित इस मशीन ने माइक्रोफैक्टरी की क्षमता में सुधार किया है और उच्च परिशुद्धता ल्यूब्रिकेशन (Lubrication) प्रौद्योगिकी एवं माइक्रो बीयरिंग (Bearing) के विकास को प्रारम्भ किया है।

सामग्री (Materials) विज्ञान समूह डाइ सेन्सिटाइज सोलर थिन फिल्म (Dye Sensitized Solar Thin Film), एडवांस स्ट्रक्चरल सेरामिक कम्पोजिट्स (Advanced Structural Ceramic Composites), मल्टी फेरोइक्स एवं स्पिनट्रोनिक्स (Multi-ferroics & Spintronics), ऑपटोइलेक्ट्रानिकक्स (Optoelectronics), थर्मोइलेक्ट्रिक जंक्शन (Thermoelectric Junction), टिश्यू इंजिनियरिंग (Tissue Engineerings) के लिए पोरसबॉयोमेटिरियलस (Porousbiomaterials) के विकास में संलग्न है। शोधकर्त्ता विचार कर रहे हैं किस प्रकार ईकाई कोशिकाओं के भीतर का विकार एवं जटिलता और नैनो स्ट्रक्चरड मेटिरियल (Nanostructured Materials) दक्षता बढ़ाने के लिए अग्रणी भूमिका निभा सकते हैं।

रसायन एवं बॉयोमिमिटिक्स (Biomimetics) समूह की उत्कृष्ट उपलब्धि माइक्रो-उपकरणों के विकास के लिए अग्रणी मेटेलेशन (Metallations) के बाद कोपोलाइमिनजिएशन (Copolyminzeation) पर केन्द्रित है। हेट्रो ऐरोमेटिक ट्राइजोल (Hetroaromatic Trizoles), जो इस्टर (Ester) क्रियाओं द्वारा मेटल लिगेंड (Metal Ligand) के समन्वय से संवर्धित है, को धातु शामिल कर हाइब्रिड पॉलिमर (Hybrid Polymer) को राह सकने के लिए तैयार किया जाता है।

सी. एस. आई. आर. – सी. एम. ई. आर. आई. उर्जा रूपांतरण, उर्जा संरक्षण की क्षमता बढ़ाने एवं उन्नत तापीय अभियांत्रिकी प्रौद्योगिकी के विकास के उद्देश्य से संबंधित अनेक परियोजनाओं में लगी हुई है। सोलर ऐडसॉर्पशन रेफ्रिजेरेशन (Solar Adsorption Refrigeration) के क्षेत्र की गतिविधियों को उल्लेख करने की विशेष जरूरत है।

डिजायन एवं स्ट्रेस विश्लेषण (Design and Stress Analysis) समूह सारस विमान के लिए वाल्व नेटवर्क (Valve Networks) से जुड़े वाल्व एवं नियंत्रण प्रणाली (Valve and Control System) के विकास तथा लैंडिंग गियर के विश्लेषण में शामिल है। एडवांस्ड डिजायन एवं ऑपटिमाइजेशन (Advanced Design and Optimization) समूह ने विशेष उपयोग के लिए कम क्षमता के ट्रैक्टर के विकास में महत्वपूर्ण रूप से योगदान किया है।

रियो प्रेशर डाई कास्टिंग (Rheo-Pressure Die Casting) के क्षेत्र में एक बड़ी परियोजना को आरंभ किया गया है। आस्टेमपरड डक्टाइल आयरन (Austempered Ductile Iron) (एडीआई)(ADI) से संबंधित गतिविधियाँ पूरे जोर से चल रही हैं। मैकनेलि भारत (Mcnally Bharat) समेत अनेक औद्योगिक ईकाईयाँ भागीदार के रूप में विभिन्न फाउंड्री की समस्याओं से संबंधित क्षेत्र में काम कर रही है।

परिवर्ती उर्जा साइक्लोट्रॉन केन्द्र (Variable Energy Cyclotron Centre) (वी ई सी सी) (VECC) के साथ आर एफ क्यू लाइनेक (RFQ LINAC) के क्षेत्र में साझेदारी के एक और वर्ष को सफलता पूर्वक पूरा किया है। पिछले वर्ष इंम्प्रूवड बीम बन्चर (Improved Beam Buncher) के विकास से संबंधित गतिविधियों पर ध्यान केंद्रित था।

ड्राईव एवं कंट्रोल (Drives and Control) के अनुसंधान का केन्द्र निर्दिष्ट ड्राईव के लिए बुद्धिमान पॉवर इलेक्ट्रानिक्स इंटरफेस (Intelligent power electronics interfaces for designated drives), नानलिनियर स्लाइडिंग मोड स्पीड (Non-linear sliding mode speed) को सम्मिलित करते हुए कंट्रोल की विभिन्न कार्यप्रणाली का अनुप्रयोगों के साथ परीक्षण, बी एल डी सी मोटर्स (BLDC Motors) के विकास पर विशेष जोर देने के साथ विभिन्न प्राइम मूवर्स (Prime Movers) के साथ प्रयोग, लिनियर मोटर्स (Linear Motors), रिलक्टेंस मोटर्स (Reluctance Motors), स्टैपर (Stepper) और सर्वो कंट्रोलर (Servo Controllers) आदि के विकास को समाविष्ट करना है।

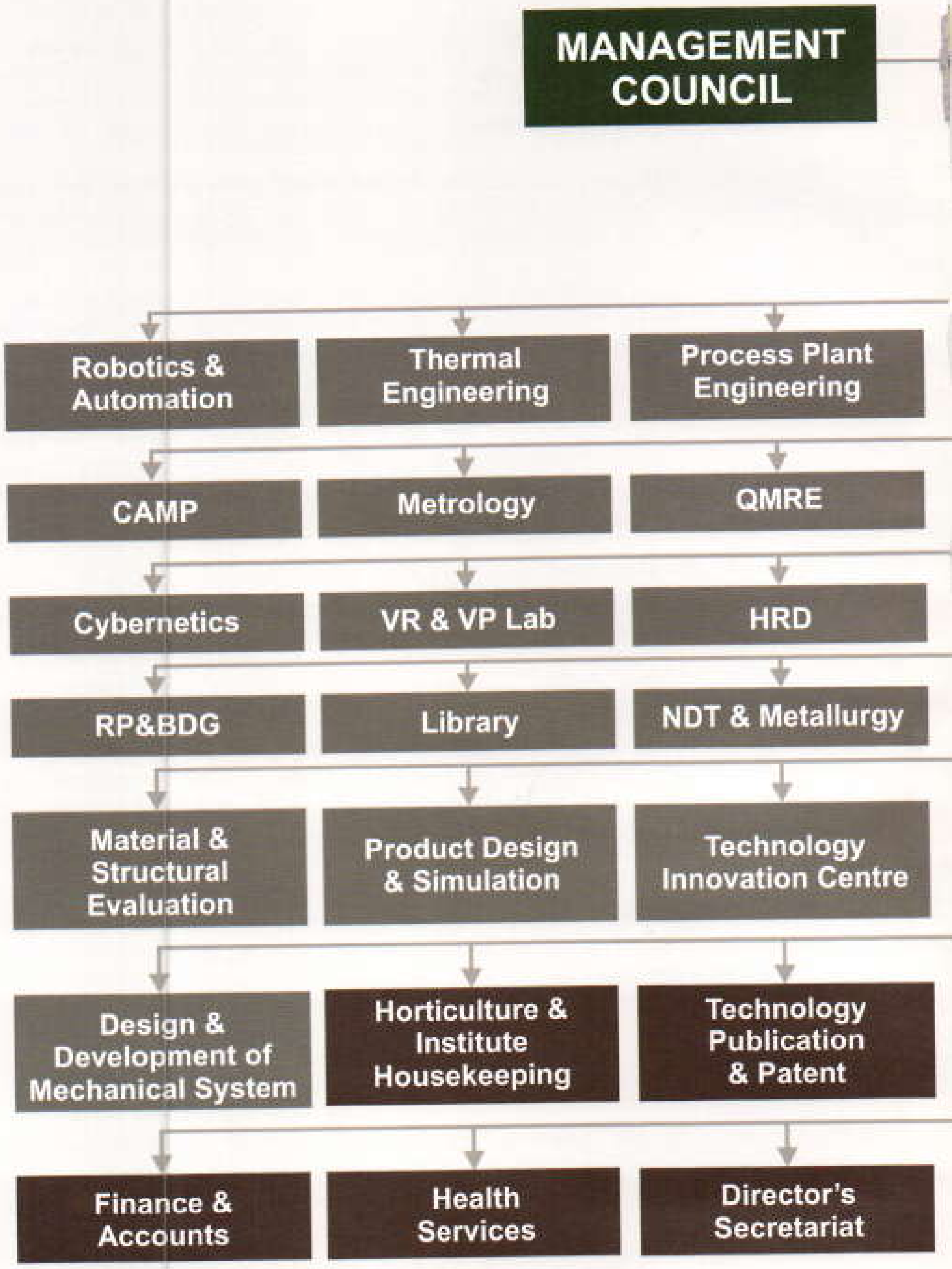
लुधियाना में स्थित विस्तार (Extension) केन्द्र फार्म मशीनरी में उत्कृष्टता केन्द्र से संबंधित गतिविधियों में लगा हुआ है। इंटर-रो कल्टीवेटरस (Inter-Row Cultivators), नोवल रोटावेटरस (Novel Rotavators) और सटीक बीज प्लांटर्स (Precision Seed Planters) के विकास पर मुख्य ध्यान केन्द्रित किये हुए हैं।

सी. एस. आई. आर. – सी. एम. ई. आर. आई. में अनुसंधान गतिविधियों को सुविधा जनक बनाने के लिए केंद्रीय अनुसंधान सुविधा (Centre Research Facility) का गठन किया गया है। एनर्जी डिस्परसिव स्पेसोग्राफी (Energy Dispersive Specography) के साथ स्कैनिंग इलेक्ट्रान माइक्रोस्कोप (Scanning Electron Microscope) तथा रिहोमीटर (Rheometer) (1000°C तक) को केंद्रीय अनुसंधान सुविधा में रखा गया है।

सी. एस. आई. आर. – सी. एम. ई. आर. आई. को स्वयं एक प्रौद्योगिकी स्त्रोत के रूप में स्थापित करने या व्यवहारिक विज्ञान एवं अभियांत्रिकी के क्षेत्र में एक राष्ट्रीय अनुसंधान एवं विकास के मंच के रूप में स्थापित करने के अतिरिक्त इसके पास कोई विकल्प नहीं है। वैज्ञानिकों को सदैव मौलिक ज्ञान, नवीन अनुप्रयोगों एवं परिणामों की शुद्धता जैसे तीन तत्वों के संयोजन के लिए प्रयत्नशील रहना चाहिए। जो दिख रहा है उससे अतिरिक्त देखने के लिए उन्हें भावनात्मक रूप से शामिल होना पड़ेगा।

गौतम बिश्वास

CSIR-CMERI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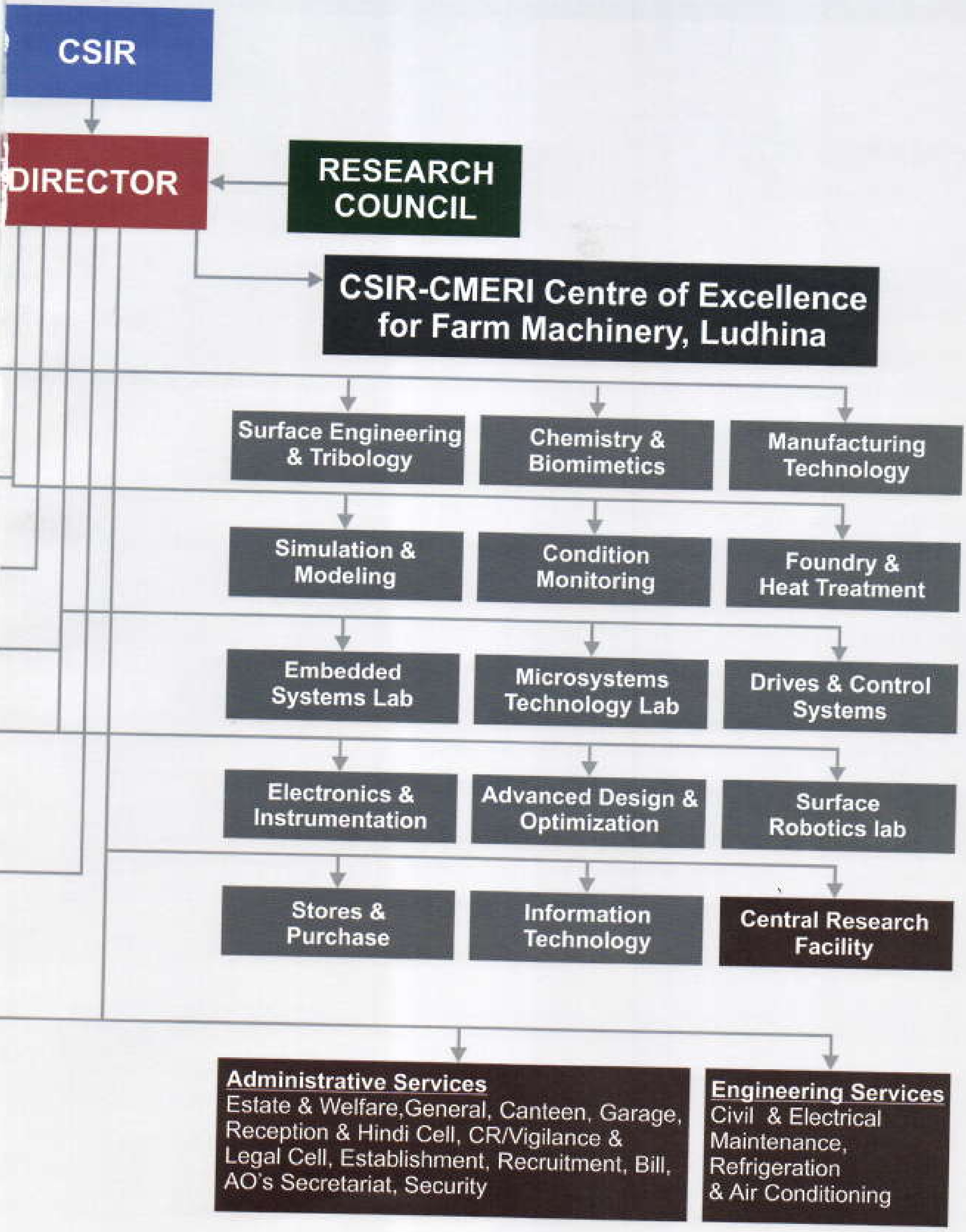

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RESEARCH INITIATIVES IN THE RECENT YEARS

- DESIGN DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE: END OF A SUCCESSFUL MISSION AND THE BEGINNING OF A NEW JOURNEY
- REMOTELY OPERATED VEHICLE FOR OPERATING AT A SEA-DEPTH OF 500 M
- CAPABILITY BUILDING IN MOBILE ROBOT DEVELOPMENT FOR INDUSTRIAL, OUTDOOR AND HAZARDOUS APPLICATIONS
- HIGH SPEED INTER-POINT BRAILLE EMBOSSER
- MOBILE ROBOTIC SYSTEM FOR VISUAL INSPECTION IN HAZARDOUS ENVIRONMENT
- SOLAR ADSORPTION COOLING SYSTEMS: AN ATTRACTIVE ALTERNATIVE
- A SIGNIFICANT STEP TOWARDS DEVELOPMENT OF BIO-INSPIRED MECHANICAL DEVICES
- CSIR-CMERI LENDS ITS EXPERTISE IN SELECTIVE MECHANIZATION OF DURGAPUR STEEL PLANT
- DEVELOPMENT OF NET-SHAPED PARTS WITH CRITICAL GEOMETRY THROUGH ADI TECHNOLOGY
- METAL INJECTION MOULDING (MIM) TECHNOLOGY FOR NET SHAPE MANUFACTURING OF STEEL COMPONENTS

RESEARCH INITIATIVES IN THE RECENT YEARS

DESIGN DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE : END OF A SUCCESSFUL MISSION AND THE BEGINNING OF A NEW JOURNEY

As fields of research, Underwater Robotics in general and design development of Autonomous Underwater Vehicle (AUV) in particular have significant future impact, leading to vigorous R&D efforts in many technologically advanced countries such as the USA, Australia, Germany, Russia, Korea and Japan. Underwater robotic technologies are important since these promote a host of spin-off technologies, many having decided strategic importance. Autonomous Underwater Vehicle (AUV) Technology will be an essential technology of the future as dependence on the hitherto untapped ocean resources increase. The need for AUVs is already being felt for activities such as inspection, location of objects and survey on the ocean floor and surveillance. India needs to indigenously build capability in designing and developing AUVs, and it is in response to this requirement that CSIR-CMERI took up the AUV development project for working up to a depth of 150 m under sea with necessary resources for sea bed mapping & data collection.

The Autonomous Underwater Vehicle - christened **AUV-150** - was subsequently developed by CSIR-CMERI, Durgapur in collaboration with IIT Kharagpur, under the sponsorship of Ministry of Earth Sciences (MoES), Government of India, through the OASTC, IIT Kharagpur. The **AUV 150** can autonomously operate under water up to a depth of 150 m and can perform specific designated tasks like sea-bed mapping, collection of oceanographic data like temperature, salinity and conductivity, etc. A summary of the specifications of the system is presented in Table-I. Figure 1 illustrates the modular design for **AUV-150**.

Table I Specifications for AUV-150

Depth of operation	100 m-150 m
Material of construction	Al alloy body (Special Grade)
Speed	2-4 knot
Configuration	Cylindrical, Modular
Degrees of Freedom	5 , Stable against Roll
Energy system	Lithium Polymer Battery
Mission Time	4-6 hr
Navigational Sensors	Inertial Navigation System, DVL, load GPS, Acoustic Tracking System, Forward looking Sonar, Altim and Pressure Sensor
Payload Sensors	Underwater camera, Side Scan Sonar, CTD
Control	Network Based Distributed Control
Communication	Acoustic & RF
Decision Making Software	Overall Mission Management including intelligent trajectory management, obstacle avoidance, autonomous navigation and control. Diagnostic tests during pre-launching and post-retrieval periods

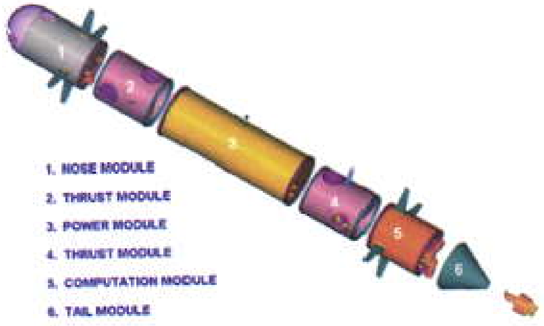


Figure.1 - Design View of AUV-150

Figure.2: AUV-150 during Sheltered Water Trials

The Trek

In reality, the development proceeded through a number of interrelated phases entailing hard problem solving. Initially a full scale steel mock-up unit was fabricated, assembled and tested at the Shallow Basin Facility at CSIR-CMERI, Durgapur. Design deficiencies as emanating from the extended trial of the steel mock-up unit were duly addressed, to be incorporated later into the final prototype made of special grade aluminium alloy. The final prototype had undergone a series of rigorous tests at the Shallow Basin facility. The size of the AUV being larger than what could be comfortably accommodated in the Shallow Basin Facility, faster & long duration missions could not be executed, and for this reason testing in a larger still water facility was deemed necessary before the actual trial at open sea. The first trial of the AUV at a wider and higher depth region was thus carried out at the Idukki Lake, Kulamavu, Cochin during September 2009. Successful still water trials were carried out at Idukki up to a depth of 5 m in spite of inclement weather and associated hurdles.

Issues leading to possible system malfunction as singular or combined contribution of system power, electrical isolation, ground looping, remote switching of the Digital Video Server (DVS), thruster collapse, damage to the pressure hull, etc. that came up during the developmental phase were resolved judiciously by appropriate diagnosis and action plan.

The first phase of the trial consisted of checking for static stability, performance of controller and dynamic stability of the vehicle, functioning of all sensors assisting navigation, performance of payload sensors for ground mapping, storage of environmental photograph, etc. Time constraints engendered by inclement weather forced abortion of system check for proper acoustic communication and obstacle avoidance. Analysis of data and test results from the first phase of trials led to identification of design drawbacks, some of which were incorporated for improving the hardware architecture and the control system so as to render the system more rugged against uncertainty & disturbances.

The second phase of trial at the Shallow Basin facility was followed up by trial at the Idukki Lake during September 2010 with the objective of achieving higher depth, more reliable performance of the controller for avoiding obstacles, various long duration missions and subsequent floor and acoustic communication. The second phase comprising the aforementioned missions was also concluded successfully in spite of severe weather conditions. The test data along with the associated hardware was analyzed critically to judge the system performance and to incorporate minor modifications to make the AUV seaworthy.

Having successfully undergone these Sheltered Water Trials at the Idukki Lake, Cochin with active support extended by NPOL, sea trials for verifying sea-worthiness of **AUV 150** and the entire set of designated functionalities were conducted recently at high sea off the Chennai coast onboard the research vessel ORV Sagar Nidhi.

The day of reckoning

The **AUV 150** was transported from CSIR-CMERI, Durgapur directly to the Chennai Port. The CSIR-CMERI sea trial team reached NIOT during July 7-8, 2011. Due to preoccupation and other unforeseen reasons, IIT, Kharagpur could not take part in the trials. The materials were loaded to the deck of ORV Sagar Nidhi on the afternoon of July 8, 2011. The team members underwent medical check-ups required for sea cruise. With logistics support organised by the NIOT, all the team members from CSIR-CMERI, NIOT and four seamen cleared all the formalities including immigration checks at Chennai port before signing on the research vessel. The team members boarded the research vessel at noon on 9th July 2011. List of members present during trials are given below:

S.N. Shome	Chief Scientist
S. Nandy	Principal Scientist
S.R.K. Vadali	Senior Scientist
D. Pal	Scientist
S.K. Das	Junior Scientist
J.P. Maji	Technical Officer
Debasish Datta	Senior Technician (1)
Sk. Hasanujjaman	Project Assistant
Chandan Har	Technical Assistant
Pratik Saha	Technical Assistant
J. Karmakar	Technical Assistant
R.K. Mondal	MSE

A brief meeting was organised by the captain of ORV Sagar Nidhi so as to acquaint the research team with the protocols for handling various on-board facilities, and were finally assigned accommodation. In the afternoon Mr. S.N. Shome, Chief Scientist, briefed the captain and officers of ORV Sagar Nidhi about the objectives of the AUV project and the activities proposed to be carried out during the sea trial.

With active support from the NIOT functionaries, the CSIR-CMERI team positioned the control container, AUV system and other accessories on board Sagar Nidhi. Power connections to various points on ship were arranged. The support for the logistics, envisaged deck support and handling of AUV system for launching and retrieval was planned jointly with NIOT in consultation with master and other officers of the ship.

Sea trials were conducted in various phases targeted towards qualifying the **AUV-150** with the following objectives:

- Dry tests for integrity and conformity onboard the ship
- Soak tests and other functional tests at shallow depths of 30~40 m
- Progressive depth qualifications for up to 150 m in sea water
- Sea-bed mapping with Side Scan SONAR
- CTD Profiling towards observing salinity, conductivity and temperature at various depths/ pressure levels and underwater videography
- Autonomous navigation for following a pre-defined trajectory
- Exception handling capabilities towards detection of leakage/low power status
- Acoustic communication and tracking of **AUV-150** during subsea operations with Ultra Short Base-Line (USBL) positioning system integrated with an acoustic modem

Test Description

Sea Trials of AUV-150 were conducted during July 9-17, 2011 at three identified testing sites as indicated in Table-II. Trial operations were carried out, and system checks were performed as follows:

- Physical verification and recording of remarks as 'pre dive' requisites before powering up the various subsystems (**AUV-150** and the control console) for test sequence
- After powering the system, performance checks were carried out as "pre-operational dry test (on ship deck)" requisite before actual deployment
- Critical monitoring parameters were ascertained and recorded as "pre-operational wet test (on water surface)" after actual deployment for integrated system healthiness prior to diving
- After completion of "pre-operational tests", the total system was tested for its operation according to an operational test plan
- After completion of dive operation, checks were carried out as "post-dive" requisites to verify the physical and functional status of the system

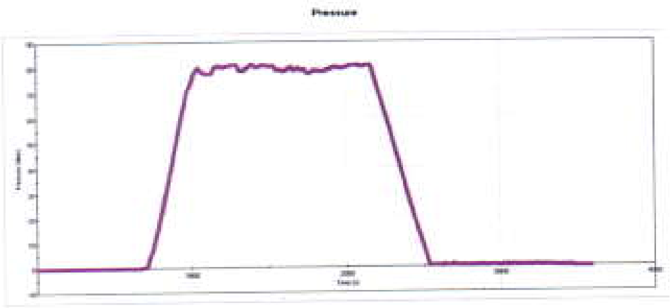


Figure 7: Depth of 81 m as logged by CTD Profiler

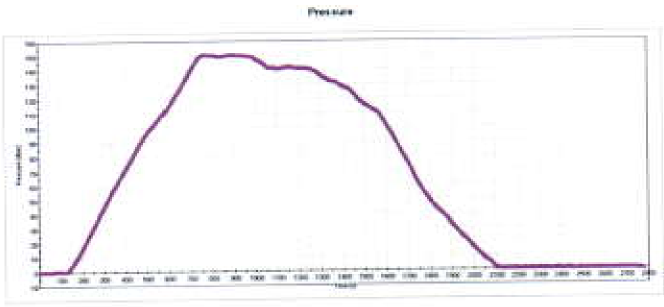


Figure 8: Depth of 150 m as logged by CTD Profiler

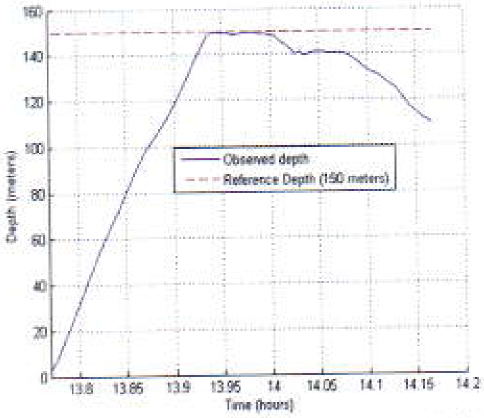


Figure 9: Depth of 150 m as logged by Depth Sensor

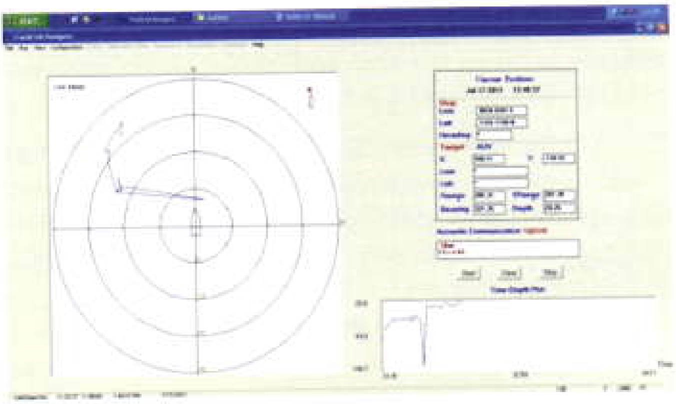


Figure 10: Acoustic Tracking done by

Figure 11: Monitoring inside Operator's Console

Figure 12: Underwater Video-Snapshot

REMOTELY OPERATED VEHICLE FOR OPERATING AT A SEA-DEPTH OF 500 m

Background

A Remotely Operated Vehicle (ROV) is essentially an underwater robot that allows the operator to remain in a remote environment while the vehicle performs the operation in some specified hazardous surrounding. The system includes a robotic vehicle with onboard sensors, an electronics & control module, a surface control station, an umbilical cable that connects the vehicle and the operators on the surface, a cable handling system, a launching and retrieval system and associated power supplies. The umbilical cable carries power, command & control signals to the vehicle and the status, camera picture and sensory data back to the operator topside. Sub-sea control boxes are provided for harnessing electronic hardware. A number of state-of-the-art payload and navigational sensors are mounted on the ROV frame. In many cases, the umbilical cable incorporates additional strength members to allow recovery of heavy devices or wreckage.

As in many other areas of sub-sea technology, commercial development of ROVs demands capability for sea-bed surveys. The tasks include identification of debris/wreckage; monitoring health of off-shore installations; inspection of damages and failures e.g. cracks, corrosion dented members, deflected members; search and recovery of lost items; pipeline route surveys; oceanographic data collection and data provision for sub-sea engineering design studies, etc. Though available commercially on rent, their prohibitively high rentals restrict their deployment for regular inspection, monitoring and maintenance of offshore structures. To solve these problems, indigenous developmental programmes for ROV have been initiated, in which CSIR-CMERI, Durgapur enjoys a position of prominence. At the behest of the then Department of Ocean Development (DOD), Government of India, CSIR-CMERI, Durgapur has already developed ROV-200 – a vehicle that works up to a depth of 200 m under the sea. ROV-200 was successfully tested on August 2001 off Chennai coast with active support from National Institute of Ocean Technology (NIOT), Chennai, which spawned the programme for development of a ROV with enhanced features for operating at a depth of 500 m under the sponsorship of the Ministry of Earth Sciences, Government of India.

System Description

ROV-500 designed by CSIR-CMERI, Durgapur employs an open frame structure with onboard sensor and computational modules that can be maneuvered under the water from an on-ship surface control station. An opto-electro-mechanical umbilical cable connects the ROV with the surface control station via a cable handling winch system. The pressure in which the ROV works is directly proportional to the depth of operation. Four sub-sea control boxes are provided for harnessing

Figure 1: ROV-500 prototype equipped with thrusters, navigational & payload sensors

SERPENTINE ROBOT

Background

In case of a serpentine robot, design is principally guided by gait implementation philosophy. The first qualitative research on biologically inspired serpentine robot was carried out by Hirose. Early works of Burdick and Chirikjian on locomotion of hyper redundant robot are worth mentioning. Since then many multi-segmented articulated serpentine robots have been attempted by researchers for implementation of crawling gaits. Some of them use wheels, tracks, legs or other means for locomotion while others rely solely on body undulation. In most of the cases the segments are connected with revolute joints, though prismatic joints are also employed. These joints may be active or passive. Though revolute joints in general are considered for yaw and pitch, a few models using roll DOF were also studied. Figure 1 shows a comparison of such robots based on different design philosophies.

This project deals with the design and development of experimental serpentine robots CSERP-X (CMERI SERPENT) series, which can perform multiple gaits depending upon the requirement. Serpentine gaits that were implemented results from body waves in two orthogonal planes. To allow undulation in both horizontal and vertical planes the design needs to be flexible and compliant in both the directions. CSERP-X essentially has a robotic arm with seven degrees of freedom with on-board battery pack, microcontroller, wireless camera, light, and Infra Red (IR) obstacle detection system. The brief specification of the system is given in Table I.

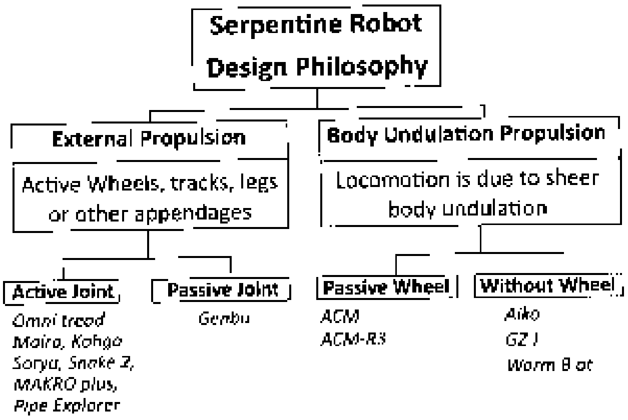


Figure 1

Table I

A brief specification of CSERP-X

Overall length	**807 mm**
Number of Segments	8
Number of joint actuators	7 R/C servos
Joint actuator torque	9 kg-cm
Joint to joint	**96 mm**
Segment cross section	70 mm x 70 mm
Overall weight (including battery)	**1.26 kg**
Obstacle detection	IR based
On board micro controller	**PIC 16F84A**
Power source:	
Servo actuators	6x900 mAh@6 V DC
μ-controller and other electronics	900 mAh@6 V DC
Camera, video transmitter & light	9 V DC

Design Issues

The design of the serpentine robot is modular and there are six body segments with one head and one tail module. Body segments are almost identical in shape and size, though the head and tail segments are completely different. Each compartment houses a rotary actuator, carries its own battery and associated electronics and harnessing. The head segment does not house any rotary actuator but accommodates some sensors.

The modular construction facilitates easy removal or addition of compartments. All components are made of plastic and the design is highly optimized so that the overall weight is kept to a minimum. Each joint has a rotational freedom of 90°. The head segment houses a miniature wireless video camera and IR obstacle detector. The tail houses the microcontroller, the battery charging socket, etc.

As some non-serpentine gaits utilize all four sides of body segments, a square segment cross section was chosen to maintain uniformity in all states of gait. Otherwise, variation in dorsal and ventral shapes would have led to anomalous behaviour in various stages of those gaits which utilize all the four faces of the body segment.

The overall weight of the serpentine robot is 1.26 kg including the weight of the servos, battery, electronics, cabling and weight of the body segments. When sleeved with a flexible outer jacket, the total volume is about 3675 cm^3 and the overall robot density of 0.34 g/cm^3 allows the robot to float on water surface.

Friction plays a pivotal role in serpentine locomotion. To achieve meaningful locomotion sometimes directional friction helps to a large extent. A biological snake enjoys certain advantages as far as directional frictional is concerned. This is often termed as frictional anisotropy. Particular orientation and overlap of body scales helps serpents achieve directional friction and this allows easy forward slide. The advantages of frictional anisotropy can also be seen in daily usage - e.g. a wheel can roll forward easily rather than skidding sidewise. Frictional anisotropy on a serpentine robot can be achieved in many different ways. Many serpentine robots have been developed using passive wheels to achieve this. The CSERP-X makes use of fine saw-tooth corrugations intentionally introduced on the bottom surface of the head and the tail segments to achieve frictional anisotropy. In case of inchworm movement, where two ends of robot body interact with the ground, this design provides substantial help.

Figure 2. The experimental serpentine robot CSERP-X.

Actuators

There are seven actuated joints, three of which contributes to the undulation on the horizontal plane and four to undulation on the vertical plane. The adjacent actuators are perpendicular to each other. Joint pitch on any plane is 192 mm. At the most four pitches could be fitted on overall length of 800 mm (192 mm x 4 = 768 mm). Radio control or R/C digital servos are used as rotary actuators. These are small DC geared motors with onboard electronics that provide closed-loop position feedback control. The R/C servos are very robust, compact and cost effective. Only for this reason, R/C Servos are widely being used in robotic systems, scaled models of planes, helicopters, cars, boats and many more.

A potentiometer attached to the shaft of the motor rotates along with the motor. Due to this, the rotation of the R/C Servo is limited to approximately 180^0 and they are not suitable where continuous rotation is required. It provides good activation for limited positional control without exclusive additional hardware.

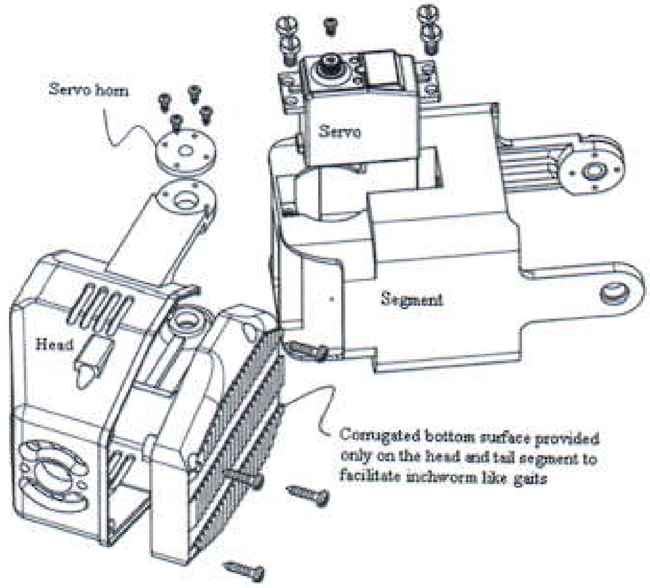


Figure 3: Exploded view of head segment and servo location. Alternate joints are orthogonal

Power Supply

Battery is the main power source of the serpentine robot and has the highest contribution to the overall weight. Batteries come in various shapes and sizes; choosing the right kind of battery is very essential for the design.

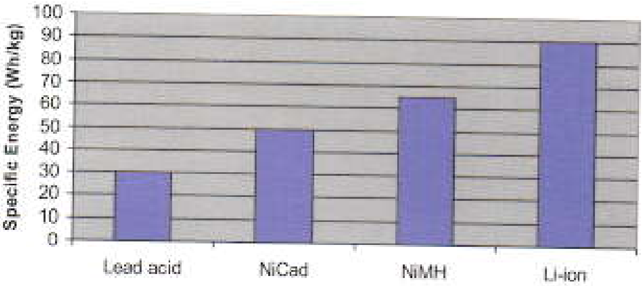


Figure 4: Comparison of specific energy for various battery types

The performance criteria of a battery include specific energy, energy density, typical voltages, energy efficiency, commercial availability, cost, operating temperatures, etc. A battery with high specific energy contributes less to the overall weight of the system.

Figure 4 shows the specific energy of different types of batteries. Considering all these, battery modules consisting of five NiMH cells, each of 1.2 V, were used as power source. Six battery modules each of 900 mAh@6 VDC were distributed within the segments for supplying power to the servos. Light, camera and video transmitters are powered by a 200mAh@9 VDC battery pack. The microprocessor and associated electronics is separately powered from a 6VDC battery pack.

Electronics

The microcontroller board is placed at the tail segment and the cables run throughout the length of the robot to transmit signal to the servos. A small wireless video camera mounted at the head segment of the robot provides video and audio feedback online to the control station.

Figure 5: Video transmitter attached to the camera housed inside the head

Figure 6: Front view of the serpentine robot

A narrow passage through which the robot navigates may not be properly illuminated, thereby causing the video quality to degrade. To overcome this problem, an array of six white light LEDs surrounding the camera is provided to produce sufficient light for good picture quality. The in-built transmitter sends signals at a frequency of 1.2GHz up to a distance of 100 m. A small wireless receiver receives the signal directly to a video monitor and to a computer through a frame-grabber card for further processing.

The video image is often found to be jerky when the robot is in locomotion. Surrounding survey posture was thus devised to obtain a clear picture. In the survey posture the serpentine robot raises its hood above the ground while making a small loop at the rear for firm seating on the ground. The head segment also mounts one IR based obstacle detection and avoidance system and associated electronics.

System Architecture

The serpentine module is fully deployable and does not have any umbilical cord or other cable connection for command signal or power supply. Onboard microprocessor assumes overall control of the system and the deployed module carries all the batteries along with it. This factor limits the mission time: however, deployment of locomotion gaits are accurate and uninterrupted as dragging the umbilical cord along all the time is obviated. Figure 7 depicts the system architecture of the serpentine robot.

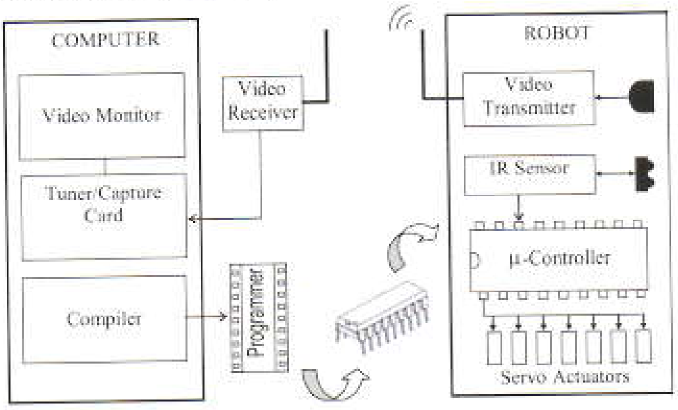


Figure 7: System Architecture

On detection of any obstacle in the trajectory, the IR based obstacle detection system gets activated. The system offers excellent capability for gait experimentation. The utility of the robot can be further enhanced by introducing features for online command and control.

Kinematic Model

Kinematic freedom of the model can be better understood from Figure 8. Adjacent joint axes are perpendicular to each other, thereby providing overall flexibility in two orthogonal planes. The body segments of the serpentine robot are named as:

Head – B1 – B2 – B3 – B4 – B5 – B6 – Tail

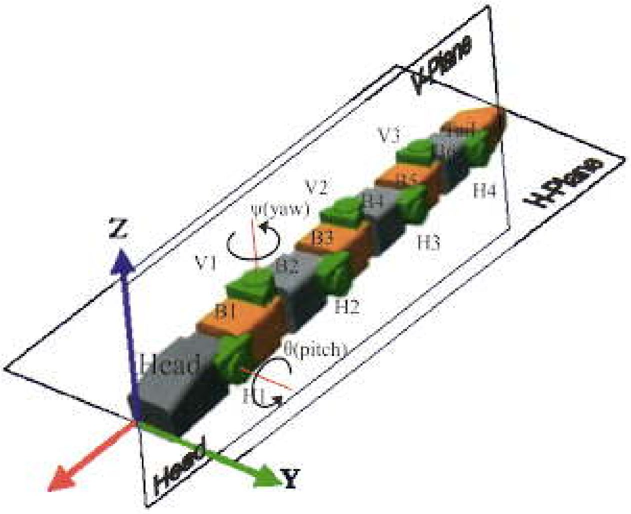


Figure 8: Kinematic model of the robot (CSARP-X).

Considering spatial orientation of the robot, four actuators have axes on the horizontal plane (viz. H1, H2, H3 and H4) controlling pitch and three on the vertical plane (V1, V2, and V3) for yaw.

The pattern of oscillation of each servo is governed by the microcontroller and is termed servo orientation function, which are sinusoidal time-dependent functions. Characteristics of orientation functions are governed by the parameters such as mean, amplitude, period and phase. The parametric expressions for orthogonal servo orientation functions are:

$$\text{Yaw, } \psi_i = M_V + A_V \sin(\frac{2\pi}{T_V} t + i\alpha); \quad i = 1 \text{ to } 3$$

$$\text{Pitch, } \theta_j = M_H + A_H \sin(\frac{2\pi}{T_H} t + j.\beta); \quad \text{j} = 1 \text{ to } 4$$

Here M, A and T are the mean, amplitude and period of joint oscillations. The suffix H and V denotes of horizontal and vertical joints respectively. Vertical sinusoid contributes to the sinus lift which is essential for this robot irrespective of its speed as it creates proper ground interaction to propel. The phase difference between two successive joints on horizontal plane is denoted by 'α' and the same for the vertical plane is denoted by 'β'. Suffix 'i' and 'j' are the joint positions numbered from the head side.

Determination of joint parameters (servo parameters) is crucial and need iteration, trial and experimentation in visual Nastran simulation environment.

Gait Implementation

Various parametric combinations of servo orientation function produce different gaits. Period (T) dictates how fast a snake moves. A biological snake performs different locomotion speeds at different situations and environments. Physical limitation of speed in an electromechanical system may not match that of a biological snake. Gaits of a particular locomotion type are performed sequentially within a specified period, after which the process is repeated. For the sake of performance comparison, all the gaits were simulated with a period of 4 seconds. Again, simulation time and real time were different. In the simulation environment it takes much longer time to simulate a 4 second activity depending upon simulation time step, computational power available, etc.

Mean (M) is the mean value of the sinusoid about which the servo oscillates. For straight heading it is at 90°. By adjusting mean values of V1, V2 and V3, turning and steering can be achieved. The phase difference between two successive servos of a plane determines the nature of wave produced along the length of the serpentine body.

Though various gaits were implemented successfully, the results of sidewinding and rectilinear gait implementation are presented here. For the serpentine robot, these parameters simulate the gaits in a most realistic and effective fashion. These can further be adjusted to cope with varying environments and situations. Orientation function parameters were programmatically transferred to the onboard microcontroller of the serpentine robot for gait implementation.

Sidewinding

It is a mode of sidewise movement where a portion of the body gets lifted, moved laterally and placed on the ground. Sidewise undulations are relatively larger than V-Plane undulations. V-Plane undulations help it to locomote even on loose soil or sand and depending upon the soil condition the parameters may be adjusted. Plots of servo orientation functions are segregated for H-plane and V-plane to avoid clutter. Actual behaviour of the experimental serpentine robot in sidewinding motion is shown in Figure. 9.

Figure 9: Frames showing gait sequence of Sidewinding locomotion. Frames are not necessarily at regular interval.

Caterpillar Rectilinear

This is a non serpentine gait, but can easily be implemented on a serpentine robot. In this mode of locomotion a pure sinusoidal wave is generated on the V-plane only and it travels through the length of the body. The direction of motion of this wave is from the rear to the front while the robot moves forward. The serpent moves without sliding any one of the segments on the ground.

Figure 10: Caterpillar Rectilinear gait sequence

All the servos contributing to horizontal undulation (V1, V2 and V3) are held at 90^0 (i.e. the mean value) for straight heading. These servo parameters can be adjusted to steer the serpentine robot left or right.

Conclusion

Machine locomotion using wheels, tracks or legs is common whereas generating locomotion in a limbless, wheel-less system is more challenging, and this is where the study of serpentine locomotion provides meaningful insight. Most of the research on serpentine locomotion focuses on mathematical modeling of gaits, yet their implementation is dependent on specific models. A snake robot has the capability to move within a confined area and traverse all terrains that is not possible by traditional wheeled or walking robots. These robots are more suitable for its stability, terrain ability, high redundancy and compliant mechanism. Snake like robots can be used in surveillance, inspection of pipe lines, search and rescue after any disaster and in many more similar situations.

TELEOPERATED AERIAL ROBOT WITH AUTONOMOUS HOVERING

Background

In recent times, CSIR-CMERI has ventured into the field of aerial robots which expectedly has opened up a plethora of new possibilities. CSIR-CMERI initially focused on Rotary-Winged Flying Robot (RWFR) with the aim of developing a reliable model of vehicle dynamics using system identification and devising a controller for controlling the dynamic behaviour of flying robot by stabilizing the non-linear dynamics, with emphasis on hovering for close inspection. The linear model, with small perturbations, accurately captures the essential effects of vehicle dynamics. As any control strategy requires accurate estimate of the state of a robot, sensor data fusion from a combination of sensors mounted on the flying robot was attempted. Specific sensors used included INS, GPS, compass, altimeter, etc. for state estimation, control and navigation.

Approach

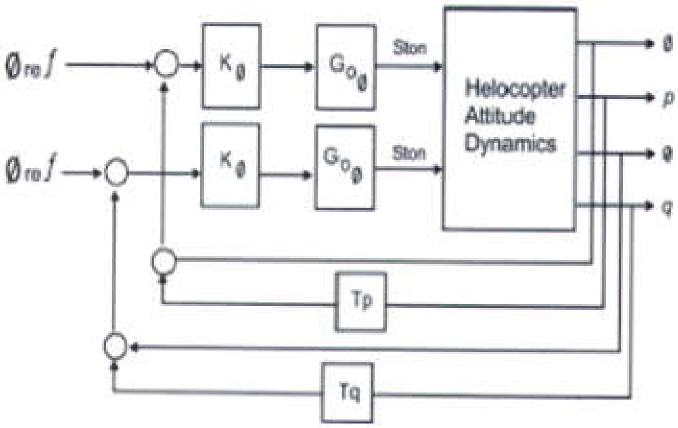
As the focus is on autonomous hovering for close inspection, initial work was directed towards developing a digital controller for attitude control for maintaining the hover. Experiments were carried out on a Bergen Turbine Observer model equipped with CrossBow NAV420CA, XSens Mti-G INS with integrated GPS,

KVH C-100 compass. The array was mounted on a test rig with bending flexibility along all axes. A SICK Laser was added for altitude mapping along with a thermal vision FLIR camera for navigation in poor visibility conditions.

The first task comprised interfacing kinematic and navigational sensors to the system with hybrid communication protocols i.e. RS-232 based serial communication with INS sensors and compass and TCP/IP based communication for SICK laser and thermal vision camera.

Next came the interfacing of PC-104+ based high speed digital I/O card with programmable clocks and incremental encoders for controlling throttle/pitch, aileron, elevator and rudder digital servos using PWM based actuation. The qualitative behaviour of the non-linear model of RWFR was found to be quite complex in regard to shape and motion. As the non-linear aerodynamic forces and gravity acts on RWFR in a non-intuitive manner, a host of unknown physical parameters needs to be determined. These include, among others, mass and moments of inertia of the fuselage and rotor components and aerodynamic parameters such as the blade lift curve slope, stabilizer bar lift curve slope and fuselage drag coefficients.

Owing to the innate limited accuracy, a non-linear dynamic model tends towards instability. Four linear SISO controller structures were used – one for each of the desired outputs to be controlled – for controlling the position and attitude of RWFR in a bid to improve the stability. As the model was strapped to the test rig, the first task was to control the attitude of RWFR simulating a hover condition. The Figure below illustrates the control scheme for continuous compensation from linear SISO controller to control the nonlinear dynamics of RWFR.



Φ, θ, p, q = roll, pitch, roll rate, pitch rate;□

Tp, Tq = ratio of rate to angle feedback

K_Φ= Roll angle feedback gain

K_θ = Pitch angle feedback gain

Ge_Φ= Transfer function describing open-loop roll angle response to the lateral input, d_{lat}

Ge_θ = Transfer function describing open-loop pitch angle response to the longitudinal input, d_{lon} such that closed-loop transfer function describing the roll angle response to the reference roll angle command is given as $Ge_\Phi K_\Phi / (1+ Ge_\Phi K_\Phi)$

Similarly, closed-loop transfer function describing the pitch angle response to the reference pitch angle command is given as $Ge_\theta K_\theta / (1 + Ge_\theta K_\theta)$

This is derived from the continuous state space system

$?x = Ax + Bu$

$y = C$

where A, B, C are system, input and output matrices respectively and helicopter state vector is given as

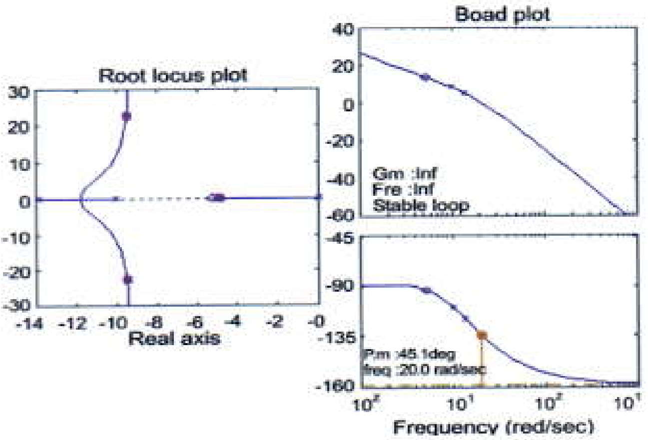
$x = [u, v, w, p, q, r, \Phi, \theta, \psi]$

and perturbative input control vector is given as

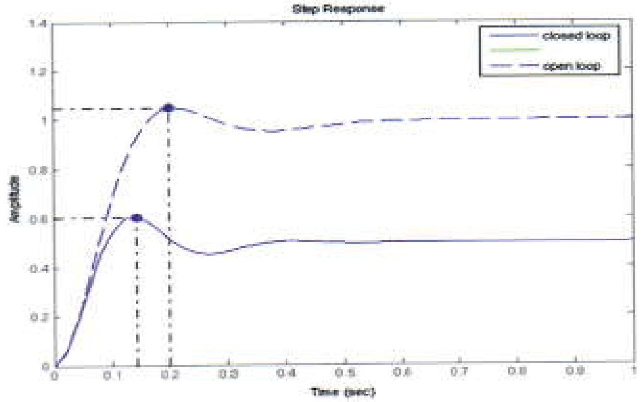
$u = [d_{lat}, d_{ion}, d_{ped}, d_{col}]$

such that in reduced state space model for SISO structure

$Ge_\Phi = C_\Phi [sI - A] \cdot 1 B_{lat}$ *and* $Ge_\theta = C_\theta [sI - A] \cdot 1 B_{lon}$ where - I is the unity matrix, $-C_\Phi$ and C_θ are special output matrices with unity element at the roll and pitch angle index and zero elements everywhere else, - B_{lat} and B_{lon} are the special input matrices with a unity element at the lateral and longitudinal cyclic input index and zero elements everywhere else.



Root locus and Boad plot of closed loop system for roll compensator



Step response of open-loop and closed loop system

The stability of the attitude compensator scheme is analyzed. The criteria consists of eigenvalue location that constrains the real parts of all closed-loop system eigenvalues to be less than or equal to zero, thus ensuring that all the dynamics are stable or neutrally stable. Gain and phase margins are chosen to ensure robustness to unmodeled dynamics and changes in the dynamics near hover. The specification of the frequency response envelope of the closed-loop attitude is designed to penalize a resonance peak in the roll and pitch attitude responses, thus limiting the response overshoot and oscillations. In qualitative terms, the goal is to optimize the system for three levels of performance measured in terms of the speed of response (rise time), overshoot of response and oscillation-free response without violating stability margin criteria. A high pass first order compensator is utilized for improving the transient response, raising bandwidth to increase the response speed.

Finally, a detailed analysis of the controller performance is provided through closed loop identification. Experiments are carried out on Hirobo Scheadu50 model. The outputs that are of direct interest for the present analysis are the attitude angles and rates. The identified closed-loop frequency responses are used to validate the model and to extract the loop gain functions needed for performance and stability.

OUTDOOR MOBILE ROBOT

The Outdoor Mobile Robot is basically the fourth generation of all terrainean mobile robots developed by CSIR-CMERI, Durgapur, its predecessors being the ATR (All Terrain Robot), the SR (Sub-terrainean Robot) and the Modified ATR (ATR2).

Two different variants of the basic OMR have been developed, and are respectively christened OMR v 1.0 and OMR v 2.0.

Outdoor Mobile Robot v 1.0

This version of the robot is specially designed for stair climbing capability. In this variant, double-sided timer belts are used as tracks. These tracks are guided by flanged timing pulleys of 300 mm diameter. The diameters of these pulleys have been kept large for better ground clearances. Two DC servo motors have been used for differential steering. DC hub motors have been used in other robots. The system uses Li polymer battery bank for onboard power supply. The systems are remotely operated from a command control station/ joystick.

OMR v 1.0 has the following major tentative specifications.

- Size: 1000 mm X 670 mm X 315 mm
- Weight: 45 Kg
- Endurance: 0.5 Hr
- Speed: 0.5 m/s (avg): 1.5 m/s (max)

The diameters of the wheels are increased than all the earlier versions of terranean robots for better terrainability. OMR v 1.0 is also compact in comparison to the earlier versions. The motors are directly mounted on all four wheels. The rear wheels are disconnected from the motor and driven by a tracked belt. The large diameter wheels also help to overcome large obstacles and to climb up staircases easily.

Outdoor Mobile Robot v 2.0

The uniqueness of the second variant of the OMR, namely OMR v 2.0 is that it can run in any direction owing to its four wheel drive. The tentative system specifications of OMR2 are as follows.

- Size: 1090 mm X 795 mm X 320 mm
- Weight: 38 Kg
- Endurance: 1.0 Hr
- Speed: 0.5 m/s (avg); 1.5 m/s (max)

Here four DC hub motors have been used for driving. The front pair of the motors is connected to a steering motor to facilitate orientation in any angle from 0 to 90 degrees. Similarly, the rear pair of the motors is also connected with another steering motor.

VISION GUIDED MOBILE ROBOTIC SYSTEM FOR HANDLING HAZARDOUS MATERIALS

Background

This project had as its objective the development of a vision guided mobile robot for indoor application that would navigate in and inspect an unstructured environment. Reduced to the basics, such a system comprises a wheeled type mobile robot with differential drive system driven by two brushless DC motors. The robotic system is connected to a remote computer by wireless LAN, thereby enabling operator interactions with the help of a suitably developed GUI at the remote computer. The system, carrying its own power pack as energy source, suitable cameras for inspection and a host of external sensors operates in the autonomous mode guided by vision, and is also amenable to remote control.

For effective navigation, the robot requires its own positional information at every instant. This was achieved by different techniques and with the help of different sensors. The position of the robot was measured with reference to fixed landmarks or features of the environment. Data on feature positions, stored in an array and referred to as a 'feature-based map' was built with the help of vision data obtained from the vision guided robot developed at CSIR-CMERI. The corner points of different structural parts were extracted as features, and the feature positions were iteratively computed simultaneously with the position of the robot with reference to these features. The feature positions were stored and updated as a feature based map of the environment. In parallel, another map called occupancy grid map was developed with LRF data, and this map stored the information of the occupied and empty spaces of the environment. After the completion of the mission, the robot computed the shortest path of return by the help of this map to minimize battery consumption.

Features were extracted from the left hand and right hand images obtained from the stereo camera. Corresponding features were matched and the depths were computed by SIFT algorithm. The features of the left image are sequentially matched with the features of the previous data. The matched features are used for update of the feature positions and robot positions.

As image features are not free from noise, it is necessary to carry out error analysis for the landmark positions. Kalman filter based approach is most popular to track these landmarks in a dynamic environment.

Previous approaches to feature detection, such as the widely used Harris corner detector are sensitive to the scale of an image and therefore are not suited to building a map that can be matched from a range of robot positions. Considerable research has been undertaken for developing affine-invariant features, but a much higher computational cost for detection is involved. A performance evaluation of various local descriptors has, however, ascertained that Scale Invariant Feature Transform (SIFT) descriptors perform best in extracting features, for which different algorithms can be used. The invariance of these features to image translation, scaling and rotation makes them suitable landmarks for mobile robot localization and map building, thereby rendering the SIFT method the best choice in this case.

Since the central idea in any vision-based navigation is to provide a sequence of landmarks expected to be encountered during navigation, the task of the vision system is to search and identify the landmarks observed in an image. Once these are identified, the robot can use the provided map to estimate the robot's position (self-localization) by matching the observation against the expectation (landmark description in the database).

For this work, suitable image features have been adopted that possess properties suitable for matching differing images of a scene. The features are invariant to image scaling and rotation, and partially invariant to change in illumination levels. These are well localized in both the spatial and frequency domains, thereby reducing the probability of disruption by occlusion, clutter or noise. The cost of extracting these features is minimized by adopting a cascade filtering approach, in which the more expensive operations are applied only at locations that pass an initial test. Following are the major stages of computation used to generate the set of image features:

1. Scale-space extrema detection: The first stage of computation searches over all scales and image locations. It is implemented efficiently by using a difference-of-Gaussian function to identify potential interest points that are invariant to scale and orientation.
2. Keypoint localization: At each candidate location, a detailed model is fitted to determine location and scale. Keypoints are selected based on measures of their stability.
3. Orientation assignment: One or more orientations are assigned to each keypoint location based on local image gradient directions. All operations are performed on image data that have been transformed relative to the assigned orientation, scale and location for each feature, thereby providing invariance to these transformations.
4. Keypoint descriptor: The local image gradients are measured at the selected scale in the region around each keypoint. These are transformed into a representation that allows significant levels of local shape distortion and change in illumination.

For image matching and recognition, SIFT features are first extracted from a set of reference images and stored in a database. A new image is matched by individually comparing each feature from the new image to this previous database and locating candidate matching features based on Euclidean distance of their feature vectors.

For executing SLAM, the robot utilizes the corner point features for localization. But in 3D unstructured environment, these point features are not sufficient for practical navigation. For this reason, a suitable grid based map is required. In the Occupancy Grid approach, the environment is divided into a discrete grid and to each grid a probabilistic value is assigned corresponding to the occupancy by an obstacle. Laser sensor readings are used to determine regions where the obstacles are anticipated. The grid locations near obstacles have increased probability values than in the other regions. A suitable algorithm for obstacle avoidance has also been developed and tested by simulation.

The estimation of the vehicle pose is performed using the Extended Kalman Filter algorithm. In the non-linear case, the system is described by suitable process and observation models. To estimate the state of this non linear system, it is assumed that the process and observation models are locally linear, and the process model is linearised as a Taylor series expansion. Here extraction of the features is also necessary. Getting the exact feature from a host of other features requires calculating the distance between the consecutive feature locations with respect to the global coordinate frame and also a threshold value.

Work Description

The conceptual design of a vision guided mobile robotic system has been completed, and a prototype system has been fabricated. Assembly of the subsystems has been completed and various software modules have been tested on the Pioneer 3DX model. The robotic system so designed has the capability of navigating in an unstructured environment and inspecting a specified hazardous working environment as per the instructions provided. The system enables operator interaction with the robotic system with the help of a remote computer, which is connected to the autonomous vehicle through wireless LAN. After the development, the system has been tested on the laboratory floor. The autonomous vehicle has been designed & developed along with the related software. The robot is equipped with a host of external sensors. Though most vision guided robots use sonar range sensor due to their affordable cost, the system developed at CSIR-CMERI dispenses with sonar range sensor and uses a laser counterpart as its primary spatial sensor in order to increase on the accuracy level.

Figure 1: Prototype of Vision guided Robotic System

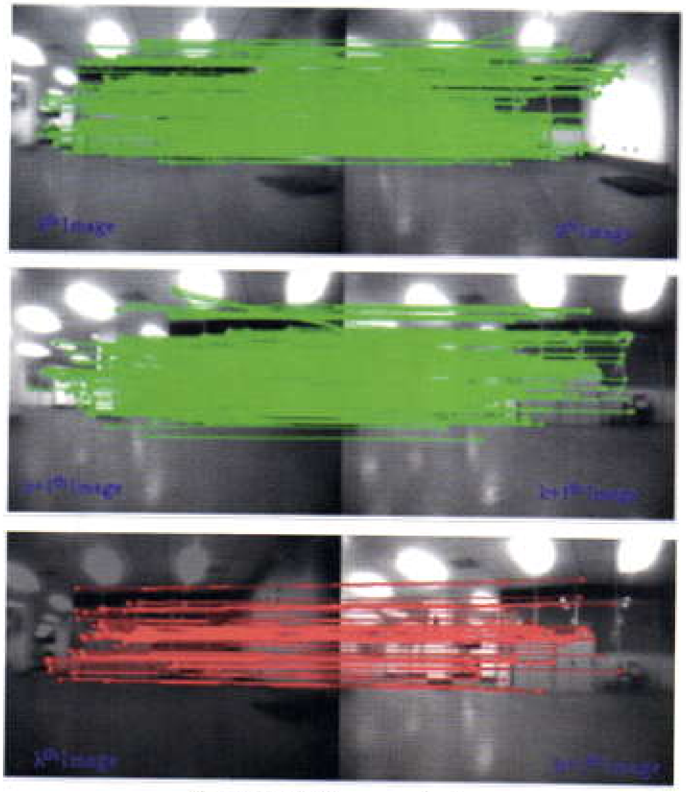


Figure 2: Data association

Simulation Results

During navigation through different given via points, stereo images along with laser data have been collected. The left and right images at a particular position or via point are matched to obtain the 3D information of each feature. At the same time, different instances are also matched by SIFT algorithm for data-association. These are viewed as following:

Map Based Self Localization

In order to solve of the existing data association problem of mobile robotics, Scan Correlation technique has been used by the robot to navigate in a given environment, which comprises the following sequential steps:

Initial localization: Here the input is the global map. Templates are generated for a range of orientation angles using local laser data in the current position. The best matched position is then detected by scanning the entire global map with the templates. Robot position and orientation are initialized over the global map from the result of the matched point before the robot begins navigation.

Pose prediction over map: After initializing the pose of the robot the next position is predicted on the basis of the command provided to the robot, and this is treated as the predicted pose of the robot.

Scan area determination: It is obvious that scan area is nothing but the global map of the environment. The template image therefore needs to be matched within the reference image using cross correlation. The online application, however, is quite difficult. This problem can however be overcome by reducing the scan area. For this purpose, it is assumed that robot position will be within 250 mm around the predicted position and it is also assumed that heading angle error will be within the limit of $\pm 5^0$.

Cross correlation measurement: Matching is done on a pixel-by-pixel basis, where the template image is matched within the predetermined scan zone using correlation and some maximum value is obtained. The template image is then rotated through some small angle around the predicted orientation and this process is continued until the maximum value of correlation is evaluated.

Pose Update: After obtaining the best match region while the template is searched within the determined scan zone, the pose of the robot can be estimated from the result of matched region.

Experimental Results

The technique has been implemented in a PIONEER 3-DX model and it has been validated first offline and afterwards in an office-like environment of real world. Figure 3 shows a real indoor environment for conducting the test.

Workspace is taken as (35000x16000) sq.mm to perform the experiment. The total working zone is utilized to build the global map of the working environment which works as the a-priori map. The local maps are also built within this workspace so that the robot is able to localize itself within this unknown environment using scan matching technique. Laser and Robot pose data have been collected at 43 different places.

In Figure 4, the red line shows the path of the robot. This is the map which is built by obtaining data from laser range finder and the known pose of the robot that is obtained from encoder. This map is called the global map (shown in blue color in Figure 4) or a-priori map which works as a reference map for localization purpose. But as shown in the picture, it is seen that this map contains substantial error and this error is encountered as odometry data is used, from which the pose is obtained. This error can occur due to various reasons like unequal wheel diameter, difference of wheel base and wheel diameter from the nominal wheel base, wheel slippage, etc. It is obvious that one cannot proceed with this erroneous result. To rectify it, an algorithm has been devolved.

Figure 3: Real environment for conducting the test

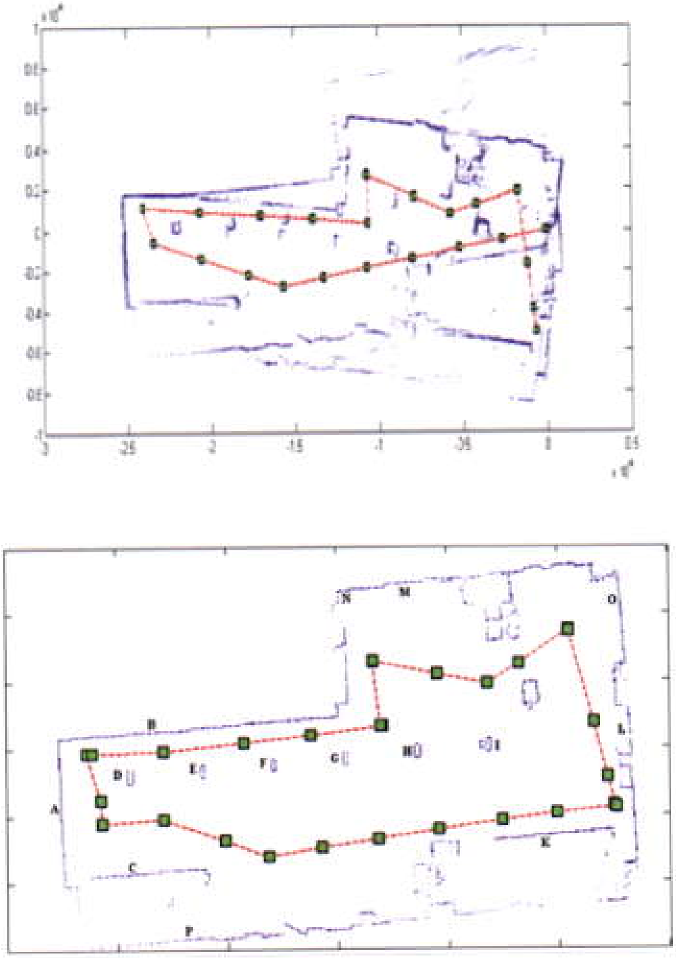


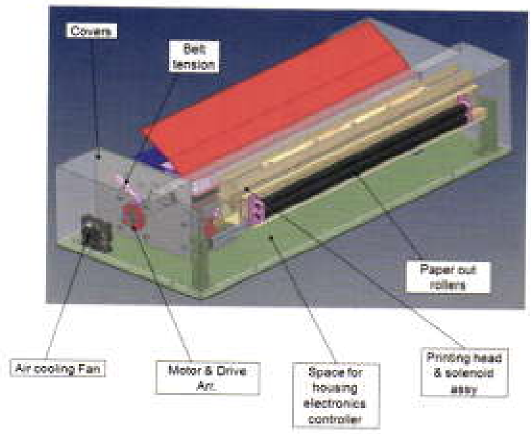
Figure 4: Generation of i) global map with odometry error ii) global map after eliminating the errors

HIGH SPEED INTER-POINT BRAILLE EMBOSSER

The project envisages developing experimental prototypes of High Speed Inter-point Braille Embosser – basically an impact printer used for printing Braille text formed by sequence of dots embossed on both sides of a paper medium. The project is sponsored by Department of Information Technology, Ministry of Communications and Information Technology, New Delhi with CSIR-CMERI and Webel Mediatronics Limited (WML) as joint collaborators.

CSIR-CMERI, Durgapur took up the task of indigenously developing a High Speed Interpoint Braille Embosser using state-of-the-art technology so that Braille books can be produced economically in bulk. It should be mentioned in this context that as of now, no indigenous Braille Embosser is commercially available in India. Even when procured from overseas, the maintenance support available is poor. The developed technology has immense societal benefit to blind academies. An experimental prototype of High Speed Inter-point Braille Embosser with a target speed of 30-35 characters per second with continuous paper feed was designed and developed, which would soon be commercialized for facilitating bulk printing of Braille books for the visually challenged.

The project focuses on the theoretical, numerical and experimental approaches to achieve a comprehensive understanding of the kinematic and dynamic phenomena occurring in nonlinear products, especially in products with parts involving impacts. The print head of a Braille embosser consists of an impact hammer – basically a spring-loaded ferromagnetic core placed inside a coil. When a dot is needed, a current pulse is sent through the coil. This creates an electromagnetic force on the core in the direction of the paper, forcing the hammer to strike the paper and the front stop. In the present development, the motion of the impact hammer (single-degree-of-freedom system) has been utilized to develop a Braille embosser. Braille systems accommodate a number of mechanical parts, which result in large noise and vibration, as has been ascertained through measurements. It is found that the system is very sensitive to changes in velocity through which the impact mass is moving. Altogether, this work contributes to better knowledge about aspects to consider when designing these types of products.



3D CAD Model of Developed Embosser

Design details

a) Printing Speed : 30 to 35 cps

b) Paper feed : Continuous Tractor feed

c) Paper type : 120 – 140 GSM, Fanfold papers

d) Paper size : Width: 210 - 297 mm, length: 297 - 500 mm

e) Print format : Single & double sided

f) Interface with PC : Through serial port / USB port

g) Power Supply : 180 to 240 V AC, 1 Ph, 50 Hz

h) Control Panel Buttons : Start, Stop, Change set up, Online / Offline, Form Feed

i) Display : LCD based Display of Operations with Audio Support

j) Print set up : Through control panel buttons, Instructions through audio messages and feedback.

k) Target price : Rs 1.50 lakhs (approx.) for bulk production.

Braille Embosser

RESEARCH INITIATIVES IN THE RECENT YEARS

MOBILE ROBOTIC SYSTEM FOR VISUAL INSPECTION IN HAZARDOUS ENVIRONMENT

Backdrop

Mobile robots have many popular and potential applications. These may be used for material handling and transportation in manufacturing environment, as also in nuclear, hazardous chemical or battlefield environments where human intervention is dangerous and costly. Mobile robots also find application in remote or inaccessible surroundings such as mining, outer space or microscopic environment.

According to International Atomic Energy Agency (IAEA), surveillance is very important for safety in nuclear power plants [Safety Series No. 50-SG-O8 (1990)]. For the management of safety over the lifetime of a nuclear power plant, in-service inspection (ISI) is an important measure for assurance of equipment integrity and the avoidance of failure. The necessity of risk-informed in-service inspection is rapidly increasing, particularly after the Chernobyl disaster of the late 80s. If properly implemented, risk-informed in-service inspection programmes can lead to the improvement of plant safety. Robotic systems armed with appropriate manipulators comprise important means for carrying out surveillance operation and/or transport of material inside the nuclear vault. The technology, while matured in advanced countries, is not readily available due to strategic reasons, and this was the motive force that prompted undertaking of the project by CSIR-CMERI, Durgapur.

In terms of surveillance objectives, this project deals with the inspection of tanks filled with radioactive liquid in an enclosed environment, with 11 tanks residing in an underground chamber. The chamber, 60 m X 9 m X 6 m in dimension, is provided with a 1 m X 1 m opening on its top roof for the passage of inspection equipment. In the underground chamber, the tanks are installed on steel structure on the floor and the bottom level of the tanks is at a height of approximately 1.5 m from the floor of the chamber. A massive steel structure including piping is installed inside the chamber and most of the structure is laid above the tanks. Additionally, a network of AC ducts runs just above the proposed track of inspection. Considering the layout of the chamber and given that the environment is highly radioactive, the site for all practical purposes remains inaccessible to human operators, thereby ruling out permanent installation of surveillance equipment requiring regular maintenance. The only possible means of inspection rests on the deployment of a suitable robotic system armed with necessary equipment.

Even then, the task of deploying a robotic inspection system is daunting since the robot has to traverse a severely constrained path imposed by the geometrical limitations of the construction. The maximum width of the track space is only 450 mm and the maximum allowable height is 650 mm. The task is rendered even more critical by the total absence of illumination.

The dimensions of the robotic vehicle including the manipulator have been designed under these given constraints, where the width of the vehicle is 420 mm and the overall height – including the manipulator in folded condition – is 650 mm. The designed mobile robotic system – comprising a robotic vehicle and an installed manipulator – operates in an untethered mode and carries its own power pack, onboard intelligence and a number of camera and lights. The system navigates on a properly designed slotted track installed at the site. The robotic surveillance system is equipped with suitable navigation sensors with the help of which navigation takes place by following the slots laid on the tracks. A specially developed navigation algorithm guides the system during the operational phase. The system is launched at the site through the top hole of the chamber roof. The system operator controls the robotic system from the remote control station. The system has hybrid operational capability and responds to both autonomous and teleoperation intervention.

The working prototype being developed at CSIR-CMERI is a dual mode (manual & autonomous) system.

- Capable of manoeuvre through narrow path
- Six-axis manipulator can handle up to 6 kg payload with a reach of 700 mm
- RF Communication network with radiation protected permanent passive device inside vault
- Online transmission of huge video data (56 Mbps) through the unstructured mesh of steel structure over a range of 100 m
- Virtual representation of vehicle and environment inside vault in the remote station
- Emergency handling with power management

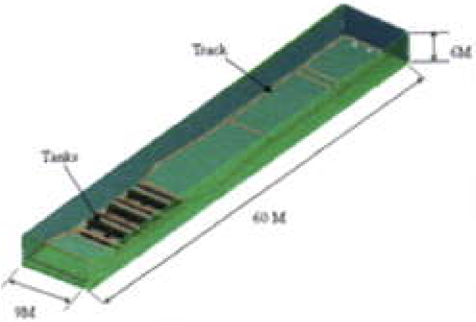


Figure 1: Schematic view of the tanks and the track

Figure 2: Robotic System – Vehicle with Manipulator

The Robotic Surveillance System

The configuration of the robotic vehicle is shown in Figure 3. Two individually controlled motors are fitted with two wheels for driving the vehicle. Two main wheels are mounted on two sides at the center of the vehicle, and four idler wheels are provided at the four corners. As the environment is enclosed and not accessible, the robotic system is equipped with redundant sensor modules for efficient environmental perception, navigation and data acquisition. The vehicle is designed to work in an untethered manner since the working environment is expected to be cluttered, thereby leading to unwanted entanglement if tethered.

The overall dimension of the vehicle is shown in Figure 3. The shape of the body is like an enclosed rectangular box. The casing of the body is made of steel plates of 5 mm thickness. To protect the components inside the vehicle from radioactivity and combat the generated heat, judiciously planned inlet and outlet passages for continuous flow of air have been introduced in the design.

The arrangement of the battery banks, controller, SBC and Infrared sensors are shown in Figure 3. The motors are arranged vertically to reduce the width of the vehicle. A number of guide rollers are fitted on each side of the vehicle to prevent damage due to collision of the vehicle with the sidewall of the track.

There are a number of openings on the body of the box for suitable assembly of motor shafts, electric wires, WLAN antenna, IR sensor, etc. Proper care has been taken to ensure sufficient protection of these locations from radioactivity and for facilitating maintainability and accessibility.

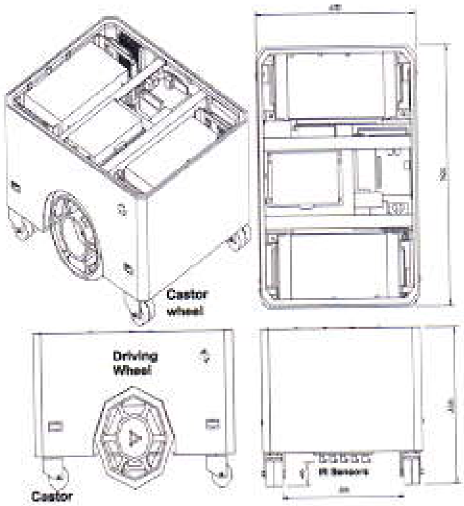


Figure 3:

Manipulator Design, Workspace and Control

The manipulator, as has been discussed earlier, has a highly constrained working zone of only 450 mm width along which the robotic vehicle is supposed to navigate. Over and above, the path has many sharp 90° turns. The area for placing manipulator base is small, which is disadvantageous from the stability point of view. The end-effecter is a camera for visual inspection. Considering these issues, articulated configuration of the manipulator is selected, where all the joints of the manipulator are revolute in nature. The manipulator has five degrees of freedom and rotation ranges are selected considering that the manipulator will rotate 90° through first and then inspect the cylinders. Accordingly, the links have been designed as shown in Figures 4 & 5. To achieve the desired reach, the manipulator has been mounted on an elevated base. The relevant design parameters of the manipulators are given below:

Configuration	Articulated or jointed
Payload	3.0 kg
Reach	750 mm
Degrees of freedom	5
Actuators	DC servo motors
Operating mode	Programmed &/or Manual
Material of Construction	SS 304L/SS316L
Joint ranges :	
Joint 1	± 120°
Joint 2	0° to 200°
Joint 3	-60° to 150°
Joint 4	±90°
Joint 5	±90°

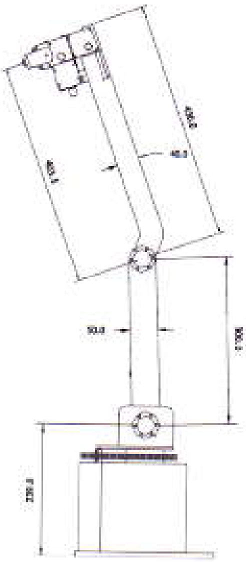


Figure 4: Manipulator - fully stretched condition

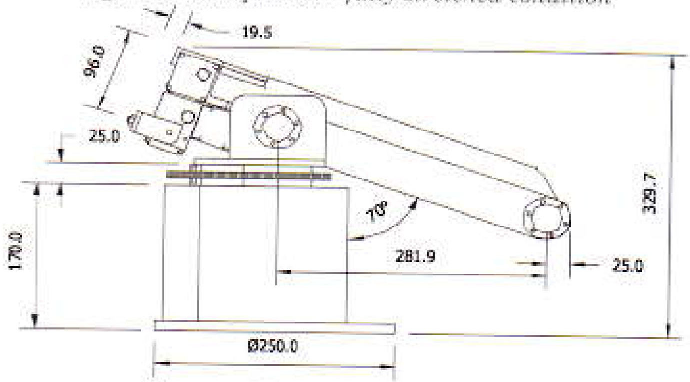


Figure 5: Manipulator - closed condition

The workspace of the manipulator indicates the region within which the manipulator carries out the desired activity. The workspace is dependent on the configuration, link lengths and ranges of various joints. Based on the manipulator parameters, the workspace has been evaluated and is shown in Figure 6.

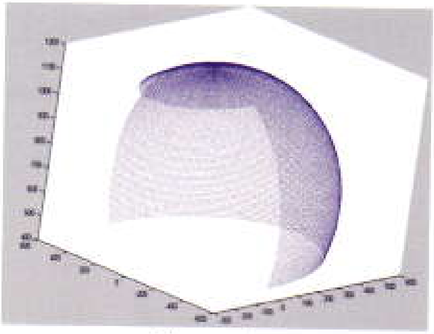


Figure: 6

During inspection, the operator controls the manipulator from the remote control station with the help of a GUI. At first, the operator places the vehicle in the desired location by proper localization technique. The image of the manipulator along with the local environment is transmitted through the wireless communication link to the GUI window. The operator controls the motion of the manipulator from the GUI with the help of the image. The manipulator also operates in auto-mode.

Power

The payload, speed & mission times are directly related to the energy pack the system carries. The capacity of the driving motors is evaluated based on the total weight and speed of the system. The power pack comprising the battery is one of the heaviest components that increases the weight of the vehicle and hence consumes more power. The increment in one parameter may affect others. Judicial selection of parameters is therefore very important for efficient and optimal performance of the system. A number of optimizing iterations have been carried out for finalizing the design.

Considering such parameters as the specific energy (energy-to-weight ratio) and energy density (energy-to-volume ratio), standard high-performance Li-polymer batteries having high energy density, high specific energy and low self-discharge have been selected for the power pack since these batteries have less packed weight (10-30%) and do not suffer from any electrolyte leakage.

For vehicle, power for two motors	70 x 2 W= 140 W
Power required for articulated manipulator	300 W
Motor Controller Card (for both vehicle & manipulator)	105 W
SBC	125 W
DSP card	15 W
Camera	20 W
Others	100 W

Weight

Weight of the manipulator (with controller)	35 kg
Weight of RF, Bumper, Camera	7 kg
Weight of the vehicle (with battery, motor etc)	80 kg
Total weight of system	122 kg

Navigation

In the manual intervention mode, the operator controls the robotic vehicle from the remote control station with the help of a suitably developed GUI. The robotic vehicle is linked to the control station by a server-client network (WLAN) where the robotic system acts as the server and the control station as the client. The positional information of the vehicle is transmitted to the remote computer (i.e. the client) through wireless communication link. In addition, the camera fitted on the manipulator grabs the image of the identification number of the tanks and sends the image to the client.

The position of the vehicle in the working environment is ascertained with the help of suitable landmarks installed at selected places and with the help of encoder data from motors. Identification numbers are engraved on the tanks used as landmarks. With the help of the camera fitted on manipulator, the operator identifies the landmark and ascertains the position of the vehicle. Encoder data is used for position localization when the vehicle is between two landmarks. The combination of landmark & encoder data provides a safe and reliable technique for vehicle localization. With the positional information of the vehicle, the operator controls the vehicle with the help of four commands viz. "Go Ahead", Go Back", Turn Left", and "Turn Right" as and when required.

During the execution of these commands the control of the vehicle along the desired path is achieved autonomously with the help of sensor based navigation. The vehicle tracks the slot on its path by camera and IR sensor during the forward, backward or turning motions.

An array of five IR sensors, facing downwards and placed at the bottom of the vehicle, measures the deviation of the vehicle from the slotted path, which acts as a guide. The measured data helps to initiate control action for adjusting the speed and maintain alignment of the vehicle.

Figure: 7(a)

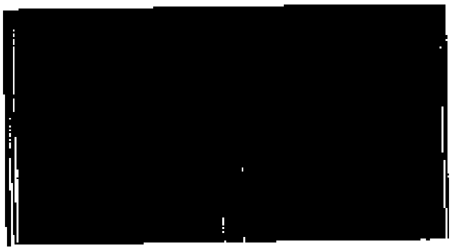


Figure: 7(b)

Cameras used for navigation purpose carries their own light source and are fitted at the front of the vehicle in the vertical direction and at the rear to capture the images of a portion of the path. The image with six distinct parallel lines indicates a straight path. Two pairs of outer lines represent the edges of the guide channel, whereas a pair of inner lines represent the edges of the slot at the centre of the path. To reduce the computational load, only a portion of the central image is processed from the full image. The deviation of the inner pair with respect to the central axis of the image provides the measure of the positional and rotational error of the vehicle [Figures 7a & 7b].

The high deviation from the central axis and the encoder data of the motors help in taking decision for turning of the vehicle. Hence, the image data confirms the encoder data regarding the turn ahead and also provides a measure of the turn. A number of experiments simulating the navigation of the robotic vehicle in real situation were carried out for understanding the suitability, effectiveness and performance of the IR and vision sensors before finalization of the conceptual design of the system.

The robotic vehicle may have positional error due to (i) a little offset sidewise or (ii) a little rotation about its own CG or (iii) a combination of position and orientation. The error in position and orientation of the robotic vehicle can be computed from the image.

The task of the surveillance robotic vehicle is to acquire images for visual inspection of the tanks. After the complete inspection it follows a straight-line path for return. One landmark is used for every turning position. The landmarks, simple strips of plates or pieces of magnet or some other means, indicate the turning positions. The exact type and nature of the landmarks have been finalized based on the exposed nature of the environment to radioactivity. Proper logic incorporated in the navigational algorithm assists in taking right decision at the junction points with the help of sensor data and landmark.

Control & Communication

The vehicle is connected to the remote control station above the ground by wireless communication with the help of server client architecture, where the robotic system acts as the server and the computer at the remote control station acts as a client. Among the three channels in the communication link, two channels are used to transmit camera images from the inspection site to the client node and the unidirectional data flow and the third channel is used to transmit control command, control data, navigational information, etc. in bidirectional mode.

The electronic circuitry in the surveillance system has been shielded against radiation through enclosure in a radiation proof container. A frequency band 1.3 to 2.4 MHz suitable for the wireless network has been selected and a repeater installed in the opening of the chamber to avoid link failure due to penetration of wall. Since radiation-hardened sensors are scarcely available, the selection rests with image sensors for navigation and visual inspection, infrared sensors to follow the track, and bump switches to avoid collision damage instead of LRF and acoustic sensors, as optical devices are affected by radiation and acoustic devices by the adverse echo effects. Image processing is carried out by DSP processor where a box made of radiation hardened steel covers the entire electronic circuitry. The controller circuitry of the mobile robot is made of SBC, DSP based ARM controller and PSK transmitter for wireless network.

Launching

After being placed on the track, the operation of the mobile robotic system and inspection of the cylinder can be carried out with the help of the manipulator in either manual or the auto mode. The vehicle returns to its home position for retrieval after completion of inspection. The proposed launching system is shown in Figures 8 (a, b, c).

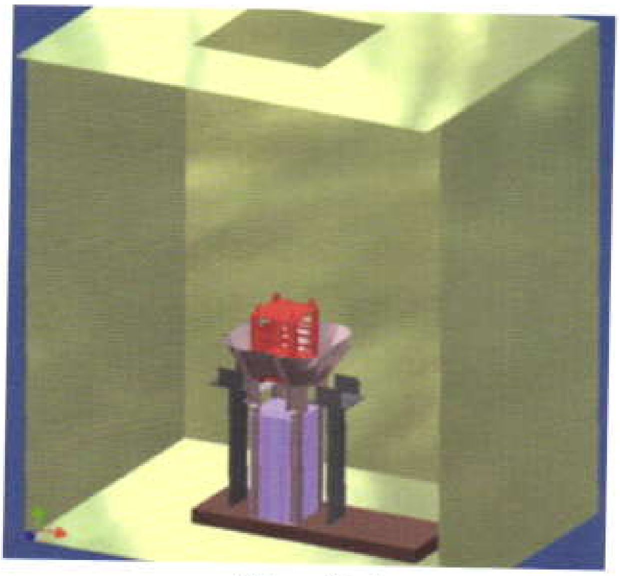


Figure : 8 (a)

The vehicle is carried by a cage as shown in Figure 8a. The cage is suspended with the help of a guided pulley through the top opening. A conical shaped hopper ensures proper positioning and orientation of the cage – as also of the robotic vehicle – on the desired position of the track (Figure 8b). A suitable locking lever mechanism has been designed that unlocks only during the escape from the cage and locks when the vehicle enters into the cage.

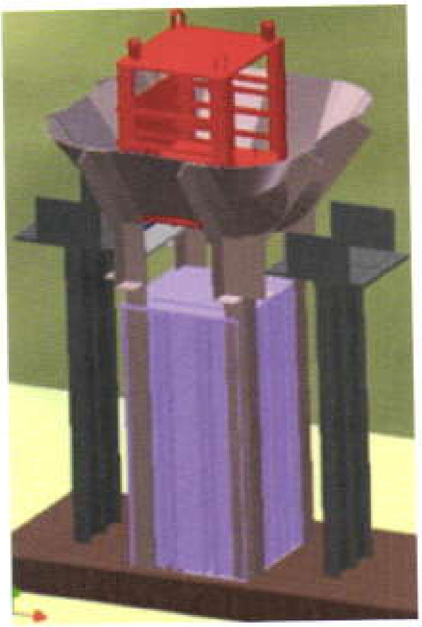


Figure: 8 (b)

Figure : 8 (c)

SOLAR ADSORPTION COOLING SYSTEMS: AN ATTRACTIVE ALTERNATIVE

Introduction

Demand for human comfort and industrial requirement for air-conditioning, especially in a developing country like India, is increasing at a fast rate. Sixty percent of present air-conditioner market in India is served by small window and split AC systems, and the rest by central AC systems. Most of this demand is being met by vapour compression based refrigeration systems. Recently, though nominal, some vapour absorption based refrigeration systems have been introduced for industrial and office building use.

Conventional vapour compression based air-conditioning systems consume substantial electrical energy, thereby contributing to the depletion of fossil fuel resources. Moreover, peak electricity demand during summer is being re-enforced by the propagation of air-conditioning appliances. Refrigerants in use pollute the environment through greenhouse gas emission and release of ozone layer depleting substances.

Solar energy driven sorption refrigeration systems do not have these problems. The peak requirement for air-conditioning coincides most of the time with the availability of the solar radiation, making solar cooling a much more attractive option.

Adsorption systems are 100% environmentally benign, having zero Ozone Depletion Potential (ODP) as well as zero Global Warming Potential (GWP). No mechanical power is needed, saving valuable fossil fuel resources.

Solar adsorption technology

Adsorption is a process resulting from the interaction between a solid and a gas, based on a physical or chemical reaction process. The adsorption process concerns separation of a substance from one phase, accompanied by its accumulation or concentration on the surface of another. An adsorption refrigeration machine utilizes the phenomenon of physical adsorption between a refrigerant and a solid adsorbent. The adsorbent is heated by solar radiation for desorption of refrigerant. Natural refrigerants of the adsorption system such as water, methanol, etc. have zero ODP and zero GWP. It is also attractive for the efficient use of solar energy and low-grade waste heat. Adsorption systems are compact and noise free, less sensitive to shocks and to the installation position. These do not require frequent replacement of adsorbent. Such systems have minimum rotating parts, no refrigerant/adsorbent pump and so entail extremely minor maintenance/service issues. Moreover, adsorbent systems are totally free of either corrosion or crystallization problems. Flexibility in regeneration temperature for part load operation is much more than that in absorption systems (Figure 1).

Worldwide, many groups are undertaking advanced research on a number of adsorbent–adsorbate pairs like

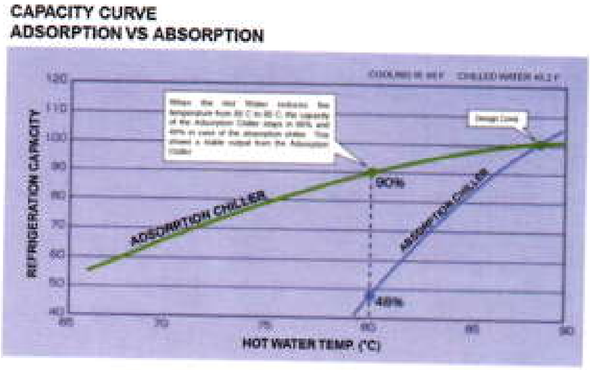

CAPACITY CURVE
ADSORPTION VS ABSORPTION

Figure 1: Effect of temperature variation on chiller performance

zeolite–water, activated carbon–ammonia, activated carbon–methanol and silica gel–water, etc. Among the pairs, silica gel–water system appears to be ideal for solar energy utilization due to its low regenerating temperature.

The technical feasibility of solar thermal adsorption cooling system is well established. It is also clear that these systems offer an environmentally clean alternative technology for cooling and refrigeration. However, since the system performance in terms of initial and running costs plays a major role for the end-user, it is essential to make these systems economically viable: herein lies the challenge.

Research at CSIR-CMERI on solar adsorption chiller

CSIR-CMERI, Durgapur in collaboration with the Solar Energy Centre, Ministry of New and Renewable Energy is executing a research project on solar-powered adsorption based space cooling system with the adsorbent-adsorbate pair of silica gel and water. Silica gel, a well known water adsorber, is used for dehydration purposes in different domestic and industrial applications. Micro-pored silica gel, which has larger adsorption capacity at low humidity, is suitable for utilization in a closed cycle at sub-atmospheric pressure refrigeration system. Compared to other adsorbents, silica gel can be regenerated at a relatively low temperature, below 100°C and typically at about 85°C, which makes it the ideal choice for solar-powered adsorption system. Water has large latent heat of vaporization and it is suitable for air-conditioning applications, because chilled water temperature required is in the range of 8° – 12°C. The flow diagram pertaining to silica gel-water adsorption chiller is illustrated in Figure 2.

In order to emerge as an elegant and effective technology, adsorption systems must have their size and cost reduced. The achieve these goals internal and external heat transfer of the adsorber should be enhanced to increase the Specific Cooling Power (SCP) and heat management has to improve to increase the COP. The main technologies to enhance the external heat transfer in the adsorber are related to the increase of the heat exchange area, the use of coated adsorbers and the utilization of heat pipe technology. To improve the internal heat transfer, the most suitable option is the employment of consolidated adsorbents. An optimum compromise should be achieved between the high porosity necessary for fast vapour diffusion and the high density required for good thermal conductivity.

Although investment costs for adsorption chillers are still high, the environmental benefits are impressive when compared to conventional compressor chillers. The absence of harmful or hazardous products such as CFCs, together with a substantial reduction of CO_2 emissions due to very low consumption of electricity creates an environmentally safe technology. Low-temperature waste heat or solar energy can be converted into a chilling capacity with minor maintenance costs.

With improvement in sorbent and reactor technology, there is a strong possibility of adsorption systems offering a viable alternative. Sustained efforts are needed to make these systems efficient and economically viable.

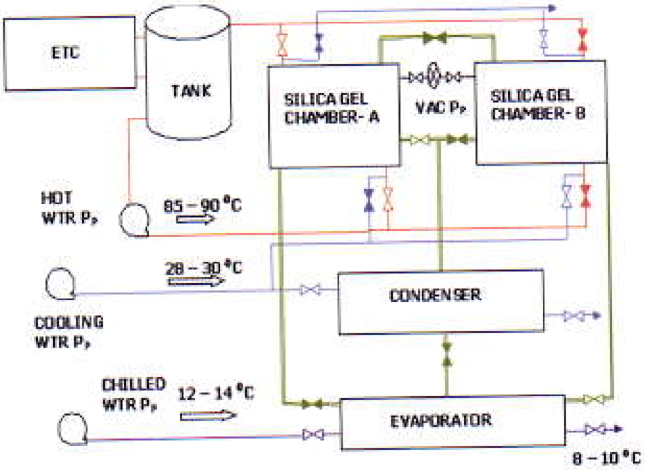


Figure 2: Flow diagram of silica gel-water adsorption chiller

Figure 3: Solar Water Heating System and Sorption Heat Exchangers at CMERI

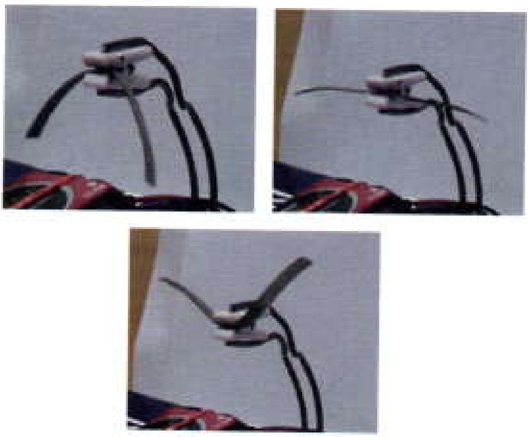
A SIGNIFICANT STEP TOWARDS DEVELOPMENT OF BIO-INSPIRED MECHANICAL DEVICES

The Chemistry & Biomimetics Group at CSIR-CMERI, Durgapur took up an ambitious project for mimicking stimulation of Ionic Polymer Metal Composite (IPMC) membrane by biological nerves/cells with a view to develop bio-inspired mechanical devices – an area that is sure to emerge in the cutting edge of science in the near future. The Project had as its primary aim the following:

- Development and micro-fabrication of Ionic Polymeric Metal Composites (IPMC) / bio-compatible polymers through patterning and plating electrode, optimization of the performance by choosing ions and polymers
- Adhesion of living bio-materials on to the polymeric micro-structures and activation of IPMC through action potential generated by nerves to generate a voltage, which is subsequently amplified and applied to an electro-active IPMC sample (ionic polymeric artificial muscle) to cause it to bend, flex, and deform
- Demonstration of movement of the IPMC cantilever sample and polymeric micro-structures triggered by living cells, and optimization of the movement (bending, flexing and twitching) of the IPMC made artificial muscle

In the course of the Project, the Group could contrive a novel method of metallization of Nafion film using $[Pt(H_2O)_4]^{2+}$ complex. An ionic polymer-metal composite (IPMC) was derived through surface electroding of Nafion membrane. However, the $[Pt(NH_3)_4]Cl_2$ complex is very expensive, and its preparation from chloroplatinum salt is quite time consuming as a number of steps are involved. Preparation of $[Pt(H_2O)_4](ClO_4)_2$, however, is comparatively cheaper and simpler as relatively inexpensive K_2PtCl_4 is used. Actuation response of the developed IPMC was measured through chrono-potentiometry with a square wave of 5 s duration as a function of a bidirectionally applied current of 200 mA strength. The IPMC actuators used measured 2 cm x 5 cm and the displacement of the free end of the actuator was measured at a distance of 3 cm from the fixed point by a laser displacement sensor at room temperature. Recently, efforts for replacing the expensive platinum salt with a nickel compound has met with success and an actuator using the IPMC so developed has been found actuating at a considerably low potential range (+2.5V to -2.5V) and have further been found to be exhibiting very regular and quite comparable electrical, electrochemical, and actuation properties.

A cell culture room equipped with Laminar flow, Inverted microscope, CO_2 incubator, Autoclave, low temperature centrifuge, low temperature refrigerator (up to -85 °C) was built up during the course of the Project. Encouraged by the obtained results, the possibility of developing IPMC by surface deposition of copper is being explored.



Successive photographs of the IPMC strip showing deformation under time-varied voltage from +2.5 to -2.5 V.

CSIR-CMERI LENDS ITS EXPERTISE ON SELECTIVE MECHANIZATION OF DURGAPUR STEEL PLANT

Durgapur Steel Plant (a unit of Steel Authority of India under Ministry of Steel, Govt. of India) has executed a MOU with CSIR-CMERI, Durgapur for mechanization of selected activities of operation in order to reduce human intervention, so that issues related to industrial productivity, safety and human fatigue are addressed. These tasks are broadly classified as follows:

- Automation in the process of feeding the coil tip in Coiler Pinch Rolls (CPR) in the Skelp Mill, automation in the process of fixing the clip in the last lap of the coil with the penultimate lap in the coiler assembly set-up
- Design & development of an electromechanical system for holding & shifting of red hot forged wheels in the Wheel & Axle Plant and automated cleaning system for Rail wheels before NDT in the Wheel & Axle Plant, and
- Design of a mechanized system to replace tuyeres in the Blast Furnace.

Automation in the Skelp Mill

The Skelp Mill at the Durgapur Steel Plant employs a continuous process with roughing mill and finishing mill trains. It was commissioned in the year 1968 and its annual production capacity is 250000 Metric Ton. It produces skelps in widths varying from 146 mm to 235 mm in thicknesses varying between from 2-4.33 mm, the output being used for making pipes. The tolerance of the skelp is -0.0 to +4.0 mm on the width and -0.2 mm to +0.2 mm on thickness. In the existing system, the moving hot skelp tip from the apron conveyer end is grasped with the help of an extended tong by the operator and placed between the CPR (Figure 1). The moving pinch roll is then closed from the remote control cabin. The CPR then drives the hot skelp through the guide rolls which finally gets coiled in the vertical coiler. Next, fixing of the last lap of the coil with the penultimate lap of the coiled skelp is the done with the help of a clip by the operator as shown in Figure 2.

Figure 1: Present method of hot skelp coil tip feeding in-between CPR (a) Hot skelp on conveyor bed (b) Operator grasping the hot skelp with a tong (c) Operator feeding the hot skelp in-between CPR

Figure 2: Present method of clip fixing

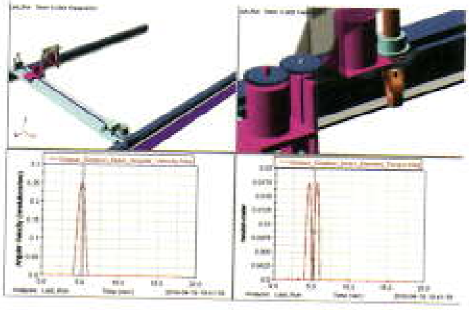
The process, labour intensive in nature demanding direct human intervention in hazardous conditions, needed a system for automated fixing of the hot skelp coil tip in the CPR (skelp feeding) and automated clip fixing to increase the productivity and augment human safety. CSIR-CMERI, Durgapur stepped in to solve this problem through appropriate automation of the process; the foregoing report provides the details.

The temperature of the skelp recorded at the conveyer entry portion is about 860^0-870^{0}C and near the entry of the Pinch Roll this is about 659^0- 671^{0}C. The ambient temperature at a distance of about 5 m from the conveyer is about 70^0-80^0 C. Hence robust electrical interlocks with adequate redundancy are preferred in the first stage of development over microprocessor based sophisticated electronic control with multiple sensors. The choice also adds to the mechanical and structural integrity of the system enabling it to withstand collision with hot skelp in the event of jamming at the time when the hot skelp is to be removed from the conveyer with the help of EOT cranes.

The challenging task of providing an innovative solution for automating the feeding of hot skelp coil tip in CPR with vertical axis coiler was carried out at CSIR-CMERI, covering all the engineering aspects right from conceptual designs, system analysis to detail design. The conceptual schemes were jointly evaluated by DSP and CSIR-CMERI on their effectiveness and on mutual agreement work on detail design and analysis commenced after selection of the conceptual model.

Conceptual design of the proposed system was accomplished using solid modeling software and simulated in ADAMS (scale 1:1) to analyze its dynamics including all its drives. The five drives included the Linear Guide drive (Motor M1), the Cross Slide Drive (Motor M2), the Vertical Drive (Motor M3), the Gripper Rotation Drive (Motor M4) and the Transporter Drive (Motor M5). Multibody dynamic simulation pertaining to the drives 1-5 are provided in Figure 3.

a



b

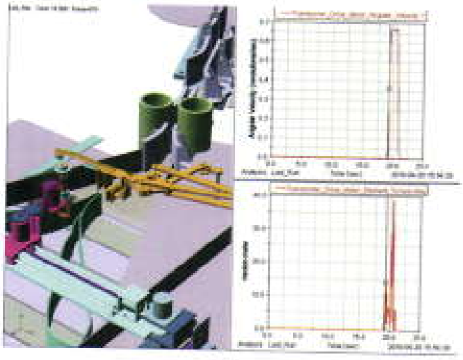


Figure 3: Multibody dynamic simulation (a) Gripper Rotation Drive (b) Transporter Drive

The Transporter Assembly, which is in direct contact with the heat affected zone, is one of the important units of the system for automatic feeding of the hot skelp in-between the CPR. Finite element analysis of the assembly was carried out to analyze the level of stress and deformation in different components of the assembly. The assembly basically consists of linkages which work on the principle of peaucellier straight line mechanism. The model was created in HYPERMESH and analysis was carried out using explicit nonlinear finite element code LS-DYNA. The meshed model of the system (Figure 4) was developed where the tubular components were meshed using 4 node shell elements and the tie rod, being solid, was meshed with 8 node brick elements.

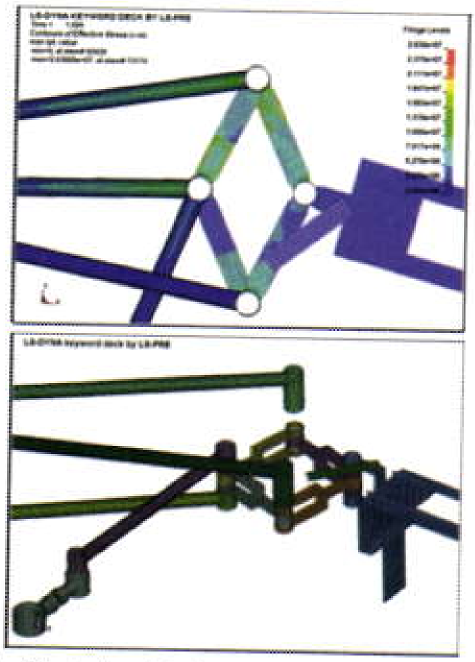


Figure 4: Meshed model & FE Simulation of the transporter assembly

Observations revealed that the maximum stress (maximum 314.8 MPa) developed in the tie-rod of the driving link due to the bending of the link in the x-y plane while in the other links the stress level was low (maximum 78.2 MPa) due to longitudinal stresses only.

The detail system engineering comprising designing of mechanical gripping, positioning, transporting and feeding devices for automatic feeding of the randomly oriented hot skelp coil tip in-between the CPR without manual intervention in the conveyor region was then completed so as to form a compsite set-up. Figure 5 represents an isometric view of the detail design, which consists of two important sections, namely (i) skelp gripper and puller section and (ii) skelp transporter section.

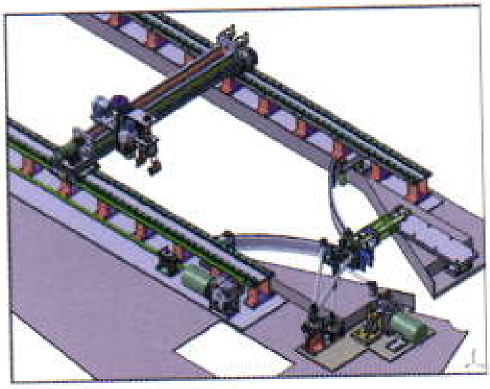


Figure 5: Isometric View

The skelp gripper and puller section consists of a four-axis drive unit, that comprises the linear drive, the cross drive, the vertical drive, along with an arrangement for rotational orientation of the gripper to grip the hot skelp coil tip. After gripping, the skelp tip is pulled through a distance and fed to the transporter section. The transporter consists of a pair of metallic pads – the left pad being attached to the link bracket of the peaucellier mechanism and the right pad to a bracket with a pneumatic cylinder. When some portion of the skelp tip protrudes out of the deflector guide, the pneumatic cylinder is actuated to grasp the flat surface of the skelp in-between the pads and feed it to the existing CPR. Thereafter, the existing system operates i.e. the moving pinch roll presses the hot skelp against the idler pinch roll, controlled from the remote control cabin by the operator. Subsequently, the CPR drives the hot skelp through the guide rolls on to the vertical coiler. It is to be noted that as soon as the hot skelp reaches the mouth edge of the deflector guide the system is fully under automatic control.

Automation in the Wheel & Axle Plant

Mechanization in Wheel & Axle plant comprises design and development of an electromechanical device for holding and shifting of red hot forge-rolled wheels to ensure human safety. Presently forged wheels are left in red hot condition on the floor: shifting it to a desired place is difficult and presently it is handled by overhead cranes using brackets made of normal rods. This also entails human intervention (Figure 6).

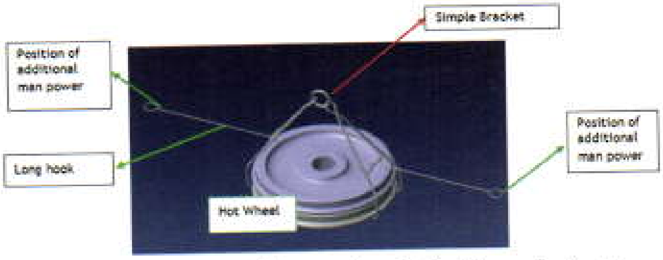


Figure 6: Present shifting method of hot forged wheels

The wheel is at a temperature of 900^{0}C, due to which it is impossible to venture near the wheels. However, additional manpower is required in such a hazardous environment to fix the brackets under the hot wheel using long hooks. This system is neither economical nor safe. CSIR-CMERI proposed a novel mechanical device, which can automate the present system requiring only remote intervention of an operator. After several joint brainstorming sessions with DSP on appropriate automation of the system, a choice of concepts were produced. Out of these, one was chosen jointly, for which detail design and manufacturing drawings have been produced at CSIR-CMERI (Figure-7).

Figure 7: Various concept design and their lab scale prototypes

Automation in Blast Furnace

To run the blast furnace, high pressure blast furnace gas is injected continuously through copper tuyeres around the blast furnace. During continuous operation of the blast furnace, some of these tuyeres need to be replaced due to leakage of blast furnace gas and jamming of slag or coke in front of tuyere. At present, the replacement of tuyere is done manually. Around 10-15 persons and normally 3-4 hours are required to replace one tuyere. Sometimes one tuyere replacement takes 7-10 hours when lancing is required. These factors render replacement of tuyeres highly laborious. Moreover space limitation, humidity and high temperature around the blast furnace makes work environment miserable. This problem has been addressed in this ongoing project through selective automation.

The system designed for replacement of tuyere is remotely operated, and has been shown in Figure 8. It consists of five major components (assemblies): Table to hold the tuyere stock assembly (Table assembly), Table lifting scissors (Scissors assembly), Mobile platform (Base assembly), Puller for dismantling and placing the tuyere (Puller assembly) and Motor assembly to circulate oil in the cylinders of the hydraulic system.

The table of the system has four movements viz. X-X direction (longitudinal), Y-Y direction (Transverse) Z-Z direction (Up and down) and Swiveling (angular rotation of X-Y plane) for easy alignment of tuyere stock assembly during dismantling and refitting. A hydraulic system is provided to power the X-X, Y-Y and swiveling movements of the table. The Z-Z movement is provided by a robust scissor lifting mechanism fitted under the table and powered by two hydraulic cylinders provided with two scissor arms. The table and scissor lifting mechanism are placed on a mobile platform to facilitate movement of the entire assembly from one place to another. The oil tank and motor of the hydraulic unit is fitted in the mobile platform which supplies hydraulic oil to all the cylinders including the puller cylinder fitted to the system. To avoid any movement of the platform and to increase stability during operation, two hydraulic ground locking devices have been attached at the extreme end of the platform. No operation is possible without engaging ground locking. During dismantling of the tuyere, a pulling force is required. This force is generated by the hydraulic cylinder of the puller assembly. The system is designed to apply a pulling force of 6T. (Figure 8)

The successful completion of the project will lead to tangible benefits in regard of the safety issues, and also contribute to productivity enhancement. The detail cost benefit analysis has been done by DSP.

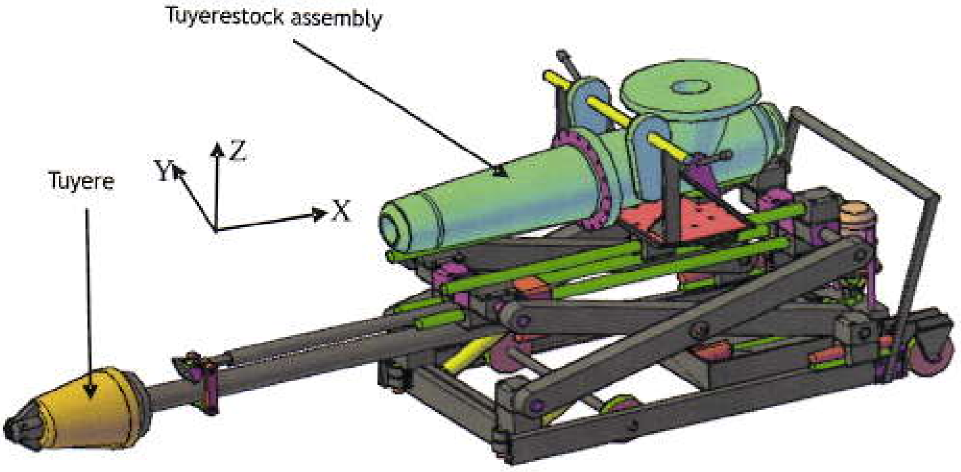


Figure 8: 3D CAD model of the designed mechanize system to replace tuyere

DEVELOPMENT OF NET-SHAPED PARTS WITH CRITICAL GEOMETRY THROUGH ADI TECHNOLOGY

Backdrop

Crank shafts of automobile engines are conventionally manufactured through the forging route. With the maturing of Austempered Ductile Iron (ADI) technology, manufacture the crankshafts through the ADI route is being attempted in a bid to replace steel crankshafts. CSIR-CMERI, Durgapur undertook a major R&D initiative to explore automobile crankshaft development through the ADI route and for this purpose identified the crankshaft of 3 cylinder, 35hp Sonalika Tractor Engine with the objectives of:

- Producing superior quality crankshaft from SG cast iron
- Developing and optimizing the austempering cycle to achieve the desired mechanical properties of ADI material
- Developing a comprehensive process technology consisting of casting, heat treatment, machining and balancing operation for manufacture of the identified product
- Conducting extended endurance tests and field trials for performance evaluation.

Promises of Austempered Ductile Iron

Austempered Ductile Iron (ADI) is a special type of cast iron that enjoys exceptional properties imparted through customized metallurgy. ADI is far more superior to commonly available cast irons and offers even better strength-to-weight ratio over steel. ADI has immense application in production of components having complex geometries and since the developed product is near-net-shape, the machining and associated expenditure can be drastically reduced. Some of the major advantages of ADI are:

- Good castability facilitating Near Net Shape castings
- Mechanical properties are comparable to some grades of structural steels
- Superior wear resistance properties in comparison to steel
- Higher damping capacity in comparison to steel
- 10% lighter than steel
- Require less energy for processing than steel components

Approach

The crankshaft of the 3 cylinder 35 hp Sonalika tractor engine is normally manufactured from EN19 steel having a bulk hardness of 277–311 BHN. Pin and Journal areas are induction hardened to a hardness range 54-56 HRc followed by grinding and polishing. Since the crankshaft is one of the most loaded components of an automobile engine, it is essential to ensure that the SG iron cast crankshaft is free from any casing defect. Additionally, the microstructure should have minimum carbide content (less than 5%), a high nodule count (> 150) and nodularity above 80%. In order to minimize the effects of impurities, it is also essential to judiciously select the correct grade of raw material and to follow the correct melting and melt treatment processes – all of which finally tell on the quality and reliability of the final product. To ensure adherence to a proper scientific methodology, the work content was divided into two major parts, namely, development of the specific grade of ADI material as per the international specification (EN/ASTM) to be followed by process technology development for the manufacture the ADI Crankshaft.

Development of ADI material

Austempered Ductile Irons have complex microstructure consisting of a mixture of acicular ferrite, carbon stabilized austenite, spheroidal graphite and carbide. Initially, the correct grade of raw material had to be selected, for which low manganese steel scrap, low manganese pig iron, selected foundry returns and broken graphite were charged and melted in a 100 kg induction melting furnace. At the end of melting, the carbon equivalent (CE = wt% C +1/3 wt% Si) of the molten iron samples was measured by C-Si analyzer and CE value was maintained between 4.3 and 4.6 by adding measured quantity of C and Fe-Si granules. Other alloying elements like Cu, Ni, and Mo were also added to the melt. Mg treatment of the melt was carried out in the ladle by plunging method followed by addition of Fe-Si dust. Mg content of the melt was maintained between 0.03 and 0.05 wt%. To achieve higher nodule count in the cast product, Fe-Si dust was also added in the stream during pouring of molten iron in the mould. Composition of the cast SG iron sample was maintained in the range of wt%: C - 3.4/3.8; Si - 2.3/2.7; Ni-1.2/1.6; Cu 0.7/0.8; Mg - 0.03/0.05; S-0.02 max. , P- 0.02 max. Figure 1 illustrates the SEM Microstructure of SG iron sample.

Figure 1: Microstructure (100X) of SG iron sample showing high nodule count of graphite

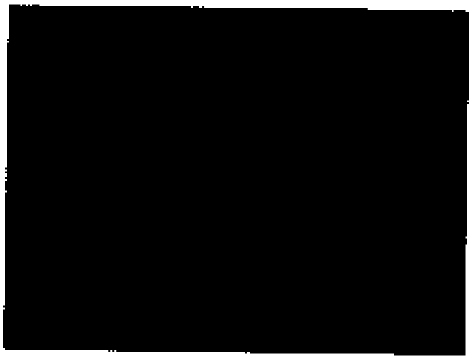


Figure 2: SEM Micrograph(900X) of ADI sample, showing graphite nodule, acicular graphite, C stabilized austenite and very little carbide

Considering the geometry and the end application of crankshaft, composition of the melt and austempering cycle was finalized. Test specimens were austempered at an Austenitizing temperature of 880°-910°C, with soaking time of 2-3 hrs so that temperature is uniform in all sections of the part and to saturate the austenite with carbon. This was followed by quenching of the specimens in a salt bath at an isothermal ambience of 370°-400°C for 2-3 hrs to produce an ausferrite matrix. Finally, the specimens were cooled to room temperature. Test samples, prepared as per the ASTM standards were tested for UTS, YS, %EL, Impact, and Fracture toughness (K Ic). Tensile tests and fracture toughness test were carried out in Instron machine. Tensile tests were carried out at a strain rate of 10-4. Tensile properties of ADI Gr-II as per EN/ASTM standards and mechanical properties of ADI samples are shown in Table 1. SEM Microstructure of SG iron and ADI sample are shown in Figure 1 and Figure 2 respectively.

Table 1-

Specification of ADI Gr II and the Mechanical properties of the developed ADI material

Specification of ADI Gr – II material	UTS (MPa)	YS (MPa)	% EL	Un-notched Impact (J)
EN 1564-1000/700/5	1000	700	5	80
ASTM 897-1050/700/7	1050	700	7	80
Mechanical Properties achieved				
No.1	1092	840	8	154
No. 2	1096	823	6.8	156
No. 3	1186	895	15	156
No. 4	1108	813	11.5	108
No. 5	1085	811	9.2	148
No. 6	1109	860	11.2	155

Development of ADI Crankshaft

Before manufacturing the ADI crankshaft for tractor engine, it is essential to cast SG iron blank without any casing defect. Brief outline of the process technology for manufacturing of ADI crankshaft is shown in Figure 3. Incorporating the necessary shrinkage and machining allowances, a three dimensional model was developed from the two dimensional drawing of the crankshaft. Figure 4 shows the 3D model of 3 cylinder 35hp crankshaft.

2 D drawing → Solid Model (3D) → Computerised Methoding → Pattern Making → Making of Sand Mould → Melting & Casting of SG Iron Crankshaft → Fettling & Inspection → Rough Machining of Cast Blank → Austempering Treatment of crankshaft to achieve desired hardness → Final Machining → Grinding & Polishing of Pin and Journals → Balancing → NDT & Dimensional Inspection → Assembly → Engine Test

Figure 3: Flow chart for development of ADI Crankshaft

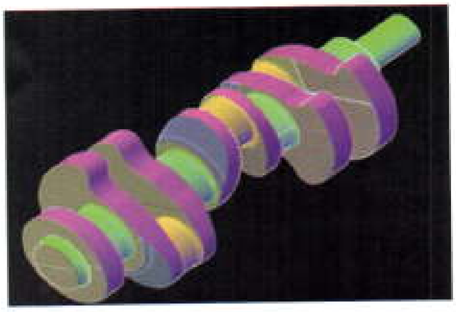


Figure 4: Solid model of the crankshaft of 3 cylinder 35hp tractor engine

The 3D model was subjected to computerized methoding with the help of AFS solidification software to finalize the optimum geometry of the riser and the runner. Figure 5 shows the location of the solidification shrinkage and geometry of the riser. Output of the methoding process was utilized for developing wooden patterns and core boxes. CO_2 sand moulds and cores were prepared from the wooden patterns and core boxes. Ceramic foam filter was used in the in-gate before assembly of cope and drag, which helped in minimizing the entry of oxide inclusions and the turbulent flow of liquid metal inside the mould cavity. These steps helped produce sound SG iron castings. Low manganese pig iron, steel scrap and graphite were charged and melted in the 100 kg induction melting furnace. Ferroalloys and pure Cu were finally added before tapping the molten metal from the furnace to the ladle at a temperature of 1450^0/1500^{0}C. Immediately after tapping, Mg treatment was carried out in the ladle by plunging FeSiMg and FeNiMg mixture to maintain Mg content of the bath between 0.03-0.05 wt%. Subsequently Fe-Si dust was added to the bath to produce the required grade of SG iron material. Clean molten metal was poured slowly in the sand mould at 1330^0/1350^{0}C. Exothermic compound was finally sprinkled on the riser to ensure proper feeding of liquid metal during solidification of the casting. After cooling to room temperature, the castings were taken out from the moulds (Figure 6). The soundness of the cast crankshafts were checked by visual inspection and radiographic test. Moreover, one sample was sliced at different locations to identify central line micro-shrinkage, but none could be found, establishing the soundness of casting (Figure 9). After fettling, the shaft was rough machined and an oil hole drilled through.

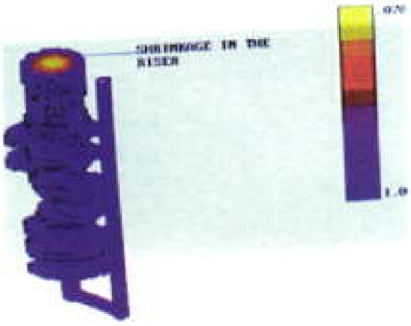


Figure 5: Photograph of computerized methoding of crankshaft carried out by AFS software

Figure 6: Photograph of SG iron cast crankshaft

Figure 7: Photograph of different section of the crankshaft showing no casting defect

It was observed that austempering treatment results in dimensional growth and distortion of ADI crankshaft mainly due to transformation of austenite to acicular ferrite. Proper fixtures were developed to restrict distortion of the crankshafts within a specified limit. The crankshaft was then austenitised at 880°/900°C for 2 hours and was followed by austempering in a salt bath at 380°/400°C for 2-3 hours. The heat treated crankshaft was then cleaned in warm water to remove traces of salts from critical part locations. Four semi-finished ADI crankshafts were delivered to M/S ITL, Hoshiarpur where final machining, grinding, polishing of pins and journals and balancing operations were completed. After final inspection, one of the crankshafts was assembled in a 35hp tractor engine and the engine was installed in the test cell of ITL's engine test bed (Figure 8). The testing of the engine was carried out for 500 hours as per procedural guidelines for engine testing, with the engine RPM varying between 1200 and 2100, and the applied torque between 204-170 NM respectively. All essential parameters were continuously monitored during the test procedure and no abnormalities were noticed. At the end of 500 hours the condition of all critical locations of the ADI crankshaft were examined, and was found to be quite satisfactory (Figure 9).

Technical challenges which were satisfactorily addressed are:

- Selection of correct grades of raw material and foundry chemicals
- Development of correct sand mould to ensure non turbulent flow of liquid metal to prevent unwanted casting defects in the finished SG iron castings.
- Optimization of heat treatment parameters with respect to chemical composition and geometry
- Controlling of salt bath temperature within the desired limits (± 5°C)
- Selection of appropriate grade of tools material, and
- Selection of sequence of machining and optimization of machining parameters.

Figure 8: Photograph of 35 hp tractor engine being tested at ITL Hoshiarpur

Figure 9: Photograph showing ADI crankshaft after 500hrs engine test

Process details

MIM combines the shape and design flexibility of thermoplastic injection moulding with the mechanical properties of high performance metal powder, which renders the process a cost-effective solution serving a variety of industries. As opposed to either traditional or investment casting, the MIM process has the capability of producing parts having complex geometries. Moreover, tensile strength, elongation and hardness of parts produced through the MIM route are superior in comparison to traditional press and sinter techniques and equivalent to normal wrought parts.

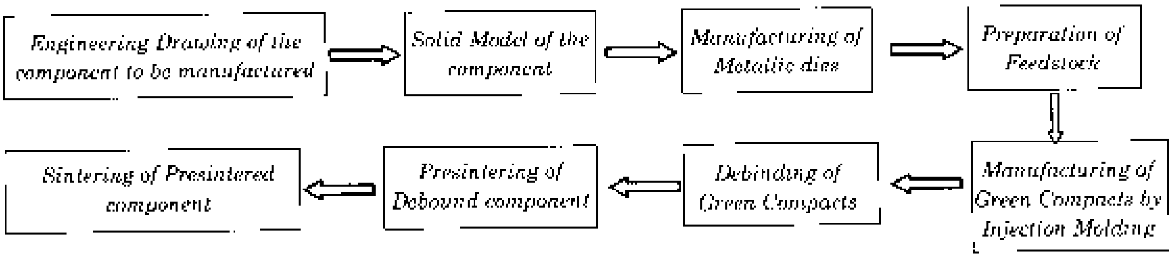


Figure 2: Flow Diagram of Metal Injection Moulding (MIM) process

The MIM process consists of mixing, injection moulding, debinding and sintering. Figure 2 illustrates the Flow Diagram pertaining to the process illustrating the various steps involved in the manufacture of a component.

The MIM process starts with the mixing of selected powders and binders at a chosen volume ratio to prepare the feedstock. The feedstock is subsequently injection moulded into the desired shape by heating in the moulding machine and hot ramming it under pressure into the tool cavity. By virtue of the binder, the feedstock viscosity reduces, causing its flow into the die cavity under pressure. Cooling channels in the die extract heat and solidify the polymer to preserve the moulded shape. The green compacts obtained are subsequently processed to remove the binder in the debinding stage in a controlled atmosphere and then subjected to sintering to obtain a higher density product.

Component development involves first preparing a solid model to determine the gating system of the die. Mould design parameters for the green compact such as shrinkage value, gating & ejection are taken into consideration at this stage. The shrinkage factor (Y), calculated from the solid loading (Φ) and the sintered fractional density (ρ/ρT) relates to each other as per Equation (1):

$$Y = 1- \{ \Phi / \rho / \rho T\} 1/ 3 \text{ ------ (1)}$$

Where ρ is the sintered density and ρT is the theoretical density for the material

The tool materials used in MIM are similar to those encountered in plastic injection moulding. The tool material choice depends on the anticipated number of moulding cycles and the required wear resistance. The tool set comprises the requisite cavity and the cavity pathway and ejectors for extracting the components from the cavity. The die cavity captures the component shape and is intentionally maintained oversized to account for component shrinkage during sintering. The location of the parting line, size and placement of the runner and design of the gate are issues important for successful moulding. The empirical equation used in analyzing the diameter of the runner is given by Equation (2):

$$D = NC \quad 4 \quad \sqrt{A} \qquad \text{--------- (2)}$$

Where A = Total surface area of product (No. of project area) mm^2, N & C are empirical factors and for wall thickness = 2 μm, C = 0.294 and N= 0.6 (For Polymer + lubricant)

The gate leading into the die cavity resides at the end of the runner, and is basically a small opening designed to freeze before the cavity, runner or sprue freezes. A solidified gate allows removal of the machine pressure while the mass in the cavity cools. Gates are usually around 3.5-4.5 mm in diameter. The actual gate size is determined by two factors: the filling shear strain rate and the section thickness. For the gate to freeze before the compact, a thickness between 10 and 50% of the compact thickness is required.

Mould Cavities

The maximum number of mould cavities follows from the ratio of shot weight S and weight of moulding W including the sprue and the runners. Equation (3) helps to determine most economical number of cavities to put into various moulds.

$$(QRT/ESC)^{1/2} \text{ --------- } (3)$$

Where Q= total number of parts to be produced

R= hourly rate of moulding machine

T= cycle time, in seconds

E= efficiency of moulding machine

C= estimated cost per cavity

S= seconds per hour

Electrodes for the cavities are machined from copper and graphite and cavities are generated by Electro Discharge Machining (EDM).

Nozzle Design and Manufacturing

The required flow pressure from the barrel to the cavities is determined following study of the characteristics of the feedstock flow with the use of the experimental mould. In the experiments conducted at CSIR-CMERI, the nozzle was designed for a 30 Ton Injection Moulding Machine and manufactured from the En-39 Grade. Two types of standard moulds were manufactured for being accommodated in the injection moulding machine and cavities for components were fitted inside. The gating and ejection systems were checked initially with polymer. Most of the tool components being available as pre-machined packages, only the cavity needed to be custom machined. Cooling/heating networks were further designed within this geometry to control the mould temperature.

The feedstock flows from the moulding machine nozzle to the mould cavity successively through the spruc, the runner and the gate. The flow path is surrounded by various clamping plates, alignment and locating pins and ejector components. Alignment of the components, proper sequencing and smooth motion are extremely important for successful filling and formation of the green compacts. A number of trials were initially carried out to check the feedstock flow and to determine the effectiveness of ejection systems.

Temperature and pressure were varied during the injection moulding cycle to deliver the feedstock to the die. This usually begins with melting of the feedstock in the heated barrel of the moulding machine. A reciprocating screw was used to pack, homogenize and pressurize the mixer. The injection temperature and injection pressure of feedstock were optimized by repeated trial and error.

Feedstock Preparation

The experimental work was carried out initially by using imported 4140,316L,420 feedstock from Advanced Metalworking Works Inc., USA. Experiments were also carried out to design the binder for stainless steel powder 316L, and feedstock of 316L prepared by mixing powder with binder in a 60:40 volume ratio. The mixing of the powder and binder was done using a Sigma Blade Mixer for 60 minutes at a temperature of 130°C. The blended lump was then removed from the mixer, cooled and granulated into feedstock.

Thereafter, indigenous feedstock was developed by mixing of fine 4140 steel powder (with particle size not exceeding 10 micron) and an organic binder consisting of LDPE, PW wax and stearic acid and by mixing the powder and the binder in a 60:40 volume ratio. As in the previous case, a sigma blade mixer was used for the mixing and the temperature during mixing was maintained at 120°-150°C. As before, the blended lump was then removed from the mixer, cooled and granulated into feedstock.

Manufacturing of Green Compacts

The standard mould along with mould cavity pertaining to the product was assembled in an Injection Moulding Machine. During moulding feedstock pellets are converted to paste in an injection moulding machine under the application of heat. The feedstock paste was injected inside the mould cavity under pressure. While there are many variables that control MIM process, mould filling is the most critical phase for manufacturing of component. Sink marks, voids, weld line and density variations are among the consequences of improper specification of moulding variables and tool design. Unless taken care of in the very beginning, these defects are not amenable to corrections in the subsequent steps of product development. The success of moulding depends not only on the rheology of the mixture but also on the design of the mould cavity and the choice of the process parameters of injection moulding like injection temperature, filling time, etc. Manufacturing of green compacts was carried out by using 30 ton and 40 ton Plastic injection Moulding Machine. Figure 3 illustrates the SEM micrograph of a sample thus moulded.

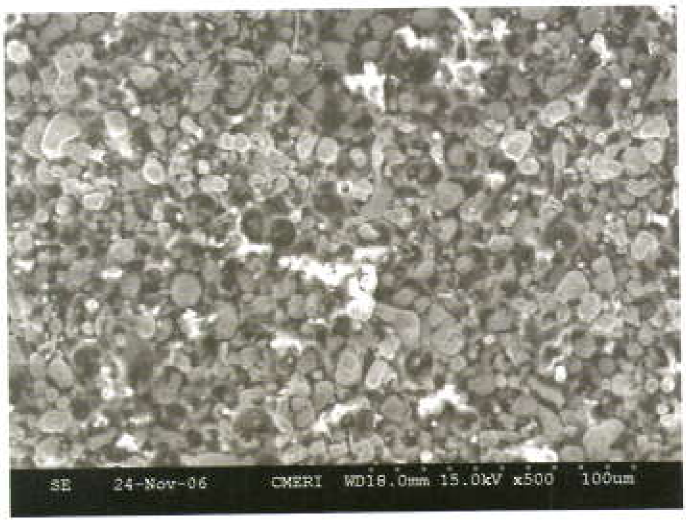


Figure 3: SEM micrograph of moulded specimen

Debinding

Removing the binder without disrupting the particles is a delicate process and is achieved in several small steps. Initially the binder holds the particles together. When the binder is heated it softens, when it fails to withstand the shear stresses from gravity, thermal gradients or internal vapour pockets. Hence to retain the proper shape, an inherent particle-to-particle friction is needed. The binder is therefore extracted from the pores as a fluid (liquid or vapour) without distorting or contaminating the compact.

The SEM photographs of dewaxing and thermal debinding are shown in Figures 4 and 5 respectively.

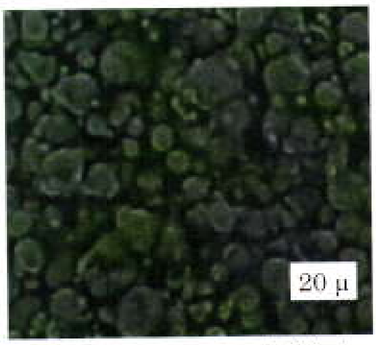


Figure 4 : Progressive removal of binder during thermal dewaxing

Figure 5: SEM photographs show the progressive removal of the binder during thermal debinding

The moulded components were placed on a ceramic tray using fine ceramic powder as wicking media. A suitable combination of the three parameters including furnace atmosphere, heating rate and debinding temperature produces a defect-free part. Wicking process that extracts the binder through capillary action has several advantages. It provides additional support, better thermal uniformity, reduction in partial gas pressure gradients at the surface of the part and homogeneous wicking out of the binder throughout the part. Green bodies are in the fluid state at the very beginning of debinding. In addition, the thermal expansion of the liquid binder induces hydraulic pressure in the capillaries which enhances binder removal rate.

Volatile binder was removed step by step by thermal degradation and evaporation and debinding temperatures were determined based on the Thermogravimetric Analysis (TGA) curve. The TGA analysis indicates the changes in weight as a function of temperature over time. These changes usually occur as a loss in weight, but a gain in weight can be seen if the sample goes through adsorption (i.e oxidation). The TGA curve helps to control furnace atmosphere, heating rate and debinding temperature.

Since multicomponent thermoplastic binder was designed, a two-step debinding process was followed. Paraffin wax and stearic acid was removed by solvent debinding and polyethylene removed by thermal debinding. The solvent used here was n-hexane. It was observed that no distortion takes place during thermal debinding if 80% of paraffin wax and stearic acid is removed from the component.

Sintering

Sintering, constituting the final procedure in Metal Injection Moulding, is an irreversible step which leaves no chance of curing defects introduced in compacts during mixing, moulding or debinding. The debinding and sintering processes are performed in a single step sintering cycle using inert atmosphere. The debound components are placed inside an alumina tube on a refractory base, with the tube communicating with an inert gas cylinder. Sintering is indicated by the density achieved in the MIM components. After debinding, components are often near 60% dense, while the final density approaches 45 to 96%. Proper tool design and close tolerances require reproducible and homogeneous shrinkage. Since shrinkage is inversely dependent on the green density, it is desirable to maintain a high and uniform powder packing density. A high packing density system can be obtained through the selection of equiaxed (near spherical) particles with graded particle sizes or broad particle size distributions. Surface diffusion often dominates at lower sintering temperatures. Slow heating consumes the driving force for sintering without densification of the compact. Rapid heating at low temperatures followed by slow heating in the intermediate temperature range with a final short term high temperature hold is suggested where densification is active while grain growth is retarded. Sintering cycle for 4140 is shown in Figure 6.

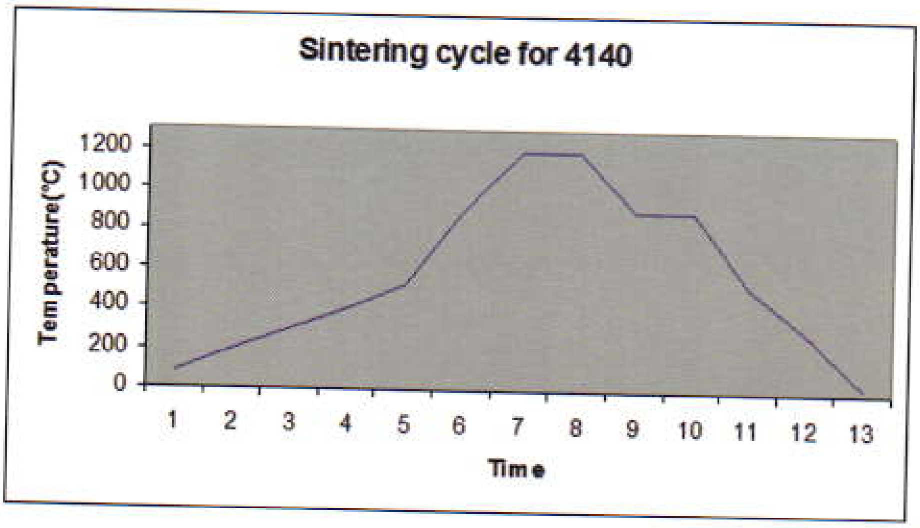
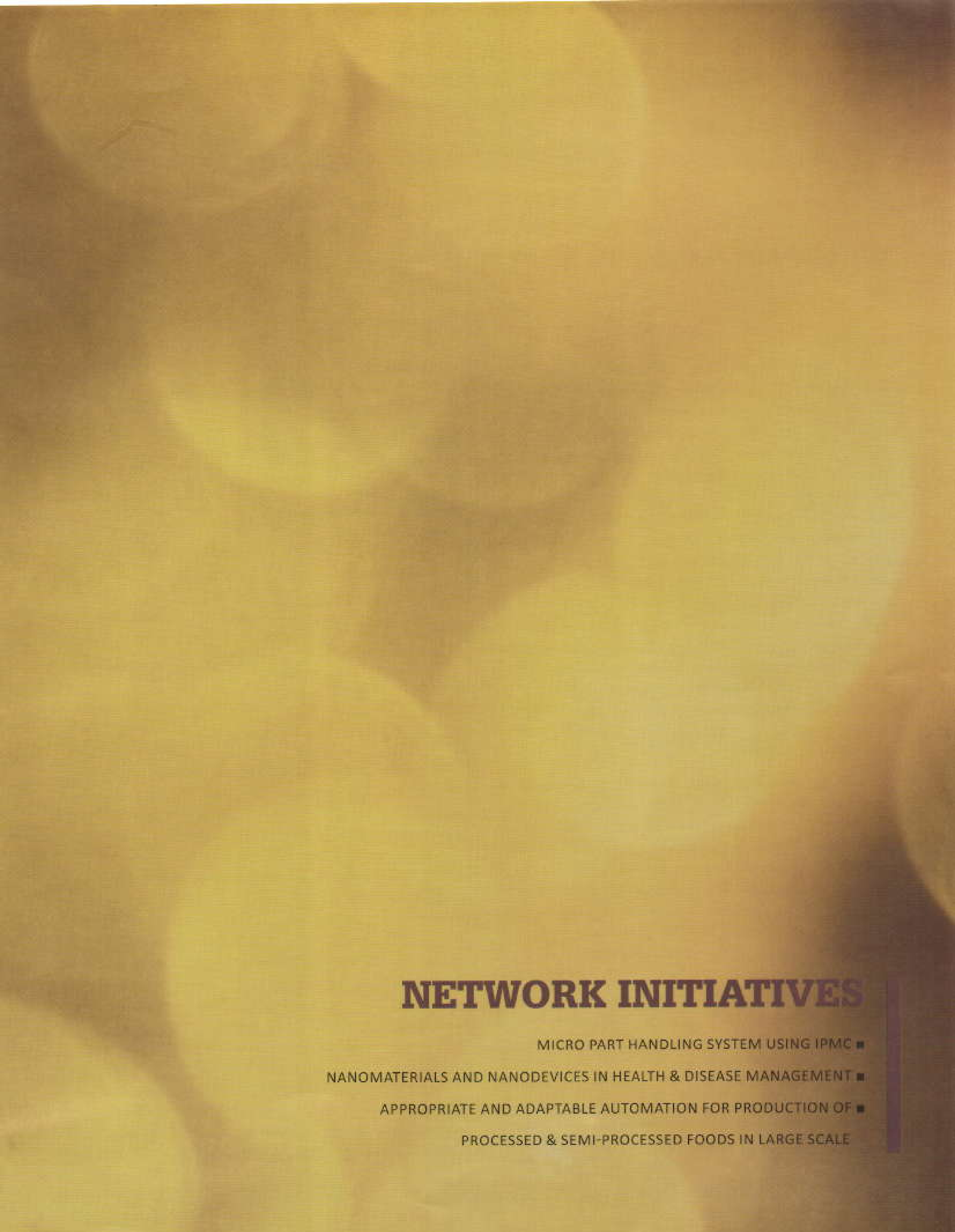


Figure 6: Sintering cycle for 4140 feedstock including debinding



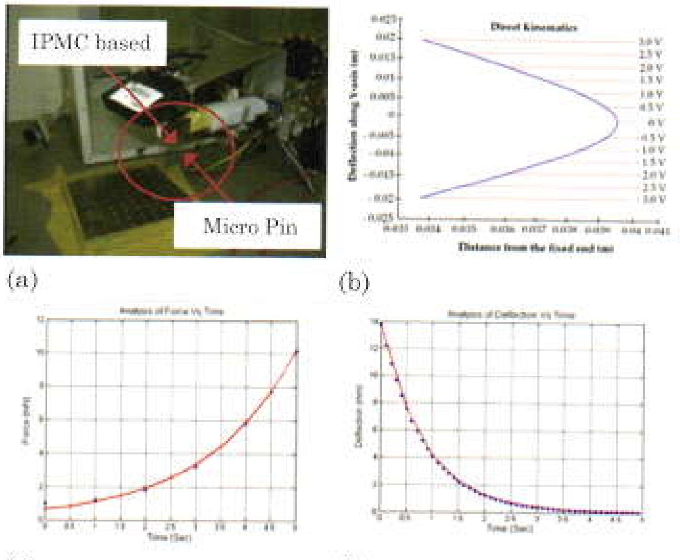
NETWORK INITIATIVES

- MICRO PART HANDLING SYSTEM USING IPMC
- NANOMATERIALS AND NANODEVICES IN HEALTH & DISEASE MANAGEMENT
- APPROPRIATE AND ADAPTABLE AUTOMATION FOR PRODUCTION OF PROCESSED & SEMI-PROCESSED FOODS IN LARGE SCALE

MICRO PART HANDLING SYSTEM USING IPMC

Micro system engineering facilitates the assembly operation of very small mechanical components using miniature actuators. Employing soft Ionic Polymer Metal Composite used for making fingers or grippers the actuators make possible the performance of functional tasks such as grasping, micro manipulation, etc. A component of the research carried out under the network umbrella of **Modular Reconfigurable Micro Manufacturing Systems** was directed to the development of a micro gripping and manipulation system for facilitating assembly of very small mechanical/electronic components like micro pins, LEDs, resistors, capacitors, etc. The major objective was to evolve a novel design for a micro gripping system with an integrated micro manipulator for a micro factory test bed offering flexibility in handling of a peg and its manipulation within a larger work space. The handling of peg-in-hole constitutes quite a difficult task in micro assembly.

In performing these tasks, the micro manipulator comprises an essential tool in an industrial environment for micro assembly. An integrated micro manipulating system including a micro gripper is required for easy implementation in a "Micro factory test bed". An IPMC actuator is used for development of micro gripper which provides the facility to handle the components without any conventional motor. It is operated by only a 0-3V signal. An electromechanical characterization of IPMC has been carried out for load lifting capability. A novel micro manipulator has also been designed and developed. The system has been demonstrated for pick and place of miniaturized pins in the bread board. The micro manipulator covers 100 mm work space within 81 positions as shown in Fig.1 (a). The kinematic behaviour of the micro gripper is shown in Fig 1(b). The electromechanical characterization of IPMC is carried out as shown Figure 1(c) and (d).

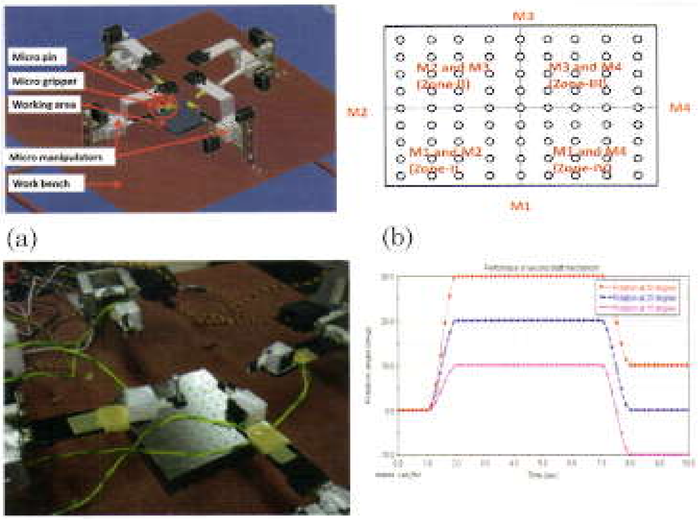


(a) (b)

(c) (d)

Figure. 1

The multi micro manipulation system covers the design and development of four systems on a single work bench to achieve the manipulation task in a large work space. The CAD model of assembly operation is shown in Figure 2a. As handling of micro parts is a challenging issue in a large work space of an assembly, a 81 hole grid pattern (9X9 square pattern of hole) is considered in the design. The total size of 81 holes grid pattern is 100 mm X 100 mm where the distance between two holes is 10 mm. The grid pattern is divided into four zones for smooth and proper handling of parts as shown in Fig. 2b. In this design, each zone covers 16 (4X4) holes in the grid pattern, thereby rendering the total travel distance of one manipulator 40 mm. To increase the work space for achieving 81 holes in assembly (as one manipulator can perform operation in two different zones), four micro manipulators were mounted in different positions i.e. M_1, M_2, M_3 and M_4 (Figure 2b). In this approach, four micro manipulators were developed and integrated orthogonally in a single work bench. The manipulation task is achieved by coordination of each manipulator. Figure 2c shows the desired position of the object whereas Figure 2d shows the performance of the joint.



(a) (b)

(c) (d)

Figure 2: Multi micro manipulation systems

The bio-mimetic behaviour of IPMC was studied through EMG signal, where the movement was transferred to a single link micro robotic arm (Fig. 3).

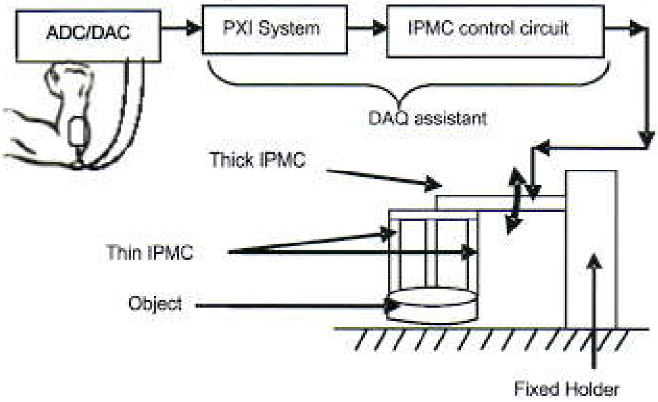


Figure 3: Layout of single IPMC micro robotic arm actuated through muscles

The signal generated during movement of the forearm in different angles was transferred to the IPMC that allows bending (Fig. 4). This bending behaviour is utilized for micro manipulation. The performance of the micro robotic arm shows reasonable lifting capability. Voltages ranging upto ±5mV is acquired through the motion of a human forearm via EMG signal for actuation of the IPMC. After data acquisition, the voltage signal is amplified up to ±3V with a reasonable amplification factor (450-650) through PXI system and supplied to the IPMC based lifting arm for manipulation. The IPMC based micro robotics arm moves in a manner similar to that of a human forearm with a displacement up to 14 mm.

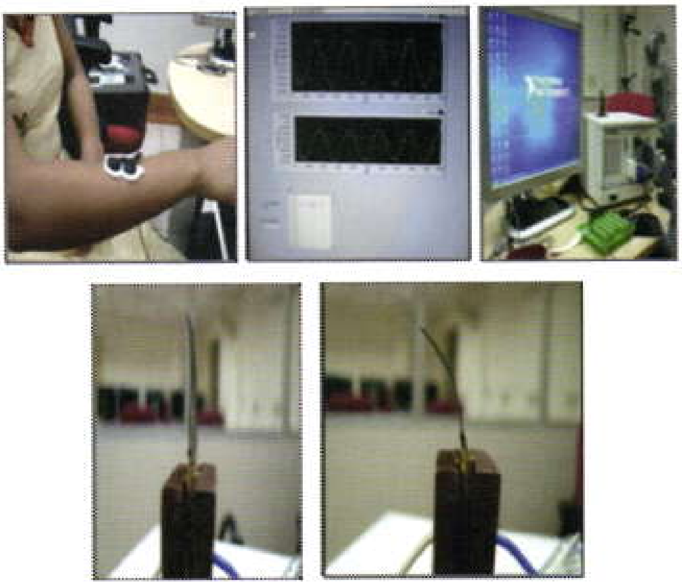


Figure 4: Stages of activation of IPMC through our muscles via EMG signal

A novel IPMC micro gripper employing three fingers was also developed as a part of the project. The fingers connected to a 'wrist' made of perspex sheet and were individually activated. The wrist along with all the fingers was connected to a single IPMC based flexible micro robotic arm as shown in Fig. 5. During operation, the three IPMC based fingers were used to grasp an object while the micro robotic arm lifted the object in the assembly. Remote centre compliance (RCC) based micro gripper was developed to facilitate the insertion of peg-in-hole (PIH) operation for micro assembly, and the performance demonstrated through a prototype. Suitability of RCC compliance assembly during PIH operation is shown in Fig. 6.

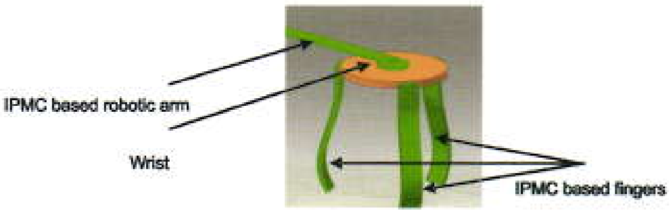


Figure 5: Design of IPMC based micro gripper for RCC assembly

Assembling parts of sub-millimetre size is important for Microsystems fabrication and development of micro robots. The most useful task is the grasping

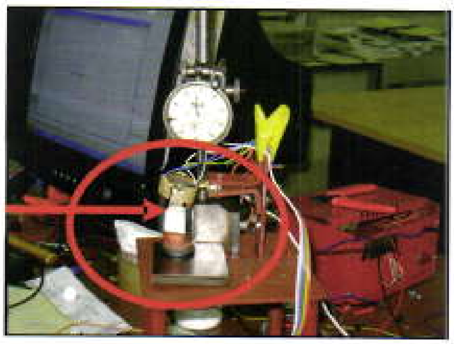


Figure 6: Testing of three finger based micro gripper with RCC assembly

and manipulation of mechanical and electronic components, 'hybrid' parts, i.e. objects made of different materials (silicon, metals, polymers) for different functions (structural, actuation, sensing, processing). These components can be assembled by automated procedures for mass manufacturing, or by manual procedures for small-scale manufacturing/prototyping. Micro manipulation systems have been developed for assembly lines and are extensively used in industry (e.g. the watch industry). It is demonstrated that handling of miniature part is possible in a micro factory test bed through flexible links. The technology for development of micro end effectors using IPMC has further been demonstrated. IPMC based micro-gripper has compliant beams that allow the gripper tips to bend for holding the micro objects, and these have been found to provide reliable actuation and reasonable energy consumption. A compliant gripping system along with micro manipulation system was also developed where the fingers were mimicked through electrical actuation instead of conventional motor. Each finger was actuated individually so that dexterous handling is possible, allowing precise end-effector positioning. When in operation, the maximum displacement of the fingers is in the range of 5 mm. The maximum jaw opening and closing positions for micro gripper were found to be 5 mm and 0.5 mm respectively. The fingers can hold an object having a weight up to 10 mg. The micro gripper has demonstrated handling capabilities for micro components like pin in a bread board. The device has exhibited acceptable handiness, and has the potential of handling numerous millimeter scale components, requiring complex fabrication and assembly.

Micro system technology leads to the development of miniature parts applicable in automotive, space, medical, space and process control industry, etc. In terms of flexibility, conventional mechanisms suffer from a number of limitations in handling miniature parts. Various types of actuators and sensors like shape memory alloys (SMA), silicon, piezoelectric, ionic polymer metal composite (IPMC) and other electro active polymers (EAP) are available globally. Among these, IPMC actuators hold significant promise for development of end effectors having grasping capability of miniature parts. The actuation of micro gripper is controlled by a customized control system to provide uniform grasping force over the surface of the jaws. The effect of temperature on IPMC, as observed from experimental analysis, suggests that the system is capable of bending even in normal room temperature, which hold considerable promise for affording savings in downsized production systems in terms of energy, space and resources as also for integration of micro gripper with micro manipulation for the pick and place operation in bread board.

NANOMATERIALS AND NANODEVICES IN HEALTH & DISEASE MANAGEMENT

Development of nanodevices and nanomaterials for applications in health science has tremendous potential since it offers fundamentally different approaches to treat and prevent diseases. The multi-functionalities associated with nanostructures allow development of complex therapeutic vehicles with specificities and efficiencies. Nanobiotechnology requires the integration of technologies from various disciplines of S&T for its application in human health and disease. The Project targeted biointerfacing of nanodevices such as cantilevers, semi-conductor devices, development of drug delivery systems, etc. through the efficient and integrative use of knowledge existing amongst various chemical, physical, electronics, material science and biological sciences laboratories of CSIR. The Project had as its basic objectives the following:

- Developing suitable biodegradable/ biocompatible porous scaffolds for tissue engineering applications
- Fabricating monolithic or composite scaffolds by attempting several techniques like rapid prototyping and gel casting or combining the gel casting & polymer sponge techniques
- Introducing scaffold seeding techniques to realize the concept design and formulation of surfaces for studying the behaviour of tissue engineering and to develop suitable scaffolds for repairing the bone

Development of biomimetic bone replacement hydroxyapatite (HAp) and collagen bio-material is an expanding field of research for application in tissue engineering and waste water treatment for heavy metal removal. HAp is synthesized from different biological sources like fish scale, egg shell, cow bones and simplified SBF whereas collagen can be extracted from fish waste material in a cost-effective and eco-friendly manner. The phase purity and crystallinity of different calcined HAp powders were determined by XRD and FTIR analysis. Thermo Gravimetric and Differential Thermal Analysis (TG DTA) was carried out to exhibit the thermal stability and chemical deposition of the HAp powder. Collagen was characterized by FTIR, and CD Spectroscopic analyses. Cytotoxicity evaluation of HAp powder was carried out in RAW macrophage like cell line media for an incubation period of 72 hours. Porous scaffolds (Figure 1) were developed using HAp TiO_2 composite by polymer sponge casting technique; further mechanical characterization for tissue engineering application was also undertaken.

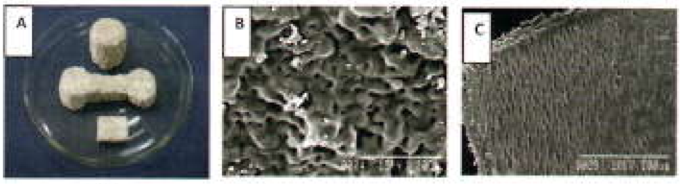
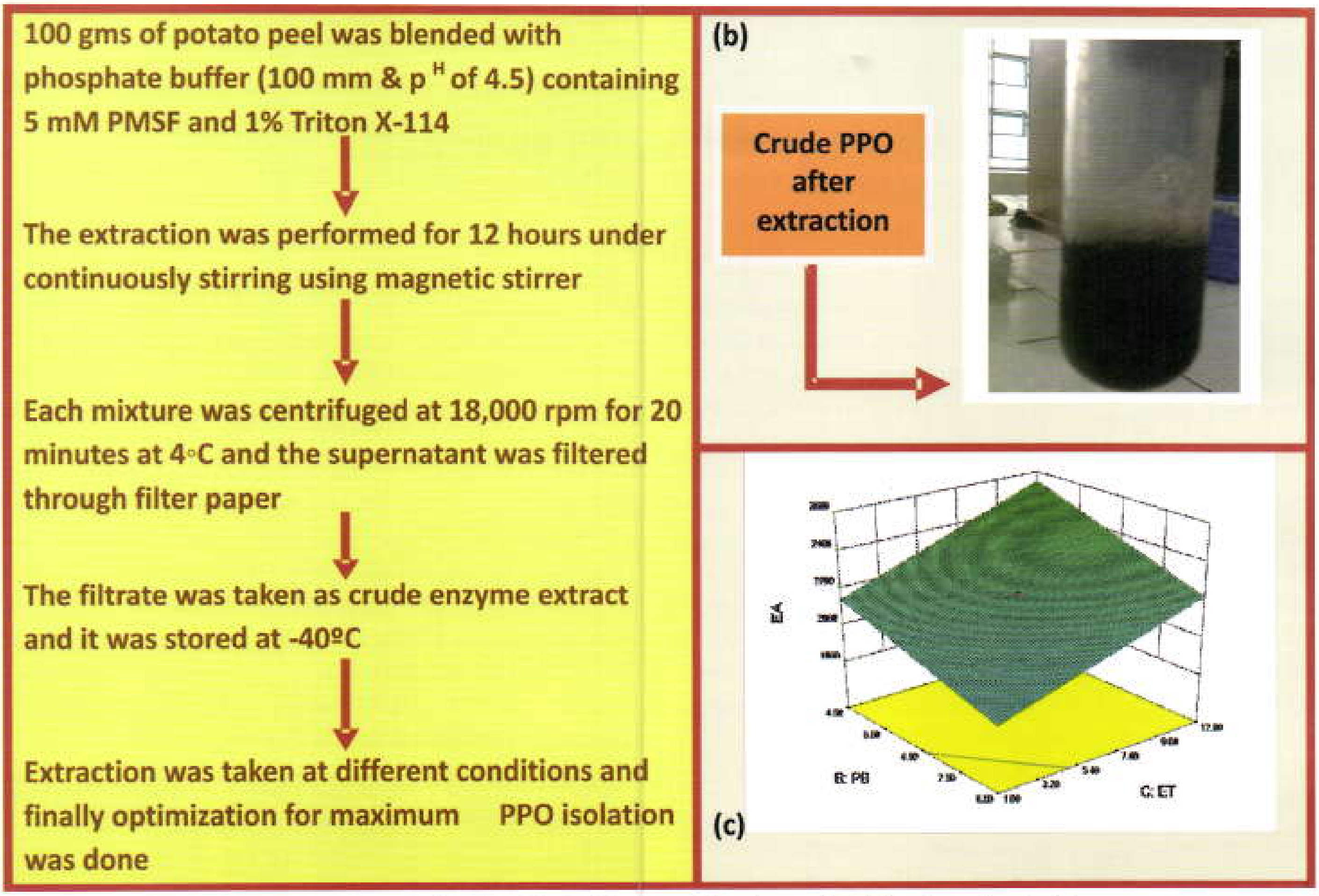


Figure 1: (A) Polymer sponge gelcasted Porous Hydroxyapatite Scaffold for bio implant (B) SEM photomicrograph of scaffold surface (C) SEM micrograph of Deproteinized Fish scale surface which is utilized as a source of HAp production.

Enzyme technology is expected to play a sterling role with the rising need for bioremediation and biomonitoring of phenolic contaminants. Polyphenol oxidase (PPO) is an oxido-reductive enzyme that can efficiently oxidize a large group of phenolic components and can be utilized for the detoxification of phenol from industrial waste water. For this purpose, the principal requirement is PPO enzyme. Keeping in view of the usefulness of PPO for various industrial purposes, CSIR-CMERI took up the task of devising analytical methods for the extraction of this enzyme in a high-yielding and cost efficient manner. Response Surface Methodology (RSM) (Figure 2) was used for the study of the effect of six independent variables, namely extraction buffer concentration, pH of extraction buffer, extraction time, extraction temperature, PMSF concentration and volume of PPO extracted from potato peel. PPO was isolated from potato peel using optimized protocol.



100 gms of potato peel was blended with phosphate buffer (100 mm & p^H of 4.5) containing 5 mM PMSF and 1% Triton X-114

The extraction was performed for 12 hours under continuously stirring using magnetic stirrer

Each mixture was centrifuged at 18,000 rpm for 20 minutes at 4◦C and the supernatant was filtered through filter paper

The filtrate was taken as crude enzyme extract and it was stored at -40ºC

Extraction was taken at different conditions and finally optimization for maximum PPO isolation was done

Figure 2: Response Surface Methodology used for the study of the effect of variables

APPROPRIATE AND ADAPTABLE AUTOMATION FOR PRODUCTION OF PROCESSED & SEMI-PROCESSED FOODS IN LARGE SCALE

There is a necessity of elevating the status of many the ethnic/traditional Indian foods and for promoting such food as healthy substitute of junk-food flooding the markets. The major bottleneck in the mass production of healthy indigenous food is the requirement of skilled manpower and drudgery involved in pre-processing. This initiative was undertaken to standardize and mechanize the production system associated with selected indigenous foods through the development of appropriate food machinery for small scale industry. Under this activity, primarily three machines with their sub-components have been identified for design and development. These are:

1. Cereal Cake Making Machine, comprising sigma mixer, extruder, cut-to-length machine and automatic packaging machine
2. Laddo making machine, Coconut grating machine
3. Machine for making food out of Puffed/Beaten/Popped Rice.

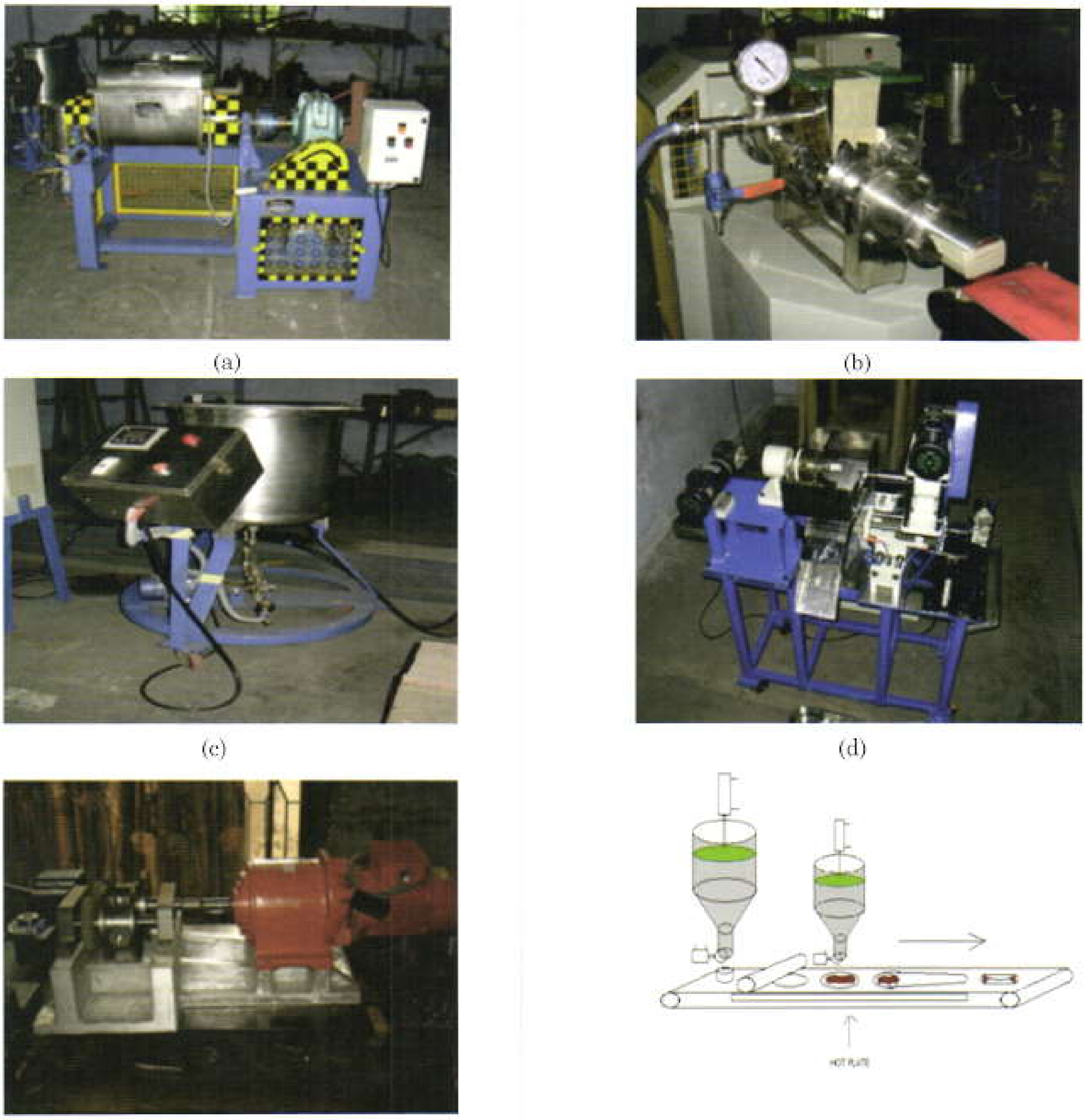
Cereal Cake Making Machine

The Sigma-mixer is required for proper mixing of dough out of highly viscous food material such as corn flour, with moisture content around 8 to 10 percent. Two Z shaped blades are made to rotate in a chamber with a clearance of few millimeters (more than the grain size) from the wall. Rotational speed is around 60 to 100 rpm. The machine prepares uniform dough out of corn-flour, honey, essential oil, salt/sugar, coco powder put together in predetermined quantities. The dough is then fed to an extruder to produce cake bars at the output. A automatic cut-to-length mechanism produces uniform rectangular bars, which are then packed using a horizontal flow-wrap machine with automatic packing and printing of the manufacturing date. The bar has a shelf life of three months. The machines are designed in such a way that no sharp corners, fissures or cracks exist where food particles might adhere even after washing. Appropriate hygiene is guaranteed in the choice of the construction material.

Ladoo Making Machine

A machine for grating coconut has been designed and fabricated for making laddo out of coconut pulp. The Coconut Grating Machine employs a circular blade movement. The blade module consists of three parts made in the shape of a quarter of an ellipse and are placed at 120 degree angular separation. During rotation, they together make half of an ellipsoid, where the ratio of the minor axis to the major axis is lesser than that of any coconut, so that it can make contact with any part of the inner surface of one half of a coconut. This shape ensures that no kernel is left over after grating, irrespective of the shape of the coconut. Initially, the blade is positioned at the centre of the coconut, the position sensing being accomplished with the help of a limit switch. When the blade assembly comes in contact with the hard shell, it can sense the change in the contact pressure with the help of a pressure sensor. The moment it senses the hardness, the blade deflects in the reverse direction on the X axis by 0.5 mm. This deflection is measured with the help of a linear position sensor. The whole process is controlled by a micro-controller. After the reverse movement of the blade, the motor is commanded to move the blade forward along the Y axis and towards the center of the coconut by 0.75 mm so that a fresh contact is established with the uncut portion of the kernel. This process is repeated till grating of one half is completed. The extent (lateral depth) to which the coconut is to be grated is controlled by changing the position of a potentiometer, which in turn controls the initialization value parameter of the timer residing within the microcontroller. Effectively the whiteness of the grated output can be controlled by the user (in terms of percentage) depending on specific requirement.

The gripper arm movement is in opposite direction with respect to cutter blade rotation and its speed is half of that of cutter blade. This helps in faster operation and uniform grating in much smaller pieces (grains) compared to other machines available in the market. The developed machine is capable of grating 120 half coconuts in an hour. Hence a total of 14400 coconuts can be grated in three shifts of a day (throughput /efficiency).



(a) (b)

(c) (d)

(e) (f)

Figure 1: (a) Sigma Mixer (b) Extruder and (c) Edible Oil Storage with Pump for Cereal Cake Machine (d) Automatic Coconut grating machine. (e) Laddo Making Machine under fabrication (f) Schematic of Petha making Machine

LOOKING AHEAD

A NOVEL ENDOSCOPIC DEVICE USING ULTRASONIC DETECTORS

Minimally invasive surgery has been well accepted in the society since it involves less operative trauma in comparison to an equivalent invasive procedure. It causes less pain and scarring, aids faster recovery and reduces post-surgical complications. An endoscope is considered as one of the most powerful diagnostic and therapeutic tool for dealing with abnormalities inside the human body. Steering and guiding a conventional endoscope in a patient's body has been a challenge for doctors for many years now. Prevailing technology allows passive bending of the endoscope by one or more cables attached to the tip where the bending motions are controlled from outside the body by wire traction. Therefore, precise operation of the endoscope is difficult in areas of complex shape such as in the intestine. Furthermore, patients suffer pain during a procedure with an endoscope. For instance, if a conventional endoscope is being inserted into the colon by simply pushing it forward and steering the tip (the only steerable part), the shaft pushes against the colonic wall until the colon and its surroundings provides sufficient counter pressure to force the shaft to bend. In practice, this means that the colon is often stretched substantially. This frequently leads to formation of loops in the flexible endoscope shaft and colon, which can hinder further advancement of the tip and can cause considerable discomfort for the patient.

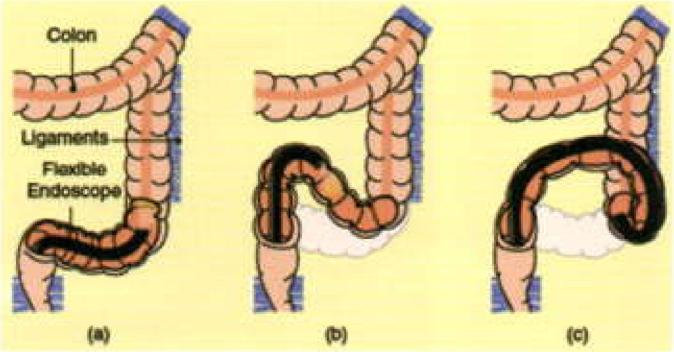


Figure 1: Endoscopy of large intestine

According to a study, each year more than 20% of Indian population have digestive problems and are hospitalized for related treatment. Early diagnosis and detection is fundamental in the treatment of these problems. Conventional endoscopic procedures are some of the preferred diagnostic and therapeutic techniques. However, these techniques do not permit investigation of most of the six meters of the small intestine due to difficulty in controlling and manipulating the scopes. Also, the associated pain and discomfort renders this procedure unpopular.

To mitigate this, Dr. Gavriel Iddan, an Israeli physician, developed an ingestible capsule containing a miniaturized video camera, light, transmitter and batteries, which makes possible investigation of the small intestine. However, such a method fails in the colon or in the stomach. The method further suffers from limitation in its field of view and its motion cannot be controlled by the physician. Therefore, this technology fails in the diagnosis of many digestive ailments since some lesions may go undetected because of the random camera orientation.

Methods like computed tomography, magnetic resonance imaging, fecal occult blood testing, capsule endoscopy and a combination of the above have been tried by researchers as alternatives to screening and diagnostic procedures. However, these alternatives do not entirely replace conventional endoscopy as they lack the therapeutic means that a conventional scope provides. If abnormalities are diagnosed, conventional scopes are still required for biopsies or for treating abnormalities by supplying medicine directly to the affected part of the human body.

The Cybernetics Group at CSIR-CMERI, Durgapur undertook a research programme for the development of a prototype robotic arm capable of following complex trajectories which navigates through different parts of the human body. The tip of the device is designated to carry an ultrasonic trans-receiver which makes possible judging the current state of the tissue by analyzing the reflected component of the sound wave. In many stages of diagnostic procedures, it is important to know the depth of an organ tissue which is damaged at any stage. For example, the extent of damage of a heart after a cardiac arrest can be estimated by measuring the thickness of the damaged tissues on the heart wall. The same applies to liver tissues also in case of a prevailing ailment.

The prototype is proposed to be machined in Teflon initially. However, in the final device, some biocompatible material has to replace Teflon. Numerous segments of the prototype would be connected to one another with ball and socket joints. Three SMA (Shape Memory Alloy) wires will be attached between adjacent blocks equally spaced around a circular periphery and at 120° from each other. Figure 2 below shows the three segments connected with a ball and socket joint.

Figure 2: Solid Model of SMA actuated segments.

SMAs generate extremely large forces if any resistance is encountered while transforming from the martensite to the austenite phase. This phase change can be produced by heating. This property of SMA can be utilized to develop a powerful actuator for performing useful work with a high work-to-volume ratio. As illustrated in Figure 2, the attached wires pull back the individual block on top when heated. The cumulative bending effect of all the blocks allows the device to follow complex trajectories in 3-D space. Figure 3 below shows a mechanism of 2-D bending of the top block when one wire is heated to a temperature above the austenite finish.

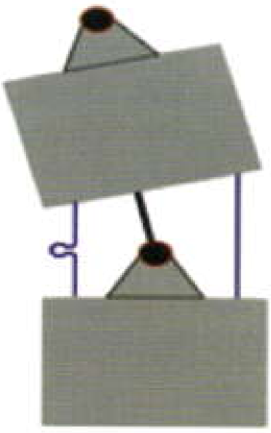
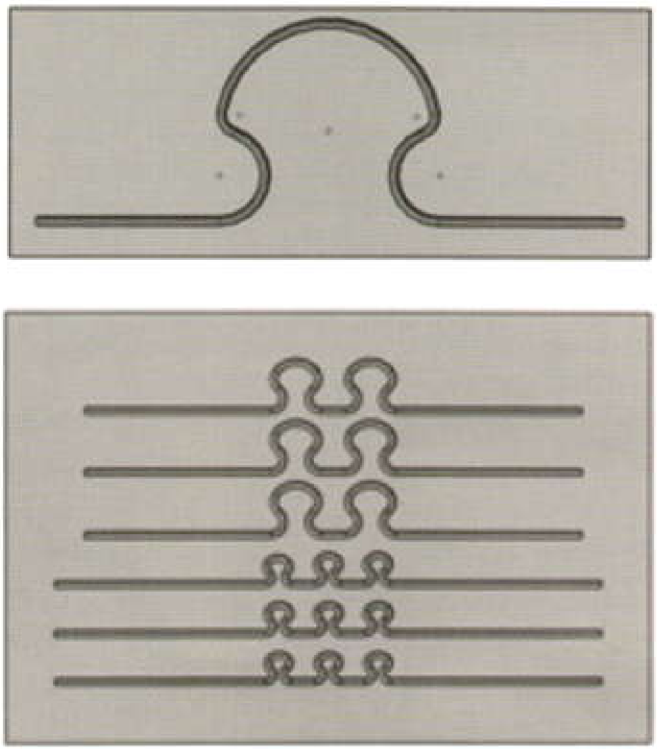


Figure 3: Bending mechanism of endoscope segments

As mentioned above, bending motion of the prototype is possible when the SMA actuator pulls the attached blocks only when the wire shrinks in length or forms a loop or when it bends. There are various ways of getting loops or bends in the parent shape. The required parent shape from a SMA block is obtained by wire EDM, or by a suitable photo-chemical process or else by using commercially available straight parent shape wire and changing the parent shape by annealing.

Figure 4 shows different loops that can be tried out to generate the appropriate force and decrease in overall length of the SMA wire.



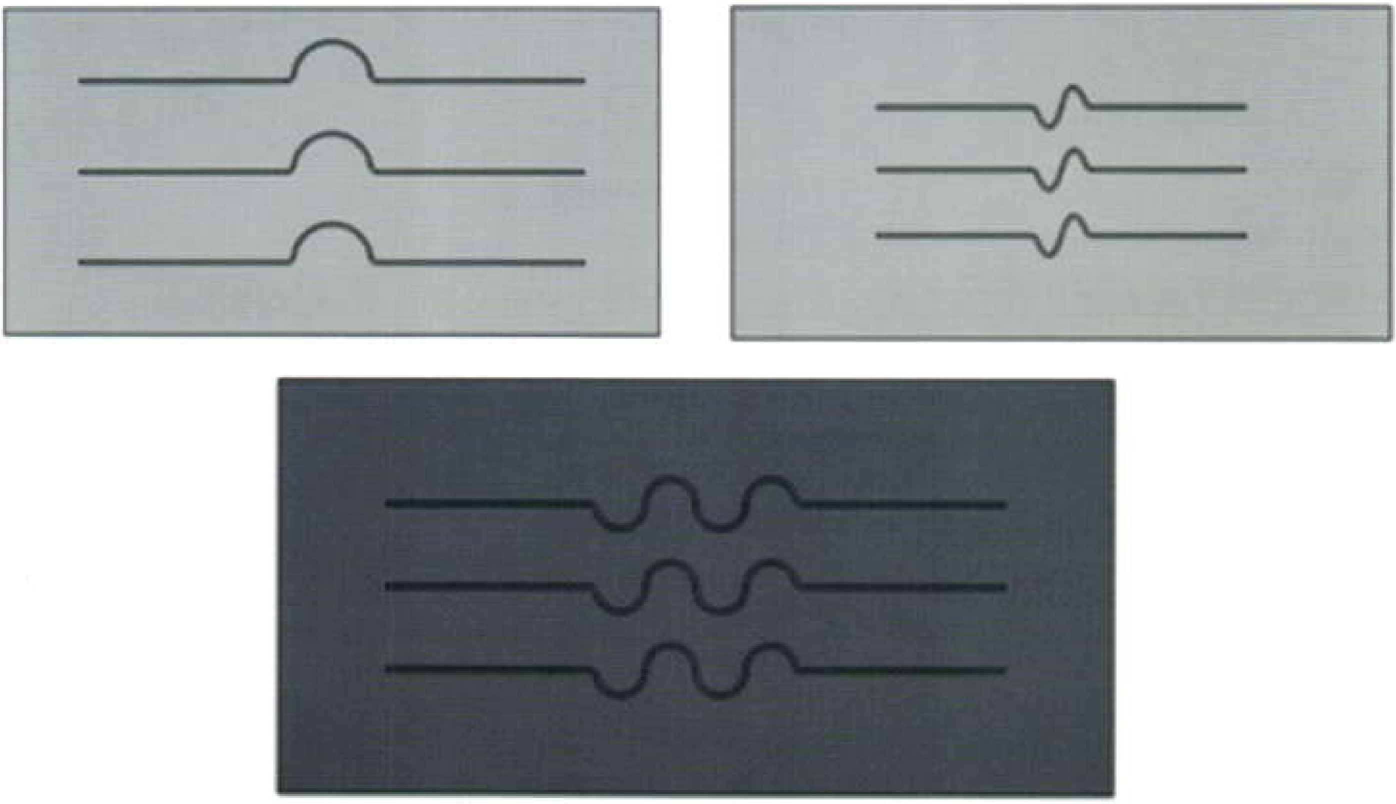


Figure 4. Aluminium blocks annealing SMA wire.

Nitinol wire that uses nickel and titanium renders the resistivity very low (Austenite-100 micro-ohm cm and Martensite-80 micro-ohm cm), which ultimately results in increase in time or current to heat the wire to austenite temperatures by Joule's heating (heat supplied = i^2rt, where i is current passed, r is the resistance of wire and t is the duration for which current is passed). Passing uncontrolled high current will raise the wire temperatures above Austenite and may result in permanent (plastic) deformation in the wire. Controlled heating of the alloy is very important so that the temperatures are maintained within limits.

A heating circuit needs to be designed to produce Pulse Width Modulated (PWM) current using a microcontroller to control the current passing through the SMA wire. The duty cycle of PWM signals would decide the response time of the device and the bending angle.

Mathematical modelling of the device maps the discrete points the tip of the device can reach in a 3D space. Depending on the application, the operator can drive the device by selectively heating the SMA wires. It is also possible to independently trigger different segments for the device to follow a given profile of the track in 3-D space.

A generic algorithm also needs to be developed for the traversing of the device. Such algorithm would address the issue of complications in maneuvering an endoscope through complex interior structures like that of an intestine and also the very important issue of navigating the scope out of human body.

AIRCRAFT VALVE DEVELOPMENT : ACCEPTING A MAJOR CHALLENGE

In a technologically competitive world, countries that have their own aircraft industry are always placed in a position of advantage. Many developing countries are now designing and building civilian aircraft to achieve economic growth and competence in the field of high tech engineering. Development of aero industries in these countries is expected to create fierce competition among the aircraft manufacturers for selling their products in the rapidly expanding Asian market. The ambitious SARAS Project undertaken by CSIR has firmly placed India in the global map of aero industries, and India is poised to further consolidate its position in the near future.

In an aircraft, the systems/sub-systems alone comprise almost 30% of the overall aircraft cost. As of now, the indigenous programme for developing civilian aircraft is totally dependent on using costly systems and subsystems imported from technologically advanced countries. Those systems, mostly developed using off-the-shelf components used in other aircraft, do not exactly match the requirements of aircraft designed in India and necessitates modification that, in its turn, adds to the developmental cost, rendering the aircraft price exorbitantly high. More importantly, the need for modification and necessary retrofitting lengthens the delivery schedule. It is therefore difficult to develop a cost competitive aircraft indigenously after paying hefty prices for the bought-out items. Though it is prudent to use proven and certified systems initially for a newly designed aircraft, indigenous serial production capability of systems and subsystems is absolutely essential for reducing the overall aircraft cost. System development and equipment development are thus as important as the capability of designing and integrating the complete aircraft in order to make significant progress in the area of civilian aircraft development.

Since the price of the aircraft is the ultimate determining factor for sale, significant benefit can be accrued if the bought-out systems and subsystems can be procured at a cheaper rate by producing them locally. Every new aircraft manufacturer is now striving to insource the systems/subsystems from within their own territory to make the final product cost competitive. This holds true even for developing nations like Brazil & China.

The reason for Indian companies lagging behind in the manufacture of aircraft related systems and subsystems could be attributed to the absence of an indigenous civil aircraft development program preceding SARAS and lack of know-how for the critical components. High-temperature & high-pressure valves comprise one such critical component in an aircraft environmental control system (ECS). A similar critical component for aircraft fuel system is the highly reliable valve having redundant drive. Due to intense competition among international manufacturers, the technology for manufacture of aircraft valves remains strategic and there is no chance of acquiring it from outside. To bridge this gap, CSIR-CMERI has taken up the challenge of designing the following three critical aircraft valves from first principles under the network project **Spearheading Small Civilian Aircraft Design, Development and Manufacture** with CSIR-NAL as the nodal laboratory:

1. Pressure regulating and shut-off valve (PRSOV)
2. Ball type motorized fuel shut-off valve (FSV)
3. Butterfly type non return valve (NRV)

Indigenous design and development of these valves is expected to lead to a cheaper product within a relatively short time frame. The advantage of designing and developing from first principles is that accommodating necessary modifications to suit the requirement of any other aircraft can be accomplished easily. Indigenous technology is expected to enable Indian companies to produce these critical valves and to stimulate indigenous development of complete ECS/fuel systems optimized for indigenously built aircraft, with a view to achieving self reliance in aircraft systems development, thereby boosting marketability of indigenously developed aircraft and enhancing the export potential. The course eventually will lead to complete self reliance for aircraft development in India.

Testing of the valves for the acceptance for its intended function and qualification for airworthiness is an integral part of the developmental process. It requires design and establishment of suitable test rigs. CSIR-CMERI has taken the initiative to set up a state-of-art valve development & performance testing facility for all civilian aircrafts under a 11th five year plan project entitled "Test Facilities for Special Purpose Valves for use in Civilian Aircraft".

Valve Description

Pressure Regulating & Shut Off Valve (PRSOV): A typical Pressure Regulating & Shut-off Valve used in the bleed air regulating system of small civilian aircrafts and is basically an electrically actuated inline pneumatic valve having a nominal diameter of 50 mm. The PRSOV is mounted within the engine bay and is designed to operate independent of the altitude. Its purpose is to regulate the pressure or shut off the air flow of engine HP bleed to the environmental control system (ECS). It operates over an upstream pressure range of 205-755 kPa and when open under sufficient upstream pressure, maintains the downstream pressure to 220 ±20 kPa.

Fuel Shut Off Valve (FSV) : This component unit is a Ball-type Shut-off valve, nominal size 5/8", which is normally opened with an electric motor operated 1/4 turn actuator and is provided with a pair of end stops to limit the maximum opening, as well as end position micro-switches. The valve unit is located in the piping connecting the engine fuel main header of the fuel feed circuit to the fuel tank downstream of the nacelle firewall. The axis of the valve is kept vertical while in installation, though the valve is designed to work in any attitude. The valve routinely opens when the engine is about to start before the flight and closes when the flight is over and the engine is stopped. It may also operate in such emergent conditions as when the engine is required to stop while in flight. The operational mode of the valve is selected by the pilot through electrical controls. The unit allows fuel flow only when opened with the actuator running forward and closes when the actuator is reversed. The valve actuator is driven by two micro-motors in parallel, so that the valve may be operated with either of the two motors, as also when both motors are running. This provides redundancy of operation on the fuel system, which is critical from the safety point of view.

Non Return Valve (NRV) : This component unit is a double-flap type non-return valve, nominal size 3", which normally remains shut with a torsion spring and is provided with a pair of over-centre stops to limit the maximum opening. The unit allows air flow only in the forward direction and automatically prevents the reverse flow. The valve unit is located in the ground connection air ducting conveying conditioned air from the ground connection to the cabin, thereby preventing air flow from the cabin inlet to the ambient, while admitting air from the ground connector into the cabin. The axis of the valve is kept vertical though it is designed to work in any attitude. The unit consists of two spring-loaded flaps which repose on two D-shaped openings and are provided with flat valve seats. The hinge of the flaps is thus at right angle to the direction of flow. The valve opens automatically when the thrust arising out of the pressure difference between the two sides exceeds the spring load and the flaps are displaced. The flaps close automatically when the pressure drop across the valve falls below the opening pressure or reverses.

The Design Approach

Theoretical design of valves : By design PRSOV is an assembly of three separate valves – namely the main valve, the relief valve for datum setting and a solenoid valve. When the solenoid is ON, the valve works as a pressure control valve and when it is OFF, the valve stops air flow from HP bleed and acts as a Non-Return Valve preventing reverse air flow. The datum setting relief valve controls the pilot chamber pressure and the main valve spool moves in the appropriate direction by the action of the differential pressure. As a result the flow area of the main valve changes and the desired output pressure is maintained. Figure 1 shows the internal construction of the valve.

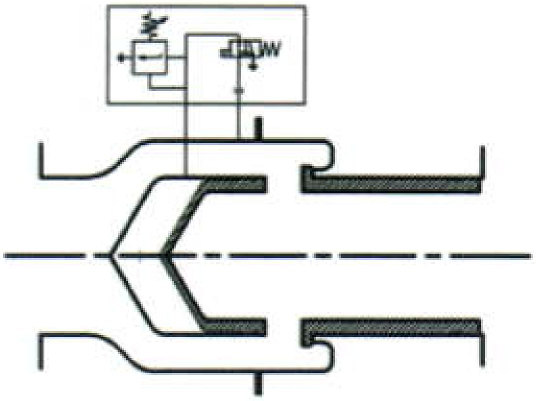


Figure 1: Schematic of pressure regulating and shut-off valve

The working principle of the valve has been determined from the pressure balance of the spool as:

$$(P_o - P_2)\frac{\pi}{4}d_o^2 = \left(\frac{P_1-P_2}{2}\right)\pi(d_o + t)t$$

Where, P_2 is the outlet pressure, P_1 is the inlet pressure, P_o is the pressure at pilot chamber, t is the thickness of pilot chamber wall and D_o is the sliding diameter of the piston.

The FSV is designed as a flanged valve assembly that is to be inserted between two pipe flanges of size 45 mm square on the 5/8" OD piping and held by means of a set of bolts & nuts. The actuator is mounted by means of a v-band clamp over the ball valve subassembly for easy removal and quick replacement without disturbing the piping on which it is mounted. Two O-rings are placed in the grooves provided on the two faces of the valve flanges to ensure leak-proof fitting. The Ball Valve body is made from a light alloy, housing a hollow stainless steel ball held between two valve seats of PEEK. To open the valve and ensure fuel flow to the engine, the hole in the ball should align with the axis of the piping. The motion of the valve ball through 90° is achieved through a differential gear train and a gear box with a large speed reduction coupled to two permanent magnet DC Micro-motors. Two fixed stops are provided to arrest ball displacement beyond 90°. Two pairs of micro-switches are provided to transmit electrical signal of valve limiting positions. When rotated through 90°, the ball shuts off the fuel flow. The valve also has an integral relief valve. The ball and the seat on the upstream side are kept floating and are loaded by means of a set of Belleville springs that makes it act as a relief valve by passing fuel upstream to the fuel tank, when the downstream pressure increases due to thermal expansion of fuel trapped in the downstream piping. When the valve is opened or closed with dual motor operation, it takes less than 2 s to complete the motion, which when operating with a single motor completes the motion in 4 s. The actuator works on 28 V DC supply. The valve is also fitted with two pairs of micro-switches to monitor opening and closing of the valve with either motor. The interconnecting circuitry between the two motors is also built in within the valve. The actuator includes EMI filters to ensure immunity from audio and radio frequency disturbances.

The NRV is designed as a sandwich type assembly, to be inserted between two pipe flanges of 3" diameter piping and held by means of a V-band Clamp. A locating pin provided in the valve prevents fitting in inappropriate attitudes. Two fixed stops are provided to arrest flap displacement beyond 90°.

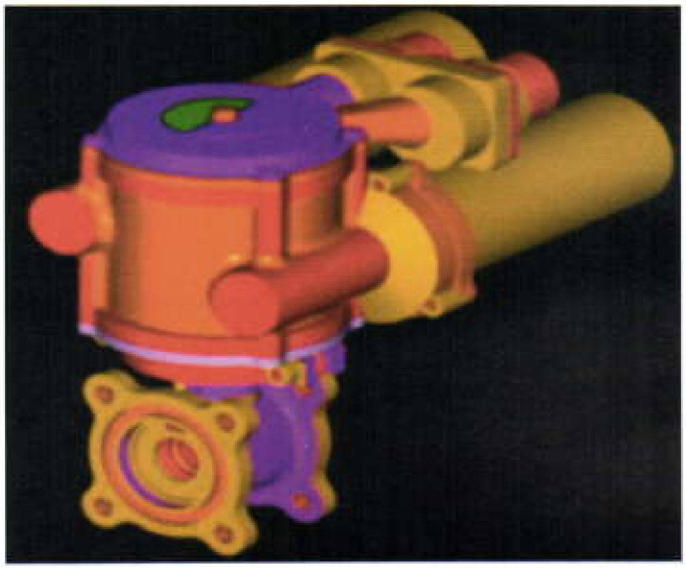


Figure 2: CAD model of fuel shut-off valve.

Design Verification through CFD analysis

In a PRSOV pilot chamber pressure is maintained by a separate control circuit, which varies with inlet pressure in a predetermined fashion. CFD analysis has been carried out to validate the theoretical design. Primary air flow takes place through the variable orifice formed by the valve body and the spool inside the valves. It has been modeled by 2D axisymmetric geometry as shown in Figure 3. Opening of the orifice varies with the movement of spool, depending upon the inlet pressure and thus constant pressure is obtained at the outlet. A secondary flow of air from upstream of the variable orifice takes place through a small fixed orifice incorporated into the pressure control circuit. Depending on the relief valve setting, this circuit regulates the pressure inside the pilot chamber. Pilot chamber pressure acts on one side of the spool head and pressure downstream of the variable orifice acts on the other side, thereby causing the spool to move in the appropriate direction. Pressure at the pilot chamber has been calculated offline. The movement of the spool has been simulated with the help of UDF in FLUENT software for dynamic mesh. Analysis to capture the flow characteristic in 3D is under way.

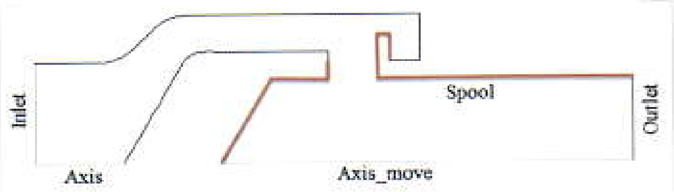


Figure 3: Axisymmetric 2D flow region of PRSOV.

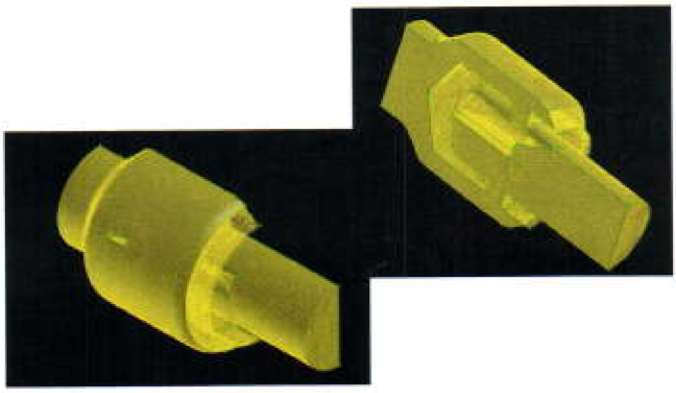
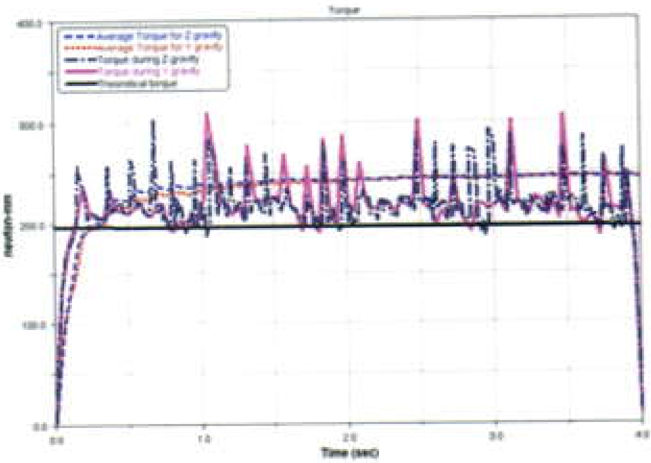


Figure 4: Modeling of flow zone of PRSOV in 3D.

Design Verification by kinematic & dynamic analyses

FSV is a combination of a specially designed ball valve with thermal relief and an electro-mechanical rotary actuator with redundant drive for additional safety. Kinematic and dynamic analyses of the combined system have been carried out in ADAMS software. Analysis for single motor and dual motor operation has been carried out to check the motor torque requirements obtained by theoretical calculation. Concept of rigid multi-body dynamics has been utilized for simulation of the quarter turn actuator and valve body.



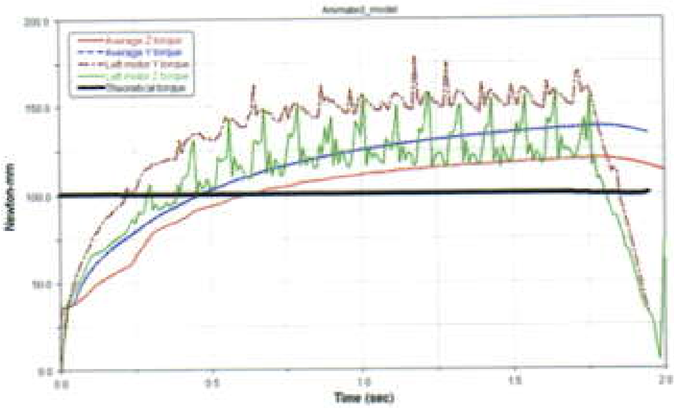


Figure 6: Dynamic torque requirement for dual motor operation.

Weigh optimization by FEM analysis

A detailed stress and deformation analysis has been carried out in ANSYS to minimize the weight of the PRSOV. The valve has been analyzed for 755 kPa and 360°C – the maximum pressure and temperature it will be subjected to during service life. A thermo-structural coupled analysis using 10 node tetrahedral element of size 1.8 mm has been used to generate the 3D mesh. Sectional views of the deformed valve body have been shown in Figures 7 and 8. Maximum outer diameter of the spool has been determined from the analysis to avoid distortion jamming inside the pilot chamber. Result of

Figure 7: Transverse sectional view of deformed valve body.

Figure 8: Axial sectional view of deformed valve body.

finite element analysis has been verified by comparing with the theoretical value of hoop stress at the outer shell of the valve body.

Testing

Developed valves are to be subjected to acceptance tests and qualification tests. In order to carry out these tests a state-of-art facility is being created at CSIR-CMERI, which is unique in the country. It will cater to the needs of the civilian aircrafts being manufactured in India. Figures 9 and 10 show the basic layout of the test rigs for PRSOV and FSV respectively.

Acceptance tests:

Various acceptance tests to be carried out for valves are:

- Pressure controller bench test
- Internal leakage tests
- Flow rate measurement at GLC
- Normal working under proof pressure at room & high temperatures
- Burst pressure test
- Thermal relief setting test (for fuel line valve only)

Qualification tests:

The valves are to be tested for airworthiness as per RTCA Do-160F standard as follows:

- Altitude Test
- Operating Low Temperature Test
- Operating High Temperature Test
- Humidity Test
- Operational Shock Test & Crash Safety
- Vibration Test
- Explosive Atmosphere
- Waterproofing Test Fluids Susceptibility Test
- Sand & Dust-proofing
- Fungus Resistance Test
- Salt Fog
- Magnetic Effects
- Power Input
- Voltage Spike
- Audio Frequency Conducted Susceptibility-Power Inputs
- Induced Signal Susceptibility
- Radio Frequency Susceptibility (Radiated and Conducted)
- Emission of Radio Frequency Energy
- Lightning Induced Transient Susceptibility
- Lightning Direct Effects
- Icing Test
- Electrostatic Discharge
- Fire, Flammability
- Endurance Test

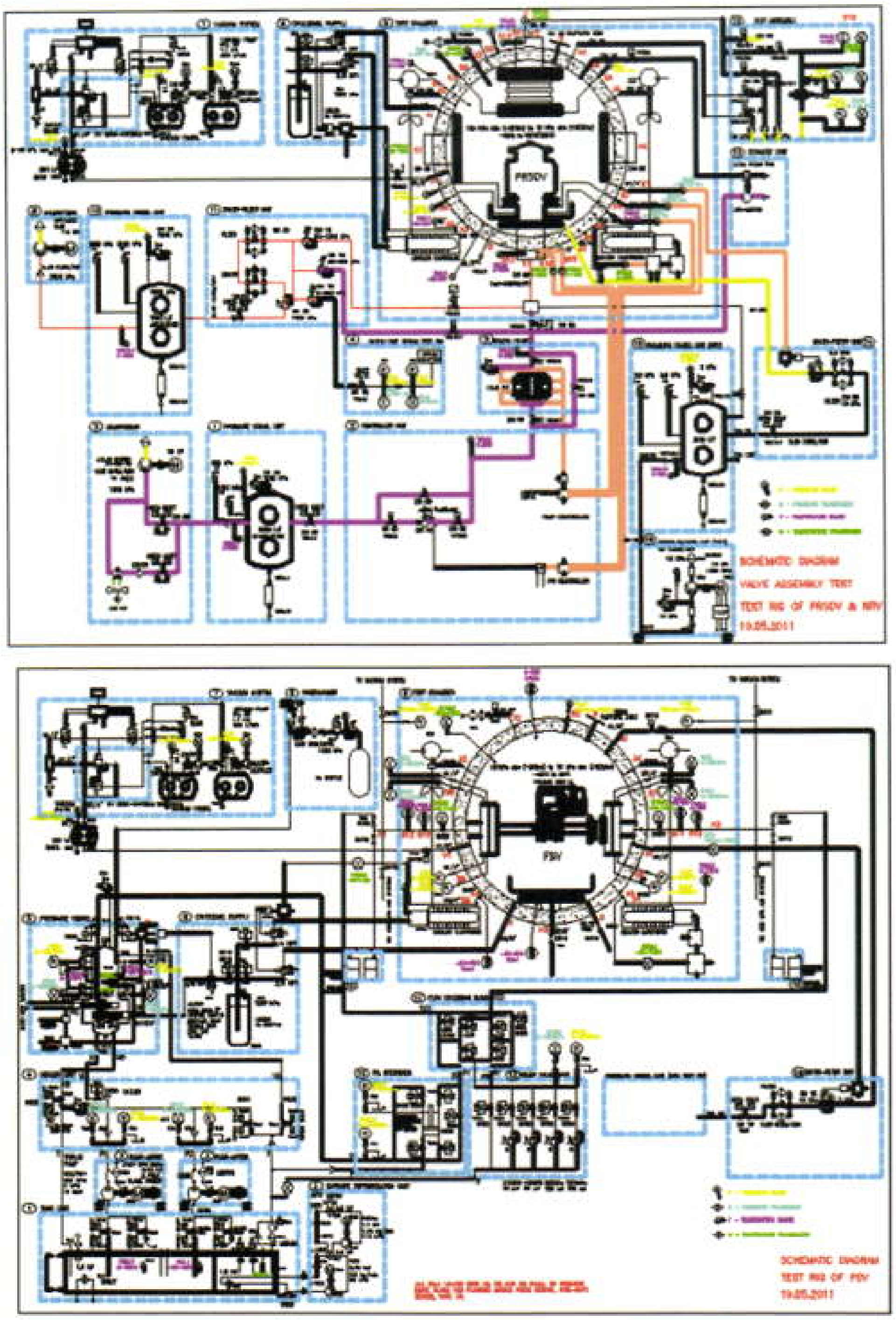


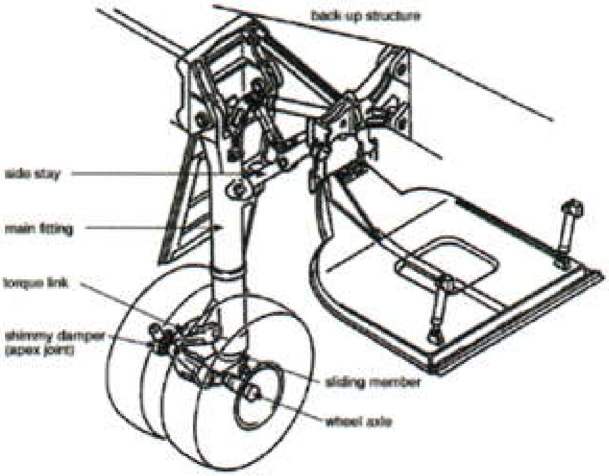
Figure 10: Layout of FSV test rig.

DESIGN OF AIRCRAFT LANDING GEAR AND SHIMMY ANALYSES AT CSIR-CMERI

Aircraft Landing Gear and Its Design Requirements

The landing gear is one of the most important and complex systems in an aircraft. According to some statistical studies, it is perhaps the most failure-prone system for many commercial transport aircraft. The design requirements on the landing gear are generally very stringent. Some of these are:

- In flight, the landing gear adds to the total dead weight of the aircraft. The mass of the landing gears typically varies between 6% and 10% of the aircraft mass. The aerodynamics of the aircraft should not be disturbed by the landing gear; thus the size of the fairing should be as small as possible to minimize the aerodynamic drag. Also a complicated retraction mechanism is required to retract and lower the landing gear during take-off and landing respectively.
- In many aircraft, the main wheels of the landing gear need to be located close to the center of gravity in the longitudinal direction. Sufficient load on the nose landing gear has to be provided to prevent aft-tipping of the aircraft. In addition, requirements may exist regarding the aircraft static attitude to provide the correct angle of attack during take-off.
- The landing gear should be able to absorb the energy of landing impact up to descent velocities of about 4 m/s. This requires a shock absorber with a considerable stroke in order to limit the loads during landing impact. On touch-down, the wheels have to be accelerated very fast. This phenomenon, called spin-up, results in very high loads on the landing gear structure. The landing gear should therefore be designed to sustain these loads.
- The vertical loads on the aircraft tires are generally very high. To minimize the damage to the runway and to have acceptable ground floatation characteristics, the tires should have a large contact area and consequently, the tire deflection will be very large. The combination of heavy loading, high deflection and high speed makes the operating conditions of aircraft tires very severe.
- The landing gear should be free from excessive vibrations induced by the brakes, possibly in connection with the anti-skid system and dynamic instabilities. Normally, the tires are not balanced or are balanced in a very limited way only. They can be sources of vibration also. Finally, shimmy can also result in undesirable vibrations of the landing gear structure.



Main components of a twin-wheeled, cantilevered, wing-mounted landing gear

Shimmy of Landing Gears

Wheeled vehicles, including automobiles, pulled trailers, motorcycles and aircraft occasionally experience self-excited, lateral oscillations due to a variety of flexibilities involved in their design. The phenomenon – conventionally referred to as shimmy – results in the wear and tear of related mechanical components and hence is undesirable for the smooth operation of a vehicle. The motion typically has a frequency in the range of 10 to 30 Hz. In extreme conditions in the case of an aircraft the induced vibration can be so violent as to limit the pilot's ability to see and read the instrument panel. It can even result in severe structural damage and landing gear collapse. Shimmy can occur both on nose and main landing gears. However, the occurrence is rare in the case of main landing gears.

Different types of Analyses with Landing Gears

The following types of analyses can be performed with landing gears:

- **Finite Element Analysis:** This is needed for weight and strength optimization of the landing gear.
- **Retraction Analysis:** This is necessary for an accurate determination of the size of the actuator which enables gear retraction into the wheel well in a short time.
- **Rebound Analysis:** This is done to calculate loads on sudden extension of the shock strut during take-off.
- **Kinematic Analysis:** This checks the trajectories of components during retraction and extension to assure that there is no interference between two components or with adjacent structures along the entire path.
- **Performance Analysis:** This includes analysis to ascertain whether the gear will shimmy during high-speed roll.

Work at CSIR-CMERI

CSIR-CMERI shall shortly be undertaking a performance analysis wherein a dedicated shimmy study will be conducted for the landing gear of the 90-seater National Civil Aircraft (NCA-90), which is being developed indigenously. To start with, simple models to analyze shimmy will be introduced. This will lead to the development of analytical expressions for shimmy stability as a function of tire and geometrical parameters of the landing gear. These methods will then be applied to study a twin-wheeled, cantilevered landing gear and an enhanced model shall be developed. Subsequently, a baseline configuration shall be identified for facilitating stability analyses. Parametric studies to optimize the baseline configuration will then be conducted. Introduction of special features like shimmy damper, tuned masses will be taken up and studies conducted. Finally, the role of different tire models proposed by several researchers on shimmy stability will be taken up briefly.

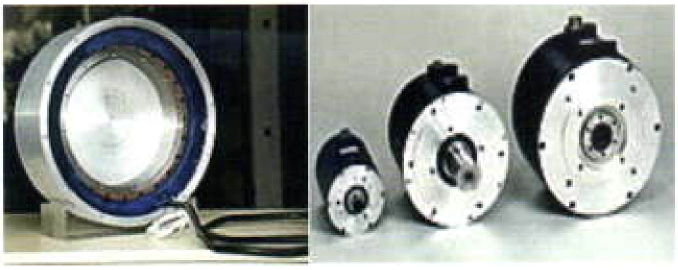
NEW VISTAS FOR ADVANCED MATERIALS PROCESSING AT CSIR-CMERI

The Center for Advanced Materials Processing (CAMP) at the CSIR-CMERI was created in 2005. As part of its mission, CAMP engages in the state-of-the-art multidisciplinary research at the intersections of the fields of materials, electronics and biology. CAMP's vision is to solve complex scientific and engineering challenges in the area of advanced materials including nano/biomaterials. This division also serves the industrial interests by forming industrial partner groups and seeking opportunities for sharing discoveries with the commercial sector. The Center has four scientists working on the above aspects; in addition, graduate students, faculty on sabbatical or summer visits, undergraduate and high school students work at the center through various internship programs.

Nanoparticles are particles that have one dimension that is 100 nanometers or less in size. The properties of many conventional materials change when formed from nanoparticles. This is typically because nanoparticles have a greater surface area per weight than larger particles; this causes them to be more reactive to certain other molecules. Nanoparticles are used, or are being evaluated for use in many fields.

Magnetic nanocomposites

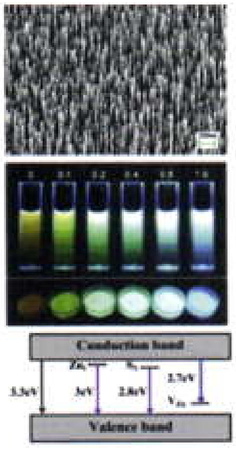
Nanocrystalline materials can possess bulk properties quite different from those commonly associated with conventional large-grained materials. In addition, magnetic nanocomposites have been found to possess properties which are similar to, but different from, the properties of the individual constituents. New magnetic phenomena, unusual property combinations, and both enhanced and diminished magnetic property values are just some of the changes observed in magnetic nanocomposites from conventional magnetic materials. These observations are assisting the rapid development of ultra-high density magnetic recording media, high temperature magnetic refrigerators, next-generation hard and soft ferromagnets, and controllable magnetic switches. Various novel magnetic nanocomposites are being synthesized including soft, hard and multiferroics with enhanced properties keeping in mind the vast area of applications.



DC motor based on permanent magnet

Semiconducting oxide nanoparticles

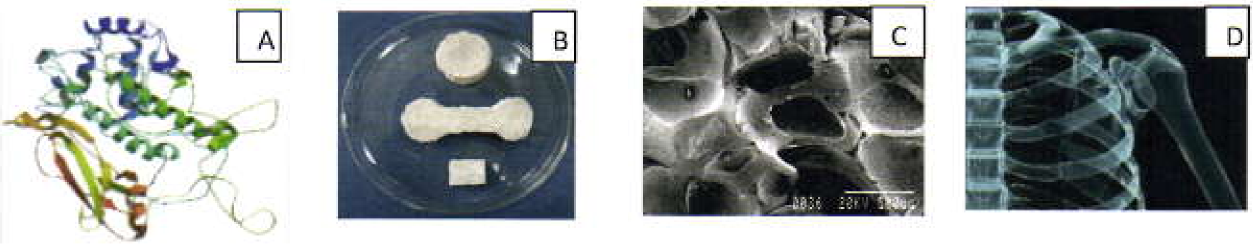
Among the inorganic materials, metal oxides such as TiO_2, ZnO, MgO and CaO are of particular interest as they are not only stable under harsh process conditions but are also generally regarded as safe materials to human beings and animals. Among others, ZnO has a wide and direct band gap and is probably the most investigated metal oxide due to its attractive and versatile properties for electronics, optoelectronics,



chemical and biological sensing, and renewable energy applications. Presently synthesizing ZnO nanoparticles are being synthesized with different shapes and size in both pure and doped forms for different potential applications. ZnO occurs as white powder known as zinc white or as the mineral zincite. In nanocrystalline form, it can produce various colours by the changes in band gaps and luminescence properties due to the defects inside the ZnO nanoparticles.

Naturally resourced Hydroxyapatite for Health and Environmental Application

Present research activity mainly emphasizes on development, characterization and application of porous hydroxyapatite (HAp) in chromatographic analysis of collagen (protein) and polyphenol oxidase (PPO), waste water treatment and most extensively for hard tissue engineering. HAp from different bio sources like fish scale, egg shell, bovine bone and simplified SBF have been synthesized and characterised in a cost effective and eco friendly manner. Porous scaffolds were developed by polymer sponge casting technique and mechanical characterization was performed for tissue engineering application. Cell culture studies showed positive and very promising result indicating biocompatibility without any direct toxic effect. Treatment and removal of both organic (specially phenolic compounds) and inorganic (specially hazardous heavy metals) pollutants have been carried out successfully using HAp and HAp-PPO conjugates. Extraction methodology of PPO has been statistically optimized using response surface methodology and isolated enzyme has been biochemically characterized by spectrometric and chromatographic analysis. As skeleton and bone related disorders are becoming a major threat to mankind, these studies may help prevent such problems. On the other side HAp and HAp-PPO conjugates can be a useful tool for bioremediation of aqueous environmental pollutants which will help provide sustainable source of pollutant free water.



(A) Crystal structure of Polyphenol Oxide (B) Hydroxyapatite scaffold (C)SEM structure of developed HAp (D) Artist Impression of Scaffold application

Functional Ceramics

Thousands of engineering components have benefited from advanced ceramic solutions for wear, corrosion and thermal resistance, providing considerable lifetime increases over conventional metal components. Although it is not always possible to provide the optimum design solution, advanced ceramics are frequently used as direct replacements for existing designs. Typical components include wear plates and thermal barriers, bearings for high speed and high stiffness spindles, bushes, gears and many others. Zirconia, aluminium like minerals are available in plenty in India which can be utilized for development of high performance ceramics. If proper mechanical property can be achieved after optimization and experimentation, these ceramics can be used in different wear resistant applications like cutting tool, valve sheet, pump components, etc. Alumina ceramic inserts are now replacing traditional carbide tools for high speed machining application due to their superior mechanical and chemical properties like high hardness, high toughness, high temperature resistance and inertness toward machining part.

Yttria based tetragonal zirconia polycrystalline in Al_2O_3 ceramic cutting inserts was developed by the chemical process route. Several machining experiments were performed and mathematical models for flank wear, force, roughness of the workpiece, etc. have been postulated by using Response Surface Methodology (RSM),Taguchi Method, Artificial Neural Network (ANN) and other soft computing techniques. Performance of the developed insert is also compared

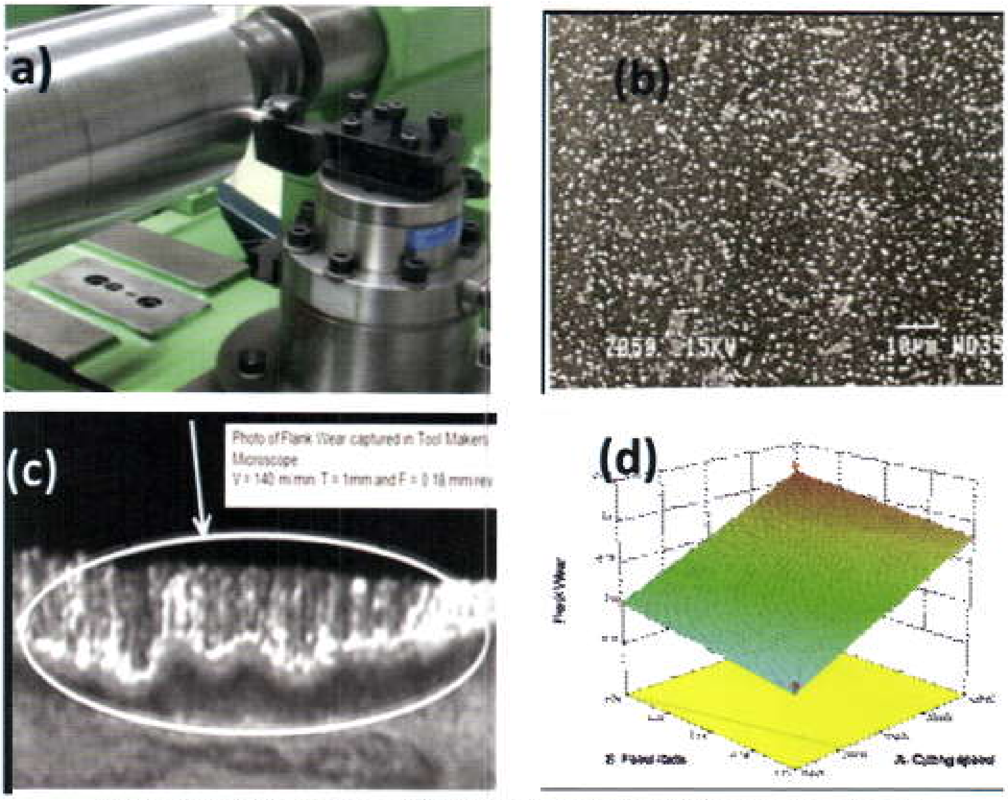


Figure (a) ZTA Ceramic tool fitted in a lathe (b) SEM image of Developed ZTA nano composite (c) Flank wear of cutting insert after 5 minutes operation (d) Relation of flank wear with other operating parameters

to other standard ceramic and coated carbide inserts with respect to tool wear, cutting forces, chip reduction coefficient and surface finish of the work.

Future plan

In future, this Group will concentrate in some of the upcoming areas of advanced materials and technology which have an immense impact in the society. These include

- Hybrid scaffold for soft and hard tissue generation.
- Multiferroic Nanocomposites: Novel materials for emerging technologies.
- Biosensing and biodegradation of aqueous phenolic contaminants from industrial waste water.
- Development & performance study of cross-flow nano-functional porous ceramics for water treatment.

SIMULATION & MODELING AT CSIR-CMERI: NEW HORIZONS

Forays in the field of Computational Fluid Dynamics

CSIR-CMERI professes a major strength in Computational Fluid Dynamics – a discipline which involves numerical simulation of fluid flow phenomena. In addition to high profile manpower, CSIR-CMERI is equipped with high end workstations with Intel Fortran, C and C++ compilers and ANSYS-Fluent flow simulation software. The Simulation & Modelling Group of CSIR-CMERI further possesses the requisite skill in the development of Navier-Stokes solvers suited for specific applications. The developed solvers are based on varied techniques including the lattice Boltzmann method, finite volume and finite element.

Within the short period of the Simulation & Modelling Group coming into being, a comprehensive numerical model based on finite volume and lattice Boltzmann methods has been developed which is useful in phase-change processes commonly encountered in casting, forging, steel making, semiconductor crystal growth and other modern manufacturing processes such as laser cutting, laser drilling or laser surface alloying. Fundamental studies on thermal characteristics of flow over bluff bodies undertaken by the Group finds application in heat exchangers, space heating, cooling towers, electronic cooling, flow around arrays of nuclear fuel rods and heat losses from high-rise buildings and chimneys. Some of the ongoing and proposed research involves flow and thermal modelling of magnetohydrodynamic and electrohydrodynamic micropumps used for transporting liquids through miniaturized systems. This is an important field due to its potential application in biotechnology, microchemical analysis, drug delivery systems and chip-integrated cooling systems. A related filed of activity is the study of wall bounded magnetohydrodynamic flow, where a conducting fluid interacts with an externally applied magnetic field. This happens in handling of liquid metal in metallurgical processes, cooling circuits of fast fission reactors and in self-cooled blankets of fusion reactors, where a liquid metal is used both as a coolant and a breeder material.

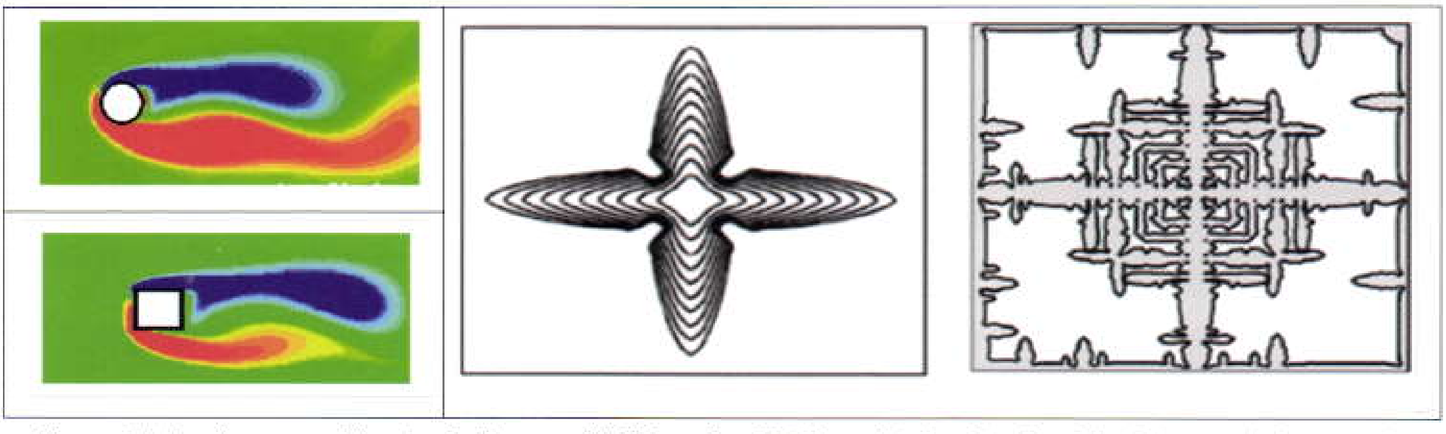


Figure 1: Left column - vorticity plot for flow over bluff obstacles; Middle and right - Simulated dendritic morphologies in the absence of fluid flow during crystal growth, corresponding to a thermal undercooling of 10K. Middle - Dendritic envelopes with deactivated thermal noise mechanisms. Right - Solidified phase fraction distribution with thermal noise mechanisms activated.

In recent times there has been a flurry of multidisciplinary research centred round biological systems. A proposed project which will be one of the major activities of the group in the future is aimed at a deeper understanding of the dynamics of biological cells in micro scale conduits in response to either a chemically changing environment or shear stress imparted by the background flow. Scientists involved in this project will also be focussing on modelling and simulation of microbial enhanced oil recovery (MEOR). The ultimate goal of this latter direction is to improve the recovery of oil entrapped in porous media, increasing economic profits. The numerical approach will be to solve a set of coupled nonlinear parabolic differential equations including equations for the rate of diffusion of microbes and their capture by the porous medium and differential balance equations of nutrient transport, including the effect of adsorption. The bacterial growth kinetics will be based on the Monod equation. Artificial neural network modelling will be used for the description of in situ MEOR processes.

In any complex flow scenario, vortices play an important role. The Simulation & Modelling Group is involved in the study of vortices in both incompressible and compressible flow regimes using advanced numerical techniques such as the compact and high order MUSCL schemes for evaluation of the convective derivatives and spectrally optimized multistage Runge-Kutta time integration schemes. Investigations on innovative use of boundary conditions have led to the numerical simulation of an isolated vortex subject to background shear in a relatively small numerical domain. A pressure-velocity formulation has been employed for this study. Research is also undertaken on solving similar problems using a stream function and vorticity approach. The high accuracy schemes mentioned before are required to capture these vortices and their interaction with the surroundings, leading to growth of smaller vortices – features which are difficult to resolve using standard schemes at high Reynolds numbers. These fundamental studies equip the numerical analyst with much needed insight as he encounters more complex flow configurations. The CSIR-CMERI-built autonomous underwater vehicle (AUV) provides an excellent opportunity for utilizing the innate numerical skills in accurately predicting the lift and drag forces on the AUV. This project, currently underway, gains more importance as the AUV proudly aims at diving to greater depths below the sea surface. When the incoming flow hits the vehicle at a large angle of attack, the AUV would be shedding vortices sideways. The fundamental studies on isolated vortices form the platform based on which these real life situations can be carefully assessed. Capturing these vortices would require careful grid generation, an area where the Simulation & Modelling Group members have adequate background. Though it is possible to design a vehicle based on available theoretical and empirical data, well validated numerical tools lead to a more reliable design – one with lower factors of safety and therefore, capable of handling its power resources more efficiently. Using numerical tools, the designer can estimate the performance of the vehicle in off-design conditions. Compared to experiments, these numerical data come at a significantly lower cost. In future, the plan is to estimate the hydrodynamic coefficients using CFD simulation. Full six degrees of freedom motion studies of the vehicle can then be conducted using these coefficients in the governing equations.

Aircraft and missiles fly at speeds where the Mach number is high, necessitating use of compressible flow solvers. There are several classes of numerical schemes for use in compressible solvers developed across the world over the past few decades. Interpretation and implementation of the schemes need simple numerical set-ups where the basic flow features are present. In a recent collaborative research effort involving the Simulation & Modelling and the Thermal Engineering groups of CSIR-CMERI and IIT Kanpur, a shock tube generated vortex has been studied numerically and experimentally. This research also led to the study and implementation of advanced boundary conditions designed for unsteady compressible flows. The primary objective of this study was to understand evolution of shock tube generated vortices and their interaction with trailing Kelvin-Helmholtz instability generated vortexlets. To complicate the situation, the primary vortex has embedded shocks. The shock waves and the cores of vortices are regions of sharp gradients of flow variables, and one needs to carefully adjust the numerical dissipation of the scheme such that it is neither too high to remove flow details, nor too low so that the solver 'blows-up' during time iteration. In a related study, a moving shock is allowed to diffract over a wedge leading to a tip vortex which interacts with reflected shocks. This study employs fifth order MUSCL interpolation schemes for the convective terms with a six stage Runge-Kutta time integrator. The resulting vorticity field is shown in Figure 2. A three dimensional version has also been developed to study mixing characteristics of air injections in a supersonic stream behind a backward facing step. This effort is likely to culminate in the development of an indigenous solver equipped with several advanced turbulence models for scramjet combustors, catering to the needs of the defence sector of the country.

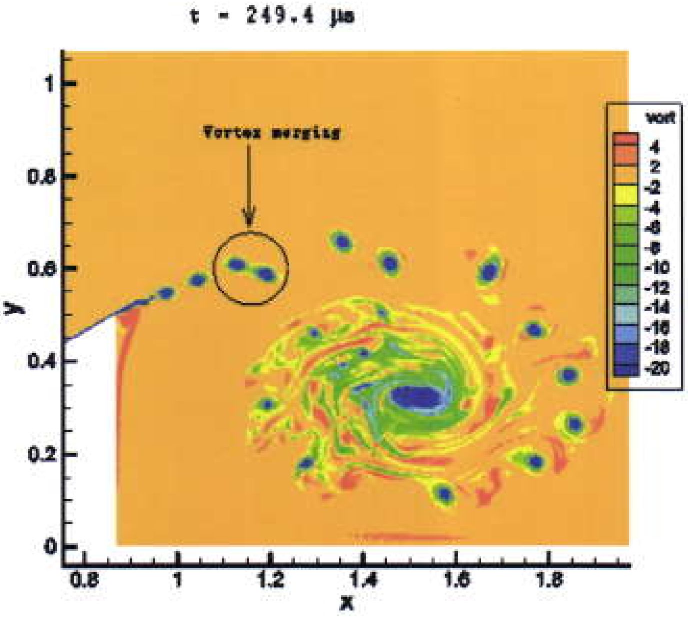


Figure 2: Vortex evolution in shock diffraction over a wedge - known as the Schardin problem.

Hypersonic vehicles operate at even higher Mach numbers. The numerical solver has to handle dissociation of the component gases of air. Effect of incorporation of an equilibrium air-chemistry is displayed in Figure 3. This solver, developed by a member of the Simulation & Modelling Group, is based on unstructured grids, enabling it to include multiple bodies in the computational domain with ease compared to a multi-block structured solver. The contour plots show that the shock locations for the perfect gas and equilibrium chemistry models under the same free stream conditions are different. The shock location in equilibrium chemistry model is closer to the body compared to perfect gas model. The density ratio across the shock is considerably higher in the former model and since the shock stand-off distance varies inversely to the density ratio, the shock is closer to the body. The difference in pressure ratio in the two models is marginal but the temperature in equilibrium chemistry model is much less. The differences increase with flow Mach number.

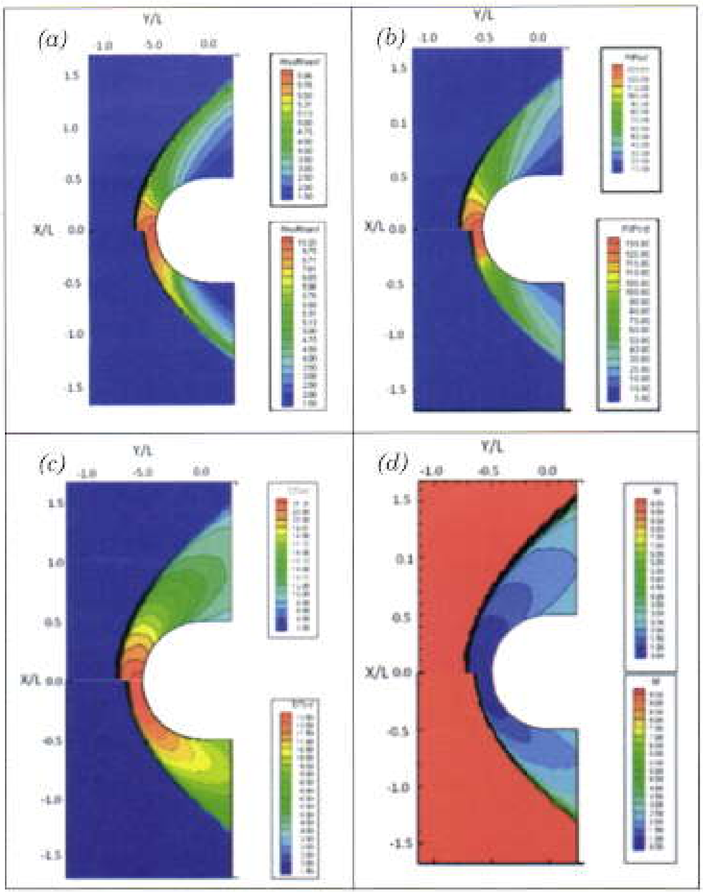


Figure 3: (a) Density, (b) pressure, (c) temperature and (d) Mach number contours over a semi-circular body at Mach 10: perfect gas model (upper) and equilibrium chemistry model (lower).

In simulation of flow over bluff obstacles, often it is assumed that the body is rigidly fixed in space. In an interesting study, a finite element based flow solver has been employed by a group member to observe the vortex shedding pattern behind a cylinder in forced vibration. Figure 4 shows the resulting vortex shedding pattern. This study will be extended to investigate more complicated fluid-structure interaction (FSI) problems in future.

In the field of Computational Fluid Dynamics, The Simulation & Modelling Group is looking forward to applying various flow simulation techniques in fundamental studies as well as practical applications.

Computational Solid Mechanics

Another component activity of the Simulation and Modelling Group (SMG) targets research in the field of computational solid mechanics, especially in the area of developing new robust finite elements that are immune to distortions. Such distortions in elements are often unavoidable due to meshing around sharp corners that occur in many problems of stress analysis. Isoparametric elements are sensitive to such distortions and yield results of considerable errors in the estimation of stresses near sharp edges.

Recent research work in error analysis of finite elements at CSIR-CMERI has given rise to new and improved class of parametric finite elements that are immune to distortions. These elements automatically satisfy the best-fit paradigm of computation. The efficacy of performance of the recently developed one-dimensional, quadratic, three-noded parametric element under distortions (arising from the offset of the internal node from the element centre) has been demonstrated. Research is being conducted to develop robust two- and three-dimensional distortion immune elements for various fields of engineering and physical sciences.

Together with the Product Design and Simulation Division, the Simulation & Modelling Group is also involved with some R&D activities for industrial requirements. These include the development of design procedures and dynamic stability analysis of aircraft landing gears, and the design and stress analysis of composite cylinders subjected to high pressures.

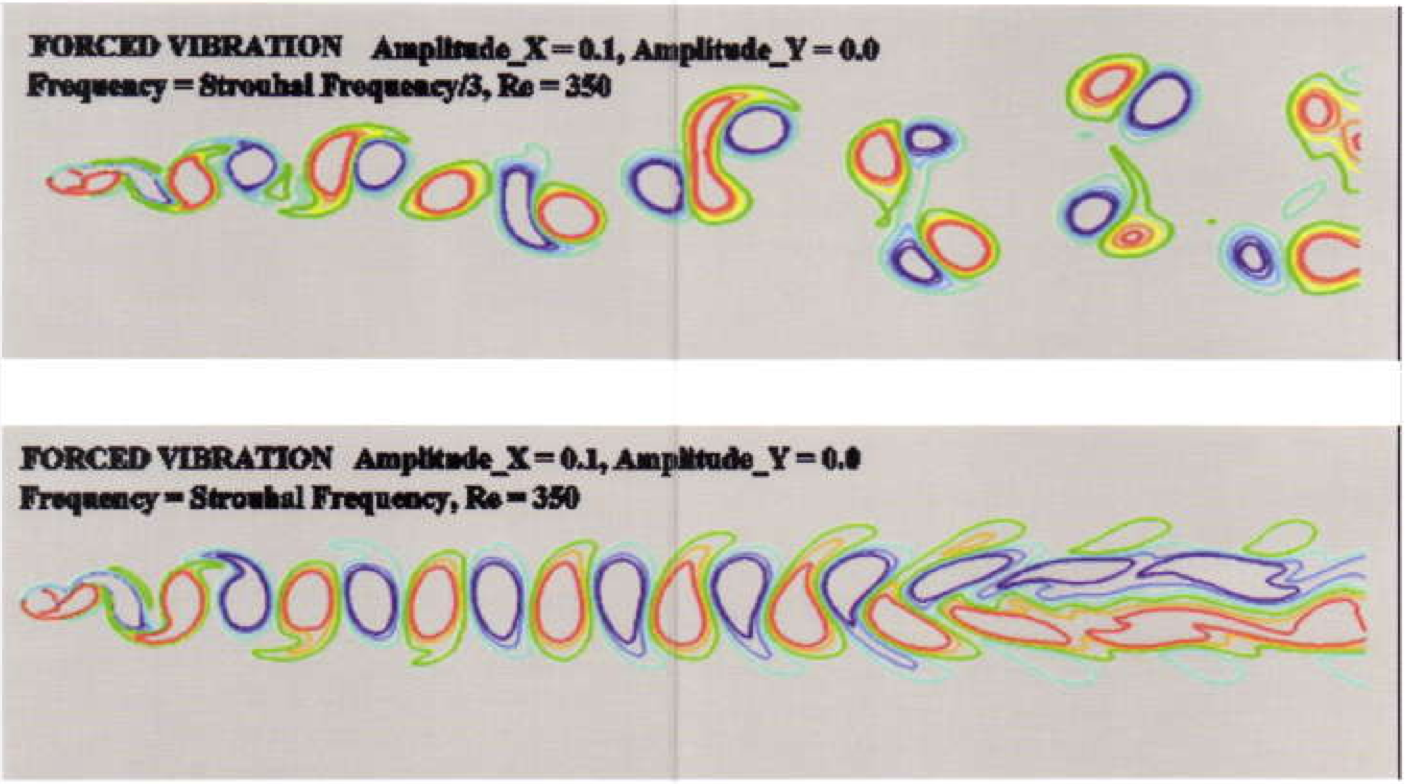
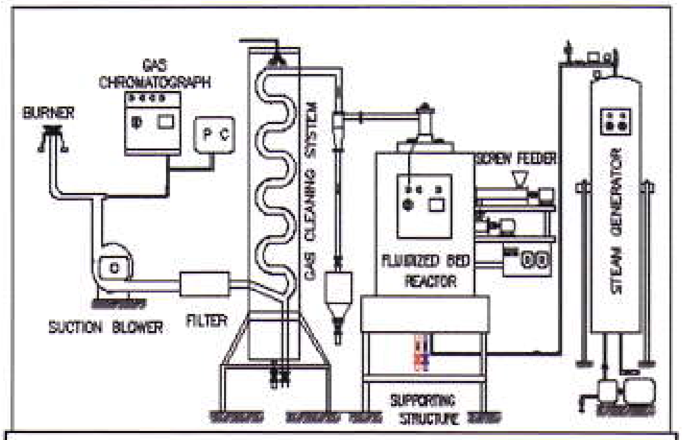


Figure 4: Vortex shedding pattern behind a vibrating cylinder. Top- The 2P mode of shedding when the forcing frequency is one-third of Strouhal frequency. Bottom- The 2S mode of shedding when the forcing frequency is equal to the Strouhal frequency.

EXPERIMENTAL INVESTIGATION OF FLUIDIZED BED GASIFICATION

The need for conserving limited supply of fossil fuel, climate change and increasing concern over global warming have prompted search for new and cleaner methods of power generation, particularly from renewable energy sources. Amongst the different renewable sources, biomass appears to be the most promising source. India has substantial biomass resources in the form of agricultural residues that are currently used as domestic fuel. However, the process of utilization of biomass in the domestic sector is quite inefficient, and such utilization contributes to pollution from inadequately controlled gaseous emissions. Gasification of biomass – basically thermo-chemical conversion of solid biomass into fuel gas containing mainly hydrogen, carbon monoxide, carbon dioxide, methane and nitrogen – probably constitutes a more efficient way of biomass utilization. The product gas from the reactor also contains some contaminants like char particle, ash and some higher hydrocarbons or tar. A limited supply of oxygen, air, steam or a combination of these serves as gasifying agent. Biomass gasification by using air produces a gas with a lower Calorific Value (4-7 MJ/Nm^3), whereas gasification with steam and oxygen produces the gas having medium to higher Calorific Values (10-18 MJ/Nm^3). In biomass gasification, fluidized bed technology is widely used due to the advantages of high heat transfer, uniform and controllable temperature, favorable gas-solid contacting, etc.

At CSIR-CMERI, Durgapur experiments are being conducted in a laboratory scale bubbling fluidized bed for devising efficient ways of biomass utilization (Figure 1). The inner diameter of the lab-scale gasifier is 50 mm and the length 1200 mm. Rice husk is used as the biomass fuel for the current investigation. Superheated steam at 200° C is introduced at the bottom of the gasifier. The steam is used both as gasifying and fluidizing agent. Rice husk is fed into the gasifier through a water-cooled screw feeder with a variable speed drive. Sand is used as inert bed material due to the non-granular and flaky nature of the rice husk. The gasifier is placed inside an electric furnace to provide the heat



Schematic diagram of the gasifier

Actual photograph of the gasifier

Figure 1: Bubbling fluidized bed gasifier

required for gasification. Temperatures are measured with R-type Platinum-Rhodium thermocouple and hot gas escaping from the gasifier is cleaned and cooled before being analysed in a Gas Chromatograph. The Gas Chromatograph is calibrated in the range used before analysis. Experiments for different temperature are carried out by initially keeping the S/B fixed and then by varying the S/B keeping the temperature fixed. The resulting product gas compositions are studied. The results of variation of gas composition with reactor temperature and steam rate are shown in Figures 2 & 3.

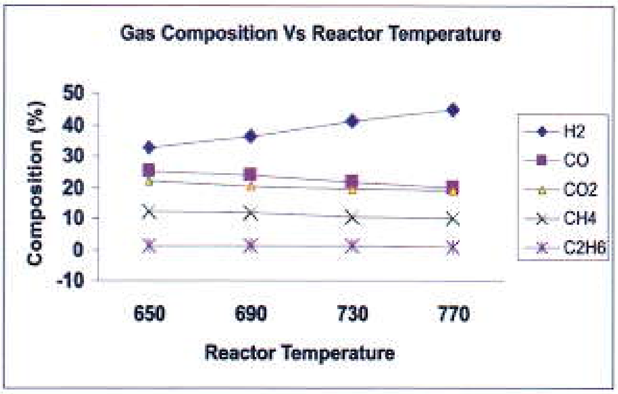


Figure 2: Gas composition with temperature

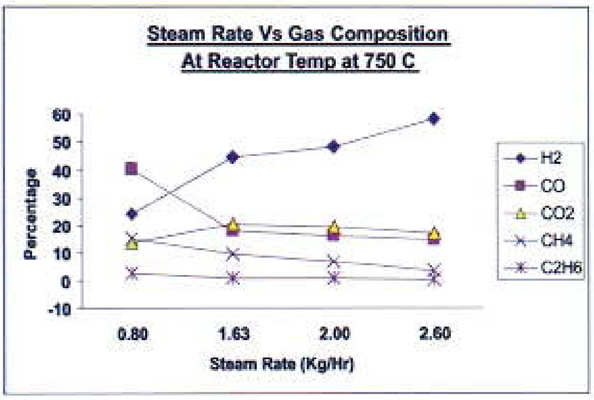


Figure 3: Gas composition with steam rate

To avoid the external heat source, a dual fluidized bed gasifier is developed as illustrated in Figure 4. This dual fluidized bed gasifier comprises two interconnected reactors, one of which acts as the gasifier while the other acts as the combustor. The heat required for gasification – which is supplied from the electric furnace in the present investigation – is replaced by the continuous transfer of hot bed material from the combustor, thereby dispensing with electrical energy. A cold model study of the dual fluidized bed gasifier has been undertaken. The study includes the effects of axial pressure drop, axial voidage and solid circulation under different operating conditions.

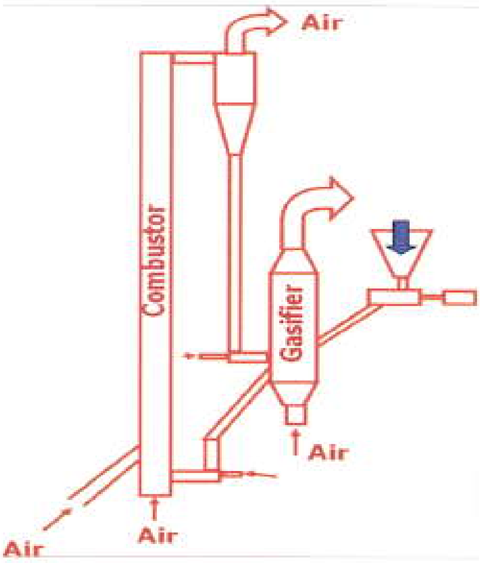


Figure 4: Twin fluidized bed gasifier

CFD simulation of fluidized bed hydrodynamics

Computational Fluid Dynamic (CFD) can be used as a powerful tool for understanding the complex phenomena of interaction between the gas phase and the particle phase in a fluidized bed system. In general, two different categories of CFD models – the Euler-Euler Model and the Euler-Lagrange model – are used for fluidized-bed simulation. In the Euler- Euler model both the gas and the solid are treated as a continuous phase. On the other hand, the Euler-Lagrange model treats the gas as continuous and the solid as discrete phases and the motion of each particle is tracked. The Euler- Euler model has been selected for the ongoing study to understand the hydrodynamics of the 2-D bubbling fluidized bed reactor with Geldert B particle. In the Euler-Euler approach, the different phases are treated mathematically as interpenetrating continua and conservation equations for mass and momentum for each phase are derived separately. Coupling is achieved through the interphase exchange coefficients and the solid phase properties are obtained by the application of the kinetic theory of granular flow (KTGF). The physical model of the reactor is shown in Figure 5 and the system property and the initial condition for the present simulation are provided in Table 1.

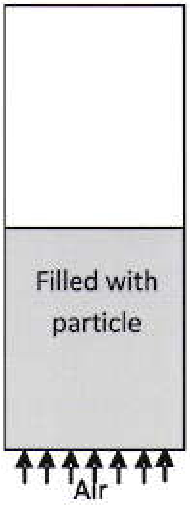
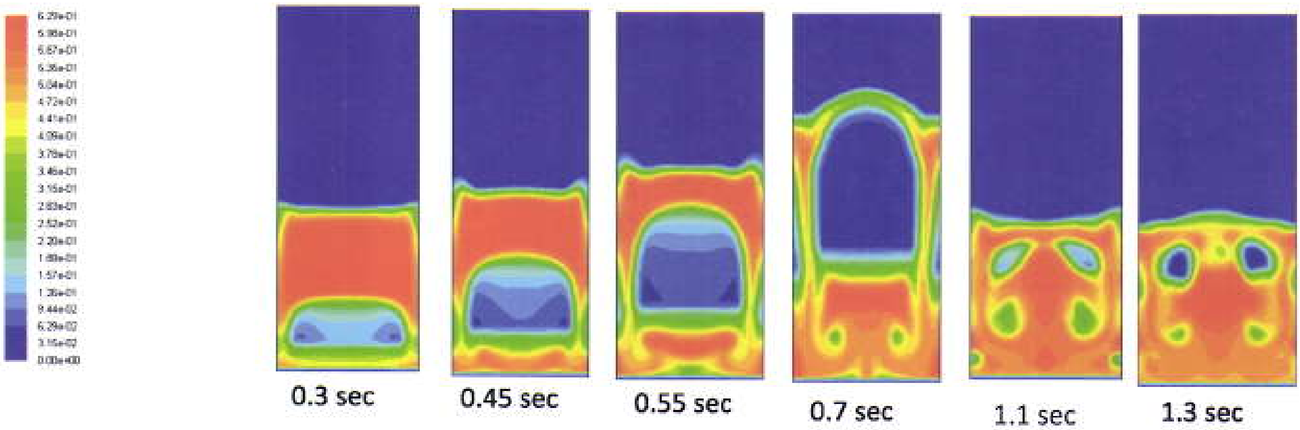


Figure 5: Physical Model

Table.1. System property and initial condition

Width of bed (m)	0.155
Height of bed (m)	0.4
Particle diameter (μm)	530
Particle density (kg/m3)	2500
Initial bed height (m)	0.2
Initial solid volume fraction	0.4
Restitution coefficient	0.99
Inlet gas velocity (m/sec)	0.587

Figure 6 shows the bubble formation with time obtained from the simulation. It shows that initially there is slug formation of a large bubble due to the sudden inlet gas flow into a stagnant bed. Small bubbles form in the bed after the slag formation of large bubbles breaks up.



0.3 sec 0.45 sec 0.55 sec 0.7 sec 1.1 sec 1.3 sec

Figure 6: Bubble formation in a bubbling fluidized bed reactor

EMERGING PROSPECTS IN SURFACE ENGINEERING & TRIBOLOGY

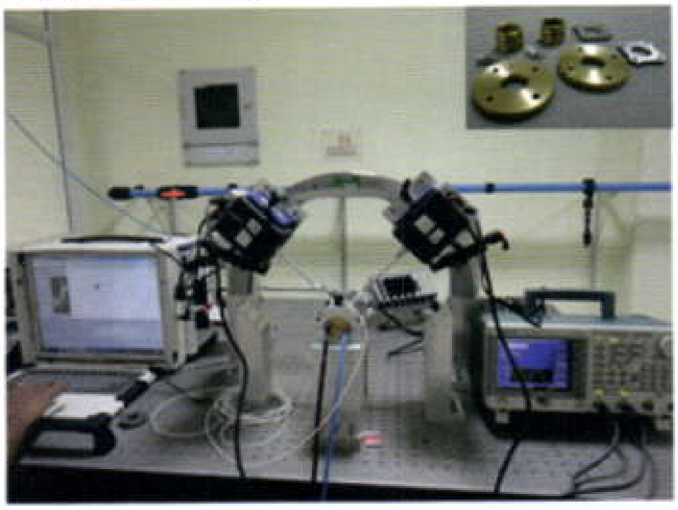
The better understanding of friction, wear and lubrication leads to superior products and processes. Frictional interactions in small scale are becoming increasingly important for the development of new products in mechanics, chemistry, electronics, life sciences, sensors, and by extension for all modern technology related to microsystems engineering. The word Tribology derives from the Greek "tribo," meaning "to rub," and "logos," meaning "principle or logic." Tribology is thus the **science and technology of interacting surfaces in relative motion.** Tribology includes research with and application of the principles of friction, wear and lubrication. Surface Engineering indeed is an interdisciplinary area in materials science that deals with the surface of solid matters. Surface engineering techniques can be used to develop a wide range of functional requirements, including physical, chemical, electrical, electronic, magnetic, mechanical, wear and corrosion properties at the required substrate surfaces. Almost all types of materials – including metals, polymers, ceramics, composites, biomaterials and nanomaterials – can be coated on similar or dissimilar materials.

Research in Surface Engineering and Tribology at CSIR-CMERI, Durgapur is primarily focused on the understanding of a range of associated phenomenon, and is aided by well equipped state-of-the-art and unique experimental facilities, mostly designed and developed in-house. The current research domains include Micro-Scale Air, Foil and Magnetic Bearings, Micro-Mechanical Machining, Nano-Lubrication and Cooling, Nanocomposite films for wear resistance, Nano-Scale Surface Texturing and Manipulation for improved tribological properties, Experimental and Theoretical understanding and prognosis of fatigue life of rolling element bearings, and enhancement of residual life of machine elements using various signal conditioning and improved noise reduction algorithms.

μAir, μFoil and μMagnetic Bearings: Under the Eleventh Five Year Plan, CSRI-CMERI extensively worked towards the development of **μ Air Bearing** along with extensive theoretical and experimental studies to generate comprehensive knowledge in these areas. The development of externally pressurized air bearings and porous air bearings are notable among these with applications in *High Speed μAir Spindle and μLinear Stage* with submicron accuracy. Also worthy of mention is the development of μTurbine with successful demonstrated running speed of **275000 rpm** maximum. These are critical technologies needed for development of μ-manufacturing machine tools and products. As evident, understanding the inherent physics of bearings holds the key to the successful development of turbo-machinery, with the experiments providing advanced information for conversion to high fidelity products.

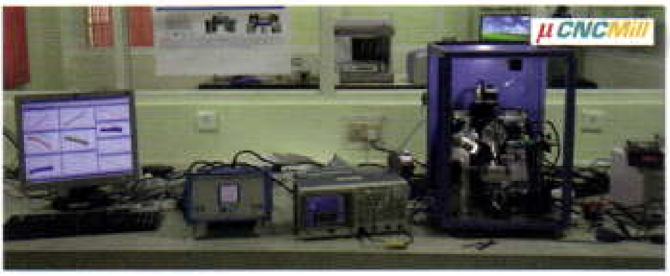
Demonstrated Microturbine running at 275000 rpm

Normally, an indirect method is used for measuring various dynamic coefficients pertaining to bearings. However, by introducing innovative loading decoupling mechanism, a test rig has been successfully developed for determining air bearing dynamic coefficients. Study of foil bearings with the target of applying the technology for spinning spindles or turbines has also been undertaken. Development of micro-magnetic bearings having typical application in ventricular assist devices, artificial heart pumps, etc. is also an area that is receiving attention.



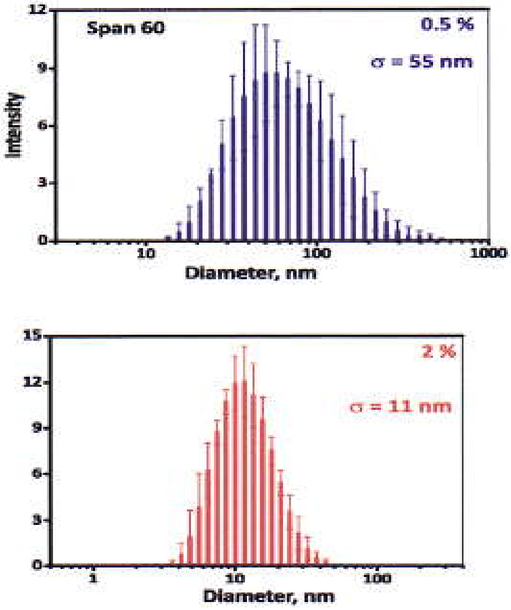
Innovative Gas Bearing Test Rig for directly evaluating dynamic coefficients of bearings

µMilling: An interesting facet of ongoing research is the development of a five axis micro milling machine, which probably is the first indigenous development and the machine is currently being calibrated and experimented on. The developed micro milling machine has a work volume of around 20 mm x 20 mm x 30 mm, with 50 nm minimum resolution, and with minimum steps along the A & C axes of the order of ~ 0.002°, and a spindle speed of around 80000 rpm. The gantry type machine has improved stiffness and better accuracy. Two types of controllers were developed comprising the National Instruments' LabView based Controller and the Delta tau controller. Extensive experiments were conducted to investigate the coating of different micro cutting tools and to find the optimal cutting conditions of different advanced materials such as INCONEL 718, Titanium alloys, etc. Development of novel cutting fluids is being pursued right now.

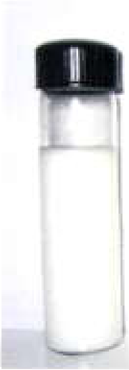


Five Axis µMilling Machine designed and developed by this group, First its kind in India.

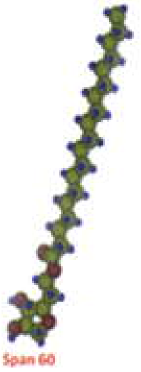
Nanotribology: The use of traditional additives in automotive and industrial lubrication leads to substantial toxicity and pollution. Gas emissions engendered by these additives are harmful for the environment; moreover, the slow degradation of the additives adversely affects the tribological properties. Initiatives are being taken to develop a new generation of lubricants based on the additives using layered nanoparticles. Conventional heat transfer fluids such as water, mineral oil and ethylene glycol play an important role in power utilities, as also in chemical, air conditioning, transportation, and microelectronics industries. The heat transfer properties of these conventional fluids can be significantly enhanced by selective dispersion of nanometer-sized solid particles and fibers (i.e., nanoparticles) in fluids. Ionic liquids (ILs) in principle are a diverse group of salts which are liquid at ambient temperatures and offer a very wide range of properties as non-volatile plasticizers, thermal and hydraulic fluids, high & low temperature lubricants and electrolytes for electrochemical cells and devices. Ionic liquids are becoming increasingly important and of particular interest because they have a number of matchless characteristics including negligible volatility, non-flammability, high thermal stability, low melting point, broad liquid range, and controlled miscibility with organic compounds. In particular focus is the use of water as a carrier for industrial cooling and lubrication.



Droplet size distribution of the emulsion made by span 80 emulsifier with oil of 0.5% and 2%.



Nano-emulsion



Energy optimized model of span 60.

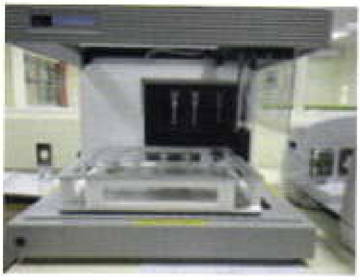
Predictive Maintence Through Used Oil Analyis:

What is blood to humans is circulating oil to machinery. Like blood, lubricating oil carries substantial levels of information about the machinery in which it circulates. Wear of moving parts, for instance, produces a good amount of minute particles, which are carried by the lubricant. These minute metal particles invisible to the naked eye can provide precise information about the machine elements that are being worn out and can be detected by using ferrography. The lubricant itself can produce or contain contaminants - wear, sludge (deterioration of the oil), soot, acids (oxidation of the oil, sulphur from fuel), temperature changes or extremes, fuel, anti-freeze, deterioration of packing and seals (e.g. deteriorating through the action of synthetic oils or brake fluids), etc.

Oil analysis (OA) is the sampling and laboratory analysis of lubricant properties, suspended contaminants, and wears debris. OA is performed during routine preventive maintenance to provide meaningful and accurate information on lubricant and machine condition. By tracking oil analysis sample results over the life of a particular machine, trends can be established which can help to eliminate costly repairs. OA can be divided into three categories:

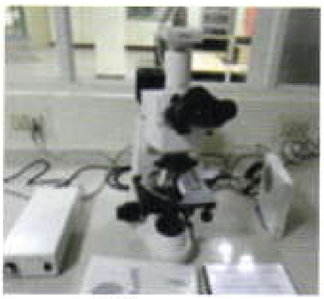
1) Analysis of oil properties including those of the base oil and its additives,
2) Analysis of contaminants,
3) Analysis of wear debris from machinery,

Several methods are used to analyze oil condition, contamination and wear debris. These include viscosity analysis, total acid number (TAN) assessment, total base number (TBN) assessment, particle counting, analytical ferrography analysis as well as detection of contaminants and degradation of lube oils like soot, water, nitration, oxidation, sulfation and antiwear depletion using Fourier Transform Infrared (FTIR) Spectroscopy.



Oil Express

FTIR



Microscope

Ferrography

Ultrasonic

Nano Particle Analyzer

Pin-on-Disk

Auto Visc *TAN/TBN Analyzer*

Used Oil Analysis Instruments and facilities at SET Group

CSIR-CMERI's oil analysis service detects abnormal equipment condition before that equipment runs into costly repairs, with time to schedule corrective action. This reduces the cost of the repairs. Problems are caught early, minimizing unscheduled and costly downtime. Physical and chemical properties are determined using sophisticated SpectroVISC Q^{300} viscometer, PerkinElmer 100 series FTIR Spectrometer and 877 Titrino plus TAN/TBN analyzer. Fluid and machine destructive contaminants are detected by particle size analyzer (Zetasizer nano ZS90 by Malvern) which measures the particle sizes ranging from 1 nm to 5 micron as well as FTIR and partly by TAN/TBN analyzer. Infra Red Analysis (FTIR) determines basic physical composition (base stock and additives), additive chemistry and their effectiveness, contamination including oxidation, sulfation, nitration, water, antifreeze and soot and lube degradation. The nature, severity and root cause of a machine wearing problem is detected by analyzing the wear particle morphology, color, size, reflectivity, surface appearance, edge detail, angularity, etc. using analytical ferrography.

Predictive Algorithms & Filter Design:

Working with industry and responding to the innovation needs of industry constitutes another area of research. Development of tool wear monitoring system for wire drawing process has been well recognized in industry due to ever increasing demand for high quality production and productivity improvement. More specifically, increasing market demands on productivity and accuracy of wire drawing process renders monitor wear necessary. Wear monitor has been extensively studied by the manufacturing industries for over three decades and no accurate and reliable product for measuring tool wear has been developed yet. As of today, no commercial tool is available for monitoring the wear of wire drawing die. CSIR-CMERI is currently working on development of innovative die wear monitoring system based acoustic signal analysis and filtering algorithms.

Future Research: under XII five year plan, it is proposed to work on fontier technologies such nano-scale surface texturing, nano-scale positioning system, nano-composite, lubrications for MEMS devices, etc.

THE WORLD OF MICRO-NANO SYSTEMS ENGINEERING

A Brief Introduction

Micro-nano systems engineering (MNST) is the science of creating, designing, integrating and manufacturing miniature components, instruments and systems having feature dimensions in few nanometers to few microns. The world of micro-nano systems engineering involves multidisciplinary approaches, integrating mechanical and electronic elements with computational, chemical, biological and optical elements, and a wide range of materials. The ability to create structures and patterns on microscopic and sub-microscopic length scales has triggered a wide range of scientific investigation, leading to development of novel miniaturized devices and systems for transporting and manipulating fluidic samples in a rapid, efficient and controllable manner. The applications are many in diverse high-technology areas including biotechnology and biomedical engineering, inkjet printing, thermal management of electronic devices/systems, etc. However, it needs to be appreciated that microsystems does not become functional by itself but requires a strong interfacing with advanced miniaturized fabrication protocols to make the devices and systems functional and effective.

CSIR-CMERI Focus

Since 2006, researchers at CSIR-CMERI are continuously striving towards engineering of systems and machines involving electronic, mechanical and chemical elements and for multiple functions on the dimensional scale of 10 nm to 500 μm. The research focus includes:

- Fundamental understanding of mechanics, heat transfer, fluidics, electronics, chemistry, optics, energy conversion and storage techniques in micro-nano systems engineering
- Multi-material micro-nano scale manufacturing science
- Development of integrated micro-machines, systems and devices
- Micro-machine elements including micro-bearings, high speed spindle and micro-nano tribology, etc.
- Lab-on-chip devices for bio-diagnostics
- Bio-inspired actuators and sensors

The First Milestone

During the XIth five-year plan period, CSIR-CMERI was charged with the nodal responsibility of implementing a network project on Modular Reconfigurable Multi Material Micro Manufacturing Systems (MRMMS) for Desktop Manufacturing Capabilities in collaboration with three other CSIR laboratories. The abiding efforts of six research groups across the four laboratories led to the successful demonstration of four micro-machines. Over the last few years, these teams have made significant contributions and many of the studies performed in CSIR have been attempted for the first time. The key achievements made under this network project include:

1. **Design of and development first generation Micro Machines**
    - Micro – EDM machine
    - 5-axis micro milling machine
    - Micro-scale laser processing machine
    - Reconfigurable micro-factory testbed (under development)

2. **Development of process technologies and a few important scientific investigations**
    - Platinization of Nafion polymer for developing Ionic Polymer Metal Composites for actuator applications
    - Parallel spark across multiple electrodes in µ-EDM: the concept towards enabling batch production capabilities
    - Selective laser (micro-laser) sintering of Cu powder <10 µm particle size
    - Synthesis of 30 nm scale Alumina powder by solution combustion method
3. **Development of micro machine elements and subsystems**
    - High Speed Spindle (160K rpm) for micro machines
    - Linear stages with magnetic bearing
    - Prototype software system for part family formation and operation clustering in reconfigurable micro manufacturing systems

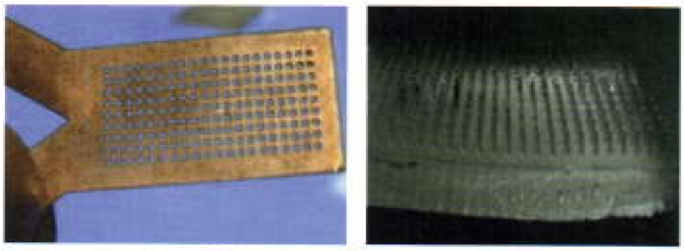
Current Capabilities

Micromachines and multi-material micro manufacturing process technologies with following operational capabilities:

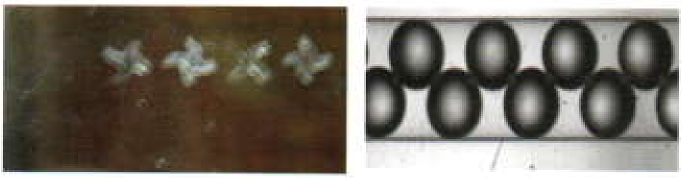
- Micro milling of 3D features
- Channels : 100 µm, holes:150 µm diameter in 1 mm thick plate
- Material: Metals, polymers, green ceramics, metallic glass, etc.
- Micro EDM-milling of 3D features
- Channels and holes : 20 µm on Copper, 50 µm on aluminium
- Pulsed Laser Ablation
- 50 µm size 2D features with complex geometry up to an aspect ratio of 200
- Microfluidic structures on PDMS substrate

Micro-Fludic Devices

Integration of the these mechanical based micro-nano scale fabrication have unique advantages of process repeatability, capability of structuring three dimensional micro-nano scale features over multi materials and provision of cost effective solutions for bulk integration. However, these processes have limitations with respect to the minimum feature size and surface finish comparing to conventional micro fabrication processes like lithography, etching, etc. At CSIR-CMERI, researchers have made use of these characteristics to develop chip based micro-fuldic devices – specifically for micro mixing, cell separation, cell sorting, etc. which are primarily required for lab-on-chip bio-diagnostic devices. Here researchers have used patterns/molds fabricated using micro machining techniques (laser ablation, micro-EDM and milling) to replicate the desired structures on biocompatible Polydimethylsiloxane (PDMS). Figure 1 shows sample micro channels structured with micro pillars of 100 µm generated on PDMS using a copper mold machined by nano-second pulsed Nd-YAG laser.



Laser machined Cu mold *Micro pillars in PDMS channel*



1.5 mm dia impellers fabricated using PDMS *Micro gel particles generated in PDMS fluidic channels*

Figure 1: Microfluidic devices

Future Directions

In summary, current capabilities of generating micro-nano scale 3D features and design and development of Micromachines to perform these operations have created wide opportunities for future research. While the research focus during the 11th Five Year Plan was to develop the process technologies and machines capable of generating micro-scale (100 - 500 µm) features on multi-materials, the researchers across the CSIR family intend to collaborate for developing Micromachines and process technologies to generate nanostructures having features <100 nm over larger areas. In addition, these teams by combining the multi domain expertise of microfludics, micro systems design and fabrication are also aiming to develop intelligent sensors, actuators and bio-diagnosis systems in coming years.

NEW RESEARCH IN SURFACE ROBOTICS

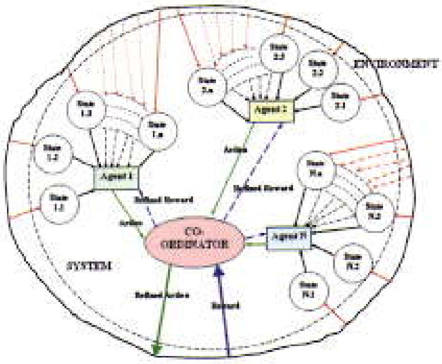
Surface Robotics is one of the major areas for R&D in CSIR-CMERI and invention and innovation are the core ethos with which the Surface Robotics Group functions, where researchers from varied disciplines are invited to participate for providing appropriate R&D solutions to myriad problems. The major and subsidiary areas of research undertaken by the group comprise:

a. Deliberative model based navigation

b. Behaviour based Robotics with Reinforcement Learning with
  - Command & Control Architecture
  - Integration and fusion of Multiple Sensory Information including Computer Vision

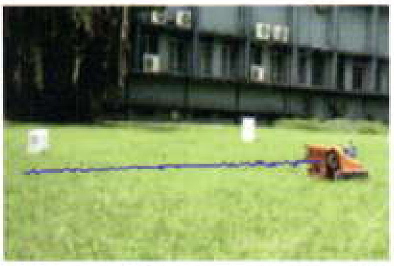
Past and present activities of this group under various funded programmes culminated in the successful indigenous development of All Terrain, Aerial, Serpentine and Amphibious robots which were designed to augment preparedness for mission requirements related to disaster management and mitigation. Inspection, law enforcement, security and surveillance are also areas which stand to benefit immensely from these developments.

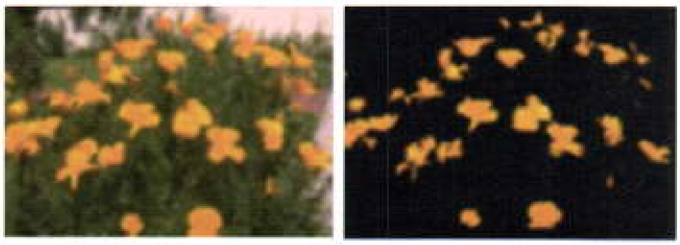
All these navigating robots essentially make use of terrain modeling and sensor fusion involving various estimation theories. While deliberative model-based navigation takes up the kinematic and/or dynamic control of the system, the sensor model detects the environmental changes so as to collaboratively perform navigational and exploration tasks. Behavior-based navigation, on the other hand, does not require a model for the system or environment and essentially uses direct sensor to actuator mapping, which does not rely on the explicit world model and path planning used in the other approach. Owing to its inherent approach using direct action for sensory stimulus, behavior-based robotics is also referred to as reactive robotics. Though such an approach on navigation cannot be considered as an optimal one, yet this approach perhaps provides the best possible action given a set of sensory stimulus from its spatial neighborhood. Such action is obviously sub-optimal, yet arguably more rational for navigational tasks since in the case of obstacle free path planning, the neighbouring objects have more influence than obstacles or objects located far from the robots. Reinforcement learning is a system-environment interaction relying on the reward/ punishment methodology against a previous action executed depending on the previous state of the system. This helps the robot to act more rationally and in a more subjective manner even when the environment changes in a completely unknown/ unpredictable manner.

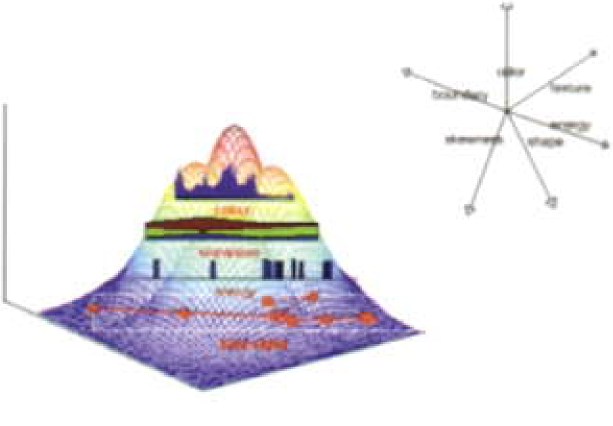


Generalized Multi-agent Q-learning for a system. The system is divided in two main parts: different agents and the coordinator. System interacts with the environment with the help of coordinator

Applying vision sensor for robot navigation and map building is the core driving force behind the initial growth of vision research, which in course of time has evolved and given way to the pursuit of involved research in the field of image processing and computer vision. Research in the field of vision was promoted from the fact that sight – a major source of sensory information for human beings – can result in the achievement of visual automation for a very broad range of applications when provided to machines. The following broad areas within the domain of computer vision are finding major attention in R&D as of now:







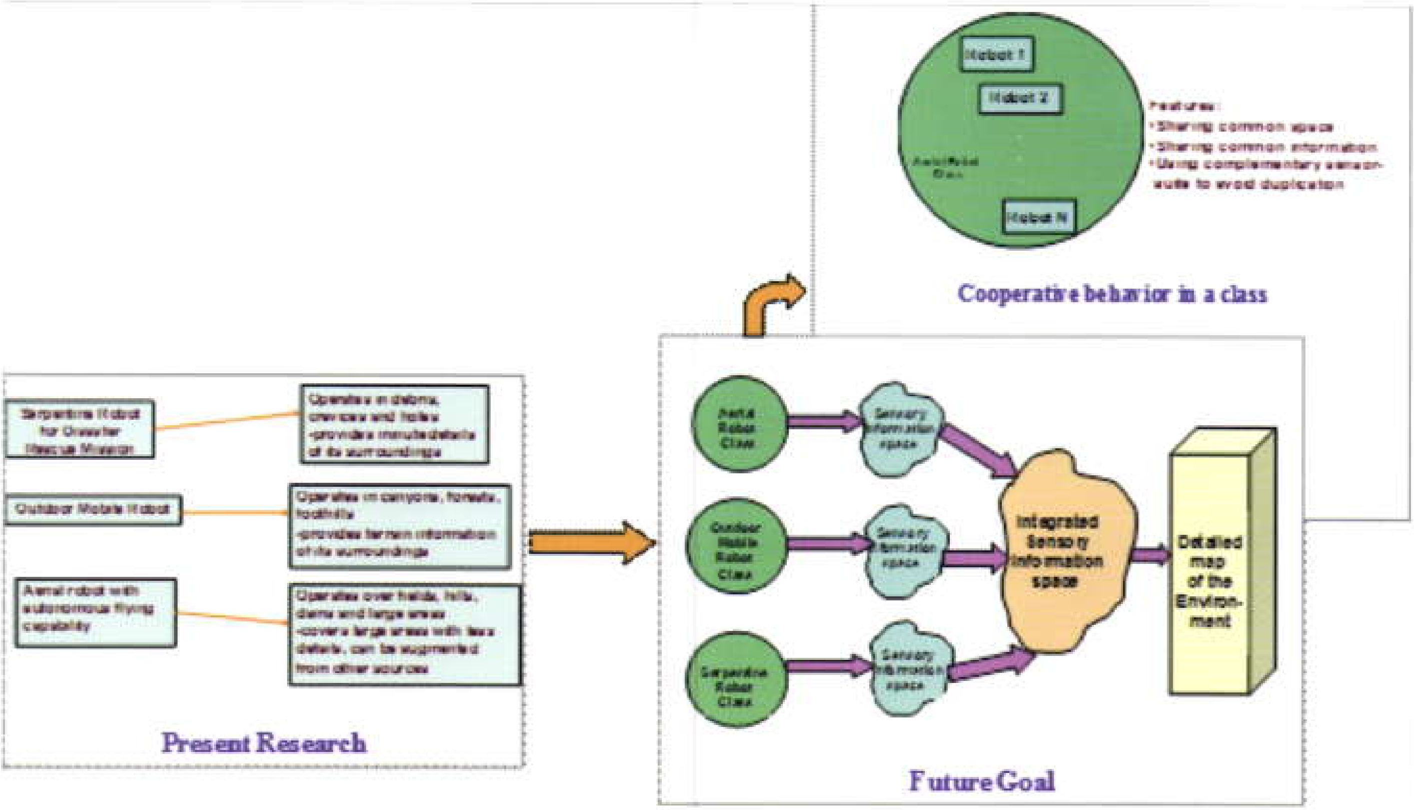
- Design and development of multipurpose scale space filters
- Object detection using a multi-parametric search space
- Real time panorama
- Object tracking
- Face recognition algorithms tackling multiple variations
- Age estimation using gender information
- Recognition of faces altered by plastic surgery from pre-surgical data
- Race information and expression recognition from face images
- Hand gesture recognition for sign language
- Visual inspection of Braille print quality

Research in robotics is being diversified and bolstered to be at the forefront in Indian scenario, and a few new concepts and ideas are being proposed for more commercial viability. These areas embrace:

- Mobile robots with enhanced capability for security and surveillance applied to various areas such as border patrolling, mine detection, IED detection & handling
- Study of the feasibility of robotic applications in underground mines
- Capability building in rover technology for planetary explorations
- Development of service robot for building and other structures

The approach as outlined above leads to the segmentation of each project into three sub tasks, each of which has the common aim of developing a decentralized cooperative exploration strategy with multi-agent systems. The approach further enhances decentralized cooperation and coordination mechanisms across multiple robots, ensuring more efficient exploration, avoidance of spatial conflicts and cost effectiveness, and can be achieved through cooperative behaviour within a class of robots, which share common information, use complementary sensor-suite and avoid unnecessary duplication of sensors.

Even when the sensory system for each robot differs widely in nature and perception range, the concept can be extended to cooperative behaviour between different classes, thereby giving rise to a system where each activity merges the acquired information in a global map of the environment increasing final accuracy, quality of localization and reduction of the occurrence of spatial conflicts.



Decentralized cooperative exploration strategy with a multi-agent system

Robotic activities at SRLab:

The experimental serpentine robot Cserp-X

Rotary Winged Flying Robot (RWFR)

Outdoor Mobile Robot (OMR v 1.0)

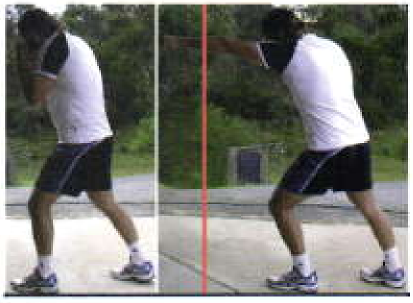
Outdoor Mobile Robot (OMR v 2.0)

Sub-terrain Robot

Behaviour based robot ARBIB-1

ARTIFICIAL MACHINES WITH EMBEDDED BIOLOGY: THE ROBOTICS OF THE FUTURE

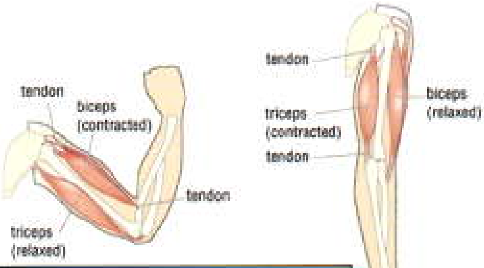
You have guessed it right: technology is scaling new heights, where it is now possible that a machine component will behave like a human limb. To be more precise, technology is bringing in biological properties within man-made machines. This is not simple replacement of an organ with an artificial one: the robustness, reliability and efficiency of an actuated mechanical device for performance of specific tasks incorporating biological principles is being greatly enhanced, which would not have been possible otherwise. These mechanical devices include leg or arm prosthetics, mechanical power amplifying devices like exoskeletons and even an advanced household assisting robot, or a robot surgical device. What biological principle is actually involved, one may ask. Every human and every muscular animal makes use of the mechanical stiffness variability in the joint actuations through the compliant musculoskeletal system for performing each and every mechanical task. Imagine a painter absorbed in his creation – when he needs to execute long gross strokes with a thick brush, he keeps his shoulder, elbow and wrist joints light and compliant; when he creates fine and intricate curves with a thin brush, he works with the wrist maintained in a stiff position. Before unleashing a knock-out punch, a boxer stores maximum energy in his muscles and releases the largest part of that stored energy to render it compliant at the hit; as a result the muscle stiffness gradually reduces aiding maximum transfer of kinetic energy at the moment of impact. The new generation of machines which are meant to interact with humans and/or augment human efforts are all making use of this property of variability of mechanical stiffness for their functional requirements; this can generally be referred to as mechanical impedance variability.



Stiffness variability makes a boxing Jab more powerful.

A linear helical coiled tension spring as against a rubber band having nonlinear stretch properties.

Most of the machines are actuated by motors, and motion transfer takes place through a transmission or coupler to the output link. Future machines for interactive work will no longer be rigid. Compliance and its variability in the transmission shall impart flexibility in the same manner in which a biological muscle acts. One may wonder how variability in compliance produces work. Let us think of a helical coiled spring, as we see it everywhere around us. It has a spring constant, which can not be varied. Let us now take instead a rubber band and stretch it. The rubber band gets stiffer as we continue to stretch it; this is exactly what happens in a biological muscle.

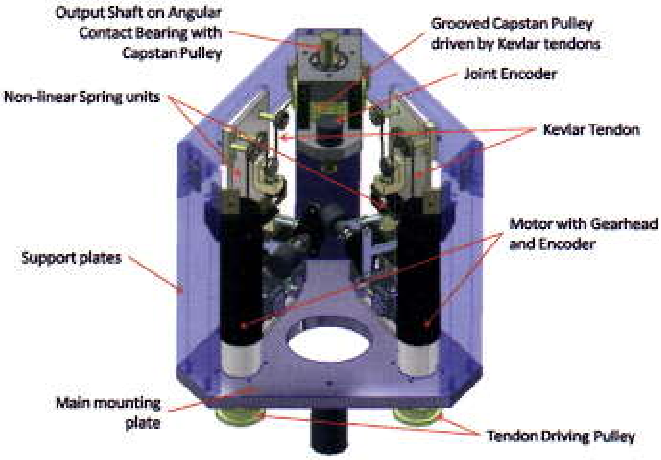


Biceps and Triceps co-ordination in moving elbow and varying elbow stiffness. Stiffness increases as muscle fibres are stretched like a rubber band.

The new generation actuation system makes use of a transmission element that is similar in nature to the rubber band which has properties of both motion transfer and stiffness variation.

A Robot Hand-Arm system with Impedance/Stiffness Variability (DLR, Germany)

But this again is not the whole picture; one needs to control both the motion and the stiffness, entailing two control inputs or two motors. In a musculoskeletal system of the animal world, a minimum of two muscles actuate a single joint; just consider the function of the biceps and triceps that allow the movement of the elbow. In a perfectly coordinated manner these two control both the motion and the stiffness in response to the specific demand of the task (painting, or, boxing). Similarly, in artificial devices also a minimum of two inputs or two motors per joint shall be needed to produce motion and stiffness.



Variable Impedance Actuator being developed at CMERI

Considerable research attention is being directed to develop such 'machines with embedded biology' at CSIR-CMERI, Durgapur. For example, efforts are being made to develop an artificial prosthetic leg (e.g. knee and ankle prostheses) which in view of its operating on biological principles shall be friendlier to the user, offering an increased degree of comfort. Once such developments are possible, a handicapped person such as an amputee will be able to adapt to varied terrains and hard and soft surfaces with more natural gaits much like a normal person. The next generation medical surgery can truly be revolutionized by the use of robots under teleoperation, where the surgeon operates remotely and a robot actually performs the operation on the patient. The variable stiffness actuation will provide feedback to the surgeon enabling realistic feel of a soft tissue or a hard surface in a virtual reality device. Nature optimizes its energy consumption and in muscular actuation, stiffness variability actually helps in saving the net energy consumption, such as when a human being runs steadily. Similarly, fishes use this energy optimal technique during steady swimming by tail (caudal) fin sinusoidal movement. CSIR-CMERI has initiated activities to understand the swimming mechanism of fishes in order to develop artificial underwater swimming vehicles for varied underwater applications.

Variable Stiffness Ankle Prosthesis

Biomimetic Underwater Vehicle / artificial fish.

LIFE ASSESSMENT OF POWER AND PROCESS PLANTS

CSIR-CMERI, Durgapur has credibility and considerable experience in the field of Residual Life Assessment and failure analysis of different process and power plant components, which contribute directly to significant improvement in individual component lives. The institute has a strong interface with various power plants over a long period of time, and Life Assessment related activities have continued to remain in its thrust areas. CSIR-CMERI is accredited as a ***Well Known Remanent Life Assessment*** organization by the Central Boiler Board, Government of India.

It is an established fact that the Residual Life Assessment route is economical, viable and the most effective means to improve the overall availability of the ageing power plants in India, which continue to operate with a high degree of obsolescence. Before any renovation and modernization / life extension programme, it is mandatory to conduct Residual Life Assessment (RLA) study of all critical components of a power generating unit, which brings into notice for mandatory replacement / modifications necessary to guarantee a minimum 75% plant load factor and 85% plant availability.

In spite of the best efforts of design engineers and material scientists, engineering components fail in service. In some cases failure may lead to serious consequences like huge financial loss, environmental contamination and even loss of life. In the event of a failure it is therefore essential to investigate the root cause of failure in terms of design, quality of material and fabrication procedure and most importantly to avoid the recurrence. The NDT & Metallurgy group of CSIR-CMERI is actively engaged in failure investigation as a part of the RLA services. This has led to minimized forced outages, thereby affording substantial, if indirect savings of the national exchequer.

This article highlights two important case histories related to failure investigation that were successfully addressed by CSIR-CMERI. The first one relates to a platen superheater header (Figure 1) which failed during service probably due to the combined contribution of start-stop transients, temperature fluctuations during operation (minor in magnitude, but large in number), isolated but severely abnormal thermal shocks, leading to the formation of thermal fatigue cracks in the ligament region. The second, even more severe and causing huge loss to the ONGC, was the typical failure of a Mast structure of a Drilling Rig. The rig mast collapsed suddenly while in operation, causing severe twist in the middle section (Figure 2). In both these cases probable cause/causes of failure were duly identified and preventive guidelines framed for

Figure 1: Failed superheater outlet header after being removed from service

Figure 2: Failed mast structure of drilling Rig-6 of ONGC, Bokaro.

avoidance of such failures in future.

Apart from various RLA and failure investigative works, NDT & Metallurgy group of CSIR-CMERI also conducts considerable research on high temperature damage mechanisms of existing and advanced materials used in thermal power plants. Extensive work is being carried out to investigate high temperature corrosion behaviour of 2.25Cr-1Mo and 9Cr-1Mo steels used in thermal power plants under SO_2+O_2 atmospheres. The isothermal corrosion studies at three regions of the elements at 973 K for 2.25Cr-1Mo steel in SO_2+O_2 environment show difference in corrosion rate at the three regions of base metal, HAZ and weldments. Some recent advancements have been planned under the forthcoming five year plan period to develop nano-structured composite coatings for high temperature applications in turbine blades, engine parts for petrochemical, aerospace and electronic device industries.

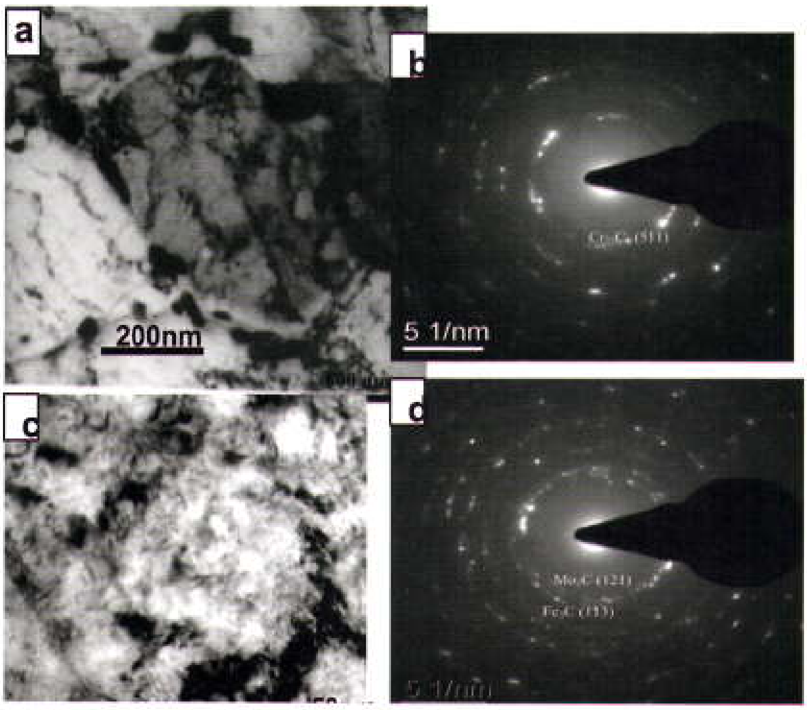


Figure 3 : TEM Micrograph of (a) Secondary precipitates in HAZ (b) Corresponding SAD analysis of the Secondary precipitates in HAZ.(c) Secondary precipitates in Base metal (d) Corresponding SAD analysis of the Secondary precipitates in Base metal

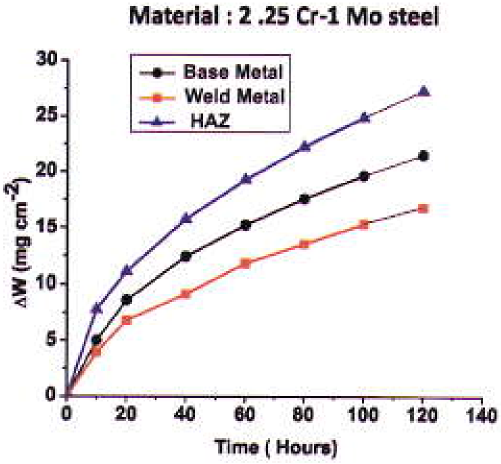


Figure 4 : Corrosion rate and the reaction kinetics of 2.25Cr-1 Mo steel at 973K for 120 hours in SO_2+O_2(ratio 2:1) environment

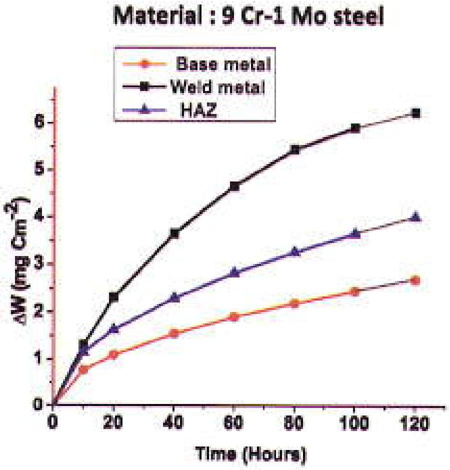


Figure 5 : Corrosion rate and the reaction kinetics of 9Cr-1 Mo steel at 973K for 120 hours in SO_2+O_2 (ratio 2:1) environment

RHEO PRESSURE DIE-CASTING

Aluminium alloy is used abundantly as material of construction in the automobile, defence, aerospace, packaging, infrastructure and housing industries because of its light weight, high strength-to-weight ratio and resistance to corrosion properties.

Conventional processing techniques for aluminium are carried out either in fully liquid (e.g., sand casting, diecasting) or in fully solid (e.g., forging, extrusion) states. Solidification in the fully liquid state is dendritic in nature and the growing dendrites form a continuous solid network in the solid-liquid zone that stiffens when the volume fraction of solid exceeds approximately 0.2. Thereafter, the partially solidified metal cannot be deformed homogeneously without cracking the network. This inhomogeneous deformation of dendritic network leads to macrosegregation in the components. Pouring of liquid metal in this process further induces turbulence in the mould causing porosity in the cast. In case of solid-state application, the plasticity requirement is mandatory. Since the raw material is in the fully solid state and therefore less deformable, this process demands high pressure and consequently high energy. Therefore, there has been a constant search for overcoming these difficulties of the conventional casting and forging processes.

It has been discovered that when metal alloys are vigorously agitated during solidification, the solid which forms has a special globular and non-dendritic structure surrounded by nearly eutectic liquid. Due to this microstructure, the partially solidified metal slurry exhibits a significantly low viscosity and deforms homogeneously, which leads to a new manufacturing technology termed **Semisolid Manufacturing.** This new technology is now widely accepted for production of commercial components of extremely high integrity castings enjoying excellent properties.

Semisolid processing: Advantages

There are several advantages of semisolid processing over conventional alloy casting processes, the major being:

- **Less shrinkage and porosity:** In liquid alloy casting, one of the major drawbacks is the formation of solidification shrinkage leading to macroporosity. Porosity is also facilitated by the turbulent filling of die, causing air entrapment. Nearly all these drawbacks can be overcome in the case of semisolid die filling.
- **Formability of thin-walled parts:** As the viscosity of semisolid material is significantly higher than that of superheated liquid metal, filling velocity can be high even at a low Reynolds number (i.e. without turbulence). With a high filling velocity and easy metal flow, thin walled parts can be cast with excellent consistency and integrity.
- **Superior mechanical properties:** The mechanical properties of semisolid cast parts are generally superior to those produced by conventional casting with the same alloys, primarily because of the non-dendritic and defect-free microstructure. Published literature reveals that there is around 25% increase in elongation, 30% increase in impact and 7-10% increase in fatigue strength. As a result, semisolid parts lead to considerable weight reduction.
- **Reduction in machining and tooling costs:** Semisolid parts can be cast in the near-net-shape form, as the surface finish is excellent and the shrinkage minimum. As die filling temperature is lower and the heat content of the metal less, less thermal shocks are experienced and the tool lives are more.

Applications

These features of advantage make the semisolid forming process ideally suited for producing a wide range of components for automotive, aerospace, defence and structural applications. However, because of lower production volume and more processing costs as compared to parts made by conventional methods, semisolid forming is generally adopted for special parts demanding high integrity, consistent quality, increased strength and/or elongation, increased pressure tightness, thin walled sections and parts which are safety-critical. Some such parts manufactured through the SS route include brake callipers, clutch cylinders, suspension arms, wheels, pistons, knuckles, engine mounts, pulleys, rocker arms, belt covers, motor housings, space frames, etc.

A major disadvantage of rheocasting is consistency, as the quality of the final product depends directly on the slurry produced beside the die-casting machine. For the process to be successful, it is important to develop a process of slurry making which can easily be standardized and commercialized. CSIR-CMERI, Durgapur is carrying out research primarily in this area.

Global R&D Trends

The focus of the foundry industry is gradually shifting to modern casting processes to meet the requirement of volume manufacturing of high performance components. China is the largest casting manufacturer, leading even the USA by a fair margin. Indian casting industries are not equipped enough to adapt to rapid changes in the production technique in terms of knowledgebase and preparedness. Among the new casting technologies, rheocasting process is being considered as one having the maximum promise and considerable research is being carried such institutes such as the MIT and the Metal Processing Institute of the USA, the Aachen University of Germany, the University of Shefield, UK, the National Research Laboratory of Thixo/Rheo Forming, South Korea, the Alcan Inc. the Aluminium Technology Centre (ATC) of the National Research Council of Canada, the Shenyang National Laboratory for Materials Science, China, etc. In India, except the National facility for Semisolid Forming at the IISc., Bangalore, no major initiatives are discernable. There is a pressing need for developing a national level facility for R&D work on rheocasting technology to target production in industrial environment.

Current R&D Focus

R&D at CSIR-CMERI, Durgapur is focussed on the design of a rheo die-casting system to be developed by integrating and synchronizing a semi-solid slurry processing unit with a high pressure die-casting machine. The schematic diagram of the proposed rheo die-casting system is shown in Figure 1.

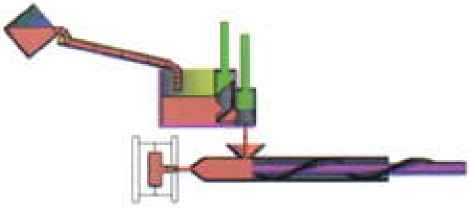


Figure 1: Schematic diagram of the Rheo die-casting system

The semi-solid slurry processing unit consists of a resistance heating furnace to melt alloys, a cooling slope to form equiaxed globular grain by breaking the long columnar dendrites in the semi-solid region (between liquidus and solidus line) and a holding bath which contains the semi-solid slurry for feeding the slurry in the pressure die-casting machine in a predefined interval. A semi-solid slurry transferring system is integrated with the holding bath to feed a metered quantity of slurry in the die-casting machine.

The production of globular fine equiaxed grain structure depends on several parameters such as length, angle and temperature distribution along the cooling slope. Pouring temperature is also an important parameter for controlling the globular fine equiaxed grain structure. The semi-solid slurry is collected in the holding bath for transferring quantity slurry to the pressure die-casting machine. As the semi-solid slurry is poured into the bath continuously and a metered quantity is transferred to the die-casting machine in a predefined interval, the semi-solid slurry needs to stay in the holding bath for some duration. During the stay of the semi-solid slurry in the holding bath, re-melting, nucleation and grain growth may take place. To keep the desired solids fraction by minimizing re-melting, nucleation and grain growth in the holding bath a close control of the process parameters is required. A system of transferring semi-solid slurry needs to be developed for feeding metered quantity at a predefined interval. During mould filling in the pressure die-casting machine, changes in solids fraction and casting defects may occur and therefore process parameters such as injection temperature, pressure, mould temperature, etc. needs to be studied in detail.

A Eulerian multi phase flow numerical model is to be developed to simulate formation of equiaxed grain in cooling slope, condition in holding bath and mould filling behaviour of the semisolid slurry in the die-casting machine.

POWER ELECTRONICS RESEARCH AT CSIR-CMERI

Grid connected smart Photovoltaic inverters

Grid connection of Photovoltaic (PV) systems is accomplished through power electronic inverters, which convert the dc power generated from PV modules to ac power used for utility power supply for electrical equipment. Some of the important functions of these inverters include maximum power point tracking (MPPT), grid synchronization of induced currents at an appropriate power factor (0.9-1), anti-islanding and maintenance of high power quality of induced currents in keeping with international standards.

Grid connected PV based distributed generation inverters form the vital part of the future "smart grid", acting as crucial load levellers at various parts of the power network, which can provide ancillary services in addition to dc-to-ac conversion. Such inverters can incorporate energy management functions and may be called upon by control stations at appropriate instants to provide ancillary services like reactive power compensation, active harmonic filtering, etc. in maintaining the overall health of the grid. Incorporating these functions also improves the utilization factor of the solar inverters which are otherwise idle during nights and cloudy days.

The very process of incorporating ancillary features ensures that the topology needs minimum (or no) modifications other than that of its application as an energy extraction device. Only the control architecture needs to be changed which can easily be achieved by reconfiguring the codes in signal processors.

Microinverter Technology

Building Integrated Photovoltaics (BIPV) comprises PV materials and systems that replace conventional systems in parts of the building, thereby providing savings in materials and electricity costs. Conventionally PV panels in BIPV are connected to a grid using a centralized inverter, which converts into ac the dc sum of the voltages of all the PV panels connected in series. Such a system suffers from disadvantages of less-than-optimal energy harvest, lack of flexibility, danger of dc arcs, etc. Microinverter technology consists in integrating individual dc-dc boost converters and dc-ac inverters to each and every PV panel. The output of these individual dc-ac inverters is at the grid level and these are connected to the grid in parallel to each other.

The main challenge in the design of such microinverters lie in the fact that dc-dc boost converters need to boost the voltage from a level of 20 V (individual panel) to

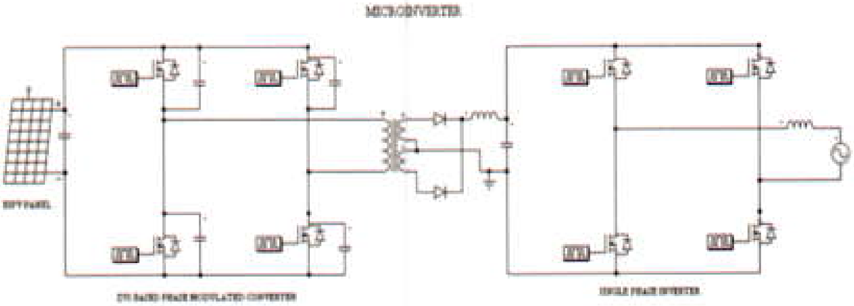


Figure 1: Phase modulated converter topology of microinverter

230V (grid level voltage in India). This process should be efficient and should also comply with international standards. The research emphasis at CSIR-CMERI is on the design of phase modulated converter topology, which has inherent isolation in the form of high frequency transformer, high power density resulting from high switching frequencies and high efficiency afforded by incorporation of zero voltage based switching of MOSFET's in the converter. Once this challenge is met, dc-ac inverters will have the challenge of efficient design of single phase locked loops (PLL) to achieve grid synchronization. Figure 1. illustrates a typical phase-modulate topology for microinverters.

Sliding mode current control of BLDC motor

Brushless dc (BLDC) motor speed control schemes usually have two loops, i.e. the outer speed control loop and the inner current control loop, as shown in Figure 2. The outer speed loop provides the torque/current reference, which is to be tracked by the inner current loop. The inner current control loop has three phase currents as states and corresponding phase voltage switching functions as their control inputs. Fast and accurate tracking of reference currents generated by the outer speed loop is very important, as the outer loop is designed assuming the inner loop to be fast and accurate.

Many schemes based on PID controllers are traditionally being used to obtain the required control specifications. In the design of these schemes the discrete time-variant power electronic inverter is converted into linear time-invariant structure using the state-space averaging method. Assuming application of efficient filtering schemes, the chattering associated with the switching is neglected while designing the controllers. While one can obtain constant frequency switching using this method, it is difficult to consider the variable structure model of BLDC motor due to continuous commutations. In a 120° conduction mode of the inverter used for BLDC current control scheme, only two phases conduct at a time. However, owing to inherent phase inductance, all the three phases momentarily conduct together during commutation from one phase to another. This problem can be overcome by using a variable structure controller like hysteresis controller, which is very robust and insensitive to parametric disturbances. But it has disadvantage of variable frequency which makes filter design difficult.

For the variable structure systems sliding mode control – which works on switching from one structure to another structure – may be better suited to maintain the state on the desired sliding mode surface. At CSIR-CMERI, research is being carried out to design sliding mode controller for the current control of BLDC motor taking into consideration the above nonlinearities.

Power Electronic Interface for Battery-Ultracapacitor Hybrid Energy Storage System

Hybrid energy storage system is a combination of two or more energy sources with complementary characteristics designed to provide solution to a particular energy problem. Battery, together with ultracapacitor constitutes an excellent hybrid storage system for electric vehicles. However, proper interface electronics and control is required to obtain the desired

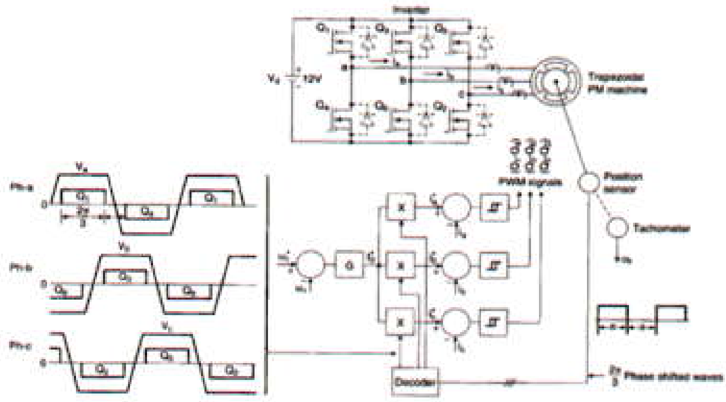


Figure 2: Closed loop speed control of BLDC motor showing inner current control loop and outer speed control loop

benefits like longer driving range, better acceleration performance, controlled regenerative braking, smaller battery pack and longer battery life. Research at CSIR-CMERI targets minimizing stresses on battery that surface during periods of acceleration and braking of PMDC traction motor through selective addition of ultracapacitor in parallel to serve as an auxiliary power source. Unidirectional and bidirectional dc-dc converters are used with battery and ultracapacitor respectively to ensure proper energy flow to and from the motor during different stages of the driving cycle. The power management algorithm intelligently divides the current demanded by the motor between battery and ultracapacitor currents. The control scheme is an appropriate combination of linear and non-linear controllers, PI controller for outer speed loop and hysteresis controller for the inner current loop. Bode plot based design technique is used to design the speed controller.

A complete topology and corresponding control algorithm was tried out with a PMDC motor and simulated in MATLAB/SIMULINK. To validate the simulation results a PC based experimental setup was devised and experiments carried out on a RL (resistive & inductive) load and an appropriate PMDC motor. Figure 3 shows the proposed circuit topology, while Figure 4 provides a view of the experimental set-up. Figures 5(a) through 5(c) show the results obtained.

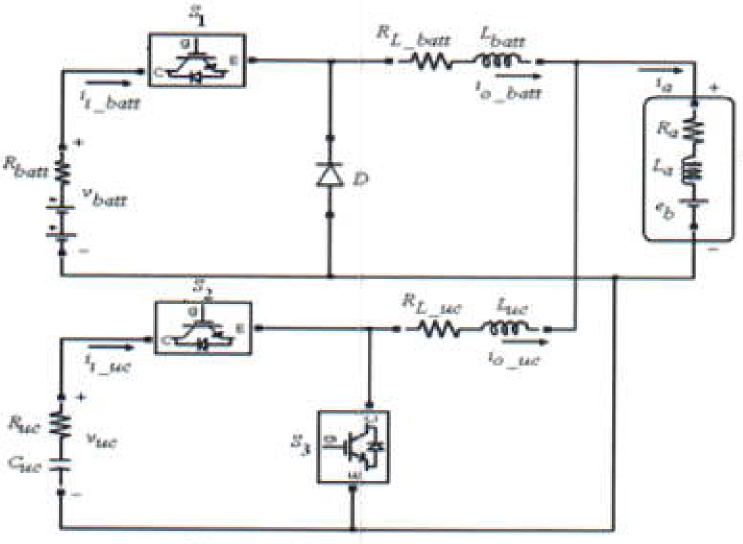


Figure 3: Proposed Circuit Topology

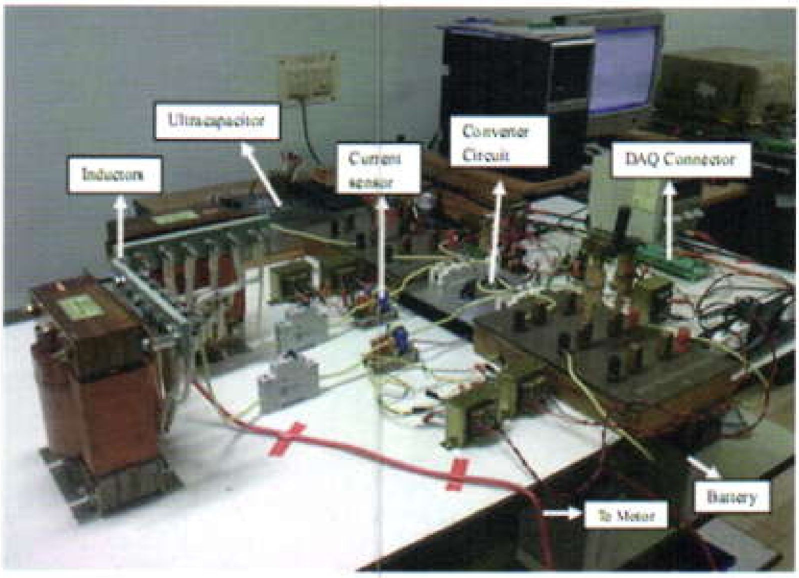


Figure 4: Hardware Setup

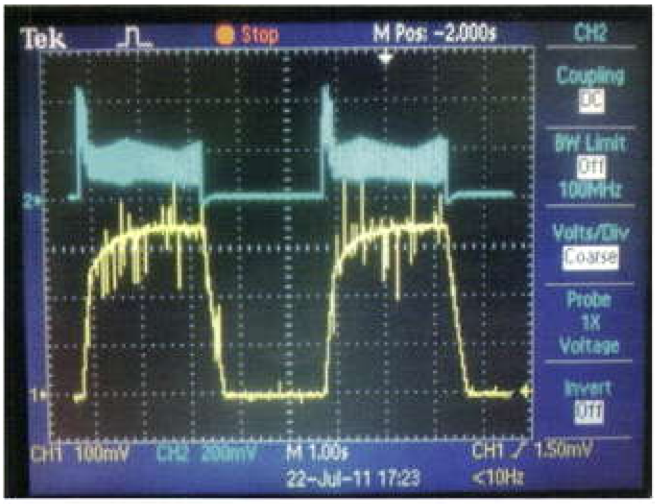


Figure 5(a): Experimental Results for Motor Current (Blue) and Speed (Yellow)

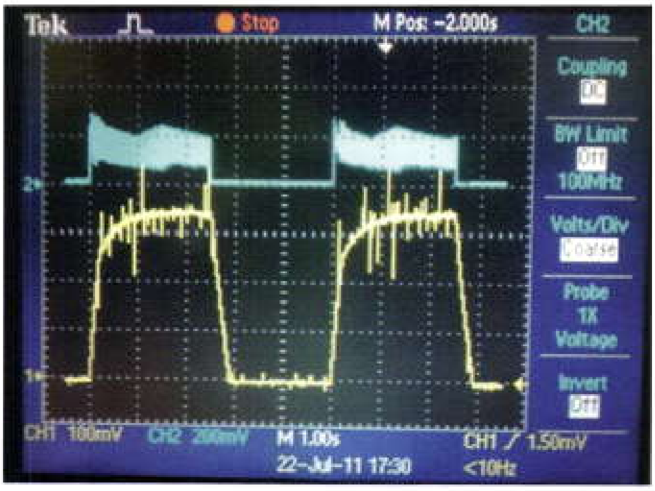


Figure 5(b): Battery Current at Different Speed of Motor

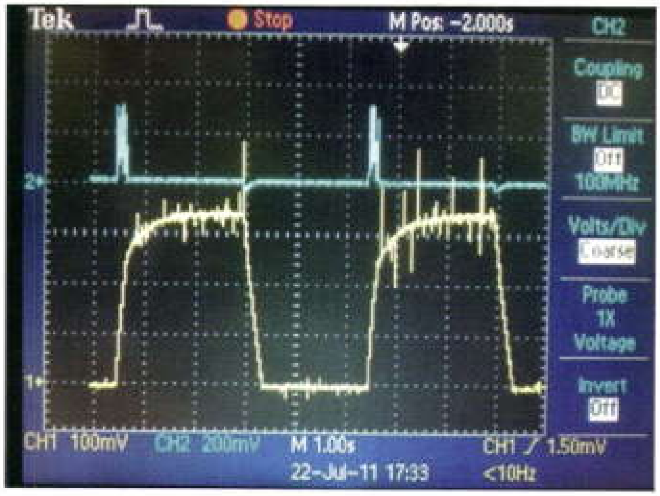


Figure 5(c): Ultracapacitor Current at Different Motor Speed

RADIO FREQUENCY QUADRUPLE (RFQ) LINAC.

The high energy Radioactive Ion Beam (RIB) plays an important role in R&D in nuclear physics, nuclear astrophysics, material science, biology and medical science. The technology needed for developing RIB facility is extremely complex and requires extensive R&D in the field of particle accelerators, ion sources, instrumentation and manufacturing technology.

To carry out this challenging task, the Variable Energy Cyclotron Center (VECC), Department of Atomic Energy, Kolkata has signed an MOU with CSIR-Central Mechanical Engineering Research Institute, Durgapur for collaborative work in system design and development of Radioactive Ion Beam (RIB) facility at VECC, Kolkata.

The conceptual and system design from accelerator physics and beam dynamics principles has been done by the scientists of VECC, Kolkata. CSIR - CMERI Durgapur and VECC, Kolkata have worked collaboratively for engineering design, system analysis for the development of Radio Frequency Quadrupole (RFQ) Linac along with Electron Cyclotron Resonator (ECR) as its ion source and Beam Rebuncher (Linac-RB) for rebunching its medium energy output ion beam. (Figure-1).

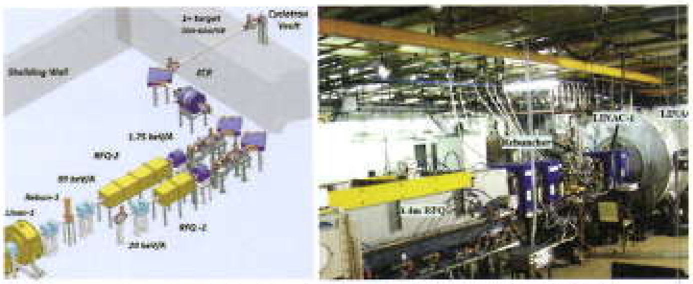


Figure-1: RIB facility layout and operational RFQ LINAC at VECC.

The first half-scale 2kW prototype with vane length 1.7 m (input energy 1.68 Kev/u and output energy 29.5 Kev/u) was designed, developed and tested back in September 2005 for optimizing the design parameters. After studying its performance the final 40kW RFQ Linac with 3.2 m vane length (input energy 1.68 Kev/u and output energy 97.5 Kev/u) was designed, developed and tested in 2008 with design modifications. This facility is only the second one in Asia, the first one being in Japan. Very few countries in the world have this capability. After achieving this feat India joined the club of USA, Canada, France, Germany, Israel, Japan and Russia for indigenous development of this highly guarded technology.

RFQ is a linear accelerator (Operating Frequency ~ 33.7 MHz in this case) of very pure copper that houses four (quadrupole) precisely sculpted vanes (electrodes) which take care of the acceleration, bunching and focusing of the ion beam. RFQ Linacs are now widely used as injectors for linear accelerators and synchrotrons, and also in ion-implantation systems as stand alone accelerators. The advantage of RFQ is its high beam transmission efficiency for low velocity, high current beams, and it is the optimum choice as a single structure is used for bunching, focusing, and acceleration of radioactive ions. Depending on the type of ions and the energy regime of interest one chooses the structure of the RFQ. Owing to the inherent complexity of the structure – especially in the machining of the electrodes – design and construction of an RFQ becomes an onerous task involving substantial R&D efforts.

In the 4-rod RFQ resonant structure, each diagonally opposite pair of vanes (electrodes) is supported on alternate posts while the whole assembly reposes on a base plate as shown in the Figure 2. The basic rf cell can be viewed as a $\lambda/2$ resonator of resonance frequency $f=1/\sqrt{LC}$, originating from the capacitance C of the vanes and inductance L of the posts. The vanes are given a modulation along the length creating an axial electric field which accelerates the ions. At an excitation snapshot when a positive ion enters the first cell, it sees a net negative potential on the axis and gets accelerated. By the time it reaches the next cell, the next cycle begins and again acceleration takes place. There is therefore a continuous acceleration and the ion travels along the axis z through the RFQ. (Figure-2).

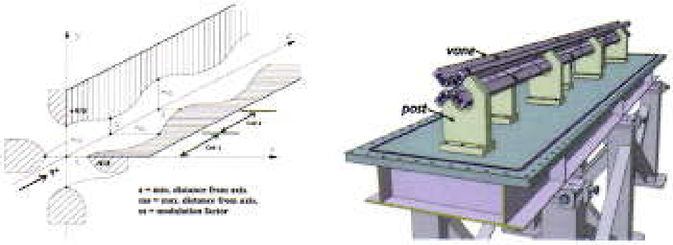


Figure -2: RFQ Operation principle.

The present design splits very long heavy-ion RFQ vane (3.2 m) into smaller segments of approximately 1 m ensuring full functionality (Figures 3 and 4). This directly eliminates the requirement of special and expensive 3D profile machining. This design was previously tested in the 2 kW (1.7 m) RFQ prototype and its performance monitored. After fine tuning some design parameters, this scheme was implemented in the final 40kW, 37 MHz, RFQ Linac (3.2 m) where 80% - 85% transmission efficiency was obtained.

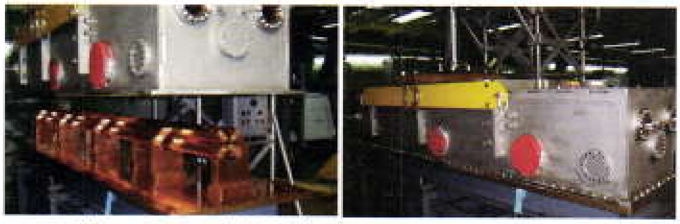


Figure -3: 40kW RFQ Cavity opened and closed.

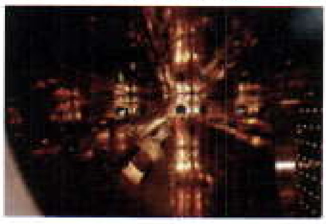


Figure -4: Inside view of 40kW RFQ.

The new segmental vane architecture design improves geometrical accuracy of the modulated profile for individual vanes, and makes handling and replacement much easier. Moreover, the architecture allows self aligning, renders high stiffness and keeps the cooling channels inside the vanes without using the conventional cut-&-cover technology which is highly susceptible to leakage under high vacuum environment in the order of 10-7 tor (Figure 5). Further, the brazing process – which produces thermal distortion and may generate micro cracks in the brazed seam due to flow induced vibration – gets completely eliminated. The micro cracks develop as a result of the vibration caused by the continuous turbulent flow of cooling water at pressure 10 kg/cm^2. The most significant aspect of the design is its self alignment and the stable quadruple symmetry (within 50 µ during operation) of the entire vane within the required limits during assembly and operation.

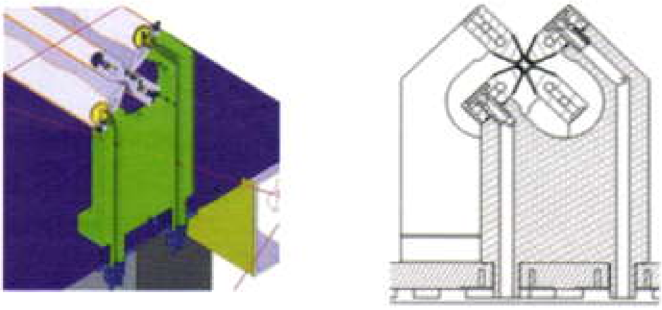


Figure -5: LCW transfer mechanism

The accelerating unit consisting of vanes and posts comprise the most critical area from the design and manufacturing points of view. The vane parameters have been optimized for achieving stability of transverse and longitudinal motions for the beam particles. The beam dynamics simulation codes GENRFQ and PARMTEQ were used for the calculation by the VECC. The goal was to achieve the desired acceleration with maximum transmission efficiency, minimum vane length, and a modest intervene voltage.

The beam dynamics output of the vane modulation data, which is basically the grid of spatial coordinates with longitudinal and transverse modulations, was refined to the extent possible to take care of the point density in an adaptive way for the tangential section, the tip curvature section as also for smooth transition from one to the other. Several iterations for

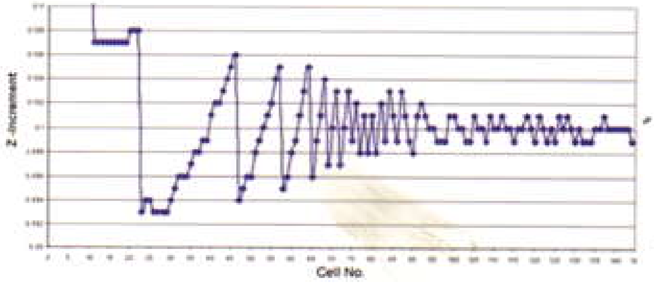


Figure -6: Noise in Z increment.

the Z-increment along the beam axis were performed to achieve a near-constant value in cell lengths in the beam entry and radial matching zones. The variation in the Z-increment in the input data sets is shown in Figure 6. The noises (erroneous and repetitive points) in these huge data sets have been eliminated by using an adaptive filtering algorithm. Extreme care has to be taken in this step in selection of filtering techniques to eliminate the noise so that the original data integrity is not compromised mainly on the peaks. The distribution of residual error after filtering lies well within ±σ (σ = 0.04) and this is depicted in Figure 7.

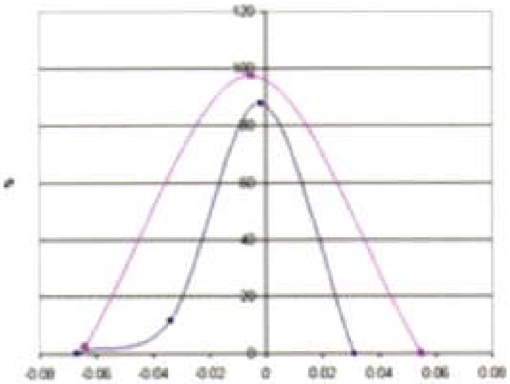


Figure -7: Residual Error.

The cooling behaviour of the RFQ structure due to the thermal loading has been investigated with Finite Element Method. The cooling phenomenon has been modeled with convective heat loss due to the flow of the cooling water through embedded channels in the vanes and the posts (Figure 8). Investigation shows that at steady state condition and with constant heat-flux load, the maximum temperature rise is in the post-base plate interface region, specifically in the region nearer to the cavity wall. Mathematically the temperature range is calculated to be 60°-70°C.

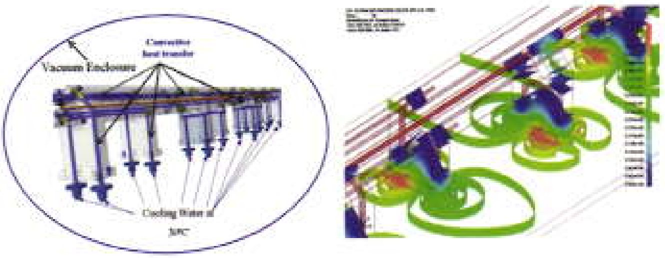


Figure -8: Heat distribution

The modal response of the acceleration structure has been analyzed and found very interesting. The unit is susceptible to both harmonics and its submultiples which was not clear during the initial phase and later found on experiment. (Figure 9)

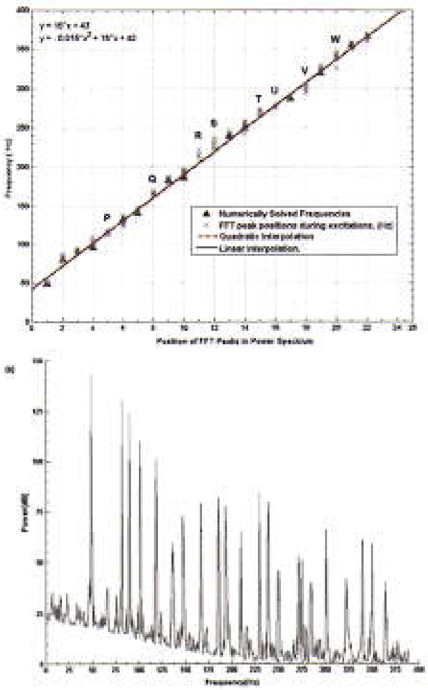


Figure -9: Correlation of natural frequencies and power spectrum plot.

Most of experiments conducted till date focuses on the aspects related to material science. In this domain using RFQ, one can implant radioactive tracers at controlled depths, introduce time dependent chemical changes in the sample, and study in-situ the lattice environment of the implanted probe. The implanted nuclei interact with the electric or magnetic fields of the surrounding lattice structure and the emitted radiation (γ or β) act as information carriers.

One of the significant experiments done by VECC scientists using beams from RFQ was aimed at studying room temperature ferromagnetism in spintronics material Zinc Oxide (ZnO). This material potentially has interesting device applications due to its combined semiconductor and magnetic properties. ZnO is predicted to show ferromagnetic ordering at room temperature if doped with few atomic percent of transition metal ions such as Mn, Fe, Ni, etc. In the VECC study, ZnO was implanted with 1.63 MeV 56Fe6+ beam from the RFQ. The amount of saturation magnetic moment in implanted ZnO was observed to be two orders higher than that in chemically prepared Mn doped ZnO sample. This observation is significant and may indicate preferential filling up of vacant lattice sites created in implantation process by Fe rather than by Zn atoms. More experiments are underway for further studies.

FACILITATING THE SOCIETY

- SOLECKSHAW: A GREEN CSIR 800 INITIATIVE
- CSIR-CMERI FOOTPRINTS IN THE NORTH EAST
- INNOVATION PROMOTION
- CENTRE FOR PRECISION & CONSERVATION FARMING MACHINERY

SOLECKSHAW: A GREEN CSIR 800 INITIATIVE

Soleckshaw, a Pedicab, is an optimally-designed, pedal-operated, motor assisted, zero-carbon emission urban transport vehicle. The soleckshaw is a major programme under the Flagship CSIR 800 initiative, which aims to make available the Fruits of cutting-edge science to improve the avality of life for 800 million Indians residing the bottom of the "pyramid of quality of life". The concept of ***Soleckshaw*** owes its genesis to the realization that the dignity of human labour needs to be upheld while ensuring sustainable environment and that all devices must be designed to decrease human strain and also greenhouse gas emission.

Backdrop

Tricycles and auto rickshaws provide a major mode of transport in the busy streets of cities in the South Asian subcontinent. Auto rickshaws, driven by fossil fuel, produce extensive emissions and cause substantial environmental pollution. In contrast, cycle rickshaws, which are manually driven and provide excellent transportation in busy, narrow urban by-lanes do not contribute to any kind of pollution. However, the effort demanded for manual steerage is very high, which routinely leads to serious health issues for the ill-paid rickshaw pullers. Considering the climatic changes engendered by widespread pollution, introduction of green vehicles has become important, and it is in this context that **CSIR 800** has come up with the ***Soleckshaw,*** which basically is a Solar Powered Motor Assisted Pedicab developed to afford the twin advantages of green transportation for the urban passenger and mitigation of health hazard for the rickshaw pullers.

Soleckshaw is a novel motor-assisted three-wheeled rickshaw or pedicab. The acronym ***Soleckshaw*** is derived combining **SOL** of Solar, **E** of Electric and **CKSHAW** of Rickshaw. This vehicle is amenable to both manual and electric steerage. When engaged electrically, the steerage is provided by a resident **battery** charged using **solar energy**. In comparison to a normal rickshaw, the ***Soleckshaw*** requires lesser driving effort on the part of the rickshaw puller since a part of the effort is provided on demand by the electric motor. Electric locomotion in the ***Soleckshaw*** affords traversing longer distances compared to its manual counterpart, which translates into increased earnings for the rickshaw pullers. On the other hand, the option of reverting to manual steerage ensures lesser depletion of battery in comparison to electrically driven pedicabs, and thus more distance can be covered in a single charge. Hence, ***Soleckshaw*** optimally utilizes both human effort and electric power, and potentially constitutes a very useful green vehicle for tomorrow's world.

Soleckshaw Design

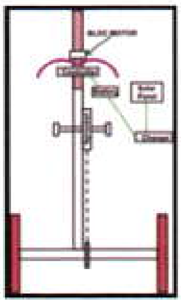


Figure 1

Figure 2

Figure 1 represents a schematic concept diagram of soleckshaw and Figure 2 shows the 3D CAD model of the entire vehicle. As depicted in Figure 2, a flexible hood [1] is hinged to the body [2], which is mounted on the main chassis [3] of the vehicle. The body has been designed to comfortably accommodate two passengers. The driver's seat [4], adjustable in height, is mounted on the main chassis.

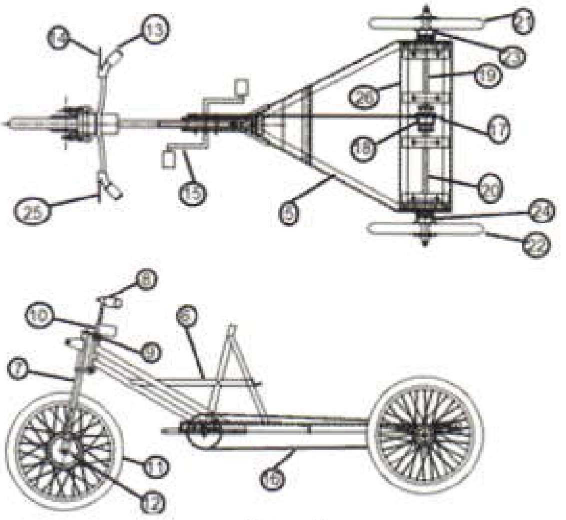


Figure 3

Figure 3 represents the 2D drawing of the main chassis of the pedicab. The base frame [5], on which main body is mounted is fabricated with structural angles. The vertical frame [6] is a structure welded out of MS pipes. The front fork [7] and handle [8] are attached to the front of vertical frame through thrust bearing [9] and controller box [10]. The front wheel [11] along with a BLDC hub motor [12] is mounted at the bottommost end of the fork. This motor is directly coupled to the front wheel through spokes and is controlled by a throttle [13] through an electronic controller residing within a box [10]. The motor is provided with proper braking system operated by the right lever [14] mounted at the center of the hub. The motor is driven by a 36 V-18 AH lead acid battery placed in the main body under the passenger seat. On the other hand, the rear axle is driven manually by the driver through pedal crank [15], chain [16] and driven sprocket [17]. The driven sprocket is mounted on an override mechanism [18]. For proper adjustment of the speed of wheels during turning, the rear axle is split in two parts – the right axle [19] and the left axle [20]. The right wheel [21] and the left wheel [22] are attached to axles through right [23] and left [24] brakes operated by the left lever [25] on the handle. The entire rear axle drive mechanism is attached to a machined structure [26] for proper alignment of the axles. The transmission system is attached to the main chassis and is described in Figure 4, representing the speed override mechanism (shown as item 18 in Figure 3), in detail in the 3D CAP model. This mechanism helps in speed adjustment of the rear wheel during turning of the vehicle.

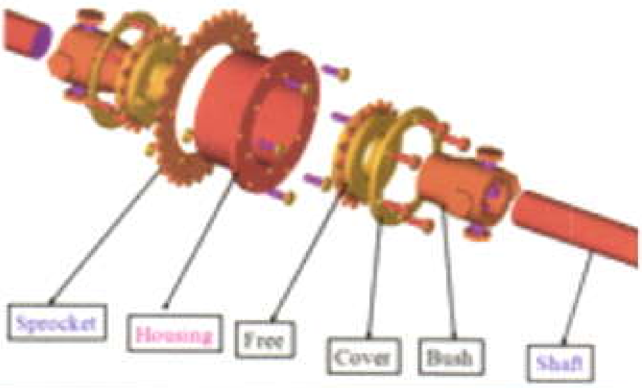


Figure 4

Two different models of SOLECKSHAW, as developed at CSIR-CMERI, are shown below:

Technical Specifications of BLDC motor based vehicle

Power source	:	Electric and human
Type of drive	:	Motor assisted pedal driven (hybrid)
Electric motor	:	BLDC Hub Motor (240W, 36V) mounted on front/rear wheel
Charging	:	Batteries may be charged from solar charging station or from mains power supply source by battery swapping mechanism
Battery	:	Deep discharge type lead acid batteries
Transmission	:	Chain & sprocket drive
Brakes	:	Drum and shoe brake on both rear wheels, Brake on motor drum on front wheel
Axle	:	The entire rear axle system is mounted on a separate structure to ensure better alignment of both the axles
Pay load	:	210 Kg (driver and two passengers)

Societal Impact

The Chief Minister of Delhi, **Smt. Sheila Dikshit,** ceremonially launched the first TDP (Technology Demonstration Project) of Soleckshaw on 2nd October, 2008, (commemorating Gandhi Jayanti) at the Chandni Chowk Metro Station in the august presence of Shri Kapil Sibal, the erstwhile Union Minister of Science, Technology and Earth Sciences and the then Vice-President, CSIR and Prof. Samir K. Brahmachari, Director General, CSIR was among the other dignitaries present on the occasion.

At Chandni Chowk, regular operation was attempted with a fleet of 7 vehicles, 5 amongst which were manufactured by CSIR-CMERI and rest supplied by M/s Modular Machines, Faridabad, one of the earliest licensees of the technology. A model solar charging station, manufactured by M/s Central Electronics Limited (a public sector entity administered by the Department of Science & Technology, Government of India) was also installed at the Yudhbir Singh Park at Chandni Chowk for charging of the batteries. The responsibility of operation was entrusted to M/s Centre for Rural Development, an NGO represented by Dr. Pradip Sharmah. The TDP continued successfully for 2 years and the feedback of the operators was collected for design validation and improvement.

Figure 5: Demonstration of BLDC based SOLECKSHAW at Chandni Chowk, New Delhi

Thereafter, the Department of Science and Technology (DST), Government of Chandigarh expressed their eagerness to operate ***Soleckshaws*** in Chandigarh in a bid to promote solar energy usage, and went in for the purchase of 10 vehicles from M/s Modular Machines, Faridabad (a CSIR-CMERI Technology licensee), and a solar charging station was ordered from the CEL. The Department of Science & Technology, Government of Chandigarh, however, opted to individually distribute the vehicles to a few identified drivers instead of following the earlier model of entrusting the responsibility to a NGO. Ignorance of the technical aspects gave rise to technical snags which could not be properly addressed by the individual rickshaw pullers. In addition, a major obstacle was presented in accessing the solar charging facility since it was installed on the roof of a fire service station and was out of bounds for the general public. The problem was further compounded by the absence of a secured parking place for the vehicles leading to substantial damage of the vehicles by miscreants. All these resulted in the rickshaw pullers becoming disinterested in the operation of the vehicles, and finally the entire scheme came to a halt. The Government of Chandigarh subsequently attempted to have the vehicles repaired but the supplier (M/s Modular Machines), for some unknown reason, refused to do it even at an additional cost. The operation remains suspended till date.

Based on feedbacks, a fresh attempt was taken to develop and try out a number of improved variants and to rectify the defects of the first base model. The main focus was on longer operation for gathering reliable feedback of the technical, economical and social aspects of ***Soleckshaw*** deployment. The overall business model for the proliferation of this new technology has to be different from the existing pattern. As the unit cost of ***Soleckshaw*** is substantially high compared a conventional rickshaw and as in the absence of a well-conceived business plan there remains considerable uncertainty of revenue generation by individual rickshaw pullers, individual purchase of the vehicles is nearly ruled out as of now. It is felt that the best market dynamics can be obtained through the intermediate involvement of a management entity in the form of a financier, a community based organisation or a consortium to support and sustain the activity, where the presence of a proper management entity ensures availability of adequate number of vehicles to identified "operators" and quality after-sales service secured entity directly from the 'manufacturer'. These three components must be brought together to ensure "Sustainable Operation", as depicted in Figure 6.

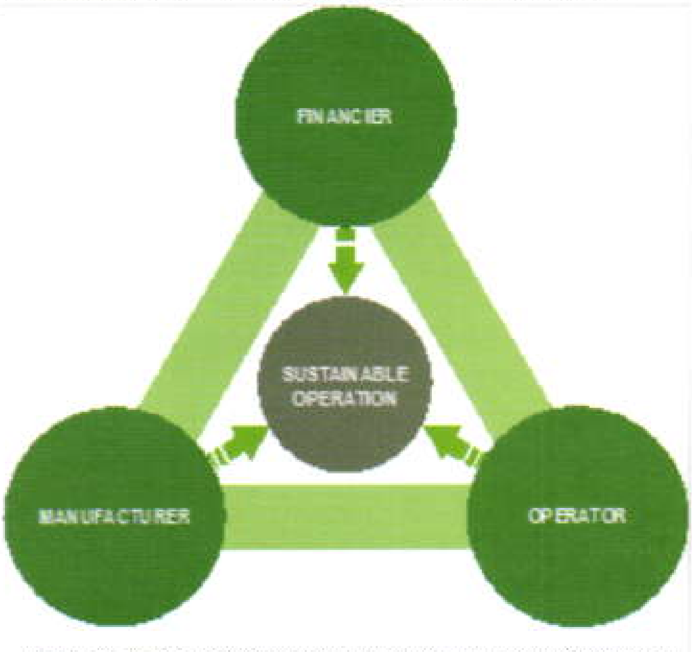


*Figure 6: Model of **Soleckshaw** Deployment and Operation*

Under normal circumstances, particularly in case of a matured technology, it is not so difficult to get financiers, or CBOs or private entrepreneurs. Unfortunately, in this case, the technology has not traversed the time curve needed for its maturity, which, in its turn, leads to the difficulty of receiving private or consortium finance. The best option, however, may be offered by direct involvement of government welfare agencies or public sector entities with defined corporate social responsibilities as intermediaries. There, however, remains the issue of whether the activity of promoting ***Soleckshaws*** through corporate intervention is in conformity with individual CSR policies that helps in creation of brand images for individual PSU entities. The best option is therefore afforded by the involvement of state or central governments through their varied social welfare schemes. On an earlier occasion, the Government of Chadigarh came forward to act as the financier but no specific operator could be identified and therefore the activity could not be sustained. The vehicles procured were also technically not reliable enough to sustain the operation. In the absence of a reliable manufacturer, it is also not possible to attract the government agencies to invest in the project. Based on all these considerations, it was decided to generate extensive market feedback data in order to refine the technology as well as identify the problems of market penetration.

Two alternative sources of financing could be worked out: 1) Full funding by CSIR-CMERI (from their newly approved project on market seeding) and 2) Joint funding by CSIR-CMERI and identified agencies of state or local governments. However, in both these cases, only a one-time funding in the form of capital investment (primarily the cost of the ***Soleckshaws*** and the solar charging station, if any) is possible. The operation and maintenance (O&M) expenditure of the project must be raised by the "operator" through a suitable revenue model and all identified "Operators" must agree to this pre-condition. Taking into account the overhead expenditure of the operator and the cost of maintenance of the vehicles, maintaining a minimum fleet of 15 vehicles is required for sustainable operation. Having 50-100 vehicles per fleet would further help in improving the efficacy of operation.

Based on the user's feedback and ready availability of interested operator in the form of either NGO or a start-up company, following locations have been chosen for the operation of Soleckshaws:

1) Gurgaon; 2) Jaipur; 3) Faridabad; 4) Kolkata; 5) Durgapur; and 6) Ajmer. NGOs / start-up companies/

organisations who have agreed to take part in these programme are: 1) "Uthhan" at Gurgaon; 2) M/s Solarick Tourism at Jaipur; 3) "Umeed" at Faridabad; 4) Bengal Engineering and Science University at Kolkata and 5) Swami Vivekananda Vani Prachar Samity (SVVPS) at Durgapur. So far, 50 of Soleckshaws have been procured from different licensees (Manufacturer) and distributed to operators at five different locations. The details are given below: -

Location	Financier	Manufacturer	Operator & Fleet Size	Remarks
Gurgaon	CSIR-CMERI	Stilam Faridabad HBL Gurgaon Modular Machines Faridabad	Utthan From Stilam: 5 From HBL: 10 From Modular M/Cs: 8 23 Vehicles	Operation started with 5 Soleckshaws in January 2011 and is continuing presently with 15 units. 8 more units have been received by the operator
Jaipur	CSIR-CMERI	Stilam Faridabad	Solarick Tourism 17 Vehicles	Operation started in February 2011 and is continuing presently
Faridabad	Municipal Corporation of Faridabad	Modular Machines	Umeed 10 Vehicles	The site has been selected and operation is supposed to commence soon. The entire proposal submitted by CSIR to the Municipal Corporation of Faridabad is under active consideration
Kolkata	CSIR-CMERI	Dean Systems Kolkata	Bengal Engineering & Science University 1 Vehicle	Demonstration is continuing at the BESU Campus
Durgapur	CSIR-CMERI	Dean Systems Kolkata	SVVPS 8 Vehicles	Under operation within Durgapur Steel Plant Township and Waria
Ajmer	India Post	Kinetic Motors Pune	India Post 5 Vehicles	Successfully running for the last three months at Ajmer

Postal Soleckshaw

CSIR and M/s Kinetic Motors, Pune have collaborated to put into the streets a variant of the ***Soleckshaw*** for use in postal deliveries. 5 units of this ***Postal Soleckshaw*** have been procured by the India Post from M/s Kinetic and **formally launched at Ajmer on 17th January, 2011 by the Hon'ble MoS, C&IT, Shri Sachin Pilot.** Currently the vehicles are being used by identified postmen on a regular basis at Ajmer under the administrative supervision of the Senior Post Master, Head Post Office, Ajmer. Full technical support is being provided by the representatives of M/s Kinetic Motors. Feedback from the operators is being documented on a daily basis for further improvement/ modification of the vehicles as well as their operation.

Remarks

Based on the feedback of the different Technology Demonstration Projects launched at different places of India, it has been found that the ***Soleckshaw*** variant employing both front and rear wheel drives manufactured by M/s Hyderabad Batteries Limited (HBL) is running successfully on a self-sustainable basis under very good maintenance and service support of the manufacturer. Adequate infrastructure and manufacturing facility at the disposal of M/s HBL ensures manufacture and delivery of 50 units within a space of six weeks only. M/s HBL has recently secured an order of 500 ***Soleckshaw*** units from the UP government. The selling price per ***Soleckshaw,*** supplied at Gurgaon TDP by M/s HBL, is approximately pegged at Rs 45,000/-per unit. Presently these ***Soleckshaws*** are generating for the rickshaw puller an average revenue Rs 450/- per day as against Rs.200/- of a common rickshaw.

The specification of the HBL make ***Soleckshaw*** is as follows:

Power source : Electric and human
Type of drive : Motor assisted pedal driven (hybrid)
BLDC motor : 240W, 36V mounted on front/ rear wheel
Battery : 36V, 40 AH (2 sets per vehicle is recommended)
Average range : 50 Km per charge
Pay load : 210 Kg (driver and two passengers)

However M/s HBL is also capable of manufacturing SOLECKSHAWs with higher powered motors (350 W) and higher battery capacity.

- It is recommended that suitable Technology Demonstration Projects (TDP) for ***Soleckshaw*** should be initiated at different locations in Kolkata in order to create proper awareness among the users about the benefits of the new technology
- As mentioned earlier, each TDP needs to be initiated with a fleet of at least 20 ***Soleckshaws*** in close association amongst a licensee (manufacturer), an interested operator and users (Rickshaw pullers).
- The manufacturer should provide regular after sales service and necessary training to the users and operators.
- ***Soleckshaws*** are more suitable at places where the average distance between destinations is more than 5 Km and roads are less congested, like in Rajarhat, Salt Lake of Kolkata, etc
- Initially the financial back up may be provided by The Government of West Bengal or any other agency identified by the Government.
- NGOs (operators) should be selected locally by the Government of West Bengal
- Rickshaw pullers should be selected locally by the NGOs

Soleckshaw technology has already been transferred to the following industries:

1. M/s Stilam Automobiles Pvt. Ltd.,
   Plot No -16, Sector- 27 C,
   Industrial Area,Faridabad-121005, Haryana
   Ph: +91-0129-4135200, 4136200.
   M: +91-9910339976.
   E-Mail : rajiv.vashishta@stilam.net.
   Website: www.stilam.net
2. M/s Modular Machines
   6/2, Karkhana Bagh, Mathura Road,
   Faridabad (Haryana) - 121 002 .
   Fax No: 0129-2227079 .
   Mobile No: 09810829404
   E.mail: modularmachines@gmail.com/
   avbhatnagar@yahoo.com
3. M/s HBL Power Systems Limited,
   8-2-601, Road No 10, Banjara Hills,

Hyderabad - 500 034
Mobile No: 09958798546 ,
E.mail: anilsahoo@hbl.in

4. M/s DEAN Systems
New Green Park, Narendrapur
Kolkata 700103
Telephone: 033-24773375,
Fax No: 033-24770627
Mobile No: 09331841091/ 9432745125,
E.mail: dean01@vsnl.net / deansystems01@gmail.com

5. M/s Kinetic Motors, Kinetic Motor Company Limited, Pune, Maharashtra,
E-mail:sfm@kineticindia.com.

NRDC has been provided authority to transfer the technology to Indian entrepreneurs on a non-exclusive basis.

Soleckshaws manufactured by M/s Stilam, Faridabad deployed at Gurgaon and Jaipur by M/s Uthaan, an NGO

Launching of Postal Soleckshaw at Ajmer

FACILITATING THE SOCIETY

CSIR-CMERI FOOTPRINTS IN THE NORTH EAST

Backdrop

Thermal Engineering is one of the core activities of CSIR-CMERI and constitutes a major division which conducts R&D in the field of Energy, Process Plant Technology, Post Harvest Processing, etc. The group is active in the broad research field of Thermal & Fluid Engineering comprising activities on fluid flow, heat transfer, combustion, gasification, fluidization, renewable energy, waste management, drying, etc. In the area of Post Harvest Technology the group has been working on drying for more than a decade, during the course of which the Group has designed improved Tray dryers, Mixed flow LSU dryers, Fluidized bed dryers (batch/continuous), Spouted bed dryers (batch/continuous), Column dryers, Microwave dryers, etc. for different agro crops and seeds.

Recently the Government of India has placed major emphasis on making available technological solutions to the people of North East India through the provision of research outputs for typical issues related to the area, and also on their implementation so that the region can emerge as a strong economic entity. Ginger, turmeric, chili, etc. are typical cash crops of Mizoram and the Arunachal Pradesh. At present there is no post harvest processing of these crops in these states, and due to lack of preservation and value addition, the farmers suffer as they receive poor prices for the base product. Since the crops are normally being sold immediately after harvesting, the poor farmers receive a pittance for their produce. CSIR-CMERI has been working for the last few years for providing proper technological solutions for preservation and processing the agro produce and adding value to these produce by increasing their shelf-life, all of which has translated to significant increase in earnings of the farmers. Enthused by the response this effort is receiving from all quarters of the society, CSIR-CMERI has established two Centres for Post Harvest Technology, one each at Mizoram and Arunachal Pradesh. It is heartening to note that these Centres are fast becoming a major hub for fostering economic activity in the state, particularly for the youth of the region.

Land development at CSIR Centre for Post Harvest Processing & Research at Mizoram

Efforts

As a part of the North East initiative, CSIR-CMERI established post harvest processing centers at Mizoram and Arunachal Pradesh for processing ginger, turmeric, chili and other spices. The centers, along with their outreach counterparts, is working continuously on the drying, grinding and packaging of ginger, turmeric and chilies. Problem-specific research is carried out at these centers on post harvest processing of various agro crops in the north-east states of Mizoram and Arunachal Pradesh.

Tribal youth of Mizoram working in CSIR Rural Centre, Tuirial

In the course of this work, it is proposed to evolve a generic model of value addition through the deployment of low-cost, stand-alone agro-processing units in different parts of the disadvantaged states with the ultimate objective to augmenting the economy of rural people. To start with, CSIR-CMERI proposes the establishment of local level centres in each of the districts of Mizoram and Arunachal Pradesh, which shall be run and maintained by NGOs / SHGs, later extending the scope to cover the entire state. CSIR-CMERI has made a significant mark in these two north-eastern states through the establishment of post harvest processing centers and a commitment for strong economy in the coming years.

Driers for Ginger / Turmeric / Chili

Ginger / Turmeric Washing Unit

Ginger / Turmeric Slicing Unit

Intervention

To facilitate the evolution of a generic model of value addition through the deployment of low-cost, stand-alone agro-processing units, CSIR-CMERI, in collaboration with Community Development–Action & Reflection (CDAR), an NGO based at Aizawl, has come out with a complete technological solution to help the farmers of Mizoram. The technology package consists of the following:

Rotary Drum Washer: Freshly harvested ginger/ turmeric from field contains substantial mud/dirt attached with it. It is first washed with water jet in a rotating drum.

Slicer: Washed ginger/turmeric is sliced to 2 to 3 mm thick chips for faster, more uniform and efficient moisture removal.

Cabinet Dryer: Slices of freshly harvested ginger/ turmeric contains about 90% water, which if not dried within 2-3 days leads to bacterial attack and mould formation. Slices are dried to 8-10% moisture level with hot air by electrical heater. Suction fans and zigzag air flow paths result in uniformly dried product. This increases the shelf life of the agriculture produce and leads to value addition of the product.

Grinder: Dried Slices of ginger/turmeric are then ground to fine powder and packaged to market ready product.

The final product is a complete organic one. The technology helps the farmers to receive proper value for their produce.

Construction of CSIR Rural centre at Aizwal, Mizoram

Rural People at work in CSIR Centre for Post Harvest Processing & Research, Mizoram

Centre for Post Harvest Processing and Research, Aizwal

Training of Rural Tribal Youth by CSIR-CMERI and University of New South Wales, Australia

Construction of CSIR Centre for Post Harvest Processing and Research, Jengging, Upper Shiang, Arunachal Pradesh

Site selection at Pashighat, Arunachal Pradesh for the CSIR Centre for Post Harvest Processing and Research

Tribal youth working in CSIR Rural Centre, Jengging, Arunchal Pradesh

Outcomes

Site selection, procurement and development of land have been completed at two sites. The main processing unit at Tuirial has been completed, along with the establishment of the Training Centre for the rural youth. Prototypes of the sub units of the processing plant have been fabricated and installed at site, and technology has been transferred. At the moment, self-help groups are being organized with the assistance of a community based organization. The processing centre is fully functional, and is providing livelihood to 30 farmers and their families. ***So far 2000 man days of employment has been generated in Mizoram and 6000 farmers / entrepreneurs already registered with complete data of their land. In Arunachal Pradesh, 40 man days of employment has been generated daily and the process of farmers / entrepreneurs registering with complete data of their land is under progress.***

Based on the inputs provided by the local farmers, CSIR-CMERI is now designing improved and more efficient versions of the sub processing units in order to ensure faster drying, reduction in the labor cost, maintaining hygienic conditions of production with uniform quality, etc. Efforts are also on for obtaining necessary certificates for organic production so as to increase the product value in the market.

INNOVATION PROMOTION

TePP Outreach Centre

The mandate of the CSIR-Central Mechanical Engineering Research Institute, Durgapur is to conduct research and development in mechanical engineering technology so that India's dependence on foreign collaboration is substantially reduced in the strategic and economy sectors. In addition to this, CSIR-CMERI is mandated to facilitate innovations and inventions for establishing the claims of Indian talent in international fields where Indian products shall finally compete. It was with this objective that the **TePP Outreach Centre** at CSIR-CMERI was established in September 2008 which became fully functional from 2009.

The TePP – Technopreneur Promotion Programme – is a flagship programme for innovation promotion administered by the Department of Science & Technology, Government of India and comprises the largest network programme supporting independent innovators. The network – now with its 30 Outreach Centres across the country – provides grants, technical guidance and mentoring support to independent innovators belonging to the informal and formal sectors. The purpose of this support is to enable innovators emerge as entrepreneurs by incubating their ideas and enterprise. The support is extended in two distinct phases: the first phase is directed towards innovation incubation, and the second towards enterprise incubation. Over the years, TePP has emerged in a network mode as a unique framework with contribution from various players involved in the scheme. To date, TePP has accessed over 7000 ideas and supported in excess of 300 innovators. TePP has successfully demonstrated that once the necessary opportunity and support is extended, the vast multitude of independent innovators would rise to provide and devise solutions and opportunities to commercial entities.

Since its inception in September 2008, TUC-CMERI has received funding from the DSIR for six innovations. Three are in various stages of consideration for funding. Out of the six, two projects have been successfully concluded, with one poised for entry into the TPF Phase II stage. Two projects are almost near completion, while two are in the midway.

The completed projects are:

- Self-propelled three row potato seeding device
- Electricity from tidal waves

Projects nearing completion are:

- Portable Microscope Slide Projector (Teaching Aid)
- Solar powered DC/BLDC motor operated kerosene dispensing unit with biometric/bar-code access control

Ongoing projects comprise:

- Low specific-cost solar parabolic dish concentrator system
- Alternate growth medium for increasing mushroom cultivation.

CSIR-NIF Innovation Fellowship initiative

The CSIR-NIF Innovation Fellowship Scheme was instituted with the objective of strengthening R&D linkage between various scientific institutions under the umbrella of the CSIR and grassroots innovators and traditional knowledge holders in a bid to promote commercial and non-commercial applications of green grassroots innovations. Since the inception of

SL.	Author	Title	JOURNAL Details
11	Partha Hajra, Mrinal Pal, Anindya Datta, Dipankar Chakravorty , Vyacheslav Meriakri and Michael Parkhomenko	**Magnetodielectric properties of nanodisc bismuth ferrite grown within Na-4 mica nanochannels**	JOURNAL OF APPLIED PHYSICS Vol. 108 , Issue 11 pp. 114306 - 114306-5
12	S. Patra, S. Sarkar, S.K. Bera, G.K. Paul and Ranajit Ghosh	**Influence of surface topography and chemical structure on wettability of electrodeposited ZnO thin films**	JOURNAL OF APPLIED PHYSICS Vol. 108 , Issue 8, 083507 doi:10.1063/1.3493735 (6 pages)
13	UK Bhaskar, S. Bid, Biswarup Satpati, et al.	**Mechanosynthesis of nanocrystalline titanium nitride and its microstructure characterization,**	JOURNAL OF ALLOYS AND COMPOUNDS Vol. 493 Issue: 1-2 , pp.192-196
14	Pankaj Saha and Gautam Biswas	**Assessment of a shear-improved subgrid stress closure for turbulent channel flows**	INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER Vol. 53, Issues 21-22, pp. 4789-4796
15	Sandip Sarkar, Amaresh Dalal , Gautam Biswas	**Mixed convective heat transfer from two identical square cylinders in cross flow at Re = 100,**	INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER Vol. 53, Issues 13-14, pp. 2628-2642
16	Atanu Saha, Dipak Kumar Mondal and Joydeep Maity	**Effect of cyclic heat treatment on microstructure and mechanical properties of 0.6 wt% carbon steel**	MATERIALS SCIENCE AND ENGINEERING: A Vol.527, Issue 16-17, pp 4001-4007.
17	Murugan Thangadurai and Debopam Das	**Characteristics of counter-rotating vortex rings formed ahead of a compressible vortex ring**	EXPERIMENTS IN FLUIDS Vol. 49, Number 6, pp. 1247-1261
18	Suman Saha, Saptarshi Das, Ratna Ghosh, Bhaswati Goswami, R. Balasubramanian, A. K. Chandra, Shantanu Das and Amitava Gupta	**Design of a fractional order phase shaper for iso-damped control of a PHWR under step-back condition,**	IEEE TRANSACTIONS ON NUCLEAR SCIENCE Vol.57, Issue 3, pp. 1-11
19	S. Dechoudhury, V. Naik, M. Mondal, Avik Chatterjee, H. K.Pandey, T. K.Mandi, A. Bandyopadhyay, P. Karmakar, S. Bhattacharjee, P. S. Chouhan, S. Ali, S. C. L. Srivastava, A. Chakrabarti	**Design & development of a Radio Frequency Quadrupole (RFQ) linac post-accelerator for the VECC RIB project**	REVIEW OF SCIENTIFIC INSTRUMENTS, AMERICAN INSTITUTE OF PHYSICS Vol. 81, 23301
20	Aditya Kr. Lohar, Biswanath Mondal, S.C. Panigrahi	**Influence of cooling rate on the microstructure and ageing behaviour of as-cast Al–So–Zr alloy**	JOURNAL OF MATERIALS PROCESSING TECHNOLOGY, Vol. 210, Issue 15, pp. 2135-2141
21	S. Kumar	**Object-Oriented Finite Element Programming for Engineering Analysis in C++**	JOURNAL OF SOFTWARE,Vol. 5, No. 7, pp. 689-696
22	Arpita Mukherjee, Aparajita Sengupta	**Likelihood function modeling of particle filter in presence of non-stationary non-gaussian measurement noise**	SIGNAL PROCESSING, Vol. 90, Issue 6, pp.1873-1885
23	Dipankar Chatterjee	**Lattice Boltzmann simulation of incompressible transport phenomena in macroscopic solidification processes**	NUMERICAL HEAT TRANSFER B ,Vol. 58 pp. 55-72
24	Dipankar Chatterjee	**Mixed convection heat transfer from tandem square cylinders in a vertical channel at low Reynolds numbers,**	NUMERICAL HEAT TRANSFER A ,Vol. 58, Issue 9, pp 740-755
25	Gurunath Gandikota, Sakir Amiroudine, Dipankar Chatterjee and Gautam Biswas	**The effect of aiding/opposing buoyancy on two-dimensional laminar flow across a circular cylinder**	NUMERICAL HEAT TRANSFER A .Vol. 58 pp. 385-402

OTHER ACTIVITY FACETS

LIST OF PUBLICATIONS

PAPERS PUBLISHED 2010			
SL.	**Author**	**Title**	**JOURNAL Details**
1	Biplab Choudhury, Pradip Kr. Chatterjee, J.P. Sarkar	Review paper on solar-powered air conditioning through adsorption route	RENEWABLE AND SUSTAINABLE ENERGY REVIEWS, Vol.14, Issue 8, pp 2189 – 2195
2	Y.S. Chaudhary, S. Panigrahi, S. Nayak, B. Satpati, S. Bhattacharjee and N. Kulkarni	Facile synthesis of ultra-small monodisperse ceria nanocrystals at room temperature and their catalytic activity under visible light	JOURNAL OF MATERIALS CHEMISTRY, Vol. 20, pp. 2381–2385,
3	Pramod Kumar Verma, Anupam Giri, Nguyen T. K. Thanh, Le Duc Tung, Oindrila Mondal, Mrinal Pal and Samir Kumar Pal	Superparamagnetic fluorescent nickel–enzyme nanobioconjugates: synthesisand characterization of a novel multifunctional biological probe	JOURNAL OF MATERIALS CHEMISTRY, Vol. 20 Issue 18, pp. 3722-3728,
4	Simantini Nayak, Biswarup Satpati, Ritesh K. Shukla, Alok Dhawan, Sarama Bhattacharjee & Yatendra S. Chaudhary	Facile synthesis of nanostructured hydroxyapatite–titania bio-implant scaffolds with different morphologies: their bioactivity and corrosion behaviour	JOURNAL OF MATERIALS CHEMISTRY ,Vol. 20, pp. 4949 - 4954
5	Arpita Mukherjee, Aparajita Sengupta	Estimating the Probability Density Function of a Nonstationary Non-Gaussian Noise, Industrial Electronics	IEEE TRANSACTIONS INDUSTRIAL ELECTRONICS Vol.57, no.4, pp.1429-1435,
6	S. Mandal, N. Paul, Priyabrata Banerjee, N. Mondal and Sreebrata Goswami	1,4 Alkyl Migration Associated with Simultaneous S-C Bond Cleavage and N-C Bond formation in Platinum Complexes of 2 Aminothioethers, Characterization of Intermolecular Intelligent Charge Transfer Phenomenon	DALTON TRANSACTIONS, Vol. 39, pp.2717–2726
7	E. Luna; B. Satpati, JB Rodriguez, et al.	Interfacial intermixing in InAs/GaSb short-period-superlattices grown by molecular,beam epitaxy	APPLIED PHYSICS LETTERS, Vol. 96 Issue: 2 Article Number: 021904
8	Dipankar Chatterjee, Sakir Amiroudine	Lattice Boltzmann simulation of thermofluidic transport phenomena in a DC magnetohydrodynamic (MHD) micropump	BIOMEDICAL MICRODEVICES, Vol. 13, Number 1, pp. 147-157
9	Debabrata Chatterjee	Effect of excited state redox properties of dye sensitizers on hydrogen production through photo-splitting of water over TiO2 photocatalyst	CATALYSIS COMMUNICATIONS Vol. 11, Issue 5, pp. 336-339
10	Dipankar Chatterjee, Sakir Amiroudine	Lattice kinetic simulation of non-isothermal magnetohydrodynamics	PHYSICAL REVIEW :E Vol. 81, pp. 066703-1-6

HIGHER QUALIFICATION ATTAINED

Sl.	Qualification	Awardee
1.	Ph.D from BESU *Experimentation, Modeling and Optimization of Flexible Polymeric Mould Characteristics Using Evolutionary Algorithms*	**Dr. Arup Kr Nandi, Senior Scientist**
2.	Ph.D. from IIT, Guwahati *Analysis of Stability & Unbalanced Response of Flexible Rotor supported on Hydrodynamic Porous Journal Bearing*	**Dr. Swarup Kr Laha, Scientist**
3.	Ph.D. from IIT, Kharagpur *Multiphase flow numerical Modeling for Simulation of the Injection Stage of Powder Injection Moulding (PIM)*	**Dr. Sudip Kr Samanta, Principal Scientist**
4.	Ph.D. from IIT, Kharagpur *Processing and Characterization of Aluminium-Scandium Alloys and Composites*	**Dr. A K Lohar, Principal Scientist**
5.	Ph.D. from Jadavpur University, Kolkata *An Investigation on Performance Characteristic of Vertical Submersible Slurry Pumps*	**Dr. Lal Gopal Das, Senior Scientist**
6.	Ph.D. from IIT, Kharagpur *Monotonic and Cyclic Fracture Behaviour of AISI 304LN Stainless Steel*	**Dr. Himadri Roy, Scientist**
7.	Ph.D. from IIT, Kharagpur *Analysis of some High-speed Compressible Flow Problems Using Flux Splitting Algorithm*	**Dr. Pabitra Halder, Scientist**
8.	Ph.D from BESU *Dynamic State Estimation in Presence of Uncertainty*	**Dr. Arpita Mukherjee, QHF**

AWARDS/RECOGNITION

SL.	Awards/Recognition	Awardee(s)
1.	IEI Young Engineers in Computer Engineering discipline for the Session 2010-11	Mr Subhra Kanti Das, Scientist
2.	BOYSCAST Fellowship 2010-11	Dr. Himadri Roy Scientist
3.	Prestigious J.C. Bose National Fellowship	Prof Gautam Biswas, Director, CSIR-CMERI
4.	Member of the Editorial Board of the Indian Journal of Engineering & Materials Sciences (IJEMS) by Research Council of the National Institute of Science Communication and Information Resources (NISCAIR)	Prof Gautam Biswas, Director, CSIR-CMERI
5.	Appointed as OSD/ Acting Director in the interim AcSIR	Prof Gautam Biswas, Director, CSIR-CMERI
6.	Nominated as a CSIR member in Indian Member Committee of the World Federation of Engineering Organisation (WFEO) during April, 11	Prof Gautam Biswas, Director, CSIR-CMERI
7.	Nominated as a member of the Working Group on S&T Human Resource Development by Planning Commission	Prof Gautam Biswas, Director, CSIR-CMERI
8.	Nominated as a member of working group of the steering committee on Science and Technology for formulation of Twelfth Five Year Plan	Prof Gautam Biswas, Director, CSIR-CMERI
9.	Raman Research Fellowship for the year 2011-2012	Dr. N C Murmu Principal Scientist
10.	Expert Member-Ministry of New and Renewable Energy (MNRE), Government of India in Biofuels Division	Dr. Biswajit Ruj Principal Scientist
11.	Best Paper Award in the National Symposium on Innovative and Modern Technologies for Agricultural Productivity, Food Security And Environmental Management held at Mangalore during 22-23, July 11 (paper : Algal Biodiesel- Future Prospects And Problems)	Dr. Krishnendu Kundu Senior Scientist
12.	Best Paper Award in International Conference on ARTCom 2010, Kottayam, Kerala, 15-16 Oct 2010 Paper Title: Bio-mimetic Behaviour of IPMC Artificial Muscles using IPMC EMG Signal	Ravikant Jain Senior Scientist
13.	A Book Entitled "Biomass Gasification- Thermo Chemical Fluidized Bed Gasification of Boimass" published by Lambert Academic Publishing GmbH & Co. KG, Germany [ISBN: 9783843375773]	Dr. Malay Karmakar, Scientist Dr. P.K.Chatterjee, Chief Scientist Dr. Abhi Bhusan Datta

SL.	Name	DEPUTATION TO	DURATION
16.	Shri Dip Narayan Ray Scientist	China for participating in the IEEE International Conference on Intelligent Computing & Intelligent Systems -2010	14/12/2010 to 18/12/2010
17.	Shri U. S. Patkar Senior Scientist	Big Sky, Montana, USA, for participating in 2011 IEEE Aerospace Conference	05/03/2011 to 10/03/2011
18.	Dr. Debabrata Chatterjee Senior Principal Scientist	Visiting the UCI, Irvine for Collaboration Programme	03/04/2011 to 16/04/2011
19.	Dr. Debabrata Chatterjee Senior Principal Scientist	Visiting the University of Maine, Orono, USA for Collaboration Programme.	01/05/2011 to 15/05/2011
20.	Dr. Ranajit Ghosh Scientist	Visiting Scholar, UIC, USA, Indo-US Centre for Research Excellence on Fabrionics	15/05/2011 to 15/08/2011
21.	Ms. N.S. Lakshmiprobha QHF (Trainee)	Vancouver, Canada for International Conference on Computer Vision	01/06/2011 to 03/06/2011
22.	Dr. Sarita Ghosh Scientist Fellow	University of California, Irvine, USA Joint Collaboration in Electroactive Polymers	01/06/2011 to 01/09/2011
23.	Dr. Debabrata Chatterjee Senior Principal Scientist	Erlangen Univ. for joint programme, Erlangen-Nurnberg, Germany	05/06/2011 to 10/06/2011
24.	Mr. Atanu Maity Principal Scientist	Tallinn, Estonia for 15th International Conference on Advanced Robotics	20/06/201 to 23/06/2011
25.	Prof. Gautam Biswas Director, CSIR-CMERI	Saint Petersburg, Russia on invitation to deliver key note lecture in the Indo- Russia Workshop on Topical Problems of Solid & Fluid Mechanics	01/07/2011 to 05/07/2011
26.	Ms. Rekha J QHF(Trainee)	Las Vegas, Nevada, USA to participate in the Conference on Image Processing, Computer Vision & Pattern Recognition IPCV'11	18/07/2011 to 21/07/2011
27.	Mr. Atanu Maity Principal Scientist	Kuala Lumpur, Malaysia for presentation of paper in 26th International Conference on CAD/CAM, Robotics & Factories of Future	26/07/2011 to 28/07/2011
28.	Mr. Dip Narayan Ray Scientist	Kuala Lumpur, Malaysia for presentation of paper in 26th International Conference on CAD/CAM, Robotics & Factories of Future	26/07/2011 to 28/07/2011
29.	Mr. Samik Dutta Scientist	Indonesia for International Conference on Future Materials Engineering & Application	04/08/2011 to 04/08/2011
30.	• Mr. S. Nandy, Principal Scientist • Mr. Srinivas Reddy N • Ms. Shikha Jain QHF Trainees	Bejing, Chaina for presentation of paper in International Conference on Mechatronics & Automation	07/08/2011 to 10/08/2011
31.	Dr. Satya Prakash Singh Senior Scientist	Dalian, China for participating in 2nd International Conference on Computational Methods for Thermal Problems	05/09/2011 to 07/09/2011
32.	Mr. Amit Jyoti Banerjee Senior Principal Scientist Mr. Pranabendu Saha, TO.	Bevilard, Switzerland for training on High Precision CNC Lathe	29/08/2011 to 09/09/2011
33.	Dr. Himadri Roy Scientist	University of Bayreuth, Germany for BOYSCAST Fellowship of Advanced Characterization Techniques	29/08/2011 to 28/08/2012

FOREIGN DEPUTATION

SL.	Name	DEPUTATION TO	DURATION
1.	Mrs. Abhilasha Saksena Senior Scientist	Tohoku University, Japan for pursuing PG Study	10/04/2010 to 10/03/2011
2.	Shri Biplab Chowdhury Principal Scientist	China to participate in Research & Application seminar	19/04/2010 to 22/04/2010
3.	Dr. M K Karmakar Senior Scientist	Pontificia Bolivariana University, Colombia	01/05/2010 to 30/08/2010
4.	Shri K. J. Uke Senior Scientist	UK for presentation of paper in the 7th International Conference on Condition Monitoring & Machinery Failure Prevention Technologies	22/06/2010 to 24/06/2010
5.	Shri N. C. Murmu Principal Scientist	UK for Oral Presentation in International Conference on Condition Monitoring & Machinery Failure Prevention Technologies	22/06/2010 to 26/06/2010
6.	Shri Debashis Ghosh Principal Scientist	University of Surrey, Guilford, England for presentation of paper in 5th International Conference on High Temperature Defects in Metal	23/06/2010 to 25/06/2010
7.	Dr. Nagahanumaiah Senior Principal Scientist	Alaska, USA	26/06/2010 to 20/07/2010
8.	Shri Ravi Kant Jain Senior Scientist	Pretoria, South Africa, for participating in the 25th International Conference on CAD/CAM, Robotics & Factories of the future (CARsFOR 2010)	13/07/2010 to 16/07/2010
9.	Shri Atanu Maity Principal Scientist	Istanbul, Turkey for Technical paper presentation in the 2010 IEEE International Conference on Systems, Man and Cybernetics	10/10/2010 to 13/10/2010
10.	Shri Dip Narayan Ray Scientist	Xiamen, China for participating in the IEEE International Conference on Intelligent Computing & Intelligent Systems -2010	29/10/2010 to 31/10/2010
11.	Dr. P. K. Chatterjee Chief Scientist	Czech Republic for Joint Project on Plastic Waste Disposal & Generation of Synthetic Natural gas	30/10/2010 to 07/11/2010
12.	Dr. Biswajit Ruj Principal Scientist	Czech Republic for Joint Project on Plastic Waste Disposal & Generation of Synthetic Natural gas	30/10/2010 to 07/11/2010
13.	Dr. Ranjit Ray Senior Scientist	Massachusetts, USA for participating in the 15th IASTED International Conference on Robotics & Automation	01/11/2010 to 03/11/2010
14.	Dr. B. N. Mondal Senior Principal Scientist	University of Limoges, France for participating in 3rd International Conference (ICRACM), 2010	13/12/2010 to 15/12/2010
15.	Shri Arup Kr. Nandi Senior Scientist.	University of Limoges, France, for participating in 3rd International Conference (ICRACM), 2010	13/12/2010 to 15/12/2010

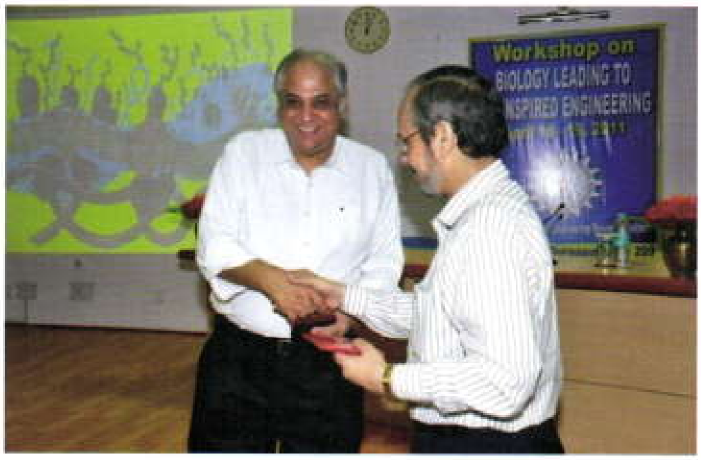
Prof. Amitabha Chattopadhyay, Outstanding Scientist, CSIR-CCMB, Hyderabad, enumerating on "Current Excitements and Challenges in Membrane Biology" at the Workshop

Dr. Sanjay Kumar speaking on 'Plant processes that need Technological Interventions'

Prof. Sudip Chattopadhyay of NIT, Durgapur speaking on the theme Light-Controlled Arabidopsis Seedling Development

Prof. Sudit Mukhopadhyay of NIT, Durgapur during the lecture on "Introduction of Life and Life Engineering"

Prof. Ron Kopito being felicitated by Prof. Amitabha Chattopadhyay

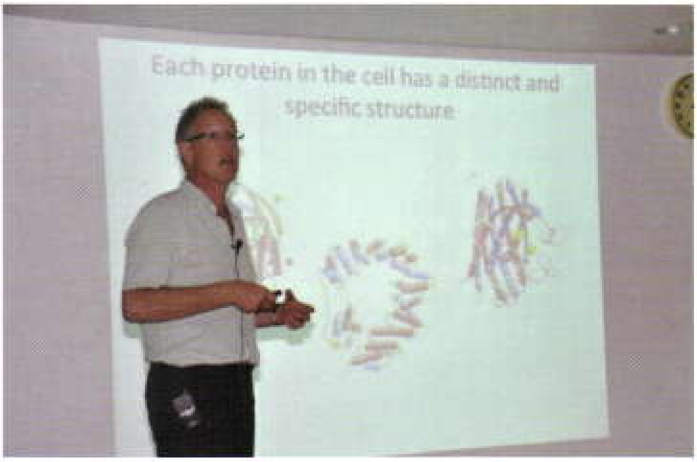


Prof. Amitabha Chattopadhyay being felicitated by Prof. Gautam Biswas, Director, CSIR-CMERI, Durgapur

Light controls growth and development throughout the plant life cycle. In unfavourable environmental conditions, an intact and healthy seed remains dormant in a dry state. A wide spectrum of light, in particular far-red, red, blue and ultraviolet (UV) light induce photomorphogenesis. It is therefore not surprising that plants have adopted the ability to sense multiple parameters of ambient light signals, including light quantity (fluence), quality (wavelength), direction and duration. Light signals are perceived through at least four distinct families of photoreceptors, which include phytochromes, cryptochromes, phototropins and unidentified ultraviolet B (UV-B) photoreceptor(s). Prof. Sudip Chattopadhay of the NIT, Durgapur and his team had been investigating the molecular basis of light-mediated seedling development in a model plant, Arabidopsis thaliana, and was successful in cloning and functionally characterizing several regulatory proteins signaling that light plays an important role in Arabidopsis seedling development. The team had recently demonstrated the genetic interrelations of ZBF1 with two well-characterized negative regulators of light signaling, COP1 and SPA1, in photomorphogenic growth and light regulated global gene expression. This very interesting vista was exposed to the workshop participants through the lecture of Prof. Sudip Chattopadhay of the NIT, Durgapur on the theme Light-Controlled Arabidopsis Seedling Development.

The workshop participants were then taken through an Introduction of Life and Life Engineering by Prof. Sudit Mukhopadhyay of the NIT, Durgapur, wherein he outlined the basic idea of Genetic Engineering along with the scope of engineering in biology. Life was first manifested in unicellular form, which, in the process of evolution became multicellular. The journey from unicellular to multicellular forms of life – including animal and plant life – was quite distinct in their features and differed from others. But the structure, functions and biochemical composition of nucleic acid (DNA, RNA) – the genetic material of life – was exactly same in all the lives on earth.

Scientists have unveiled the structure, function of the genetic material and are trying to decode the genetic language. Biologists are now creating genetically modified life of laboratory animals for understanding human diseases as also for drug discovery. This technology, called Biotechnology has enormous application in every aspects of human civilization. Now genetically modified plants have created which are insect and other pathogen resistant, drought resistant and salinity resistant. Genetically modified disease resistant veterinary animals have been produced successfully. Genetically modified microbes are using for removal of different pollutants. Bio-engineering has evolved as a discipline, where engineering knowledge is being used to develop artificial tissues, artificial organs etc. for treatment of human diseases.



Prof. Ron Kopito, University of Stanford, USA, speaking on 'Quality Control in the Protein Assembly Line'

Prof. Ranga Narayanan, University of Florida, USA, speaking on "Oscillatory Flows as a Means of Separation of Species" at the Workshop

Chattapadadhyay - CSIR-CCMB, Hyderabad, Prof. Sudip Chattopadhyay - NIT, Durgapur, Prof. Debashish Bhattacharya - CSIR-IICB, Kolkata, Dr. Sanjay Kumar - CSIR-IHBT, Palampur, Dr. Sudit Mukhopadhyay - NIT Durgapur and Prof. Pradyumna Ghosh of the Banaras Hindu University, Varanasi.

The Workshop

In his seminal address entitled Quality Control in the Protein Assembly Line. Prof. Ron Kopito of the University of Stanford, USA outlined the problem of protein folding - the process by which linear polypeptide chains are assembled into the correct precise three dimensional structures that are essential for the performance of varied functions. In contrast to the "folding problem" hitherto traditionally the domain of biophysicists and theoretical biologists – Prof. Kopito and his group at the Stanford University, USA are focusing on areas that lie at the interface between human genetics and cell biology. In the course of the workshop, Prof. Kopito discussed the majority of genetic mutations that cause devastating inherited brain disorders, like Parkinson's and Huntington's diseases, interfere with the process of protein folding, leading to the production of proteins that, if not rapidly destroyed, become toxic to brain cells. Prof. Kopito and his co-researchers, on learnt, are trying to understand how brain cells are able to make the decision to destroy these aberrant proteins and why these processes sometimes fail, with devastating consequences.

Speaking on his chosen theme Oscillatory Flows as a Means of Separation of Species, Prof. Ranga Narayanan of the University of Florida, USA succinctly explained how oscillatory flows in tubes can be used as a mechanical means to partially separate species and increase mass transport. The theory behind the phenomenon can be traced to the Taylor dispersion in tubes. The idea of species separation, he illuminated, originated with hyperventilation in lungs and has since been applied to separation of species in the gas phase. In his lecture, Prof. Ranga Narayanan explained in detail the physics of mass transfer in oscillatory flow, and thereafter proceeded to outlining the application to separation of species in the gas phase through the presentation of comparing experiments to theory. Future applications of separation in the liquid phase were also discussed along with potential problems and opportunities.

Biological membranes are complex assemblies of lipids and proteins that allow cellular compartmentalization and act as the interface, through which cells communicate with each other and with the external milieu. The biological membrane therefore constitutes the site of many important cellular functions involving transfer of information from outside to the interior of the cell. In physical terms, membranes can be treated as a complex oriented fluid which is a weakly coupled, non-covalent and anisotropic assembly of molecules in two-dimensions (and can therefore be treated as soft matter). Membranes are heterogeneous in the context of a wide range of spatiotemporal scales. A unique aspect of such an assembly is its dynamics spanning a large range of time scales, which supports a wide variety of biological processes, necessary for cellular function. Monitoring membrane dynamics with all its complexities continues to be a challenge in contemporary membrane biophysics. A fundamental issue of biological relevance is how cell membrane dynamics could be related to cellular signaling. Another important emerging area is the role of cellular membranes in the entry of pathogens to host cells. These insights emerged from the extremely lucid presentation of Prof. Amitabha Chattopadhyay, Outstanding Scientist owing affiliation to the CSIR-CCMB, Hyderabad as he enumerated the Current Excitements and Challenges in Membrane Biology and provided a broad overview of these issues with examples taken from literature as well as his own work.

Dr. Sanjay Kumar of the CSIR-IHBT, Palampur felt that there was a need to automate measurements on the visible characteristics or phenotype of the plants which include measurement of leaf growth, leaf architecture, surface characteristics, photosynthetic characteristics, leaf temperature, biomass, evapo-transpiration, water use efficiency, disease symptoms, etc. These traits, he felt, need to be monitored in a high throughput and non-invasive mode at various stages of growth and development of a plant. Dr. Kumar's deliberations on Plant processes that need Technological Interventions opened up the very interesting possibility of automating measurements for estimating metabolites (critical for medicinal and aromatic plants), protein, DNA, RNA, and nitrogen content. The root zone of a plant, he surmised, is yet another important area that could utilize Non-invasive methods to monitor root growth, soil characteristics, soil volume, water potential, all being critical parameters determining plant performance. Modules should be developed to validate these parameters for measurements under controlled as well under field conditions

WORKSHOP ON "BIOLOGY LEADING TOWARDS BIO-INSPIRED ENGINEERING"

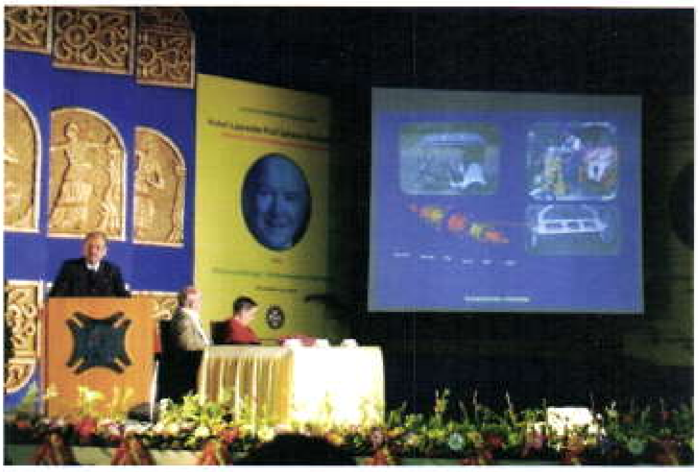
The Background

In engineering, all devices are synthesized by assembly of discrete and often pre-existing components unlike the naturally-grown, fully-integrated biological systems whose function drives the evolution of form at all levels simultaneously. Better understanding of exquisite performance of these integrated biological systems over many hierarchical levels is the key to emulate their functionality in an engineered system. This new and emergent discipline applies biological principles to develop new engineering solutions, and is broadly known as Biomimetics or Biologically Inspired Engineering. Biologically inspired engineering encompasses specialty areas in biology, engineering and the physical sciences, and aims to revolutionize the underlying principles of synthetic design through radical thinking. Even though the field of Biomimetics has just started developing, some tangible applications are on the horizon. The extremely high-density nano-wires have the capability of acting as high-density storage media due to enhanced ferromagnetic properties.

Nature uses fewer materials to create a variety of life forms, and the same material is used in many different ways to meet various needs, as can be seen in the case of collagen. Natural materials are mostly constituted from organic, inorganic crystals and amorphous phases. Biomimetics is a discipline addressing the design and fabrication of synthetic materials using the strategies adopted by living organisms. The organic/inorganic composites synthesized by the principles of living organisms often display unique and desirable morphological, structural and mechanical properties, and represent informative models for the synthesis and design of complex functional materials. Self-assembly of materials includes synthesis of self-generating, hierarchical, multifunctional, nonlinear, composite, adaptive, self-repairing and biodegradable behaviour of materials. For example, bones slowly add or lose mass and change their form in response to modifications of applied stresses. Being subjected to cyclic loading in-vivo, it changes and thickens with an increased applied load. If it is kept continuously under lower than the usual load, it thins and reduces in density and weight. This phenomenon is indicative of the ability of bone to adapt itself to the changing demands of the levels of applied load. In this respect bone is a smart material even though the response time is longer. Current interest of many branches of science ranging from electronics to molecular biology is the creation of complex, heterogeneous structures of well-controlled architecture and function.

The Motivation

In view of the immense potential Biomimetics or Biologically Inspired Engineering holds in store, it was appreciated that CSIR scientists have the responsibility of integrating Biology with the Physical, Chemical and Engineering Sciences so that the capabilities are fused coherently in order to evolve relevant and useful devices. And as a primer, CSIR-CMERI organized a workshop covering the gamut of biomimetics under the auspices of the generic theme Biology Leading towards Bio-inspired Engineering during April 18-19, 2011 at CMERI, Durgapur. The moot purpose of the workshop was initiating engineering-scientists and physicists on a track so that they comprehend and recognize the scopes of enriching Biology and find out a Pareto-Optimal way of integration. The workshop accommodated invited lectures by such eminent experts as Prof. Ron Kopito of the Stanford University, USA, Prof. Ranga Narayanan - University of Florida, USA, Prof. Amitabha



Prof. Gautam Biswas, Director, CSIR-CMERI deliberating on the R&D activities at CSIR-CMERI

Nobel Laureate Prof. Johann Deisenhofer 'closing the barrel' during his lecture

Prof. Gautam Biswas, Director, CSIR-CMERI facilitating Prof. Johann Deisenhofer

Prof. Gautam Biswas, Director, CSIR-CMERI facilitating Prof. Kirsten Fischer Lindahl

VISIT OF NOBEL LAUREATE PROF. JOHANN DEISENHOFER

Prof. Johann Deisenhofer, who, along with Hartmut Michel and Robert Huber, received the Nobel Prize for Chemistry in 1988 for their determination of the structure of a membrane-bound complex of proteins and co-factors that is essential to photosynthesis visited the CSIR-Central Mechanical Engineering Research Institute, Durgapur to deliver an erudite lecture on **Structural Biology - Achievements and Challenges**. The visit of Prof. Deisenhofer was facilitated by Prof. R.N. Roy and Prof. Pratima Roy of the Drury University, Springfield, Montana, USA. The occasion caused much enthusiasm amongst the members of the CSIR-CMERI family and the academia as well as students of Durgapur, who turned out in numbers to attend the programme on the wintry evening of December 14, 2010.

At the outset, Prof. Gautam Biswas, Director, CSIR-CMERI, Durgapur welcomed Prof. Johann Deisenhofer, Prof. Kirsten Fischer Lindahl, Professors R.N. Roy and Pratima Roy and other dignitaries to the programme, and subsequently led the audience through a journey of the research areas that are crystallizing at CSIR-CMERI. His short but succinct presentation served as the ideal backdrop for the ensuing lecture by Prof. Deisenhofer on the achievements of and challenges to the field of structural biology.

Prof. Deisenhofer started his lecture with the work of British biophysicist Rosalind Elsie Franklin who was part of the discovery of the structure of DNA. Then he discussed briefly the work of James Watson and Francis Crick that revealed a fundamental mystery about living organisms. He went on briefly explaining the work of Max Ferdinand Perutz, who shared the 1962 Nobel Prize for Chemistry with John Kendrew for the studies of the structures of hemoglobin and globular proteins. He narrated the work of Aaron Klug, the winner of the 1982 Nobel Prize in Chemistry for his contribution in crystallographic electron microscopy and his discovery of biologically important nucleic acid-protein complexes. Nigel Unwin's work on electron Microscopy to analyse the structures of protein received a special mention in his talk. His discussions then entered the paradigm of DNA manipulation, heterogeneous expression of Proteins, X-ray crystallography, dedicated synchrotron and MAD/SAD phasing. He showed the hydrophobic and hydrophilic surfaces of proteins, and talked about the generic approach for the selective extraction of detergents from mixed detergent/ lipid/ protein mice. He explained that photosynthetic reaction centre proteins are main protein components of plants. He went on to explain how ferric dicitrate complex enters the periplasm where it binds to a transmembrane protein. He finally commented on two routes for future structural biology, namely, normal mode analysis and molecular dynamics calculations. Molecular dynamics approach is facing massive computational challenges, he added.

Prof. Deisenhofer's detailed exposition helped in opening up a fascinating vista of structural biology and gave birth to a number of questions, which he, along with Prof. Kirsten Fischer Lindahl addressed during the lively interactive session that followed. He welcomed queries from a number of high school students, and was extremely patient in answering these, while helping the person with the query to better formulate the question itself. After about forty minutes, the curtains came down on the programme as Dr. D. Chatterjee, Scientist, CSIR-CMERI proposed a pithy vote of thanks.

SL.	Name	Topic	Date
20.	Dr. Lawrence Kulinsky, Sct., BioMEMs Research Group, University of California,	The Brave New World of Electroactive Polymers	10.02.2011
21.	Professor Lakshmi Narayan Mandal, Principal, Suri Vidyasagar College	Entomology : Suggestions for Micro Mechanisms	11.02.2011
22.	Professor Jyoti Majumder, Robert H Lurie Professor of Engineering University of Michigan, Ann Arbor	Intelligent Additive Manufacturing : Part Recovery, Reconfiguration & Fabrication	17.02.2011
23.	Mr. Debashis Ghosh, Scientist, CSIR-CMERI, Durgapur	High Temperature Corrosion Behaviour of Cr-Mo Steel Weldment	17.02.2011
24.	Mr. Prosenjit Das, Scientist Fellow, CSIR-CMERI, Durgapur	Manufacturing of Porous Nickel Wick Using MIM route	17.02.2011
25.	Mrs. Henal Shah, Scientist Fellow, CSIR-CMERI, Durgapur	Electrochemical Deposition	17.02.2011
26.	Dr. Nripen Chanda, Department of Radiology, University of Missouri, Columbia, USA	Metallic Nanoparticles in Catalysis and Biomedical Application	22.02.2011
27.	Dr. Arunangshu Ganguly, Senior Interventional Cardiologist & Vice-Chairman, Mission Hospital, Durgapur.	Invited Talk on CSIR-CMERI Foundation Day	26.02.2011
28.	Professor Soumitro Banerjee, Indian Institute of Science Education & Research, Kolkata	The problem of singularity in Impacting Mechanical System	26.02.2011
29.	Professor Hiranmoy Saha, BESU, Shibpur, Howrah	Green Energy and Sensor Systems	01.03.2011
30.	Dr. S. Gopukumar, Scientist, CSIR-CECRI, Karaikudi	Development of New Lithium-Ion Batteries	03.03.2011
31.	Professor R. Ganguly, Dept. of Power Engineering, Jadavpur University	Magnetic Particle-based Microfluidics	21.03.2011
32.	Professor (Dr.) Amalendu Chakraborty, Former Head, Department of Philosophy, Presidency College, Kolkata	Value Education and Management	31.03.2011
33.	Professor Sudip Chattopadhyay, J.C. Bose National Fellow, NIT, Durgapur	Light-Controlled Arabidopsis Seedling Development	18.04.2011
34.	Dr. Sanjay Kumar, CSIR-IHBT, Palampur	Plant Processes that need Technological Interventions	18.04.2011
35.	Dr. Debasish Bhattacharya, CSIR-IICB, Kolkata	Application of Bio-inspired Engineering in Snake Bite Management	18.04.2011
36.	Dr. Sudit Mukhopadhyay, NIT, Durgapur	Introduction of Life and Life Engineering	18.04.2011
37.	Professor Amitabha Chattapadhyay, CSIR-CCMB, Hyderabad	Current Excitements and Challenges in Membrane Biology	19.04.2011
38.	Professor Ranga Narayanan, University of Florida, USA	Separation of Species via Oscillating Flow	19.04.2011
39.	Professor Ron Kopito, Stanford University, California, USA	Quality Control in the Protein Assembly Line	19.04.2011
40.	Professor Ajoy Kumar Ray, Vice Chancellor, BESU, Shibpur	Recent Advances in Diagnosis of Diseases	11.05.2011
41.	Professor Gautam Biswas, Director, CSIR-CMERI	Enhancement of Heat Transfer using Streamwise Longitudinal Vortices	08.06.2011
42.	Professor Debjyoti Banerjee, Mechanical Engineering Department, Texas A & M University, USA	Nano-Devices for Enhanced Thermal Energy Storage, Cooling and Sensing	09.06.2011
43.	Professor Debopam Das, Aerospace Engineering Department, Indian Institute of Technology, Kanpur	Experimental Study of Flapping Flight Aerodynamics using PIV	13.06.2011
44.	Mr.Partha Sarathi Banerjee, Scientist, CSIR-CMERI, Durgapur	Spinal Problems and their Biomechanical Remedies	22.06.2011
45.	Professor P. Seshu, Sct-in-Charge, CMMACS, Bangalore	Computational Mechanics of Mechanical Systems	19.07.2011
46.	Professor Alok Chakraborty, Variable Energy Cyclotron Centre, Kolkata	Our Cosmic Connection	27.07.2011
47.	Professor Krishna Shenai, University of Toledo, USA	Large-Scale Sensor Networks and Robotic Surgery	28.07.2011

ERUDITE LECTURES BY EMINENT FACULTY & SCIENTISTS

SL.	Name	Topic	Date
1.	Professor Ramesh Kumar Singh, IIT, Mumbai	Laser Associated Micro Manufacturing	07.05.2010
2.	Professor Ashok Mallik, Former Professor, IIT Kharagpur	A Backward Journey from Mechanics to Geometry	11.05.2010
3.	Professor Bhaskar Dasgupta, IIT, Kanpur	• Robot motion Planning Methods • The Augmented Lagrangian Method for Optimization: Formulation & Application	18-19.05.2010
4.	Mr. Ajoy Patra, GE Infra Energy Pvt. Ltd.	Instability of Ultrathin Viscoelastic Films	01.06.2010
5.	Professor G. Reader & Prof. N. Biswas, University of Windsor	Facilities & Scope of Collaboration with Windsor University	01-02.06.2010
6.	Professor A. K. Nath, IIT, Kharagpur	Laser Processing of Materials	01.07.2010
7.	Professor C. K. Das, Materials Science Centre, IIT, Kharagpur	Use of MWCNT & Modified MWCNT in Polymer Blend Nanocomposites	19.08.2010
8.	Dr. Somnath Roy, Louisiana State University	Large-eddy Simulation of Stirred Tank Flows	20.08.2010
9.	Dr. E. Natarajan, Anna University	Solar Photovoltaic System	08.09.2010
10.	Professor G. K. Ananthasuresh, IISc, Bangalore	Biological Issues Involving Mechanics	26.09.2010
11.	Podmashri Professor N. K. Gupta, Henry Ford chair Emeritus Professor, IIT Delhi	Plasto-Mechanics of Large Deformation–Phenomenological Perspective	26.09.2010
12.	Dr. Parimal Maity, Post Doc, CVRC in deptt. of Mech. Engg., Michigan State Univ., USA	Bio-mimetic Design of Composite for air & ground vehicle & dielectric behaviour of Epoxy-Alumina Composites	29.09.2010
13.	Professor T. K. Bose, IIT, Madras	Real Gas, Properties of Gas, Gas Radiation	07-08.10.2010
14.	Professor P. L. Reddy, Technical Director, Molecular Diagnostics Lab., Medical School, University of Chicago	Molecular Assays for Cancer Diagnosis & Treatment	01.12.2010
15.	Professor Dipankar Bandyopadhyay, Assistant Professor, IIT Guwahati	Dynamics of Thin Films: A Journey from Random to Ordered Microstructures	09.12.2010
16.	Professor Johann Disenhofer, Noble Laureate	Structural Biology–Achievements & Challenges	14.12.2010
17.	Professor Amiya Bhusan Ray, Jadavpur University	Mathematics: Study of Quality, Structure, Space & Change	27.12.2010 CPYLS
18.	Professor Sreenanda Kundu, Saha Institute of Nuclear Physics, Kolkata	Surface & Thin Film	28.12.2010 CPYLS
19.	Dr. Debashis Bhattacharjee, Group Director, Research, Development & Technology, Tata Steel	Frontiers of Research in Steel Technology	06.01.2011

Bearing Testing Rig

Tests are conducted simultaneously on all the ten test rigs. The automated control system continuously monitors the various parameters of the bearings. The following parameters are considered for the bearings:

The test rigs are stopped for further analysis as soon as the pre-set parameters approach the predefined threshold values. The oil from the test rig is taken out and wear debris analysis is carried out utilizing Ferrography methods. The life of a particular bearing is determined based on these results.

Test Monitoring

Scope for future work

The establishment of National Testing Facility for General Purpose Rolling Element Bearings at CSIR-CMERI is a major leap forward and it opens up a wide scope to study various aspects of rolling element bearings. The test rig provides the facility to vary the load as well as the speed of the test bearings, the maximum load and maximum speed being limited by the strength of the respective components of the structure, while the geometry of the machine remains the same. It also helps in the study of temperature-signature of the bearings. Thus the test rig is useful for condition monitoring of bearings.

The facility can be used for condition monitoring and evaluation of the journal bearings. It can also be used for evaluation of friction force between the journal and the bearing at various loading and at various rpm. Also the same facility can be used to evaluate the comparative contact area between the journal and the bearing to estimate the bearing ratio graph.

Technical Specifications	
Radial Load	40 kg - 2000 kg
Rotational Speed	Upto 1500 rpm
Bearing Inner Diameter	20 mm - 40 mm
Bearing Outer Diameter	45 mm - 90 mm
The time duration is programmable and different lubricants can be used.	

Mechanical System

Bearings for testing are mounted on a shaft and are supported by the two support bearings. The support bearings are placed on pedestals fixed to a surface plate. The main shaft is connected to a motor through flexible coupling. The load is applied through a lever by a centralized hydraulic loading system and lubrication is provided through a centralized auto-lubrication system. The test bearing is housed in the bearing housing. An accelerometer is fixed to the bearing housing to detect and record vibration spike energy values. A revolution counter is placed near the motor to record the total revolutions of the bearing's inner race with respect to the outer race. The surface plate is placed over another base plate with a facility that allows movement in horizontal direction. This facility is provided to correct any misalignment of the test rig. The whole mechanical system is mounted on an elevated concrete pedestal and the motor is placed on another foundation to avoid vibration transmission from motor to test rig.

Hydraulic Loading System

The hydraulic loading system comprises a 10 liter tank connected through tubes to all 10 points of a plunger, which, in its turn, applies load on the lever. By using the pump, the pressure can be varied from atmospheric pressure to 150 bar. An automated control console maintains constant pressure throughout the testing period, which actuates the motor once the pressure is reduced during the loading period and adjusts it back to the pre-set value. The rig also accommodates provisions for manual loading and unloading.

Auto-Lubrication System

The Lubrication system has a 5 liter tank to store the lubricants. This system is connected to the individual lubrication points of the ten test rigs. Pressure is maintained at its preset value to supply the lubricants at the test rig points. The system further has a provision to regulate the flow of lubricants at the end of test rig.

Electrical & Instrumentation System

A 3HP induction motor, driven and controlled by a frequency drive system, is installed to drive the main shaft of the test rig at a maximum of 1500 rpm. Vibration signals are detected by the accelerometer and are transmitted to the signal-processing unit that utilizes the envelope technique for determining the vibration parameters. The value of spike energy – the single useful parameter (better known as gSE value)- is obtained from the processing unit. A proximity sensor measures the total number of revolutions and the signals are sent to the controller. When the pre-set value of either revolutions or gSE (whichever occurs earlier) approaches, the controller sends the signal to the drive to stop the motor. The bearing undergoing testing is then is taken out for investigation.

Testing Technique

The performance of Rolling Element Bearings is influenced by various factors that include fluid film thickness, dimensional variation, radial clearance, production lot, manufacturing process, etc. Hence, a single experiment may not suffice for determination of its performance. The performance of the bearings is predicted by statistical methods. ISO 281 (1990) suggests the use of Weibull Distribution for endurance limit prediction while the tests are conducted in accelerated condition.

4) M/s. Indian Ordinance Factories, Ichapur, 24 Prgs.

5) M/s. Heavy Engineering Corpn. Ltd., Ranchi

6) M/s. National Test House, Kolkata

7) M/s. Central Tool Room and Training Centre, Kolkata

8) M/s. Durgapur Projects Ltd., Durgapur

9) M/s. STQC Directorate, ETDC, Chennai

10) M/s. NTPC- SAIL Power Co. Pvt. Ltd. Durgapur.

11) M/s. ERTL (East), Kolkata

12) M/s. Alstom Projects India Ltd., Durgapur

13) M/s. Jindal Steel & Power Ltd, Raigarh.

14) M/s. Usha Martin Industries Ltd., Ranchi

15) M/s. P.I. Industries, Udaipur, Rajastan; Panoli, Gujarat

16) M/s. McNally Bharat Engg. Co. Ltd., Kumardhubi, Dhanbad.

17) M/s. Durgapur Cement Works, Durgapur

18) M/s. OCL India Limited, Rajganjpur, Orissa.

19) M/s. Nutech Calibrators & Engg., Kolkata

20) M/s. XPRO India Ltd., Bankura

21) M/s. ASKIB Engineers Pvt. Ltd., Kolkata,

22) M/s. Eastern Calibrators, Kolkata

23) M/s. Purulia Cement Pvt. Ltd., Purulia

24) M/s. Laxmi Business & Cement Co. Ltd., Hazaribagh

25) M/s. Kalyanpur Cements Ltd., Rohtas, Bihar

26) M/s. Techno India, Howrah

27) M/s. PAL Scientific Enterprise, Agarpara

28) M/s. Sova Ispat Alloys Ltd., Durgapur

29) M/s. Paharpur Cooling Towers Ltd., Kolkata

30) M/s. ALKALAB Pvt. Ltd., Jamshedpur

31) M/s. Ultra-Tech Cemco Ltd., Rajbandh

32) M/s. Jaganaths Slip Gauges & Co. Ltd., Kolkata

33) M/s. Guindy Technocrats', Kolkata.

34) M/s. Test Mech, Kolkata

35) M/s. Maithan Ceramic Ltd., Jharkhand.

36) M/s. Eastern Calibrators, Kolkata

37) M/s. Ambuja Cement, Farakka Unit

38) M/s. Exide Industries Ltd., Kolkata

39) M/s. Asbesco (India) Pvt. Ltd., Kolkata

40) M/s. Young Engg. & Calibration Services Pvt. Ltd., Howrah

41) M/s. Gammon India Ltd., Jalpaiguri

42) M/s. R.N. Dutta & Co., Durgapur

43) M/s. Ranswarup Nirmaan wires, Rajbandh

44) M/s. Durgapur Chemicals Ltd., Durgapur

45) M/s. Technomeasure, Howrah

46) Ms/. Laxmi Business & Cement Co (P) Ltd., Hazaribagh

47) M/s. OCL India Limited, Rajganjpur, Orissa

48) M/s. Associated Cement Co. Ltd., Purulia.

49) M/s. Indian Explosive Ltd., Bokaro.

50) M/s. Sibali Instruments Works, Howrah.

51) M/s. Berger Paints India Ltd., Howrah.

51) M/s.Indian Rare Earths Ltd., Orrisa.

53) M/s. Maithan Ceramic Ltd., Jharkhand.

54) M/s. CHEMIN C&I, Bankura.

55) M/s. ACC Limited, Purulia

National Bearing Testing Facility

Antifriction bearings are very important components of all machines and equipment as their malfunctioning very adversely affects the performance of the system. Therefore, understanding and evaluation of the life of rolling element bearings is of great concern. In response to this need, CSIR-CMERI has established a National Test Facility for General Purpose Rolling Element Bearings at its premises in Durgapur in collaboration with Tata Bearings, a division of Tata Steel Limited. This facility, a unique one in this country, accommodates ten test rigs designed and developed at CSIR-CMERI and can carry out accelerated life testing of bearings under controlled conditions. The load and lubricants are chosen in a manner to retain a minimum lubricant film thickness to avoid the metal-to-metal contact during the test run.

Figure 3: –Thread gauge calibration in Labconcept

Figure 4: –Snap Dial gauge calibration in Labconcept

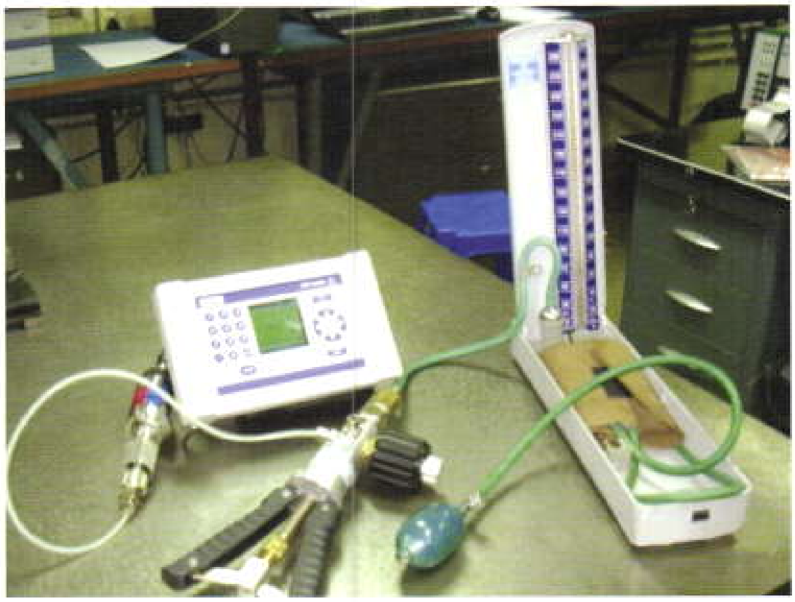


Figure 5: –Sphygmomanometer calibration in process calibrator

The facilities are being utilized for high-tech R&D assignments and calibration work for in-house and external customers. The Metrology department is providing yeoman service to industries by providing advanced facilities for calibration and measurement. On an average, the Metrology Laboratory issues more than 300 calibration reports per year for external customers. As per Mutual Recognition Arrangement of ILAC/APLAC, the SI unit of measurement and international traceability in dimension, mass, volume, pressure, vacuum and surface are being maintained in this laboratory and calibration and inspection service is being provided to numerous customers.

Major clients:

1) M/s. Indian Oil Corporation Ltd.
2) M/s. Steel Authority of India Ltd.
    a. M/s. Durgapur Steel Plant, Durgapur
    b. M/s. Alloy Steels Plant, Durgapur.
    c. M/s. Indian Iron & Steel Co. Ltd., Burnpur
    d. M/s. Bokaro Steel Plant, Bokaro
3) M/s. Senior Quality Assurance Establishments (Armts.), Cossipore, Kolkata

ADVANCEMENT OF METROLOGY FACILITIES

New infrastructure has been added to the Metrology Laboratory of CSIR-CMERI in the field of surface, form and contour measurement and 3D topography measurement by Talysurf CCI Lite. Besides, CCD camera and lighting set-up has been created to develop a modern research facility in tool condition monitoring. Environment of the laboratory is being upgraded for preventing temperature fluctuation during calibration with cleanliness of class 1000 as per NABL requirement. NABL has accredited 58 fields/ parameters (including 6 in-situ fields) and industries in the eastern region are extensively using these facilities for calibration of their equipment and gauges.

The main purpose of enhancing the calibration and measurement facilities in dimensional metrology, surface metrology, pressure metrology and mass metrology is to provide service to Indian industries catering to traceability of measurement as per International standards.

CSIR-CMERI added the following upgrades in the Metrology Laboratory:

- Sophisticated Metrological instrument - Talysurf CCI-Lite Non-contact, Automated high resolution 3D profiler for surface topography studies and calibration of surface roughness standards
- Universal length measuring machine Labconcept for measurement of Length bars, thread gauge, snap dial gauge
- One High range process calibrator for positive pressure calibration of Gauges, Vacuum, Blood pressure
- E2-class weights for mass calibration
- Image processing toolkit (CCD camera with telelens, polarizers, fiber optic guided lights, Sapera processing software

Figure: 1 -Automated high resolution 3D profiler

Figure: 2 -Analysis report of 3D surface

OTHER ACTIVITY FACETS

ADVANCEMENT OF METROLOGY FACILITIES ■
ERUDITE LECTURES BY EMINENT FACULTY & SCIENTISTS ■
VISIT OF NOBEL LAUREATE PROF. JOHANN DEISENHOFER ■
WORKSHOP ON "BIOLOGY LEADING TOWARDS BIO-INSPIRED ENGINEERING"
FOREIGN DEPUTATION ■
AWARDS/RECOGNITION ■
LIST OF PUBLICATIONS ■
OUTSIDE TRAINING SCHEDULES ATTENDED BY CSIR-CMERI PERSONNEL ■
WORKSHOPS/SEMINARS/CONFERENCES ATTENDED BY CSIR-CMERI PERSONNEL ■
IN-HOUSE TRAINING PROGRAMMES ORGANISED FOR CMERI PERSONNEL ■
SCIENTIFIC MANPOWER PROFILE ■
MEMORABLE OCCASIONS: A PHOTO TOUR ■
PERFORMANCE INDICES ■

Milestones achieved in development of Cotton Picking Head

Study of existing cotton picking mechanisms: A thorough study was undertaken to understand the functionality of commercially available machines and to identify the trend of design across the globe. Hundreds of designs of cotton pickers patented viz., mechanical systems consisting of brush type, saw type, spindle type, needle type and strippers for complete removal of bolls from the plant; suction/pneumatic type, electrostatic charging type, intermittent/pulsed vacuum type, and spindle type pickers have been studied and the inherent advantages and disadvantages of each design identified. A hand picking machine for picking cotton, now commercially available in India, was studied, tested at CICR farm as well as in farmer's field in order to assess its performance against manual picking. It was found that the machine can cover an area of 1 hectare entailing 144 man hours as against manual picking entailing 144.5 man hours with per day output of 22.82 kg and 32.67 kg respectively. Presently research efforts in India are in preliminary stage of mechanization of cotton picking.

Operational and functional requirements studied & selected: Operational & functional requirements for the system were selected. These describe capabilities and characteristics required for the proposed system. Finally the mechanism that best addresses the present capability gap and its functional requirement was developed.

Suitability testing of some Indian compact genotypes by commercially available two row spindle type mechanical cotton picker: Suitability of plant characteristics amenable to mechanical picking was studied with 10 commercially grown Bt. Cotton hybrids, namely Gold Mine, Dhanno, MRC 6025, MRC 6304, Ankur 651, Ankur 3028, Shakti 9 Bt, Bunny Bt., VICH-5 and VICH-15 planted at CICR, farm with plant geometry 90x45 cm. Six lines of each variety were planted in an area of 0.5 ha with long length of run of 67 m in each row. To study the operational parameters and working principle a two row John Deere cotton picker was tested for mechanical picking of cotton at the CICR farm. Four lines of varieties Gold Mine, MRC 6304, Ankur 651 were harvested with the picker while two rows of each hybrid were harvested manually for comparison against manual picking. The % boll bursting is also an effective parameter for the performance of machine which may decide the harvesting stage of the crop. It has been found that the plant geometry of crop including plant height affects the picking drum dimensions. The performance results of the machine having forward speed, effective field capacity, fuel consumption, total harvesting loss, mechanical picking efficiency and picker efficiency were 2.20-3.38 km/h, 0.278-0.563 ha/h, 22.0 - 24.0 l/h, 14.29-31.74 %, 55.6 - 83.1 % and 68.3-85.7 % respectively.

Plant characteristics studies of cotton varieties & hybrids of central India with their amenability to mechanical picking: A review of plant characteristics of various genotypes planted in Central India was undertaken from the year 2000 till date has been undertaken. Experimental studies were conducted to evaluate the effect of closely spaced rows for Bt. and non-Bt. Cotton hybrids. Interplant spacing influences plant height which in turn influences branch length in which cotton bolls lie because change in interplant spacing also changes the height of uppermost and lowermost boll. NHH 44 was found to be more spreading across all the spacing as compared to PKV 081. CNH 123 was found to be compact with most of the bolls lying within 60 cm from the ground and 30 cm from the row.

Design of cotton picker head model: Kinematic model of picker mechanism was developed and detailed design of cotton picker head was undertaken leading to full scale CAD model. Drum assembly provides required spindle speed of 2700 rpm and imparts rotary motion to the drum through a set of spur and bevel gears. This ensures engagement of plant having cotton bolls with the machine, removing cotton and finally traversing towards the doffer. Cam follower assembly controls the orientation i.e. advance and retardation of spindle for efficient cotton pickup as engagement time of spindles with the cotton boll is maximised. A suitable gearbox was designed to transfer PTO power to drive the drum assembly and spindles.

Figure Full scale model of cotton picker head

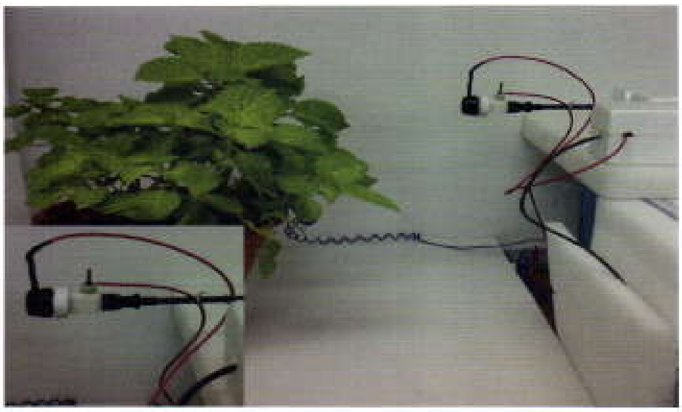


Figure Electrostatic nozzle test setup

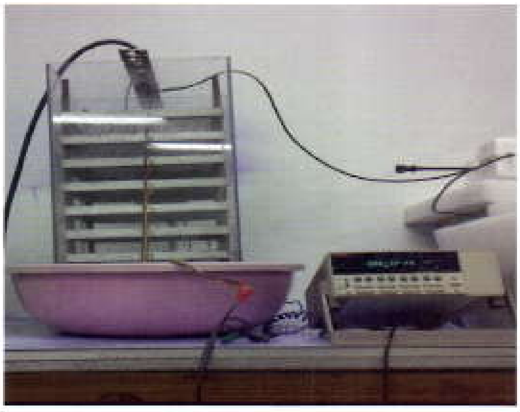


Figure Faraday's Cage

Milestones achieved in development of Inter-Row Rotary Cultivator

Design of inter row rotary weeder has been finalized based on existing information. Procurement of state of the art machine from Italy is in progress.

Design Specifications:

- Ground Clearance, mm: 600 or more
- Depth of working, mm: 50-75
- Bite length, mm: 50-75
- Working width, mm: 500-550

Row spacing, mm:

Sugarcane:	Cotton:
675-900;	675-900;
Cabbage:	Potato:
400-500;	400-500;
Brinjal:	400-500.

Figure CAD Model of Prototype

Milestones achieved in development of Irrigation Scheduler

Development of Controller: A controller with Printed Circuit Board (PCB) including pump control unit, power supply, extended memory, and driver circuit is designed & fabricated. Extended Memory has been integrated in the electronic circuit for menu driven programming.

Lab & Field Testing: Accelerating ageing test for the system has been completed at C-DAC, Mohali. Field testing of the prototype has been started for eight valves in the open field with Drip Fertigation at the Centre for Protected Cultivation Technology (CPCT), IARI farm. Field testing has been undertaken for a single valve, two valves and all the eight valves simultaneously. Pressure and discharge of drip system and lateral lines are being monitored for system evaluation. The prototype cost is approximately Rs.15000/- which is quite affordable for a farmer.

Figure Scheduler connected to irrigation & fertigation systems

Figure Automatic Irrigated field with the developed controller

Milestones achieved in development of Precision Planter for vegetables:

- Existing planters have been evaluated and design brief has been prepared
- Design of Two Row Precision Planter has been completed
- Fabrication of Two Row Precision Planter Prototype are under way
- Planting Depth Study and Survey of Planting Practices in North India have been carried out

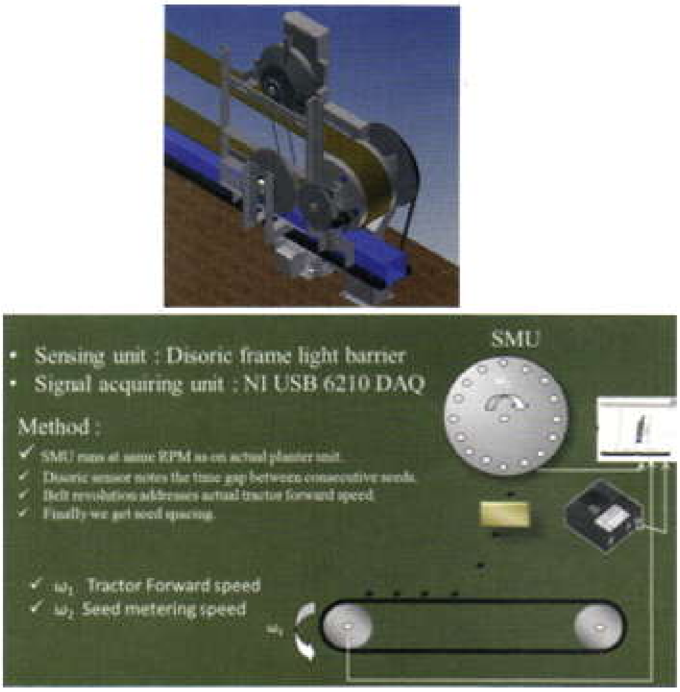
Design Specifications

- Tractor range : 35-45hp
- 98-99% singulation
- Less than 2% misses & 3-4% multiples (incl. doubles)
- Depth adjustment – 1mm step
- Row spacing range: 20 – 120 cm
- Plant spacing range: 5 – 60 cm

Option for elimination of multiples

- Planting speed : 4 - 5 km/h
- Suitable for majority of vegetables
- Modular design
- Utilization by unskilled farmers
- Total cost (preferably <1 lakh).

Figure CAD Model of Precision Planter Prototype



- Sensing unit : Disoric frame light barrier
- Signal acquiring unit : NI USB 6210 DAQ

Method :

- ✓ SMU runs at same RPM as on actual planter unit.
- ✓ Disoric sensor notes the time gap between consecutive seeds.
- ✓ Belt revolution addresses actual tractor forward speed.
- ✓ Finally we get seed spacing.

- ✓ ω_1 Tractor Forward speed
- ✓ ω_2 Seed metering speed

Figure Planter Calibration Test Rig

Milestones achieved in development of Electrostatic Nozzle

- ► Design & development of electrode for induction charging
- ► Fabrication of Electrostatic nozzle
- ► Assembly of sprayer equipment
- ► Testing of H.V. supply, electrometer, nozzle with HV
- ► Field Testing of Electrostatic Sprayer for its efficacy and comparison with conventional sprayers
- ► Design and Development of Faraday's Cage

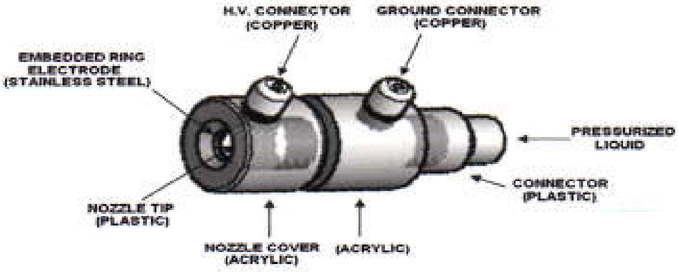


Figure Induction charge based Nozzle

- ***Metallurgical analysis of blades:*** Material compositions of the blades of reputed brands were procured and test for their composition. A comparative study was conducted along with the hardness of the blades.
- ***Optimized design of Rotavator:*** ADI casting route for the manufacture of Rotavator blades has been selected. Aluminium patterns have been made and the casting dies machining completed. The task of blade development has been taken up at the Foundry facility of CSIR-CMERI.

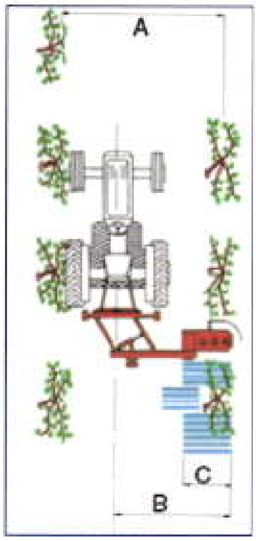
A view of measurement of PTO Power requirement

Different type of blades

Dies for the ADI casting

Milestones achieved in Offset Rotavator development

- ***Field performance evaluation of offset rotavator:*** Field performance evaluation of an indigenous offset rotavator done by PAU has been reviewed. One offset rotavator from Italy and one indigenous offset rotavator have been purchased
- ***Operational requirements of the rotavator to be studied and selected:*** 35-45 hp tractor will be required for the prototype design. Hydraulic shifting will be provided for offset. Initial conceptual design of hydraulic shifting mechanism has begun
- ***Design concept:*** The rotavator can be laterally displaced by means of a parallelogram mounted on the mast. The lateral displacement is achieved by a hydraulic cylinder which is controlled by an adjustable feeler/sensor through a distributor, which ensures that the rotavator tills soil around trees without damaging them.



A = Space required to run the tractor

B = Width of implement

C = Working width of implement

Figure Conceptual drawing of an offset rotavator working in orchard

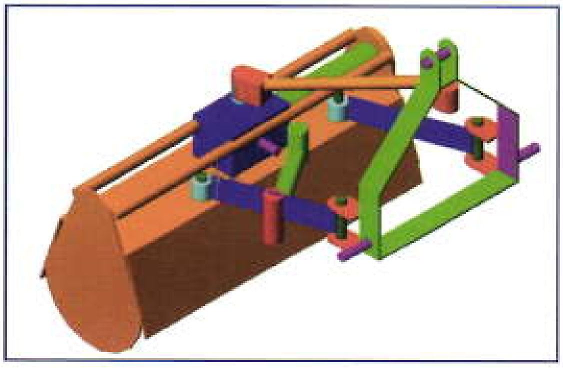


Figure Isometric view of an offset rotavator

- GB Pant University of Agriculture & Technology (GBPUA&T), Pantnagar
- Central Institute of Cotton Research (CICR), Nagpur
- Centre for Development of Advanced Computing (CDAC), Mohali
- International Tractors Limited, Hoshiarpur
- National Agri Industries, Ludhiana
- AMAR Agri Implements, Ludhiana

Initial Projects

The proposal, to begin with, included eight projects which are listed below:

S. No.	Projects	Networking Partners	Agricultural Operation
1.	Rotavator: refinement and further development	PAU, CMERI-CoEFM & GBPUA&T	Tillage
2.	Offset Rotavator: Design & Development	CMERI-CoEFM, PAU & GBPUA&T	Tillage & inter culture
3.	Pneumatic precision planter for vegetables	CMERI-CoEFM & IARI	Planting
4.	Electrostatic nozzle: Design & Development	CMERI-CoEFM, CSIO & PAU	Plant protection
5.	Inter-row rotary cultivator	PAU & CMERI-CoEFM	Inter culture
6.	Irrigation Scheduler: Programmable Systems	IARI, CDAC & CMERI-CoEFM	Irrigation
7.	Cotton Picking Head: Basic Studies & Design	CICR, CMERI-CoEFM, & PAU	Harvesting
8.	Basic Facilities	CMERI-CoEFM	

Research Facilities

- Multipurpose Test Bin : Tillage & planting studies
- Automated Patternator & Nozzle Test setup : Plant protection
- Design & Analysis Facility : CAD/CAE/CAM
- Re-engineering Lab : CMM / 3D Scanning
- Information Resource Centre : Repository of knowledge
- Small Field Lab : On-field studies
- Instrumented Tractor : On-field studies

PROJECT DETAILS

Milestones achieved in Rotavator Refinements

- ***Field performance evaluation:*** The evaluation has been carried out with three rotavators of different blade types (C, J, L) for the puddling having parameters as Power Requirement (PR), Puddling Index (PI), Infiltration Rate (IR) and Fuel Consumption (FC). 'J' type is best suited for puddling.
- ***Wear studies of rotavator blades:*** Wear studies have been done on the basis of test reports of 14 rotavators tested by the Testing center, PAU, Ludhiana by Gravimetric method i.e., by measuring the weight loss after long run test.

CENTRE FOR PRECISION & CONSERVATION FARMING MACHINERY

Backdrop

After the Green Revolution, the country saw food abundance until recent years when grains were required to be imported to feed the ever-increasing population and shrinking cultivable fields resulting from rapid urbanization & industrialization brought about a severe shortage in green production. Over the last few decades, the impact of science & technology on society and ecosystem has intensified the deterioration of the ecosystem, leading to depletion of biological resources. The agriculture of the forties, which was eco-friendly, is now fully dependent on the use of chemical fertilizers. If this trend continues, then in the near future agriculture is likely to face formidable challenges to provide adequate nutrition to the people. It is high time that proper decisions be taken for increasing agricultural productivity, as developing countries have the lowest productivity for most of the food crops. It is obvious that unless the latest tools of science and technology are applied for sustainable and equitable distribution of the natural resources, poverty and hunger will persist in the country. Novel and innovative technology-intensive options therefore need to be implemented, which might succeed in harnessing newer possibilities in managing the farm sector. These technology-aided interventions should complement the traditional methods for enhancing productivity and quality instead of replacing conventional methods, which have evolved over hundreds of years. In the light of today's urgent need, there should be a pervasive effort to use new technological inputs for the development of our society so that the Green Revolution merges seamlessly with an 'Evergreen Revolution'. The concepts of ***Precision Farming & Conservation Farming*** hold these innate promises. However, their implementation requires at the outset extensive basic mechanization in agricultural fields, following which the principles of Precision & Conservation farming can be applied in stages.

Intervention

Ensuring food security for the country through appropriate intervention in agriculture at the moment occupies a very high priority in the national S&T agenda, and rightfully finds a major place in the **IRHPA (Intensification of Research in High Priority Areas)** scheme of the Department of Science & Technology, Government of India. Under this programme, the DST has sanctioned a Networked Project entitled **Centre for Precision & Conservation Farming Machinery** to CSIR-CMERI Centre of Excellence for Farm Machinery (CSIR-CMERI CoEFM), Ludhiana for a duration of 5 years to explore novel and innovative technology-driven avenues for increasing food production in the country. Mechanization of agriculture forms a primary component of this programme. It is well known that agricultural mechanization is a complex technology that requires collaborative efforts of scientists from such diverse domains as agricultural science & engineering, mechanical engineering, electrical engineering, instrumentation, automation, industry and the agricultural community. A network of R&D organizations / Agricultural Universities / Industry has thus been forged and formal understanding has been established through MoU to support the programmes. The participating Institutions in this venture are:

- CSIR-CMERI CoEFM, Ludhiana
- Punjab Agricultural University (PAU), Ludhiana
- CSIR- CSIO, Chandigarh
- Indian Agricultural Research Institute (IARI), New Delhi

the scheme in 2005, CSIR-CMERI has been actively involved in providing the necessary research inputs for upgrading a number of grassroots innovations to entities having commercial value. Till date, CSIR-CMERI has upgraded six products innovated by different grassroots innovators, and as per the mandates of the MoU existing between the CSIR and the National Innovation Foundation have transferred these to the NIF for commercialization. The six products to which value have been added comprise:

- Motorcycle driven plough
- Auto compression sprayer
- Manually Operated Pulse Thresher
- Shivraj Multipurpose Agricultural Equipment
- Hand Operated Water Lifting Device
- Siddhant Self Propelled Windrower Reaper (Attachment part)

Three further value additions are being attempted now, comprising the following machines:

- Indigenous Sugarcane Harvester
- Indigenous wind actuated water pumping system
- Kouna mat making machine.

PAPERS PUBLISHED 2010

SL.	Author	Title	JOURNAL Details
26	J. K. Tripathi, Biswarup Satpati, Maciej Oskar Liedke, A. Gupta, and T. Som	**Effects of thermal annealing on structural and magnetic properties of Pt/Cr/Co Multilayers**	JOURNAL OF MAGNETISM AND MAGNETIC AND MAGNETIC MATERIALS Vol. 322 Issue: 21 pp. 3464-3469
27	Bala Murugan Gopalsamy, Biswanath Mondal, Sukamal Ghosh, Kristian Arntz and Fritz Klocke	**Experimental investigations while hard machining of DIEVAR tool steel (50 HRC)**	THE INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY, Vol. 51, Numbers 9-12, pp. 853-869
28	Kalyan Kr. Mistry, Swamy K. B. M, S. Sen	**Design of an SOI-MEMS High Resolution Capacitive Type Single-axis Accelerometer**	JOURNAL OF MICROSYSTEM TECHNOLOGY, Vol. 16, Number 12, pp2057-2066
29	Dipankar Chatterjee, Shyama Prasad Das	**Mixed convection heat transfer from three heated square cylinders in cross-flow at low Reynolds numbers**	HEAT AND MASS TRANSFER, Vol. 46 Issue 11, pp. 1239-1251
30	S Mondal, S Mahata, S Kundu, Biswanath Mondal	**Processing of natural resourced hydroxyapatite ceramics from fish scale**	ADVANCES IN APPLIED CERAMICS, Vol. 109 No 4 pp-234-239
31	Malay Kr. Karmakar, A.B. Datta	**Hydrodynamics of a dual fluidized bed gasifier**	ADVANCED POWDER TECHNOLOGY Vol. 21, Issue 5, 2010, pp. 521-528
32	Somenath Mukherjee, P. Jafarali	**Prathap's best-fit paradigm and optimal strain recovery points in indeterminate tapered bar analysis using linear element**	INTERNATIONAL JOURNAL OF NUMERICAL METHODS IN BIOMEDICAL ENGINEERING Vol. 26, Issue 10, pp. 1246–1262
33	S. Kumar	**Analysis of Impact Response and Damage in Laminated Composite Cylindrical Shells Undergoing Large Deformations**	STRUCTURAL ENGINEERING AND MECHANICS, Vol. 35, No. 3, pp. 349-364.
34	Aditya Kr. Lohar, Biswanath Mondal, S.C. Panigrahi	**Effect of Mg on the microstructure and mechanical properties of Al0.3Sc0.15Zr/(TiB2)p composite**	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, Vol. 210, No.15, pp. 2135-2141.
35	Atanu Saha, Himadri Roy, Awadhesh Kr. Shukla	**Investigation into the probable cause of failure of economizer tube of a thermal power plant**	JOURNAL OF FAILURE ANALYSIS AND PREVENTION, Vol.10, Issue 3,pp. 187-190
36	S. Dechoudhury, Vaishali Naik, Manas Mondal, Hemendra Kumar Pandey and Avik Chatterjee, et al.	**Design of medium energy beam transport line between the RFQ and the Linac in the radioactive ion beam facility at VECC, Kolkata**	PRAMANA, 2010, Vol. 75, Number 3, pp. 485-499
37	Debashish Ghosh & S K Mitra	**High Temperature Corrosion Behaviour of Boiler Waterwall tubes in Pyrite and Hematite Mixture under Solid-Solid and Gas-Solid Reaction states**	INTERNATIONAL JOURNAL OF HIGH TEMPERATURE MATERIAL AND PROCESSES ,Vol. 28, No 6, pp. 109-114
38	Debashish Ghosh, Himadri Roy, Awadhesh Kr. Shukla	**High temperature Corrosion failure of a secondary Superheater tube in Thermal Power Plant Boiler**	INTERNATIONAL JOURNAL OF HIGH TEMPERATURE MATERIAL AND PROCESSES , Vol. 28, No.1, pp. 109–114
39	Himadri Roy, S. Sivaprasad, S. Tarafder and K. K. Ray	**Crack tip damage mechanism under monotonic and cyclic loading conditions**	KEY ENGINEERING MATERIALS ,Vol. 417-418 pp 105-108
40	Debabrata Chatterjee, VR Patnam, A Sikdar, SK Moulik	**Removal of Some Common Textile Dyes from Aqueous Solution Using Fly Ash**	JOURNAL OF CHEMICAL AND ENGINEERING DATA, Vol. 55, Issue 12, pp 5653-5657
41	Arup Kr. Nandi, JP Davim	**Determination of optimum amount lubricant in drilling using soft-computing tools: desired surface roughness**	INTERNATIONAL JOURNAL OF MATERIALS & PRODUCT TECHNOLOGY, Vol. 37, Issue 1-2, pp. 102-116

PAPERS PUBLISHED 2010

SL.	Author	Title	JOURNAL Details
42	Debabrata Chatterjee, KA Nayak, E Ember,R van Eldik,	[Ru(III)(edta)(H(2)O)](-) mediated oxidation of hydroxyurea with H(2)O(2). Kinetic and mechanistic investigation	DALTON TRANSACTIONS, Vol. 39, Issue 7, pp. 1695-1698
43	Debabrata Chatterjee, U Pal, SK Ghosh	Kinetics and mechanism for oxidation of [Ru(III)(edta)(H(2)O)](-) with peroxydisulfate in aqueous medium	JOURNAL OF COORDINATION CHEMISTRY, Vol. 63, Issue 14-16, pp. 2598-2604
44	Swapan Barman, Ranjan Sen	Enhancement of Accuracy of Multi-axis Machine Tools through Error Measurement and Compensation of Errors using Lasert Interferometry Technique	MAPAN- JOURNAL METROLOGY SOCIETY OF INDIA, Vol.25, No. 2, 2010; pp. 79-87.
45	Himadri Roy, H.N. Bar, S. Sivaprasad, S.Tarafder & K.K.Ray	Acoustic emission during monotonic and cyclic fracture toughness tests of 304LN weldments,	INTERNATIONAL JOURNAL OF PRESSURE VESSELS AND PIPING, Vol. 87, Issue 10, pp. 543-549
46	Debashish Ghosh, Himadri Roy, T. K. Sahoo and Awadesh Kr. Shukla	Failure investigation of platen superheater tube in a 210 MW thermal power plant boiler	TRANSACTIONS OF THE INDIAN INSTITUTE OF METALS ,Vol. 63, Issues 1-2, pp. 687-690
47	S. Kumar	Object-Oriented Finite Element Analysis of Metal Working Processes	JOURNAL OF SOFTWARE ENGINEERING AND APPLICATIONS, Vol. 3, No.6, pp. 572-579.
48	Suman Saha, Saptarshi Das, Ratna Ghosh, Bhaswati Goswami, R. Balasubramanian, A. K. Chandra, Shantanu Das, Amitava Gupta	Fractional order phase shaper design with Bode's Integral for iso-damped control system	THE INTERNATIONAL SOCIETY OF AUTOMATION (ISA) TRANSACTIONS Vol. 49, Issue 2, pp. 196-206
49	Thangadurai Murugan, Debopam Das	Characteristics of noise produced during impingement of a compressible vortex ring on a wall	INTERNATIONAL JOURNAL OF AEROACOUSTICS, Vol. 9, Number 6, pp 849-858
50	Palash Kumar Maji, Partha Sarathi Banerjee, Amit Joyti Banerjee, Sibnath Maity	Electric motor-assisted pedal-driven tricycle	INTERNATIONAL JOURNAL ELECTRIC AND HYBRID VEHICLES Vol. 2, No. 3, 2010
51	Uma Datta, C. Kundu, S. Kundu	Performance Analysis of CDMA Wireless Sensor Networks in Shadowed Environment	SENSORS AND TRANSDUCERS JOURNAL, Vol. 118, Issue no.7, pp. 87-100
52	Suman Karmakar , Rudra Prasad Chatterjee, Uma Dutta	Improvement in Quality Testing of Braille Printer Output with Euclidean Distance Measurement using Camera Calibration	INTERNATIONAL JOURNAL ON ENGINEERING, SCIENCE AND TECHNOLOGY, Vol. 2, No. 1, pp. 35-48
53	Swapan Barman, Ranjan Sen	Monotoring Performance of CNC Coordinate Measuring Machine by Laser Interferometry Technique and Error Compensation	JOURNAL OF THE INSTITUTION OF ENGINEERS (INDIA), Vol. 91, pp. 3-8
54	S Samal, Debashish Ghosh and S K Mitra	Effect of crystal structure on high temperature oxidation behaviour of commercial pure iron, copper and zinc	STEEL GRIPS -PROCESS TECHNOLOGY Vol. 8, pp. 133-135
55	Subhra Kanti Das, Sankar Nath Shome, Sambhunath Nandy, Dibyendu Pal	Modeling a hybrid reactive-deliberative architecture towards realizing overall dynamic behaviour of an AUV	ICCS 2010 - INTERNATIONAL CONFERENCE ON COMPUTATIONAL SCIENCE, PROCEEDINGS, Vol. 1, Issue 1, pp. 259-268
56	Banerjee, TP; Das, S; Joydeb Roy Choudhury,; Abraham, A	Implementation of a New Hybrid Methodology for Fault Signal Classification Using Short -Time Fourier Transform and Support Vector Machines	SOFT COMPUTING MODELS IN INDUSTRIAL AND ENVIRONMENTAL APPLICATIONS, Vol. 73, pp. 219-225

Book Chapter

1. S. N. Shome, S. Nandy, S. K. Das. D. Pal, B. Mahanti, V. Kumar, R. Ray and D. Banerji. "Autonomous Underwater Vehicle for 150m Depth-Development Phases and Hurdles Faced",, FIRA 2010, CCIS 103, pp. 49-57, 2010.

2. S. K. Das, D. Pal, S. Nandy, V. Kumar, S. N. Shome, B. Mahanti, "Control Architecture for AUV-150: A Systems Approach" FIRA 2010, CCIS 103, pp. 41-48, 2010.

3. Soumic Sarkar, S. N. Shome & S. Nandy, "An Intelligent Algorithm for the Path Planning of Autonomous Mobile Robot for Dynamic Environment", FIRA 2010, CCIS 103, pp. 202-209, 2010.

4. Ranjit Ray, Bikash Bepari and Subhasish Bhaumik, "On the Development of an Intelligent Mobile Robotic Vehicle for Stair Navigation", Intelligent Autonomous Systems: Foundation and Applications, D.K. Pratihar and L.C. Jain (Eds.): Intelligent Autonomous Systems, SCI 275, pp. 87–122, 2010

5. Bikash Bepari, Ranjit Ray and Subhasish Bhaumik, "Non Contact 2D and 3-D Shape Recognition by Vision System for robotic Prehension", Robot Vision, Ales Ude (Ed.), pp. 231-260, I-Tech, Vienna, Austria. 2010

6. Arup Kumar Nandi and Shubhabrata Datta "Multi-Objective Optimization of Particle Reinforced Silicone Rubber Mould Material for Soft Tooling Process" Lecture Notes in Computer Science. 2010, Volume 6457, Simulated Evolution and Learning, Pages 414-423

OUTSIDE TRAINING SCHEDULES ATTENDED BY CSIR-CMERI PERSONNEL

SL.	TRAINING PROGRAMME ON	PARTICIPANTS
1.	Refresher Programme for the Section Officers	2
2.	Technology Led Entrepreneurship	1
3.	Scope & Prospect in Reliability Engineering	1
4.	Planning for Life after Retirement	2
5.	Induction Training for newly recruited Scientists 'B' & 'C'	2
6.	Entrepreneurship Development Programme	3
7.	Revalidation of UT Level II Certificate	1
8.	Basics of Computational Fluid Dynamics & Software	1
9.	Refresher Programme for Section Officer	1
10.	Rainwater Harvesting & Artificial Recharge	1
11.	Purchase Effectiveness	1
12.	R & D Project Management	1
13.	Internal Quality Audit for Laboratories as per ISO/IEC 17025	1
14.	Competency Development for Technical Officers	2
15.	Computational Fluid Dynamics on Graphics Processing Units	1
16.	Self Effectiveness at work place	1
17.	Micro Scale Engineering	1
18.	Records Management 2010-2011 for Record Officers	2
19.	Noise & Vibration	1
20.	Scanning Electron Microscopy for Beginners	3
21.	Competency Development for Technical Officer	2
22.	Coventor Ware	2
23.	Protein Sequence Analysis &Structure Prediction	1
24.	Emotional Intelligence for Managerial Efficiency	2

VISITING FELLOWS		
SL.	NAME OF PROGRAMME	PARTICIPANT
1.	C.V. Raman International Fellowship	Ms. Angela Mispha
2.	CSIR-CMERI visit Under DFS scheme	Prof. Ranga Narayan, University of Florida
3.	Research/Fellowship on Indo-US Fabrionics Research	Mr. Kumar Pallab
4.	Dimensional Metrology	Mr. Prasun Das, Inspectot(QA)

WORKSHOPS/SEMINARS/CONFERENCES ATTENDED BY CSIR-CMERI PERSONNEL

SL.	NAME OF PROGRAMME	PARTICIPANT/S FROM CMERI
1.	International Conference on Recent Advances in Mechanical Engineering (ICRAME -2010)	2
2.	National Workshop on Recent Trends in Object-Oriented Software Testing (R-TOOST)	1
3.	Workshop on Effective Implementation of RTI Act 2005	1
4.	National Conference on Nirman Saamagriyan: Vision 2030	2
5.	Short term Course on Advanced Topics of Digital Signal Processing	1
6.	Virtual Powertrain Conference & Exhibition	2
7.	Virtual Powertrain Conference and Exhibition	2
8.	Application Oriented Training Course in COMSOL	1
9.	Course on Basics of computational Fluid Dynamics and Software	1
10.	5th International Conference on Industrial & Information System	1
11.	Training on Mechanical Maintenance of Equipments	2
12.	Seminar Lecture on Use of MWCNT and modified MWCNT in Polymer Blend Nanocomposites	10
13.	Seminar Lecture on Large-eddy Simulation of Stirred Tank Flows	10
14.	Workshop on Interface between Water Technology Developers & Other Stakeholders	1
15.	7th International Conference on Computational Intelligence, Robotics and Autonomous	2
16.	International Conference on Computer and Communications Technology	1
17.	National Seminar on Recent Advances in PIE & Remote Sensing Technologies for Nuclear Fuel	2
18.	Workshop on Bioinformatics in Genomics, Proteomics and Metabolomics	2
19.	India Innovation Initiative Regional Fair- Eastern Region	2
20.	Conference on Advances in Recent Technologies in Communication & Computing	1
21.	Delhi International Renewable Energy Conference	1
22.	International conference on Recent Trends on Material Science & Technology (ICMST) 2010)	1
23.	Workshop on Advances in Computational Optimization & Applications	1
24.	Training Programme on Competency Development for Technical Officers	1
25.	Advances in Automotive Technology (IWAAT-2010)	4
26.	General Management Programme for Middle & Senior Level Women Scientists	1
27.	8th international Conference on Simulated Evolution & Learning	1

SL.	NAME OF PROGRAMME	PARTICIPANT/S FROM CMERI
28.	7th International Conference on Industrial Tribology	2
29.	9th International Symposium on Advances in Electrochemical Science & Technology (ISAEST-9)	1
30.	Structural Characterization of Mnsubstituted Nanocrystalline Zno using HRTEM & SANS	1
31.	International Conference on Development. & Applications of Statistics in Emerging Areas of Science & Technology	1
32.	Frontiers in Inorganic Chemistry (FIC-2010)	1
33.	International Conference on Nanomaterials & Nanotechnology	1
34.	3rd International & 24th AIMTDR Conference - 2010	1
35.	3rd International & 24th AIMTDR Conference - 2010	1
36.	Conference on AIMTDR -2010	1
37.	Conference on Vibration Engineering & Technology of Machinery	1
38.	Conference on Wireless communication and Sensor Networks	2
39.	4th IEEE International Symposium on Advanced Networks & Telecommunications Systems	1
40.	International Conference on Swarm Evolutionary & Memetic Computing	1
41.	Conference on Fluid Mechanics & Fluid power	1
42.	Conference on Fluid Mechanics & Fluid power	1
43.	Conference on Fluid Mechanics & Fluid power	1
44.	Conference on Green Energy, Computing & Communication	1
45.	IEEE INDICON 2010 Conference on Green Energy, Computing & Communication	1
46.	Conference on Green Energy & Communication	1
47.	Conference on Green Energy & Communication	2
48.	Conference on Indian Congress on Quality, Environment, Energy & Safety Management Systems	1
49.	International Conference on Computer Application	1
50.	Conference on Theoretical, Applied, Computational & Experimental Mechanics	1
51.	3rd International Conference on Electronics Computer Technology (ICECT-2011)	1
52.	4th Electricity East 2010	3
53.	Workshop on Pressure, Mass, Volume, Density, Force & Dimension Metrology	3
54.	International Symposium on Facets of Weak Interaction in Chemistry	1
55.	Seminar on Concrete Sustainability through Innovative Materials & Techniques	1
56.	Conference on Tissue Engineering Prospect & Challenges	2
57.	GIS & Remote Sensing Techniques for Water Resources Assessment Using Open Source Tools	1
58.	National in 59th Indian Foundry Congress	2
59.	International Conference on Green Productivity for Sustainable Energy & Environment	2
60.	22nd Annual General Meeting, Materials Research Society of India (MRSI)	1
61.	1st National Conference on Advances in Metrology (AdMet-2011)	1
62.	Advances in Metrology (AdMet-2011)	2
63.	International Conference on Sustainable Water Resources Management & Climate Change	2
64.	National Conference on Industrial Engineering (NCIE-2011)	1
65.	Sustainable Water Resource Management & Climate Change Adaptation	1
66.	XII IEEE International Vacuum Electronics Conference	2
67.	International Conference on Condition Monitoring (ICCM-2011)	1
68.	International Symposium on Energy Materials : Opportunities & Challenges (ISEM-2011)	2
69.	Energy Materials: Opportunities & Challenges (ISEM-2011)	2
70.	Seminar on Frontier of Science	1

SL.	NAME OF PROGRAMME	PARTICIPANT/S FROM CMERI
71.	Recent Trends in Condensed Matter of Physics(RTCMP-2011)	1
72.	National Seminar on Recent Trends in Condensed Matter Physics (RTCMP-2011)	1
73.	2nd International Conference on Recent Trends in Information, Telecommunication & Computing (ITC-2011)	1
74.	Electromagnetic Non Destructive Evaluation (ENDE-2011)	2
75.	Sensors & Actuators ;Science to Technology	1
76.	Prospects of Nuclear Power in India	1
77.	Live Colposcopy Workshop	2
78.	International Conference on Control, Robotics & Cybernetics (ICCRC - 2011)	2
79.	Nomination in the Student Seminar on Metallurgical Engineering	1
80.	3rd International Conference on Electronics Computer Technology (ICECT- 2011)	2
81.	National Conference on Design and Manufacturing (NaConDM2011)	1
82.	National Conference of Ocean Society of India (OSICON'11)	1
83.	International Conference on Sustainable Energy & Intelligent System SEISCON- 2011	1
84.	Lecture Series on Advances in Lithium Batteries	1

OTHER ACTIVITY FACETS

IN-HOUSE TRAINING PROGRAMMES ORGANISED FOR CMERI PERSONNEL

SL.	TRAINING PROGRAMME ON	PARTICIPANTS
1.	Power Electronics	17
2.	Finite Volume Method (FVM) for solution of Transport Equation	9
3.	Mechanics of Materials	14
4.	Computational Fluid Dynamics	25
5.	Kinematics Design of Robotics	37
6.	Advanced Control System with special emphasis on Digital Control	20
7.	Soft Elastic Films and Stability	15
8.	Finite Difference Method	25
9.	Micro System Technology	7

M.Tech Programme in Mechatronics (Two Years)

Collaboration	Objective	Eligibility
Bengal Engineering & Science University (BESU),Shibpur with CMERI-Durgapur, CEERI-Pilani and CSIO-Chandigarh	• To create skilled multidisciplinary manpower to facilitate the present need of the country • To provide multidisciplinary real-life experience to the students on running projects at the CSIR laboratories for their project and thesis work	• The B. Tech students from various disciplines with preferable GATE score can apply and after selection subsequently join in this course. • The number of intake students is approximately 20 per batch. • The level is very good and comparable with any standard national level institute.

DATELINE CSIR-CMERI

SL.	DATE	PROGRAMME NOMENCLATURE
1.	May 11, 2010	Technology Day Celebration
2.	September 14-29,2010	Hindi week
3.	September 26, 2010	CSIR Foundation Day Celebration
4.	December 14, 2010	Visit of Nobel Laureate Prof. Johann Deisenhofer
5.	December 27-28, 2010	CSIR Programme for Leadership of Youth in Science
6.	November 14-27	CSIR Technofest 2010
7.	January 3-7, 2011	Pride of India Exhibition
8.	January 17, 2011	Launching of Postal SOLECKSHAW
9.	February 26, 2011	CMERI FOUNDATION DAY Celebration
10.	February 28, 2011	National Science Day Celebration
11.	April 18-19, 2011	Workshop on Biology Leading to Bio-inspired Engineering
12.	May 11, 2011	Technology Day Celebration

SCIENTIFIC MANPOWER PROFILE

S.No.	Name	Group Affiliation
Junior Scientist		
1.	Shri Priyabrata Chattopadhyay	Product Design and Simulation Division
2.	Shri Satanand Mishra	Information Technology
3.	Shri Jagdish M	CMERI-COEFM, Ludhiana
4.	Sh. Srinivasan. N	Cybernetics
5.	Shri Abhijit Das	Surface Robotics
Scientist		
6.	Dr. Debashis Das	Material & Structural Evaluation
7.	Shri Virendra Kumar	Robotics and Automation
8.	Dr. Lalgopal Das	Process Plant Engineering
9.	Dr.Malay Kr. Karmakar	Thermal Engineering
10.	Shri Abhijit Mahapatra	Virtual Reality & Virtual Prototyping
11.	Shri Dibyendu Pal	Robotics and Automation
12.	Shri Dip Narayan Ray	Surface Robotics
13.	Shri Nilrudra Mondal	Centre for Advanced Materials Processing
14.	Shri Rajesh Prasad Barnwal	Information Technology
15.	Shri Subhra Kanti Das	Robotics and Automation
16.	Shri Chanchal Loha	Thermal Engineering
17.	Shri Rudra Prasad Chatterjee	Electronics and Instrumentation
18.	Shri Binod. Kr. Saha	Product Design and Simulation Division
19.	Dr. Pabitra Haldar	Simulation and Modeling
20.	Shri Samik Dutta	Metrology
21.	Shri Vineet Kr. Saini	Technology, Publication & Patent
22.	Dr. Himadri Ray	NDT & Metallurgy
23.	Shri Man Singh Azad	Microsystems Technology
24.	Sh. Ajay Yadav	CMERI-COEFM, Ludhiana
25.	Dr. T. Murugan	Thermal Engineering
26.	Sh. Hanumath Prasad Ikkurti	Drives & Control
27.	Sh. Suman Saha	Drives & Control

28.	Dr. Priyabrata Ranjan Basu Mandal	Product Design and Simulation Division
29.	Dr. Priyabrata Banerjee	Chemistry and Biomimetics
30.	Dr. Sivaprakash. S	Process Plant Engineering
31.	Sh. Santu Kumar Giri	Electronics and Instrumentation
32.	Dr. Pranab Samanta	Tribology
33.	Dr. Swarup Kumar Laha	Condition Monitoring
34.	Dr. Ranajit Ghosh	Centre for Advanced Materials Processing
35.	Shri Manoj Kr. Rawat	Process Plant Engineering
36.	Dr. Bittagopal Mondal	Simulation and Modeling

Senior Scientist

37.	Shri Swapan Barman	Metrology
38.	Shri Amit Ganguly	Horticulture and Institute House keeping
39.	Shri Kamalkishor J. UKE	Condition Monitoring
40.	Shri Atanu Saha	NDT & Metallurgy
41.	Shri Ashok Kr. Prasad	Manufacturing Technology
42.	Dr. Aditya Kr. Lohar	Foundry and Heat Treatment
43.	Shri S. R. Debbarma	Research Planning and Business Development
44.	Shri Dilip Kumar Biswas	Technology Innovation Centre
45.	Sh. Kalyan Kumar Mistry	Surface Robotics
46.	Dr. Satya Prakash Singh	Simulation and Modeling
47.	Dr. Sudipta De	Simulation and Modeling
48.	Dr. Dipankar Chatterjee	Simulation and Modeling
49.	Dr. Krishnendu Kundu	CMERI-COEFM, Ludhiana
50.	Sh. Siva Ram Krishna Vadali	Robotics and Automation
51.	Dr. Rashmi Ranjan Sahoo	Tribology
52.	Dr. Arup Kumar Nandi	Advanced Design and Optimization
53.	Shri Subrata Mondal	Advanced Design and Optimization
54.	Shri B. B. Ghosh	Advanced Design and Optimization
55.	Shri Ravi Kant Jain	Design of Mechanical Systems
56.	Dr. Ranjit Ray	Robotics and Automation
57.	Shri Anupam Sinha	Product Design and Simulation Division
58.	Shri Palash Kr. Maji	Product Design and Simulation Division
59.	Shri Pradeep Rajan	CMERI-COEFM, Ludhiana
60.	Ms. Abhilasha Saksena	Embedded System
61.	Shri R. K. Bharilya	Design of Mechanical Systems
62.	Shri Rajpal Singh	Manufacturing Technology
63.	Shri U. S. Patkar	Design of Mechanical Systems

Principal Scientist

64.	Shri S. S. Mojiz	CMERI-COEFM, Ludhiana
65.	Dr. Arup Mitter	Research Planning and Business Development
66.	Ms. Maw Nandi Sarkar	Process Plant Engineering

67.	Ms. Anjali Chatterjee	Cybernetics
68.	Shri U. S. Ghosh	Human Resource Development & Library
69.	Shri P. S. Banerjee	Product Design and Simulation Division
70.	Shri B. N. Singh	NDT & Metallurgy
71.	Ms. Sarbari Dutta	Surface Robotics
72.	Shri Pankaj Roy	NDT & Metallurgy
73.	Dr. Atanu Maity	Advanced Design and Optimization
74.	Shri Ashwani Kumar	CMERI-COEFM, Ludhiana
75.	Dr. Mrinal Pal	Centre for Advanced Materials Processing
76.	Shri S. N. Nandi	Robotics and Automation
77.	Shri Tapas Gangopadhyay	Product Design and Simulation Division
78.	Shri Rajesh Kr. Chak	CMERI-COEFM, Ludhiana
79.	Shri B. D. Bansal	CMERI-COEFM, Ludhiana
80.	Dr. Biswajit Ruj	Thermal Engineering
81.	Dr. Surendra Kumar	Product Design and Simulation Division
82.	Dr. Reeta Das	Thermal Engineering
83.	Shri G. S. Reddy	Material & Structural Evaluation
84.	Dr. Asit Kr. Batabyal	Quality Management and Reliability Engineering
85.	Ms. Manju Singh	Foundry and Heat Treatment
86.	Dr. Naresh Chandra Murmu	Surface Science and Tribology
87.	Shri Biplab Choudhury	Thermal Engineering
88.	Dr. Sudip Kr. Samanta	Foundry and Heat Treatment
89.	Dr. Debashis Ghosh	NDT & Metallurgy
90.	Shri Sankar Karmakar	Manufacturing Technology
91.	Dr. Soumen Sen	Robotics and Automation

Senior Principal Scientist

92.	Shri A. K. Shukla	NDT & Metallurgy
93.	Ms. Uma Dutta	Electronics and Instrumentation
94.	Dr. B. N. Mondal	Centre for Advanced Materials Processing
95.	Shri R. K. Biswas	Condition Monitoring
96.	Shri Amitjoyoti Banerjee	Manufacturing Technology
97.	Shri A. K. Chowdhury	Foundry and Heat Treatment
98.	Shri Abhijit Chatterjee	Material & Structural Evaluation
99.	Shri Tapas Sarkar	Quality Management and Reliability Engineering
100.	Shri Soumya Sen Sharma	Technology, Publication & Patent Drives & Control System Technology TePP Outreach Centre
101.	Shri P. K. Sen	Process Plant Engineering
102.	Dr. Nagahanumaiah	Microsystems Technology
103.	Shri Debojyoti Banerjee	Robotics and Automation
104.	Shri Tapan Kr. Paul	Condition Monitoring
105.	Dr. Partha Bhattacharjee	Cybernetics
106.	Shri Joydev Roy Chowdhury	Embedded System

107.	Dr. D. Chatterjee	Chemistry and Biomimetics
108.	Shri Avik Chatterjee	Virtual Reality & Virtual Prototyping
109.	Dr. Somenath Mukherjee	Simulation and Modeling

Chief Scientists

110.	Dr. Somajyoti Majumdar	Surface Robotics Design of Mechanical Systems Information Technology
111.	Shri S. N. Shome	Robotics and Automation School of Mechatronics
112.	Dr. Shibnath Maity	Technology Innovation Centre
113.	Shri V. R. Dahake	CMERI-COEFM, Ludhiana
114.	Dr. P. K. Chatterjee	Thermal Engineering
115.	Dr. Ranjan Sen	Metrology

Quick Hire Scientist

1.	Dr. Ujjawal Pal	Chemistry and Biomimetics
2.	Dr. Sarita Ghosh	Chemistry and Biomimetics
3.	Sh. Ravi Kumar Arun	Microsystems Technology
4.	Sh. Praveen Kumar Singh	CMERI-COEFM, Ludhiana
5.	Dr. Arpita Mukherjee	Electronics and Instrumentation
6.	Mrs. Sarika Bharilya	Advanced Design and Optimization
7.	Ms. Sikha	Robotics and Automation
8.	Sh. M.Phani Kumar	Surface Science and Tribology
9.	Sh. Amit Kumar	Virtual Reality & Virtual Prototyping
10.	Sh. Abhiram Hens	Microsystems Technology
11.	Sh. Prosenjit Das	Foundry and Heat Treatment
12.	Ms. Henal Shah	Microsystems Technology

MEMORABLE OCCASIONS: A PHOTO TOUR

CSIR Foundation Day, September 26, 2010

Professor Gautam Biswas, Director, CSIR-CMERI delivering the Inaugural Speech

Professor G. K. Ananthasuresh, Indian Institute of Science, Bangalore delivering the Eminent Lecture on "Biological Issues Involving Mechanics"

Padma Shri Professor N. K. Gupta, Henry Ford Chair Emeritus Professor, IIT Dehi, delivering Foundation Day Lecture on "Plasto-Mechanics of Large Deformation-Phenomenological Perspective"

Shri A. K. Shukla, Chairman, CSIR Foundation Day Celebration Committee 2010, presenting vote of thanks to all the dignitaries, guests and members of CSIR Celebration Committee 2010

CSIR Programme on Youth for Leadership in Science (CPYLS 2010) December 27-28, 2010

Professor Amiya Bhusan Ray, Jadavpur University, Kolkata, during the lecture on "Mathematics: Study of Quality, Structure, Space and Change"

Professor Sreenanda Kundu, Saha Institute of Nuclear Physics, Kolkata, speaking on the theme "Surface & Thin Film"

CSIR Technofest, November 14-27, 2010

A view of dignitaries visiting Soleckshaw during the CSIR Technofest 2010

A view of dignitaries visiting Soleckshaw during the CSIR Technofest 2010

A view of Postal Soleckshaw

Launching of Postal Soleckshaw at Ajmer on January 17, 2011

CSIR-CMERI Foundation Day, February 26, 2011

Dr. Arunangshu Ganguly, Senior Interventional Cardiologist & Vice-Chairman, Mission Hospital, Durgapur Lighting the Ceremonial Lamp

Professor Gautam Biswas, Director, CSIR-CMERI delivering the Inaugural Speech

Dr. Arunangshu Ganguly, Senior Interventional Cardiologist & Vice-Chairman, Mission Hospital, Durgapur delivering the Invited Talk

Professor Soumitro Banerjee, Indian Institute of science Education & Research, Kolkata delivering the Foundation Day Lecture

National Science Day, February 28, 2011

Professor Hiranmoy Saha, BESU delivering the National Science Day Lecture 2011 on "Green Energy and Sensor Systems"

National Technology Day, May 11, 2011

Professor Ajoy Kumar Ray, Vice Chancellor, Bengal Engineering & Science University, Shibpur and Professor Gautam Biswas, Director, CSIR-CMERI were present on the dais during the National Technology Day 2011

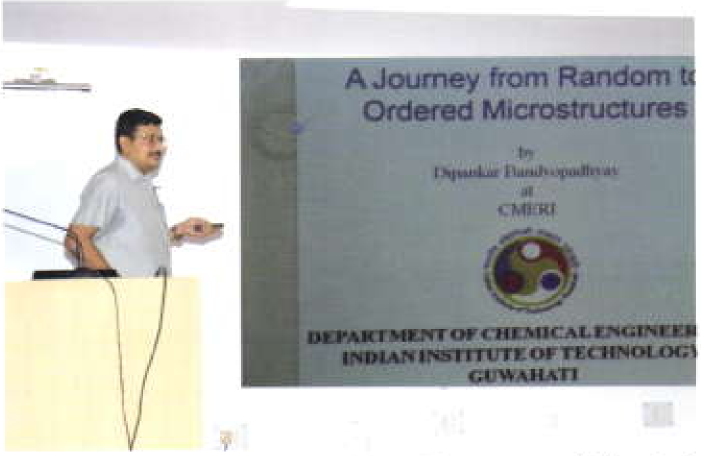
Professor Ajoy Kumar Ray, Vice Chancellor, Bengal Engineering & Science University, Shibpur delivering the Technology Day Lecture 2011 on "Recent advances in diagnosis of diseases"

ERUDITE LECTURES

Dr. Somnath Roy, Louisiana State University speaking on the theme " Large eddy Simulation of Stirred Tank Flows"

Professor CK Das Materials Science Centre, IIT, Kharagpur delivering the lecture on Use of MWCNT & Modified MWCNT in Polymer Blend Nanocomposites

Professor TK Bose IIT Madras speaking on "Real gas, Properties of gas, gas radiation"



Professor Dipankar Bandyopadhyay, Department of Chemical Engineering, IIT, Guwahati speaking on "Dynamics of thin Films: A journey from Random to Ordered Microstructures"

Dr. Lawrence Kulinsky, Scientist, BioMEMs Research Group, University of California during the lecture on "The Brave New World of Electroactive Polymers"

Professor Lakshmi Narayan Mandal, Principal, Suri Vidyasagar College speaking on the theme "Entomology: Suggestions for Micro Mechanism"

Professor Jyoti Majumda Robert H Lurie Professor of Engineering University of Michigan Ann Arbor delivering the lecture on Intelligent Additive Manufacturing: Part Recovery, Reconfiguration and Fabrication

Professor Debjyoti Banerjee, Mechanical Engineering Department, Texas A&M University delivering the lecture on "Nano-devices for enhanced thermal energy storage cooling and sensing"

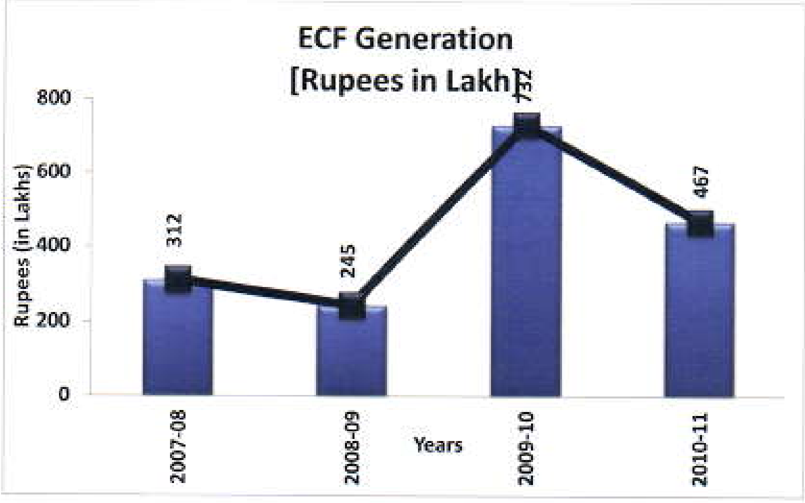
Professor Debopam Das, Aerospace Engineering Department, Indian Institute of Technology, Kanpur delivering the lecture on "Experimental Study of Flapping Flight Aerodynamics using PIV"

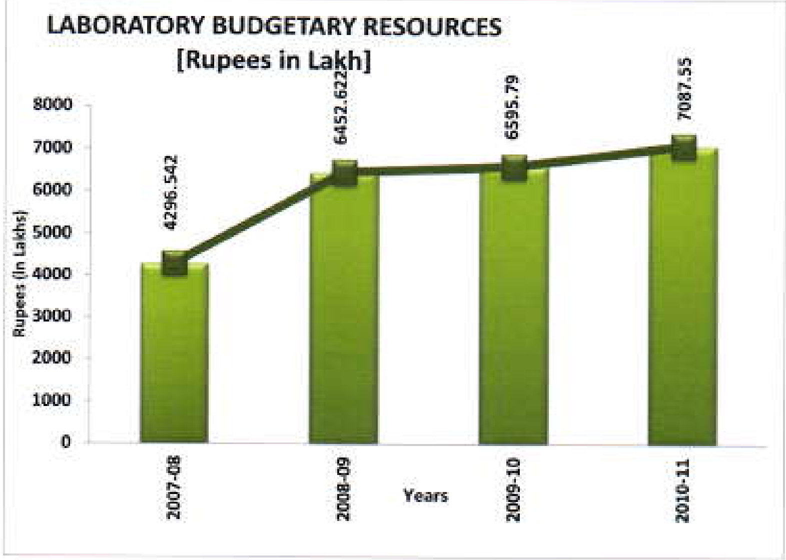
Professor P. Seshu, Scientist-in-Charge, CMMACS, Bangalore speaking on "Computational Mechanics of Mechanical Systems"

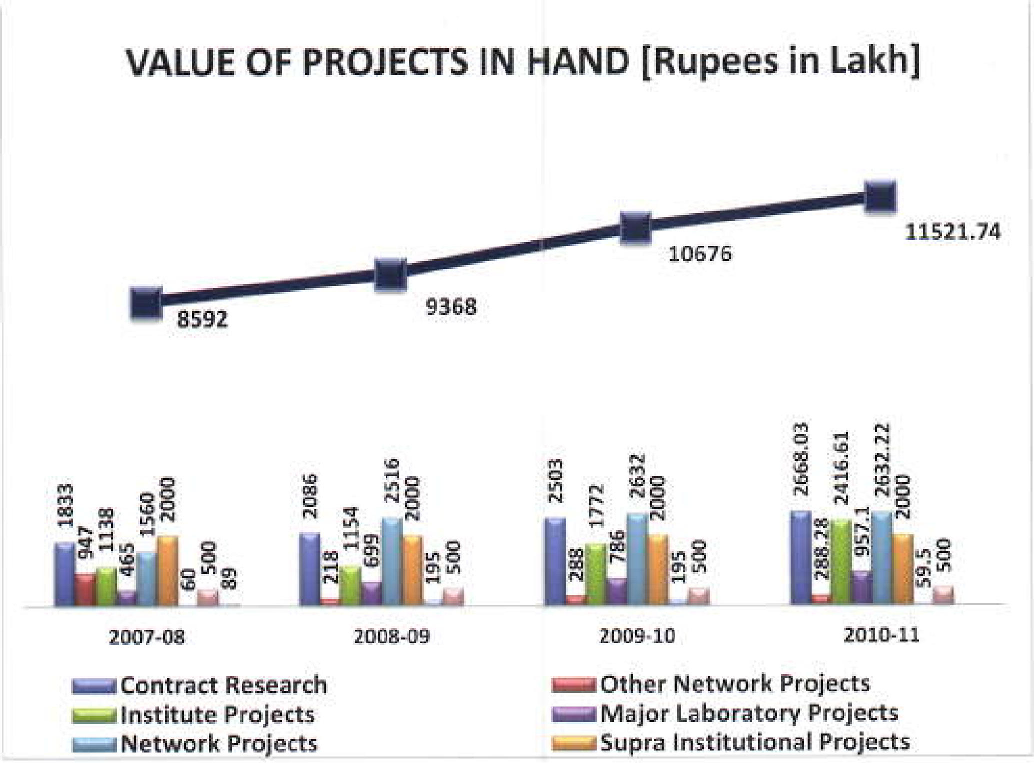
Professor Alok Chakraborty, Variable Energy Cyclotron Centre, Kolkata, enumerating on "Our Cosmic Connection"

Professor Krishna Shenai, University of Toledo, Toledo, USA delivering the lecture on "Large-Scale Sensor Networks and Robotic Surgery"

PERFORMANCE INDICES






VALUE OF PROJECTS IN HAND [Rupees in Lakh]
8592
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1138
465
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89
2086
218
1154
699
2516
2000
195
500
2503
288
1772
786
2632
2000
195
500
2668.03
288.28
2416.61
957.1
2632.22
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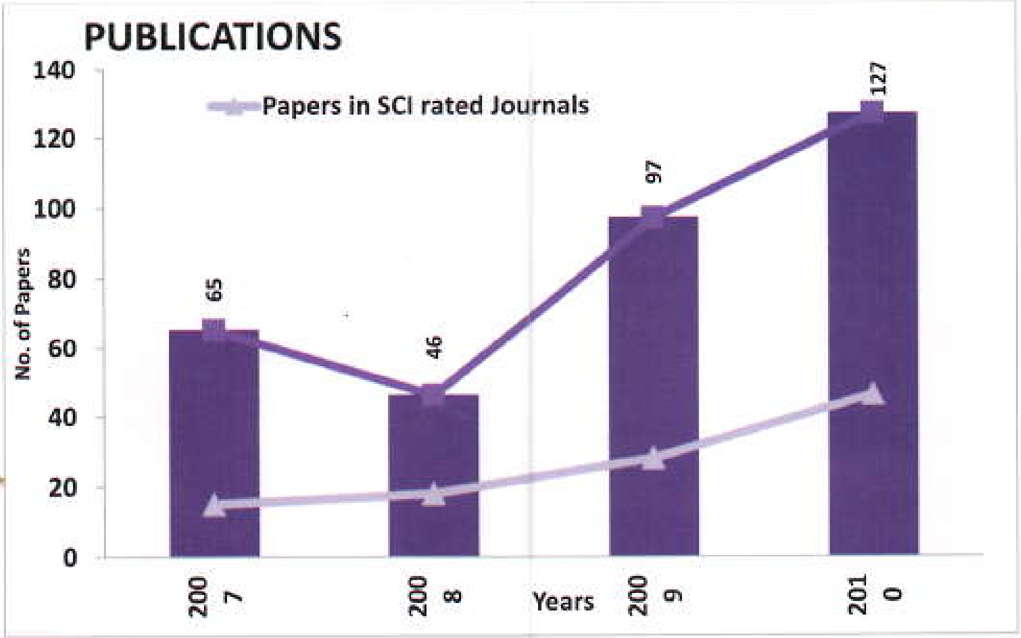
2008-09
2009-10
2010-11
Contract Research
Other Network Projects
Institute Projects
Major Laboratory Projects
Network Projects
Supra Institutional Projects


PUBLICATIONS
140
120
100
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No. of Papers
Papers in SCI rated Journals
65
46
97
127
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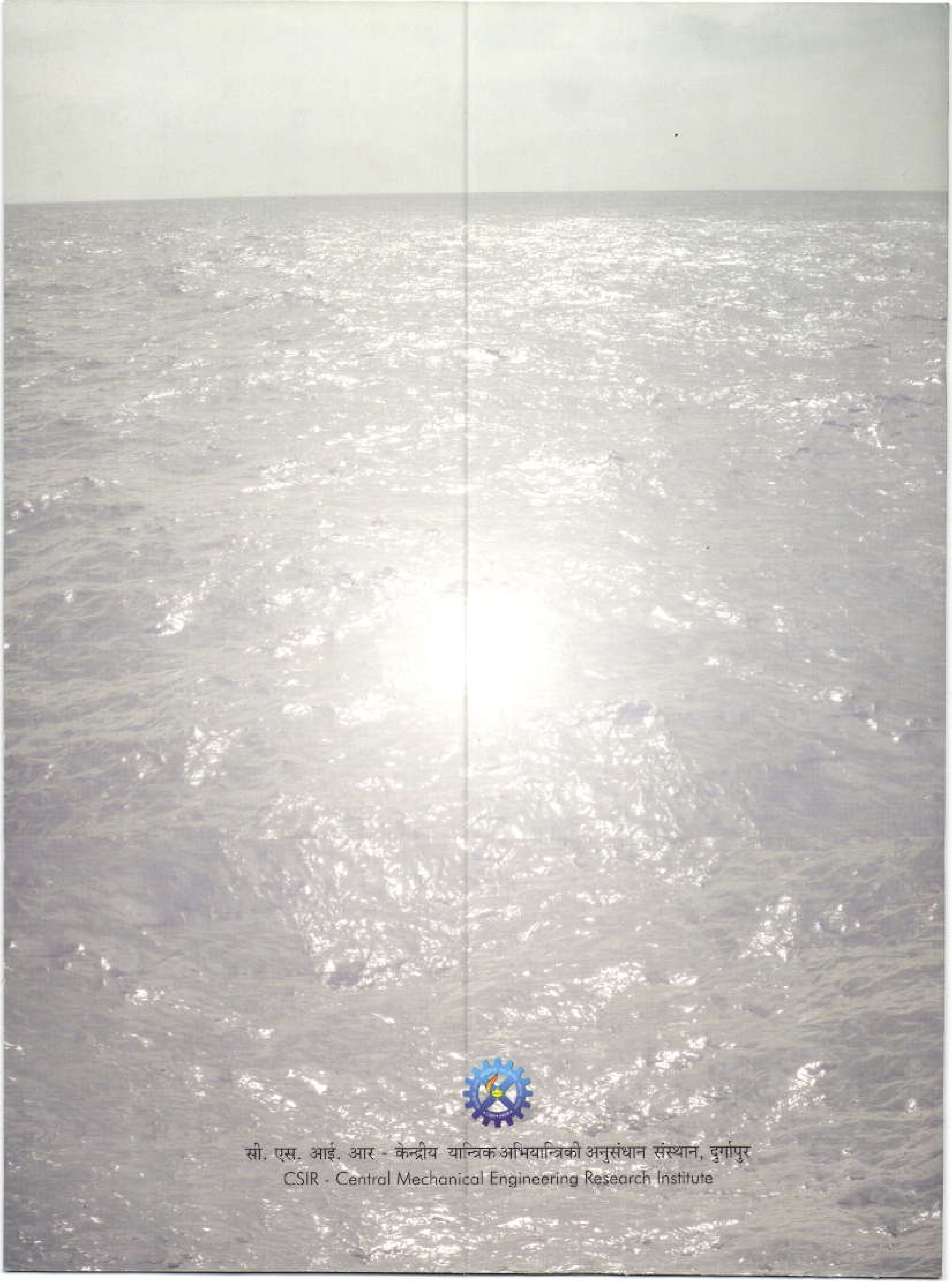
2008
Years
2009
2010



सी. एस. आई. आर - केन्द्रीय यान्त्रिक अभियान्त्रिकी अनुसंधान संस्थान, दुर्गापुर

CSIR - Central Mechanical Engineering Research Institute