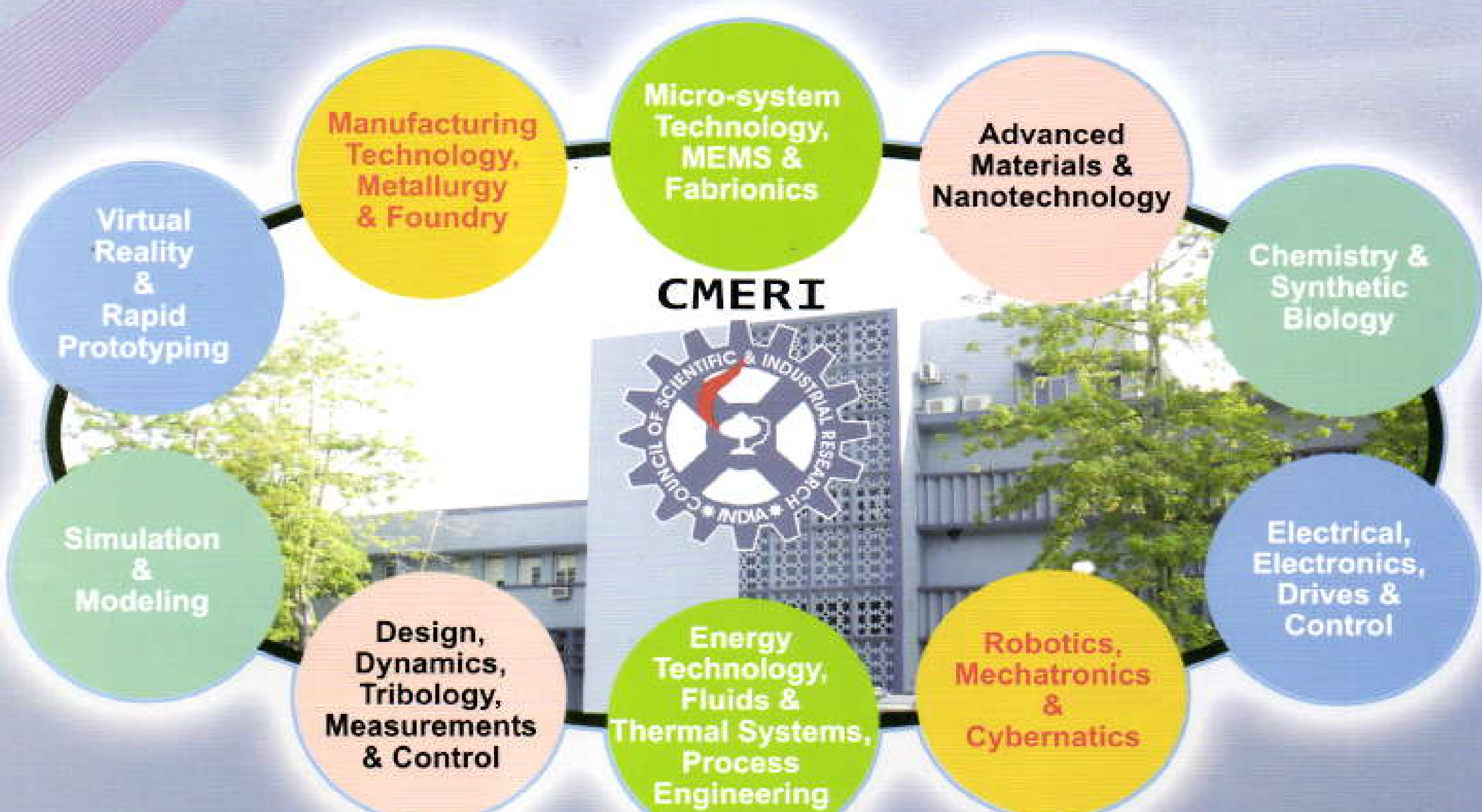
Central Mechanical Engineering Research Institute, Durgapur

केन्द्रीय यान्त्रिक अभियान्त्रिकी अनुसन्धान संस्थान, दुर्गापुर

चतुर्वार्षिक प्रतिवेदन

Quadrennial Report

2006-2010

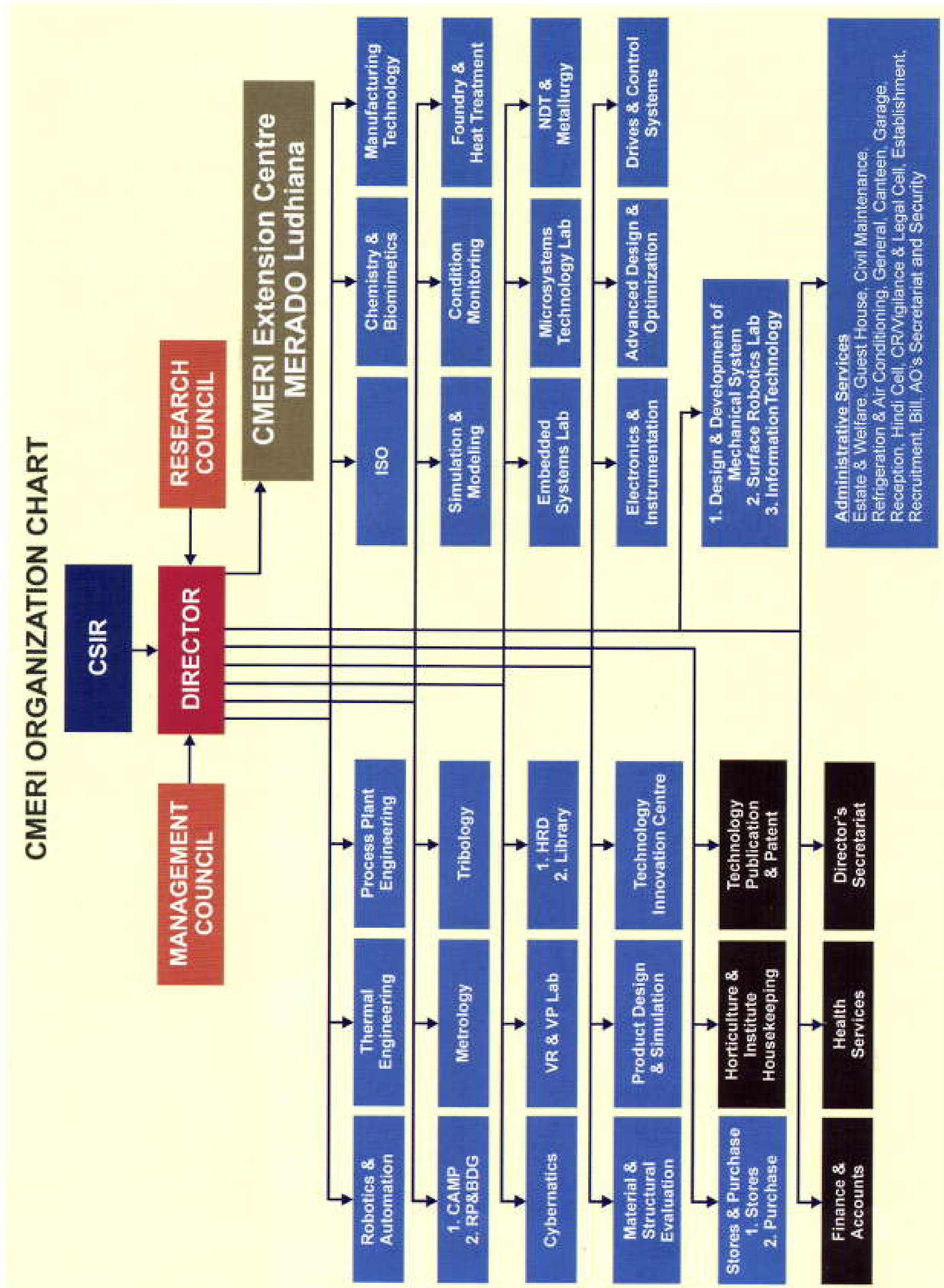


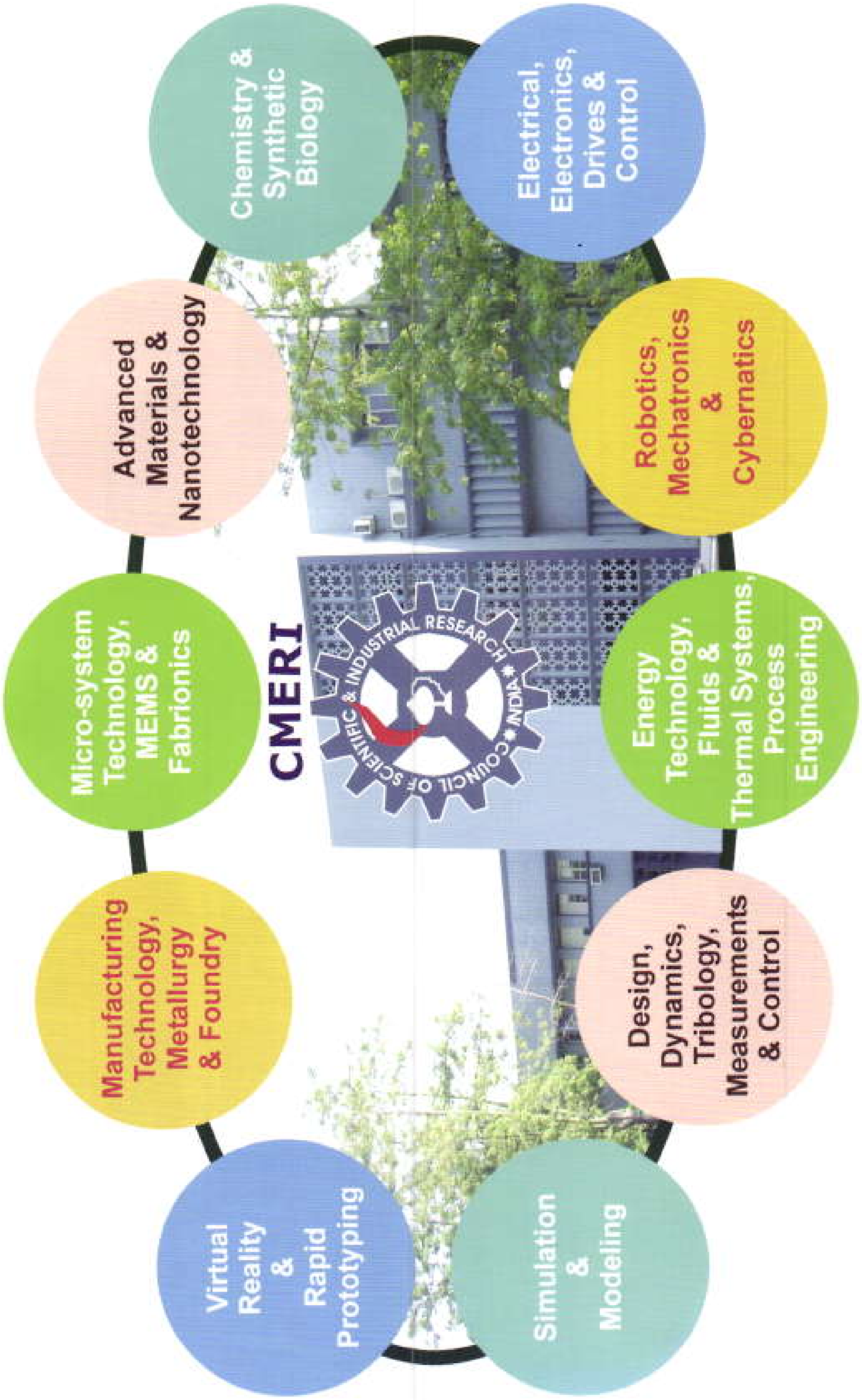
चतुर्वार्षिक प्रतिवेदन
Quadrennial Report
2006-2010

Central Mechanical Engineering Research Institute, Durgapur
केन्द्रीय यान्त्रिक अभियान्त्रिकी अनुसन्धान संस्थान, दुर्गापुर

Designed and Printed at National Institute of Science Communication And Information Resources, CSIR
Dr K. S. Krishnan Marg, New Delhi - 110 012

CONTENTS


CMERI ORGANIZATION CHART
CSIR
MANAGEMENT COUNCIL
DIRECTOR
RESEARCH COUNCIL
CMERI Extension Centre MERADO Ludhiana
Robotics & Automation
Thermal Engineering
Process Plant Engineering
ISO
Chemistry & Biomimetics
Manufacturing Technology
1. CAMP 2. RP&BDG
Metrology
Tribology
Simulation & Modeling
Condition Monitoring
Foundry & Heat Treatment
Cybernatics
VR & VP Lab
1. HRD 2. Library
Embedded Systems Lab
Microsystems Technology Lab
NDT & Metallurgy
Material & Structural Evaluation
Product Design & Simulation
Technology Innovation Centre
Electronics & Instrumentation
Advanced Design & Optimization
Drives & Control Systems
Stores & Purchase 1. Stores 2. Purchase
Horticulture & Institute Housekeeping
Technology Publication & Patent
1. Design & Development of Mechanical System 2. Surface Robotics Lab 3. Information Technology
Finance & Accounts
Health Services
Director's Secretariat
Administrative Services
Estate & Welfare, Guest House, Civil Maintenance, Refrigeration & Air Conditioning, General, Canteen, Garage, Reception, Hindi Cell, CR/Vigilance & Legal Cell, Establishment, Recruitment, Bill, AO's Secretariat and Security


CMERI
COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
INDIA
Chemistry & Synthetic Biology
Electrical, Electronics, Drives & Control
Advanced Materials & Nanotechnology
Robotics, Mechatronics & Cybernatics
Micro-system Technology, MEMS & Fabrionics
Energy Technology, Fluids & Thermal Systems, Process Engineering
Manufacturing Technology, Metallurgy & Foundry
Design, Dynamics, Tribology, Measurements & Control
Virtual Reality & Rapid Prototyping
Simulation & Modeling

From the Director's Desk

In the recent past, the world has undergone a sea-change on the scientific and technological front. Conventional roles and stereotypes have paved the way to revolutionary ideas. Now one professional is required to update his knowledge constantly.

The extent of Mechanical Engineering activities has been very wide. For example, it extends from cooling of VLSI chips to the analysis of thermal hydraulics pertaining to design of new generation Nuclear Reactors (ADSS). The horizon spreads from the analysis of spacecraft-stability to the stability of thin elastic films.

General perception about Mechanical Engineering is that it deals with the machines. The machines range from food processing machines, textile machinery to bicycles, cars and aircrafts. It is also an integral part of many electrical and electronics systems, process industry, and medical instruments. One may consider construction industry and imagine the massive cranes and their components. Railways and Automobiles are two inherent areas of Mechanical Engineering. Thus, mechanical engineering is related to a wide variety of industries. These days, companies require mechanical engineers to be proficient in soft computing and optimization. The Mechanical Engineers are needed for handling issues of CAD/CAM.

The principles of Mechanical Engineering are also traditionally used in a wide variety of technologies including Electro-mechanical systems, and Information processing. There has been considerable overlap between Mechanical Engineering and other emerging fields. The emergence of Synthetic Biology has already integrated the principles of Mechanical Engineering in a significant manner. It is believed that such interdisciplinary areas will have a leading role in the forthcoming third Industrial Revolution. Hence the researchers in Mechanical Engineering will have to think about their contribution to the Nation and to the humankind from a different perspective.

Engineering Mechanics and Mechanical Engineering have long been associated with Oncology and Cancer Research. The last decade has provided ample illustrations of the diversity and depth of mechanics connected with cancer research. For instance, Prof. Arunava Majumdar of Department of Mechanical Engineering at the University of California, Berkeley used micro-cantilever beams to provide the means for the early and accurate diagnosis of cancer from biological fluid samples. With his team, Prof. Majumder fabricated arrays of micro-beam using techniques employed in the field of micro-electro-mechanical system (MEMS). Subsequently they modified the surfaces of the beams with antibody molecules that link specifically to conjugate molecules – so called antigens. Probably it is relevant to mention here that Prof. Arunava

Majumdar is now the Director of ARPA-E of USA. ARPA-E is newly formed Advanced Research Projects Agency for Energy. ARPA-E was formed through an initiative of President Obama and modeled after the Defence Advanced Research Projects Agency (DARPA) of the USA.

Prof. Rakesh Jain and his team at Harvard University and Massachusetts General Hospital demonstrated that cancer and the surrounding tissues generally develop internal hydrostatic pressure that oppose the transport of therapeutic drugs from the blood stream into the cancer cells. The research highlighted the development of new therapeutic approaches that can overcome the pressure gradients.

Present day engineering-scientists rely in scientific knowledge in addition to relying upon inventiveness, expert knowledge and spontaneous judgment. Further the present day applied-scientist does not stop if scientific knowledge required for an application is not available. He/She engages in research to gain new and additional scientific knowledge about the fundamental processes involved.

Fig 1: Proteins produced by cancer cells can be detected quickly using a cantilever device coated with specific antigens. When the proteins bind with the antigens, it changes the cantilever's oscillation rate
Courtesy: Mechanical Engineering, The Magazine of ASME, Vol. 132, March 2010

Let us consider another situation. Suppose an archer is pulling back on a bowstring. Basically he is using a spring to store elastic energy. springs are one of the oldest means we have for storing energy. Springs have advantages for energy storage that electrochemical batteries do not. Admittedly the electrochemical batteries have replaced springs in many applications. A spring's stored energy can be released quickly, with high power density. Springs can be recharged a very large number of times without degradation. Springs also store energy in the face of wide temperature swings.

Effort is on for developing new spring materials that can offer high energy density along with the traditional advantages of springs. Ideally, a high-performance spring material will have both high material stiffness and high deformability. Although such materials are hard to develop, recent advances in nano-scale materials provide new options. One promising development uses carbon nano-tube (CNT). CNTs are essentially graphene sheets rolled up to form a tube and capped off at the ends. Carbon nano-tubes can have a single layer of atoms or multiple coaxial layers, and their diameters can range from about one nanometre to hundred of nanometers. Their lengths range from around a micrometer up to a centimeter.

Because the structure of carbon nano-tubes along their length is essentially that of a graphene sheet, their effective material stiffness is quite high (about 1 TPa). Prof. D. Walters and his colleagues working at Rice University in Houston demonstrated yield strains of up to 6 percent on small ropes of single-wall CNTs.

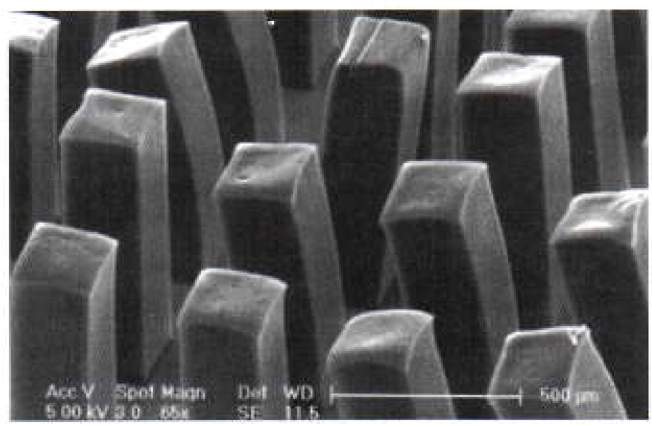


Fig 2: Grown on a substrate using vapour deposition, each of these pillars contains a million aligned nanotubes
Courtesy: Mechanical Engineering, The Magazine of ASME, Vol. 132, March 2010

There are many opportunities for basic and applied contributions in the microfluidics area. Because multiple channel characteristics (e.g., geometry, topography, surface treatments) and driving forces can be implemented and combined using straightforward fabrication procedures, it is interesting to think about innovative methods for designing valves, pumps, separation processes, etc involving microscale. Many applications involve suspended macromolecules, biopolymers, and large shear rates; hence these are conditions where significant changes in the microstructure and to the rheology of the fluid are expected. Few microfluidic studies have been reported where the viscoelastic response is important.

Some youngsters at CMERI are trying to develop microfluidic chips that can precisely control very small quantity of liquid. Scientists are trying to use these chips to analyze gene expression in single cells and to indentify mutation in cells. The technology could culminate in cheap, disposable diagnostic devices for a variety of applications. The chips will be made from flexible polymers that can be easily adapted to many functions. The technology allows performing new analyses, such as controlling the growth environment of single cells.

The amazing diversity of various micro-nano systems (MNST) is a valuable aid for the researchers all over the world. These have been used for wide range of applications as intelligent and flexible devices. Drawing inspiration from the worldwide development of intelligent and flexible devices, CMERI has strived to create some end-to-end solutions in the area of micro-machines.

Five Axis Micro Milling (μ-CNC milling) Machine

Fig 3: Five axis micro milling machine prototype (left) and sample cutting by five axis micro milling machine (right)

has 20 mm travel in X and Y axes and, 30mm in vertical axis with travel resolution of 0.1 μm . This machine has been controlled through LabView interface, which can import CNC tool path data generated in typical CAM software after minor editing. Movement of axis is controlled through CNC program used as input to the system. Air spindle with 100000 rpm has been mounted vertically. Figure shows the five axis micro milling machine prototype developed and samples machined from this prototype.

Micro Electric Discharge Machine (μ-EDM)

This μ-EDM machine test bed developed at CMERI consists of three linear precision positioning stages with travel resolution of 0.1μm and travel length of 150mm. These are mounted to have programmed 3-axis movements in X, Y and Z axis. The RC

Fig 4: Micro Electric Discharge Machining Machine prototype developed at CMERI

circuit based pulse generator has been integrated for low energy discharge power supply. The discharge voltages and currents have been measured using digital oscilloscope. These hardware systems are interfaced as a synchronized manner and controlled through LabView. The approach and retraction movement of an electrode with respect to the work piece are programmed. The discharge voltage has been continuously monitored to compensate electrode and work piece wear (as a result of material removal), so that constant spark gap between them could be maintained in successive discharges. Figure shows the first generation prototype developed currently and which is being upgraded to incorporate micro milling features, so that systems can be used as multi-purpose micro machine.

Today there are robots that can move in complex environments, such as a messy living room or a battlefield, by means of a system that coordinates navigation, mobility, manipulation, and sensing so that the machine can respond efficiently to changing circumstances. Even as house-hold devices, automated vacuum cleaners are available. By developing relatively affordable consumer robots for specific purposes, the technology has emerged successful offering more capable and expensive products. Indigenously built All Terrain Robots, Subterranean Robots are some of the precious contributions of CMERI.

Fig 5: AUV being deployed into the Lake waters

Fig 6: Underwater rocks as captured during underwater cruising an hovering operations of the AUV developed by CMERI

Recently CMERI has carried out testing of its Autonomous Underwater Vehicle (AUV) at the **Idukki Lake, Cochin** with active support from NPOL. Couple of overhead cranes were used for launching the AUV into the lake waters as well as for retrieving it back from the waters. The launching point was considered to be the start position for most of the trials. Underwater cameras were used for taking snapshots and capturing video while the AUV went down under waters.

The AUV has been successful in maintaining its own heading as well as correcting its displacement in the surge direction to reach out the desired position. The closed loop missions constituted of straight-line paths in the form of square or a trapezoidal profile. During all such trials, mission was carried out with the help of a pre-compiled mission file, which was stored in the memory of the onboard computational unit. The AUV technology is an essential technology of the future as our dependence on ocean resources increases. The need for AUV is already being felt for activities such as inspection, location of objects, survey of the ocean floor and surveillance.

Sponsored by the Ministry of Earth Sciences, the AUV has been built to operate 150m under the sea to collect sensor based data. New challenge in front of CMERI to build an AUV that can operate 6000m under the sea. Indeed this is a great challenge!

CMERI scientists are trying to manufacture new types of lithium-ion batteries that are safer than conventional versions and use less expensive elements. The materials are structures at the nano-scale in way that enables them to charge and discharge quickly. Because they are safe, the batteries lend themselves to use in conventional hybrids, plug-in hybrids, and all-electric cars. Such batteries are good choice for storing power to help stabilize the electrical grid.

Very recently, the Chemistry and Biomimetics group of CMERI achieved the success of developing ionic polymeric metal composite (IPMC) based actuator at laboratory demonstrable scale, perhaps unique in the country. Actuation response of IPMC based actuator is shown in Figure below

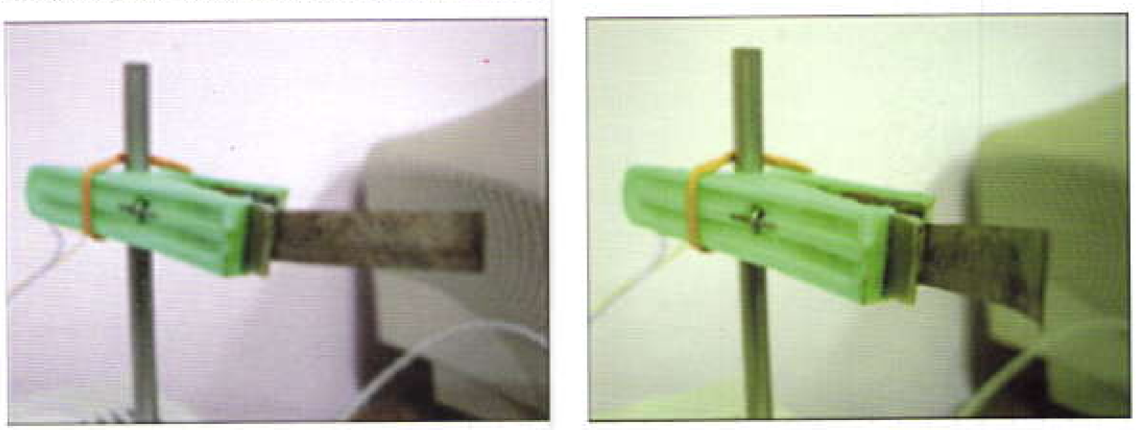


Fig 7: IPMC Actuators developed at CMERI

The expected yield from the project includes development of biologically powered micro-devices - a technologically and economically feasible reality. The economic implications of such devices lie in an extremely wide range of applications, much broader than presently possible.

Harnessing alternative fuels is another focused area, which promises a symbiotic correlation between sustainable development, energy conservation, efficiency and the protection of environment. India is grappling with the issue energy and needs priority attention. Research Institutions, like CMERI have to shoulder a great responsibility in providing appropriate technology and solutions for energy crisis, in close coordination with the Indian Industry.

More often than not, significant gains can be made by the appropriate combination of knowledge and techniques from widely differing fields. The promotion and accomplishment of these are the important roles of any leading Mechanical Engineering Research Institute. It is my trust that CMERI will excellently perform such roles.

Of course, the Institute will continue to maintain its traditional areas of strength and excel in the product development on those areas to the best possible limits. CMERI will continue its vibrant activities in the areas of Rapid Prototyping, Foundry, Fluidized Bed Technology, Tractors & Farm Machinery, Virtual Reality, NDT, Metrology and Condition Monitoring. However, the modern industrial society demands that the Institute must also play an active role in the interfacing of Mechanical Engineering with other fields, such as Nanotechnology, Chemistry, Biology, Optics, Electrical Drives, Power Electronics, Cybernetics and Electronics.

The havoc caused by water-borne diseases is well known in India. Severe degradation of water quality in India has often been attributed to indiscriminate disposal of sewage and industrial effluents into surface water bodies. Although some amount of cleaning in terms of chlorination and monitoring of water quality exists in major cities and towns, rural India is usually deprived of even such treated water. The population in rural India is mainly dependent on the ground water or water from river or estuaries as the sources of drinking water. The groundwater is often found to be contaminated with arsenic, fluoride iron and salts. Our Chemistry Department together with some other division is focused to find out a solution in the face of this crisis.

The role of Simulation and Modeling has become so important that today it can be viewed as a complete discipline. With its ability to handle the governing equations in "exact and full" form, together with the inclusion of detailed physical phenomena such as finite-rate chemical, biological and nuclear (if applicable) reactions "Simulation and Modeling" became the most important tool for analysis and design. It has occupied a permanent place in all aspects of science and engineering, from basic research to prototype demonstration. CMERI is trying hard harnessing the full potential of this rapidly emerging discipline.

The world is at the cross road of Third Industrial Revolution. "Intelligent Material Based Smart Sensors, Actuators and Devices" – are going to be the major players in this revolution. CMERI will dedicate its best effort in inventing and adopting and practising technology related to smart actuators and devices. Lithography induced self assembly (LISA) has been realized as an effective tool for manufacturing small scale features. A polymer film confined between two electrodes made to be unstable in a periodic fashion under the influence of an applied electric field yielding very regular patterns. CMERI scientists are trying to develop control parameters to manufacture small scale features using self-lithography.

The new CSIR of our Director General will have a few jewels in its crown and it is the fervent prayer of the undersigned that CMERI strives hard to be one of the jewels.

Gautam Biswas

निदेशक की कलम से

हाल ही में, विश्व में विज्ञान एवं प्रौद्योगिकी के क्षेत्र में व्यापक परिवर्तन हो चुका है । पारंपरिक भूमिकाओं एवं रूढिवादिओं ने क्रान्तिकारी विचारों के मार्ग को प्रशस्त किया है । अब प्रत्येक व्यवसायी को निरंतर अपने ज्ञान का नवीनीकरण करना आवश्यक है।

यांत्रिक अभियांत्रिकी गतिविधियों का विस्तार व्यापक रूप से हो चुका है । उदाहरणस्वरूप इसका विस्तार वीएलएसआई चिप के कूलन से लेकर नई पीढी के परमाणु रियेक्टरों के डिजाइन से सम्बन्धित तापीय-जलगति विज्ञान के विश्लेषण तक फैला हुआ है । अंतरिक्ष-यान की स्थिरता के विश्लेषण से लेकर पतली प्रत्यास्थ फिल्मों की स्थिरता भी इसके अंतर्गत आती है।

यांत्रिक अभियांत्रिकी के बारे में यह आम धारणा है कि यह केवल मशीनों तक सम्बन्धित है । यंत्रों का विस्तार खाद्य प्रसंस्करण मशीनों, वस्त्र मशीनों से लेकर साइकिल, कारों और अंतरिक्ष-यानों तक है । यह अनेक वैद्युत एवं इलेक्ट्रॉनिक्स प्रणालियों, प्रक्रम उद्योग एवं चिकित्सीय उपकरणों का अभिन्न अंग है । निर्माण उद्योग के बारे में सोचकर कोई भी बडी-बडी क्रेनों और उसके घटकों की कल्पना कर सकता है। यांत्रिक अभियांत्रिकी के रेलवे और ऑटोमोबाइल दो अंतर्निहित क्षेत्र है। इस प्रकार यांत्रिक अभियांत्रिकी विभिन्न प्रकार के उद्योगों से सम्बन्धित है। आजकल कंपनियों की आवश्यकता है कि यांत्रिक अभियंता सॉफ्ट कम्प्यूटिंग (Soft Computing) एवं ऑपटिमाइजेान (Optimization) में कुशल होना चाहिए। यांत्रिक अभियंता को कैड-कैम (CAD/CAM) से सम्बन्धित विषयों को संचालित करना आना चाहिए ।

यांत्रिक अभियांत्रिकी के सिद्धांतों का इलेक्ट्रो-मैकेनिकल (वैद्युत यांत्रिक) प्रणालियों एवं सूचना संसाधन सहित विभिन्न प्रकार की प्रौद्योगिकियों में परम्परगत रूप से प्रयोग किया जाता है । यांत्रिक अभियांत्रिकी और अन्य उभरते हुए क्षेत्रों के बीच परस्पर विशेष व्यापकता है । सिंथेटिक (Synthetic) जीव-विज्ञान का उद्‌भव पहले से ही यांत्रिक अभियांत्रिकी के सिद्धांतों को महत्वपूर्ण रूप से एकीकृत कर चुका है । यह आशा की जाती है कि इस तरह के अंतःविषयों की आगामी तृतीय औद्योगिक क्रांति में अग्रणी भूमिका

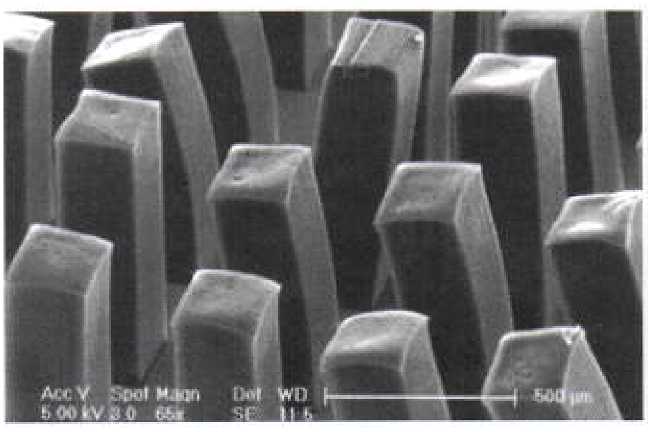
चित्र संख्या १: कैंसर सेल के द्वारा उत्पादित प्रोटीन को विशिष्ट प्रतिजनकों से लेपित कैंटीलीवर उपकरण का उपयोग करके पता लगाया जा सकता है। जब प्रोटीन प्रतिजनक के साथ बंध जाता है, तब यह कैंटीलीवर के दोलन की दर को परिवर्तित कर देता है

सौजन्यः मैकनिकल इंजीनियरिंग, एएसएमई की पत्रिका, खण्ड १३२, मार्च २०१०

होगी। इस कारण से यांत्रिक अभियांत्रिकी के शोधकर्त्ताओं को एक विभिन्न दृष्टिकोण से राष्ट्र के प्रति अपने योगदान के बारे में विचार करना होगा । यांत्रिक यंत्र-विज्ञान एवं यांत्रिक अभियांत्रिकी लम्बे समय से अबुर्द विज्ञान तथा कैंसर अनुसंधान के साथ जुड़ी हुयी है । कैंसर अनुसंधान के यंत्र-विज्ञान से संबध की विविधता और गहराई के प्रचुर उदाहरण पिछले दशक में दिखाई दिये हैं। उदाहरण के लिए बर्कले में स्थित कैलिफोर्निया विश्वविद्यालय में यांत्रिक विभाग में कार्यरत प्रोफेसर अरूणाभ मजूमदार ने माइक्रो मशीन्ड कैंटीलीवर बीम (Micro-machined cantilever beam) का उपयोग एक साधन के रूप में जैविक द्रव के नमूने से कैंसर का जल्दी और सही निदान के लिए किया है। प्रोफेसर मजूमदार एवं उनके दल ने माइक्रोइलेक्ट्रो-मैकेनिकल (सूक्ष्म वैद्युत यांत्रिक) प्रणालियों में प्रयुक्त पद्धतियों के द्वारा माइक्रो बीम की श्रेणी (श्रृंखलाओं) का निर्माण किया । इसके बाद उन्होंने प्रतिरोधी अणुओं से जो विशेष रूप से संयुग्मी अणुओ को जोड़ता है, जिसको प्रतिजनक कहा जाता है, की सहायता से बीम की सतह परिवर्तित किया। शायद यहां यह उल्लेख करना प्रांसगिक है कि आजकल प्रोफेसर अरूणाभ मजूमदार संयुक्त राज्य अमेरिका में एआरपीएई के निदेाक है। एआरपीएई एडवांस रिसर्च प्रोजेक्ट्स एजेंसी फॉर एनर्जी ऊर्जा के लिए गठित नयी संस्था है। राष्ट्रपति ओबामा की एक पहल पर एआरपीएई का गठन किया गया है और इसका प्रारूप अमेरिका की डिफेंस एडवांस रिसर्च प्रोजेक्ट्स एजेंसी (डीएआरपीए) के समान है ।

हावर्ड विश्वविद्यालय के प्रोफेसर राकेश जैन एवं उनके दल तथा मैसाचुसेट्स जनरल हास्पिटल में कार्यरत उनकी टीम ने दिखाया कि साधारणतः कैंसर और आस-पास के ऊतकों द्वारा उत्पन्न आंतरिक द्रवस्थैतिक दाब, जो कैंसर कोशिकाओं में रक्त प्रवाह से चिकित्सीय औषधियों के संवहन का विरोध करता है। उनके अनुसंधान ने नयी चिकित्सीय पद्धतियों पर प्रकाश डाला जो दाब प्रवणता की समस्या को कम करती है।

आजकल विज्ञानी एवं अभियंता वैज्ञानिक ज्ञान पर निर्भर होने के अतिरिक्त कल्पना चातुर्य (अविष्कार कौशल), विशेषज्ञ ज्ञान एवं स्वतः निर्णय लेने की



चित्र संख्या २: इन स्तम्भों में से प्रत्येक संरेखित एक लाख नैनो ट्यूब्स रखता है। सौजन्यः मैकनिकल इंजीनियरिंग, एएसएमई की पत्रिका, खण्ड १३२, मार्च २०१०

क्षमता पर भी भरोसा करते हैं । इससे भी आगे आजकल यदि किसी प्रयोग के लिए वैज्ञानिक ज्ञान उपलब्ध नहीं है तब भी व्यावहारिक विज्ञानी नहीं रूकते है । वे मौलिक प्रक्रिया में शामिल नये एवं अतिरिक्त वैज्ञानिक ज्ञान में वृद्धि के लिए अनुसंधान में संलग्न रहते हैं ।

हम एक और स्थिति पर विचार करते हैं। सोचते हैं कि एक धनुर्धर एक धनुष पर प्रत्यंचा खींच रहा है । मूलरूप से वह एक स्प्रिंग का उपयोग प्रत्यास्थ ऊर्जा को संचित करने के लिए कर रहा है। स्प्रिंग एक सबसे पुराना साधन है जिसका उपयोग हम ऊर्जा को संचय करने के लिए कर रहे हैं। स्प्रिंग ऊर्जा संचय के गुण से सम्पन्न होते हैं, जो इलेक्ट्रोकेमिकल बैटरियों में नहीं पाया जाता है । इलेक्ट्रोकेमिकल बैटरियों ने सही में अनेक अनुप्रयोगों में स्प्रिंग को प्रतिस्थापित किया है। एक स्प्रिंग की संचित ऊर्जा को बड़ी तेजी से उच्च शक्ति घनत्व के साथ मुक्त किया जा सकता है। स्प्रिंग को एक बहुत बड़ी संख्या में अपकर्ष हुए बिना रिचार्ज किया जा सकता है । स्प्रिंग व्यापक तापमान परिवर्तन क्षेत्र में भी दृढ़ता से ऊर्जा का संचय करते हैं।

स्प्रिंग के लिए नये प्रकार के पदार्थ को विकसित करने की दिशा में,जो अधिक ऊर्जा घनत्व के अतिरिक्त स्प्रिंग के पांरम्परिक लाभों को प्रदान करने में सक्षम हो, प्रयास चल रहे हैं। आदर्शतः एक अधिक क्षमता के स्प्रिंग का पदार्थ अधिक कठोरता तथा अधिक विकृति दोनों गुण रखता है। यद्यपि पदार्थों का निर्माण करना कठिन है, लेकिन हाल ही के अग्रिम प्रयासों ने कुछ नये सुझाव प्रदान किये हैं। कार्बन नैनो ट्यूब [Carbon Nano-tube (CNT)] का प्रयोग एक आशाजनक उन्नति है। कार्बन नैनो ट्यूब (CNT) आवश्यक ग्रेफीन चादर है जिनको एक ट्यूब बनाने के लिए लुढ़काया जाता है और अन्त में जिसको बंद किया जाता है। कार्बन नैनो ट्यूब (CNT) परमाणुओं की एक सतह या अनेक समाक्षीय सतह रख सकते हैं और उनके व्यासों की सीमा लगभग एक नैनोमीटर से सौ नैनोमीटर तक हो सकती है। उनकी लम्बाइयों की सीमा लगभग एक माइक्रोमीटर से एक सेंटीमीटर तक होती है। क्योंकि उनकी लम्बाई के साथ कार्बन नैनो ट्यूब (CNT) की संरचना मूलतः ग्रेफीन चादर की होती है, उनकी प्रभावी पदार्थ कठोरता अत्यधिक अधिक (लगभग एक टीपीए) होती है। ह्यूसटन में राइस विश्वविद्यालय में कार्यरत डेरोन वालटर्स एवं उनके सहकर्मियों ने एक दीवार वाली कार्बन नैनो ट्यूब की छोटी रस्सियों में छह प्रतिशत की उत्पन्न विकृति को प्रदर्शित किया।

माइक्रोफ्लूडिक्स (Microfluidics) के क्षेत्र में मौलिक और व्यावहारिक योगदान के अनेक अवसर हैं। क्योंकि अनेक चैनल विशेषताओं (जैसे ज्यामिति, तलरूप, सतह उपचार) और ड्राइविंग बलों को सरल निर्माण प्रक्रिया द्वारा संयुक्त कर कार्यान्वित किया जा सकता है। माइक्रोस्केल (Microscale) के सिद्धांतों का प्रयोग करके वाल्व डिजाइन पम्पों और विघटन प्रक्रियाओं के लिए नये तरीके के बारे में सोचना बहुत दिलचस्प है। कई प्रयोगों में सस्पेंडेड मैक्रोमोलिक्यूलस (Suspended Macromolecules), बॉयोपॉलिमर (Biopolymer) और अधिक शीयर रेट्स (Shear rates) सम्मिलित हैं, इसलिए वे स्थितियाँ जहाँ माइक्रोस्ट्रक्चर (Microstructure) में महत्वपूर्ण परिवर्तन होते हैं और रक्त प्रवाह विज्ञान में यह अपेक्षित है।

कुछ माइक्रोफ्लूडिक्स (Microfluidics) अध्ययनों के विवरणों में पाया गया है कि विस्कोइलास्टिक (Viscoelastic) प्रतिक्रिया महत्वपूर्ण है।

सीएमईआरआई. में कुछ युवा वैज्ञानिक एक माइक्रोफ्लूडिक्स चिप (Microfluidics chip) का निर्माण करने का प्रयत्न कर रही हैं जो तरल पदार्थ की अत्यधिक छोटी मात्रा को निश्चित रूप से नियंत्रित कर सके। वैज्ञानिक इन चिपों का उपयोग एकल कोशिकाओं में जीन की अभिव्यक्ति का विश्लेषण करने के लिए तथा जैविक नियंत्रित परिस्थितियों में स्टेम सेल विकसित करने हेतु प्रयासरत हैं। प्रौद्योगिकी विभिन्न प्रकार के अनुप्रयोगों के लिए सस्ते एवं प्रयोज्य नैदानिक उपकरणों के रूप में पराकाष्ठा को प्राप्त कर सकेगी। चिप को लचीले पॉलिमर से बनाया जायेगा जो आसानी से कई कार्यों के लिए अनुकूलित किया जा सकता है। प्रौद्योगिकी, एकल कोशिकाओं के विकास के वातावरण को नियंत्रित करना जैसे विश्लेषणों के प्रदान की अनुमति देती है।

विभिन्न माइक्रो-नैनो प्रणालियों की अद्भुत विविधता दुनिया भर में सभी शोधकर्ताओं के लिए एक बहुमूल्य सहायता है। बुद्धिमान एवं लचीले उपकरणों के रूप में इनको अनेक प्रकार के अनुप्रयोगों की विस्तृत श्रृंखला में उपयोग किया गया है। बुद्धिमान एवं लचीले उपकरणों का दुनिया भर में हुए विकास से प्रेरित होकर, सीएमईआरआइ ने माइक्रो मशीनों के क्षेत्र में कुछ आद्योपान्त समाधान देने का प्रयास किया है।

पंच अक्षीय सूक्ष्म मिलिंग मीन (μ-CNC मिलिंग)

सीएमईआरआई में विकसित पंच अक्षीय सूक्ष्म मिलिंग मशीन का प्रारूप गति विभेदन क्षमता ०.१ माइक्रोमिमी के साथ X तथा Y में २० मिमी तथा उर्ध्वाधर अक्ष में ३० मिमी तक संचलन कर सकता है। इस मशीन को लैबवियु इंटरफेस (Labview interface) द्वारा नियंत्रित किया जाता है, जिसके द्वारा कैम सॉफ्टवेयर (CAM software) में उत्पन्न सीएनसी टूल पाथ डाटा (CNC tool path data) को मामूली संपादन के पश्चात् आयात कर सकते हैं। अक्ष के घूर्णन को सीएनसी प्रोगाम (CNC programme), जिसको प्रणाली का निर्विष्ट की तरह प्रयोग किया जाता है, के द्वारा नियंत्रित किया जाता है। इसमें एअर स्पिन्डल १००००० आरपीएम (rpm) के साथ उर्ध्वाधर रूप में जोड़ा गया है। चित्र में पंच अक्षीय सूक्ष्म मिलिंग मशीन के विकसित प्रारूप से निर्मित नमूने प्रदर्शित हैं।

चित्र संख्या ३ : पंच अक्षीय सूक्ष्म मिलिंग मशीन का प्रारूप (बायें) पंच अक्षीय सूक्ष्म मिलिंग द्वारा काटने का नमूना प्रदर्शित करते हुए (दायें)

चित्र संख्या ४ : सीएमईआरआई में विकसित माइक्रो ईडीएम (μ- EDM)

माइक्रो इलेक्ट्रिक डिस्चार्ज मशीन (μ- EDM)

सीएमईआरआइ में विकसित माइक्रो ईडीएम (μ- EDM) ०.१ माइक्रोमिमी की विभेदन क्षमता तथा १५० मिमी गति लम्बाई के साथ तीन रैखिक परिशुद्धता की स्थिति को रखता है। ये X, Y तथा Z तीनों अक्षों में योजनाबद्ध तरीके से संचालित करने के लिए लगे हुए हैं। कम ऊर्जा प्रवाह की वैद्युत आपूर्ति के लिए आरसी परिपथ पर आधारित पल्स जेनरेटर (pulse generator) को एकीकृत किया गया है। प्रवाहित वोल्टेज एवं धाराओं को अंकीय दोलनदर्शी (डिजिटल ओस्लिस्कोप digital oscilloscope) की सहायता से मापा जाता है। ये हार्डवेयर प्रणालियाँ अंतरापृष्ठ के रूप में समकालिक तरीके से जुड़ी हुई हैं, और इनको लैबवियु (Labview) के द्वारा नियंत्रित किया जाता है। वर्कपीस के संदर्भ में एक इलेक्ट्रोड की निकट एवं प्रत्याकर्ष की गति प्रोगाम की हुयी होती है। वर्कपीस वीयर (workpiece wear) एवं इलेक्ट्रोड की क्षति पूर्ति के लिए प्रवाहित वोल्टेज को निरंतर देखा जाता है ताकि क्रमागत प्रवाह में उन दोनों के बीच निरंतर चिंगारी अंतर बनाये रखा जा सके। चित्र में वर्तमान में विकसित प्रथम पीढ़ी का प्रारूप प्रदर्शित किया गया है जिसमें माइक्रोमिलिंग मशीन की विशेषताओं को सम्मिलित करने के लिए सुधार किया जायेगा ताकि इसको बहु-प्रयोजन माइक्रो मशीन के रूप में उपयोग किया जा सके।

चित्र संख्या ५: एयूवी को झील के पानी में उतारते हुए


चित्र संख्या ६ : परिभ्रमण के समय पानी के नीचे के चट्टानों के चित्र

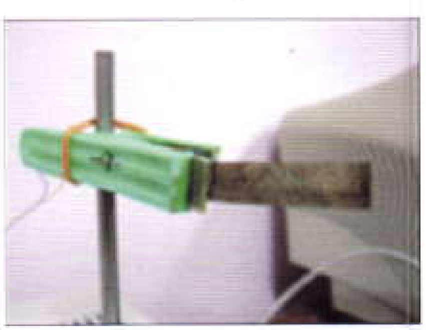
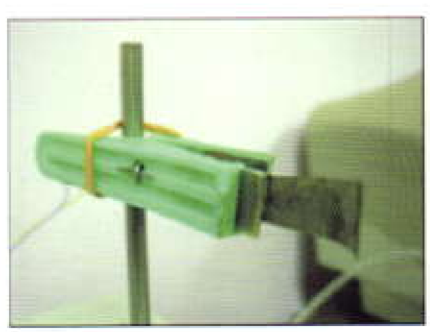
आजकल ऐसे रोबोट हैं जो कि जटिल वातावरण में भी संचलन कर सकते हैं जैसे कि एक भरा कमरा या युद्धभूमि। रोबोट एक मशीन प्रणाली है जो नेविगेशन, गतिशीलता, दक्षता एवं संवेदनशीलता को संयोजित करती है ताकि परिवर्तित परिस्थितियों मे भी मशीन निपुणतापूर्वक प्रतिक्रिया देने में सक्षम हो। यहाँ तक कि घरेलू उपकरणों में स्वचालित वैक्यूम क्लीनर भी उपलब्ध है। कुछ सीमित प्रयोजनों के लिए उपभोक्ता के खरीदने योग्य अपेक्षाकृत सस्ते रोबोट का विकास करके, प्रौद्योगिकी अधिक सक्षम और मंहगे उत्पादो को प्रस्तुत करते हुए सफल रूप में उभरी है। देश में निर्मित आल टरैन रोबोट (All Terrain Robots), सब्टरैनीअन रोबोट (Subterranean Robots) सीएमईआरआई के बहुमूल्य योगदानों में से कुछ हैं।

हाल ही में ही कोचीन की इडुक्की झील में एनपीओएल के सक्रिय सहयोग से सीएमईआरआइ द्वारा अपने एयूवी [Autonomous Underwater Vehicle (AUV)] का परीक्षण किया गया है। दो ऊपरी क्रेनों की सहायता से एयूवी को झील के पानी में उतारा गया और पानी से बाहर निकाला गया। अधिकतर परीक्षणों के लिए अवतरित बिदुं को ही शुरूआती बिन्दु समझा गया। फोटो और वीडियो खींचने के लिए पानी के भीतर स्थित कैमरों का प्रयोग किया।

एयूवी (AUV) अपने स्वयं के नामकंन को सार्थक करते हुए तथा तंरग गति दिशा में अपने विस्थापन को सही करते हुए वांछित स्थिति तक पहुँचने में सफल हुआ है। इसके विपरित, क्लोज्ड लूप मिशन वर्ग या समलम्ब पार्श्व चित्र के रूप में सीधी रेखाओं के पथों से निर्मित होते हैं। ऐसे सभी परीक्षणों के दौरान, मिशन को एक पूर्व संकलित मिशन फाइल की मदद से सम्पन्न किया गया, जिसको कम्पयूटेशनल यूनिट की मेमोरी में रखा गया था। एयूवी प्रौद्योगिकी भविष्य की एक आवश्यक तकनीक होगी जिस प्रकार समुद्र के संसाधनों पर हमारी निर्भरता बढ़ रही है। एयूवी की आवश्यकता को अनेक गतिविधियों, जैसे कि वस्तुओं के स्थान के निरीक्षण, समुद्र तल का सर्वेक्षण तथा निगरानी के लिए पहले से ही महसूस कर लिया गया है। पृथ्वी विज्ञान मंत्रालय द्वारा प्रायोजित, एयूवी को समुद्र के अन्दर १५० मीटर तक संचालित तथा सेन्सर बेस डाटा को इकट्ठा करने के लिए निर्मित किया गया है । सीएमईआरआई के समक्ष एक नयी चुनौती है एक ऐसे एयूवी का निर्माण करना, जिसको समुद्र के अन्दर ६०० मीटर तक संचालित किया जा सके । यह वास्तव में एक कठिन चुनौती है।

सीएमईआरआई के वैज्ञानिक नयी प्रकार की लिथियम बैटरियों का जो पांरम्परिक संरकरण की तुलना में सुरक्षित हैं तथा जिनमें कम खर्चीले तत्वों का प्रयोग होता है, का निर्माण करने का प्रयत्न कर रहे हैं। पदार्थों के तत्वों की संरचना नैनो स्केल पर इस प्रकार की होती है जो जल्दी से आवेशित तथा अनावेशित हो जाते हैं।

बहुत हाल ही में सीएमईआरआई के केमिस्ट्री एवं बॉयोमिमिटिक्स समूह ने प्रयोगशाला स्तर पर शायद देश में अद्वितीय आयोनिक पॉलिमर मेटल कम्पोसिट्स [Ionic Polymenr Metal Composite (IPMC)] पर आधारित प्रेरक का विकास करने की सफलता प्राप्त की है। आयोनिक पॉलिमर मेटल कम्पोसिट्स (IPMC) पर आधारित प्रेरक की प्रतिक्रिया क्रियाशीलता को नीचे चित्र में दिखाया गया है।

चित्र संख्या ७: सीएमईआरआइ में विकसित आयोनिक पॉलिमर मेटल कम्पोसिट्स (IPMC) पर आधारित प्रेरक (Actuators)

(बॉयोलॉजिकल) जैविक शक्ति द्वारा संचालित सूक्ष्म उपकरणों - तकनीकी और आर्थिक रूप से यथार्थ होने योग्य उपकरणों का निर्माण करना परियोजना के अपेक्षित उत्पादों में सम्मिलित हैं। इस तरह के उपकरणों के आर्थिक प्रभाव वर्तमान में संभव से कहीं अधिक व्यापक रूप से अनुप्रयोगों की एक विस्तृत श्रृंखला के रूप में निहित हैं।

वैकल्पिक ईंधन का उपयोग एक दूसरा केन्द्रित क्षेत्र है - जो पर्यावरण की सुरक्षा और दक्षता, ऊर्जा संरक्षण एवं सतत विकास के बीच एक सहजीवी संबंध का वादा करता है। भारत ऊर्जा के मुद्दे से जूझ रहा है, अतः इसमें प्राथमिक ध्यान की जरूरत है। भारतीय उद्योगों के निकट समन्वय के साथ ऊर्जा संकट के समाधानों तथा उपयुक्त प्रौद्योगिकी प्रदान करने के लिए सीएमईआरआइ जैसे अनुसंधान संस्थानों को अपने कंधों पर एक बड़ी जिम्मेदारी को लेना होगा।

महत्वपूर्ण लाभ व्यापक रूप से विभिन्न क्षेत्रों के ज्ञान और तकनीक के उचित संयोजन द्वारा बनाया जा सकता है। इन क्षेत्रों की समृद्धि एवं उन्नति ही किसी भी अग्रणी यांत्रिक अभियांत्रिकी अनुसंधान संस्थान की महत्वपूर्ण भूमिका है। यह मेरा विश्वास है कि सीएमईआरआइ इन भूमिकाओं में उत्कृष्ट प्रदर्शन करेगी।

वास्तव में, संस्थान अपने पारम्परिक सशक्त क्षेत्रों को बनाये रखते हुए तथा अपनी संभव सीमाओं के अनुसार उत्पाद विकास में दक्षता के लिए प्रयत्न जारी रखेगा। सीएमईआरआई रैपिड प्रोटोटाइपिंग (Rapid Prototyping), फाउन्ड्री (Foundry), फ्लूडाइज्ड बेड टेक्नोलॉजी (Fluidized Bed Technology), ट्रैक्टर्स एवं फार्म मशीनरी (Tractors and Farm Machinery), वरचुअल रियलिटी (Virtual Reality), एनडीटी (NDT), मेट्रोलॉजी (Metrology) तथा कंडीशन मॉनिटरिंग (Condition Monitoring) के क्षेत्र में अपनी जीवंत गतिविधियों को जारी रखेगी। यद्यपि आधुनिक समाज की आवश्यकता स्वरूप संस्थान को अन्य क्षेत्रों जैसे नैनोटेक्नोलॉजी, रसायन विज्ञान, जीव विज्ञान, प्रकाशिकी, वैद्युत ड्राइव, पावर इलेक्ट्रॉनिक्स, साइबर नेटिक्स तथा इलेक्ट्रॉनिक्स की यांत्रिक अभियांत्रिकी के साथ अंतरापृष्ठ करने में एक सक्रिय भूमिका निभानी होगी।

भारत जलजनित बीमारियों के कारण हुए विनाश के लिए अच्छी तरह से जाना जाता है। भारत में पानी की गुणवत्ता में गंभीर गिरावट के लिए सतह के जल स्रोतों में नाली के पानी का अव्यवस्थित निष्कासन एवं औद्योगिक बहिःस्रावी कारण बताये जाते हैं। यद्यपि क्लोरीनिकरण एवं पानी की गुणवत्ता की निगरानी के रूप में सफाई की कुछ मात्रा प्रमुख शहरों और कस्बों में ही मौजूद है। आमतौर पर ग्रामीण भारत इस तरह के प्रयुक्त पानी से वंचित है। ग्रामीण भारत की आबादी मुख्य रूप से पीने के पानी के स्रोतों के रूप में भूमिगत जल, नदी या खाड़ी के पानी पर निर्भर है। भूमिगत जल प्रायः आर्सेनिक फ्लोराइड, आयरन, तथा नमक के साथ दूषित पाया जाता है। कुछ अन्य विभागों के साथ हमारा रसायन विभाग इस संकट का सामना करने और समाधान खोजने में ध्यान केन्द्रित किये हुए है।

अंत में, सिमुलेशन एवं मॉडलिंग (Simulation and Modeling) की भूमिका इतनी महत्वपूर्ण हो गई है कि आज इसे एक पूर्ण क्षेत्र के रूप में देखा जा सकता है। शुद्ध एवं पूर्ण रूप में संचालित समीकरणों का प्रयोग करने की क्षमता तथ विस्तृत भौतिक सिद्धातों जैसे रासयनिक परिमिती दर, जैविक एवं नाभिकीय (यदि लागू) समीकरणों के समावेश के साथ सिमुलेशन एवं मॉडलिंग (Simulation and Modeling) विश्लेषण तथा डिजाइन के लिए सबसे महत्वपूर्ण साधन बन गया है। इसने विज्ञान एवं अभियांत्रिकी के सभी पहलुओं में मौलिक अनुसंधान से लेकर प्रारूप प्रदर्शन तक एक निश्चित स्थान अधिकृत किया हुआ है। सीएमईआरआइ तेजी से उभरते हुए इस क्षेत्र की सभी सम्भावनाओं को काम में लाने का भरसक प्रयत्न कर रही है।

विश्व तृतीय औद्योगिक क्रांति के द्वार पर खड़ा है। इस क्रांति में बुद्धिमान सामग्री आधारित स्मार्ट संवेदक, प्रवर्तक एवं उपकरण प्रमुख भूमिका निभाने जा रहे हैं। सीएमईआरआइ स्मार्ट प्रवर्तक एवं उपकरणों से सम्बन्धित प्रौद्योगिकी के अभ्यास एवं इनको स्वीकार करने में अपना सर्वश्रेष्ठ प्रयास समर्पित करेगी। लिथोग्राफी इन्ड्यूस्ट सेल्फ असेम्बली (एलआईएसए) [Lithography induced self assembly (LISA)] को लघु आकृतियों के उत्पादन के लिए एक प्रभावी उपकरण के रूप में महसूस किया गया है। प्रयुक्त वैद्युत क्षेत्र के प्रभाव के अन्तर्गत नियमित तरीके से अस्थिर बनाये गये दो इलेक्ट्रोडों के बीच सीमित एक पॉलिमर फिल्म से एकरूप आकृति उत्पन्न होती है। सीएमईआरआई के वैज्ञानिक सेल्फ-लिथोग्राफी का उपयोग करके लघु आकृतियों के उत्पादन के लिए कंट्रोल पैरामीटरों को विकसित करने का प्रयास कर रहे हैं।

हमारी सीएसआईआर के नए महानिदेशक के ताज में कुछ अमूल्य रत्न हैं और अधोहस्ताक्षरी की यह उत्कट प्रार्थना है कि सीएमईआरआई उनमें से एक रत्न होने हेतु कठिन संघर्ष के लिए प्रयत्नील है।

Gautam Biswas

ROBOTICS & MECHATRONICS

Programme Leader
S.N. Shome

Area Leaders
Debjyoti Banerjee
Sambhu Nath Nandy
Ranjit Ray
Dibyendu Roy
Subhra Kanti Das
Birendra Kumar

CMERI's expertise in the field of Robotic Systems, Control Engineering & Design Analysis was developed in the course of continued involvement with different project modules conducted under the Polymetallic Nodule Programme of the Department of Ocean Development, Government of India. Subsequently, CMERI developed **Remotely Operated Vehicles** that are exploring marine-wealth in the depths of the Indian Ocean and the Arabian Sea. CMERI has the requisite infrastructure and initiated human resource in robotics in specific areas of design of underwater robotic components, synthesis of intelligent control algorithms, navigational algorithms, software development on various platforms, distributed network systems, etc. Side by side, the experience was fed back for the development of conventional robotic elements and the provision of tailored solutions for industrial automation projects.

Currently CMERI in undertaking extensive research in the design and development of All terrain Robots, Autonomous Underwater Vehicle, Autonomous Mobile Robot for Manufacturing Applications, Subterranean Robots, etc

SURFACE ROBOTICS

Programme Leader
Dr. Somjyoti Majumder

Area Leaders
Sarbari Dutta
Kalyan Kumar Mistry
Dip Narayan Ray
Rudra Prasad Chatterjee

Autonomous underwater vehicle (AUV) for operation up to a depth of 150m at CMERI, Durgapur

Background/Objectives

Autonomous underwater robotic systems, designated AUVs, are gaining importance owing to their embedded advantages for applications like seabed mapping, coastal surveillance, mine countermeasure and oceanographic measurements during adverse weather conditions. With no physical cable connection to the surface control station and possessing onboard intelligence and energy supply, an AUV carries payload for carrying out a specific task. The configuration and payload of an AUV depends on specific mission requirements. The communication is hybrid in nature – RF while on surface and acoustic while underwater. Mission requirements and the use of payloads sometimes dictate the size and configuration of the AUV that can both be open or close frame.

The objective of the present project sponsored by Ministry of Earth Sciences, Government of India is to develop an operational AUV capable of operating up to a depth of 150m in the sea as per specification provided in Table-I. The developed system would be capable of mapping sea floor and sensor-based data collection.

Work done & discussion

The present AUV is cylindrical in shape like a torpedo with streamlined fairing to reduce hydrodynamic drag and has its own power, propulsion, navigation and control systems. The propulsion system consists of thrusters mounted at suitable locations. A pressure hull accommodates electronics and energy system. The vehicle is programmed with a set of instructions that enables carrying out underwater missions without assistance from an operator on the surface. For autonomous free movement under water, the AUV determines its own geographical position with the help of navigational sensors and with navigational algorithms avoid collision with obstacles after their detection through forward looking sonar. The preprogrammed onboard software renders the vehicle smart. The onboard intelligence helps the AUV to take independent decisions and accordingly re-planning the mission.

Key parameters determining AUV characteristics are: maximum working speed, depth of operation, payload capacity and mission time, which are highly interrelated. The various issues considered during design are as follows:

• Configuration	• Modularity,
• Degrees of freedom	• Stability
• Near neutral buoyancy	• Hydrodynamic modeling
• Pressure Hull design	• Energy System
• Navigational Sensors	• Communication

Table 1 : System Specifications

• Depth of operation :100m-150m	• Energy system: Lithium Polymer Battery
• Al alloy body (Special Grade)	• Mission Time: 4-6 Hrs
• Speed : 2-4 knots	• Navigation and Payload Sensors
• Modular in Design	• Intelligent Controllers
• D.O.F. –5 , Stable against Roll	• Network Based Distributed Control System
• Acoustic & RF Communication	

The AUV has six modules from nose to tail, as shown in Figure. 1. Thrusters are used to propel and maneuver the AUV. Five thrusters are mounted on the AUV for generating motion in different directions i.e to control surge, sway, heave, pitch and yaw. Rolling is strictly prevented. Lithium polymer battery has been used as power source considering its higher energy density, light weight, higher life and safety. For autonomous operation AUV is interfaced with obstacle avoidance sonar. The AUV is equipped with a number of navigational (Inertial Navigation System, Depth Sensor, Altimeter, Doppler Velocity Log, Forward Looking Sonar, Global Positioning System, APOS and payload sensors (Side Scan Sonar, camera, CTD) for execution of its operation successfully.

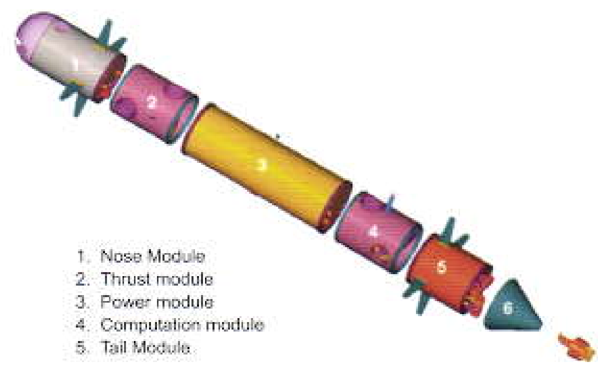


Figure 1: Exploded View of AUV

The approximate weight of the AUV final prototype including all its onboard subsystems is 490 kgf. The AUV has slight positive buoyancy (around 3kgf) including its payload to facilitate its retrieval in case of a power failure. Two arrays of fixed cross-fins at the two ends provide additional roll stabilizing moment.

The onboard intelligence based on advanced control methodology provided through preprogrammed software helps the AUV in autonomous decision-making. Hybrid communication (Radio Frequency & Acoustic) has been incorporated to communicate with the AUV for any intervention.

Initially a mock-up unit made of steel was fabricated and tested rigorously at the Shallow Basin facility at CMERI to validate various algorithms. Based on the test data the final prototype of AUV was developed and tested rigorously for evaluation of its performance at the Shallow Basin facility. Despite successfully testing the basic motions of AUV like diving and

Figure 2: AUV trial at shallow basin, CMERI

heading correction and surge errors, a full-fledged mission trial over a wider area and to a greater depth could not be undertaken owing to size constraints of the basin.

This testing was carried out at the Idukki Lake, Cochin with active support from NPOL. The AUV was made to rest on a barge fastened tightly to the boulders along the shore. A couple of overhead cranes were used for launching the AUV into the lake waters and for its retrieval. The launching point was considered to be the start position for most of the trials. External underwater cameras were used for capturing still images and video footage while the AUV went down under waters.

Testing was conducted in accordance with a test plan and checklist compiled previously. Both pre-launching and post-launching checks were committed. Trials were conducted for two categories of mission, viz. straight course-keeping and closed loop missions during diving and surface operations. During the straight course-keeping mission, the AUV had to maintain its own heading and carry out corrections in its

Figure 3: AUV on the barge at Idukki Lake, Cochin

displacement in the surge direction to reach the desired position. On the contrary, closed loop missions constituted of straight-line paths in square or trapezoidal profiles. During all such trials, the mission was carried out with the help of a pre-compiled mission file, which was stored in the memory of the onboard computational unit. Following are a few illustrations representing the trials conducted at Idukki Lake.

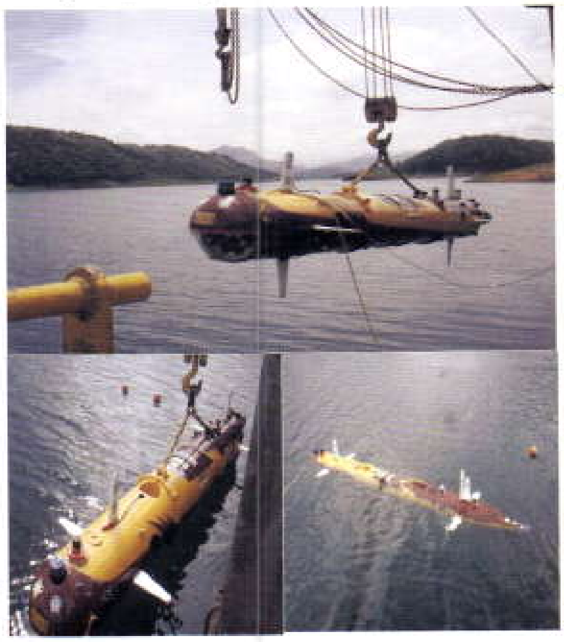


Figure 4: AUV being deployed into the Lake waters; AUV on a mission trial

Outcomes

Following are a few illustrations representing the performance of the motion controllers of the AUV during a trial for a closed loop mission.

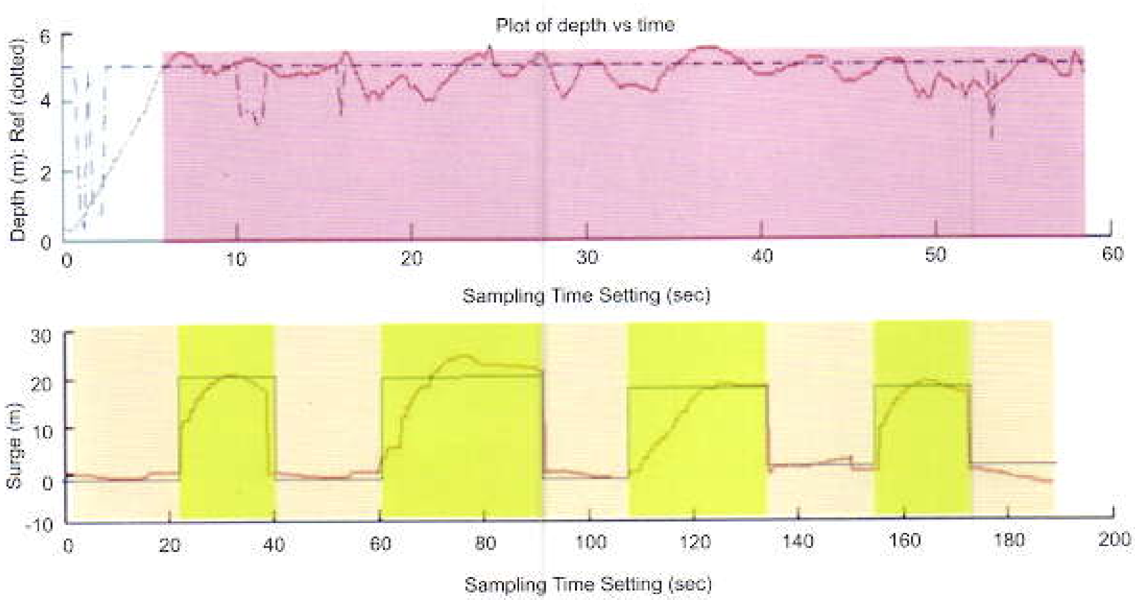


Figure 5: plot of depth vs. time (data logged during diving operation); plot of surge vs. time (data logged during underwater cruising operation)

Figures (6) (7) & (8) represent underwater images as captured by the AUV during trial missions under water.

Figures (6) & (7) : Shows the underwater rocks as captured during underwater cruising & hovering operations; Figure (8) shoal of fish encountered in deeper waters

Figure 9 : THE AUV team posing beside the system

All Terrain Mobile Robot

Background/Objectives

In general, India lacks in the state-of-the-art knowledge and proven demonstration capability for autonomous mobile robots with self navigation, exploration and intervention capabilities. Significant attempts have, however, been undertaken to bridge this chasm in order to cater to the growing need of outdoor and field robotic applications such as for port and warehouse automation, handling of hazardous chemicals and materials, defense and security services, etc. All Terrain Robots (ATR) play a significant role both in security related activities as also for the civilian sector. ATRs are generally controlled by joystick and are connected to the command console through a cable or radio frequency trans-receiver. As a result, the performance and applicability of such robots always require very high level of operational skill, which requires extensive mock-up training even before the actual deployment. This project was undertaken with the basic aim of developing necessary controls and algorithms for autonomous operation of EOD robots so as to improve their operational capability. With appropriate modification, AMRs can find substantial application in defense and field requirements.

1. Successful demonstration of ramp climbing
2. Successful demonstration of staircase climbing
3. Successful demonstration of ditch crossing
4. Decentralized data fusion of different sensor data
5. Multi Agent based control
6. Obstacle detection and subsequent reaction

Work done & discussion

The development of ATR primarily reposes on the experience gathered by CMERI in designing a remotely operated mobile robot for the nuclear sector to facilitate inspection and intervention. The All Terrain Robot being developed at CMERI is expected to have the capability of climbing up staircases, crossing a ditch, moving on sloppy land and detection of obstacles. A passive compliance mechanism has been successfully implemented in ATR for better traction. Amongst various models and theories of track-soil interaction, Janosi's formula for modeling the shearing action at the soil-wheel interface has been successfully used. Janosi's equation demonstrates that:

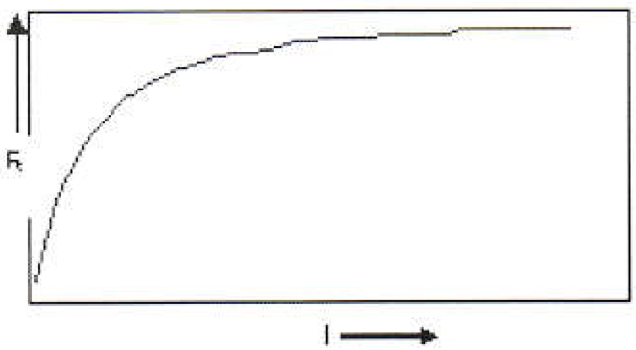
$$F_t = A\tau_{max}\{1-\frac{K}{sl}[1-\exp-(\frac{sl}{K})]\}\ \ [N] \qquad (1)$$

Where, F_t = Tractive Force; A = Ground contact area for a tracked vehicle [m^2]; l= Length of the area [m]; τ_{max} = Maximum value of the shear stress [N/m2];

$\tau_{max} = c + \mu\sigma$ (N/m2); C = Internal cohesion of the soil (N/m2);

μ=Coefficient of internal soil friction;

= Normal soil stress under a wheel; K = Shape factor of the shear diagram [m]; s = Slip



Curve for F_t Vs. l

The above expression (1) mainly depicts the relation between tractive force, ground contact area and the track length. It can be surmised from the expression that the tractive force increases with the increase in the ground contact area, or the track length, or both. It is further evident from the expression that Ft is proportional to A and it can be surmised from the graph that Ft increases with l as well as with A.

Achievements

Outdoor mobile robots for defense related applications are to be deployed mostly in rough terrains, where the robotic vehicle is expected to traverse extremely hostile and rough terrains. The ATR developed at CMERI incorporates a means for such traverse through the provision of staircase climbing capability, which is even more critical than rough terrain traverse. The following picture shows the capability of ATR for climbing stairs in an experimental setup.

A hostile and rugged terrain might also have ditches and crossing the same efficiently and smoothly throws a challenge to the mobile robotics community. The CMERI developed ATR has successfully crossed such obstacles, a trial photograph of which is depicted here:

ATR has the capability to move over an inclined plane of 15-20° slope, which will help the system to move in sloppy or hilly areas.

Figure 1: ATR climbing up a staircase

Figure 2: ATR has the capability to cross a ditch

Figure 3: Slope negotiating capability of the ATR being demonstrated

Figure 4: Demonstration of infrared sensor based obstacle avoidance capability

Like other outdoor mobile robots, the system stops automatically when an obstacle having more height than its capability, comes in the path. An indigenously developed infrared sensor detects any object that may be on its path.

Outcomes

1. Proposed Methodology for Autonomous Learning of Behaviour Based Robots", Dip N. Ray, Somajyoti Majumder, Atanu Maity; Proceedings of 22nd International Conference on "CAD/CAM Robotics and Factories of the Future, 2006", July 2006, Narosa Publishing House, Page No. 633 – 640.
2. "An All Terrain Mobile Robot with Passive Compliance", A. Maity, Dip N. Ray, S. Majumder, K. K. Mistry; Conference Proceedings of "Factory Automation, Robotics and Soft Computing", January 2007, Page 73-78.
3. "ATR X-50: Development of an All Terrain Robot", D. N. Ray, A. Maity, S. Majumder, K. K. Mistry, Proceedings of 23rd International Conference on "CAD/CAM Robotics and Factories of the Future, 2007", Bogota, Colombia, South America, August, 2007, Page 161- 166.
4. "Comparison of performance of different traction systems for Terranean Robots", Dip N. Ray, A. Maity and S. Majumder, In National Conference Machine & Mechanisms (NaCoMM-09), NIT, Durgapur, December 17 -18, 2009, Page: 151 – 158.

New initiatives planned, if any

The next phase of the project would attempt design and development of a compact, light-weight ATR along with an indigenous metal detector for surveillance & explosive handling.

Experimental Subterranean Robot (SR) for feasibility study of robotic application in underground coal mines

Background/Objectives

Flooding in active mines, roof collapse and explosions are the major causes for accidents leading to death and injury of miners. The Mines Act holds the owner, agent and manager of a coalmine accountable for enforcing safety in the mines. For example, Regulation 41 deems it mandatory to ensure safety that the manager of every mine visits and examines workings below ground for at least four days in a week. This task is time and manpower intensive, and considering the crunch in manpower now being experienced at every coal subsidiary, there is both a necessity and a scope for mechanizing the routine inspections through the deployment of appropriately designed robots armed with proper sensors and communication capability. A remotely operated mobile robotic vehicle can therefore be a very useful tool for safer and efficient operation of underground coalmines in India.

The mission demand on such robotic vehicles would, however, be quite rigorous as:

a. The vehicle would require negotiating and exploring long waterlogged underground and should be capable of transmitting back send valuable information through acoustic communication network created across the galleries, and
b. In a post disaster scenario, the system should be capable of locating trapped miners and relay information back to the control station using acoustic telemetry link to organize a quick and well-directed rescue mission.

An important aspect, which makes this project particularly challenging is the fact that system development requires assimilation of knowledge from a number of engineering disciplines. These include mechanical design, underwater robotics, sensor & signal processing, mobile robot design & system architecture, short-range data communication (particularly acoustic communication), networking & remote control, etc. Also there is no off-the-shelf system or solution that can be readily acquired and deployed in water logged coalmines of India. It is felt that the time-tested – *design, experiment and learn* – approach is perhaps the most appropriate in this case. Once successful, this system has a huge potential for widespread deployment in various mine related activities, including environment monitoring, automatic mapping, etc.

The proposed feasibility study project aims at the following:

1. To study underwater acoustic communication across a few galleries.
2. To develop an experimental robot vehicle for deployment of the equipment & study
3. To test the concept in a simulated environment created at CMERI.
4. Limited field trial of the system in suitable coal mines.

Figure 1: Shallow Basin of CMERI, Durgapur for carrying Limited Field Trial of SR

Figure 2: SR during Limited Field Trial after deploying it by the electrical hoist

Work done & discussion

Testing at Simulated Environment

On the basis of the data obtained by CMERI scientists through mine visits, a simulated test set-up was prepared at shallow basin of CMERI, Durgapur. A water tank (50 meter X 10 meter) was partially filled with water so as to obtain a depth of 5m. For easy deployment of the system, an electrical hoist was installed at one of the larger sides of the rectangular test tank. The system can be controlled from the base station using an RF modem that is kept on the bank. The main system communicates with the surface control station using RF communication. During testing at the simulated test set-up (Figures 1 & 2) interference was experienced in acoustic communication due to reflection and reverberation in the regular shaped tank. To overcome this problem the communication mode of SR was upgraded from acoustic to RF.

Field Testing at Damodar River

Incorporating the suggested modifications after the limited field trial at the Shallow Basin facility of CMERI, the Subterranean Robot (SR) was taken to nearby Damodar River for field testing. After several suitability of the system, field testing was performed for two days. This testing helped the project team in taking decisions regarding the necessary changes to be introduced to the SR.

Figure 3: SR moving to deep water communicating with the Command Station

Figure 4: SR moving in deep water with thrusters

Field Testing at Drift – 13 & 3 of Satgram Project of ECL

Before the field testing of SR at an underground coal mine several mock-ups of wheeled configuration were tested in the laboratory as the used wheel-roller-tracked belt configuration caused difficulty in moving over loose sand. Apart from the existing wheel-roller-tracked belt configuration, two other configurations were tried out, the first among which was the wheel-ski-tracked belt configuration utilizing the concept of skating over the ice; the other was a simple configuration using large wheels.

Field testing of SR at underground coal mine of ECL consisted of two parts: 1) dry run in the tunnel 2) performance in the tunnel water. The command station was set up with one laptop computer and a RF adapter. A battery pack (24V) was used for power supply. The testing was done in two phases: 1) in Drift-13 and 2) Drift-3. Some snapshots during the trials have been shown in Figures 5-8.

Figure 5: SR on way to test site

Figure 6: SR at a site near Drift -13

Figure 7: SR moving to deep water communicating with the Command Station

Figure 8: SR moving in deep water with thrusters

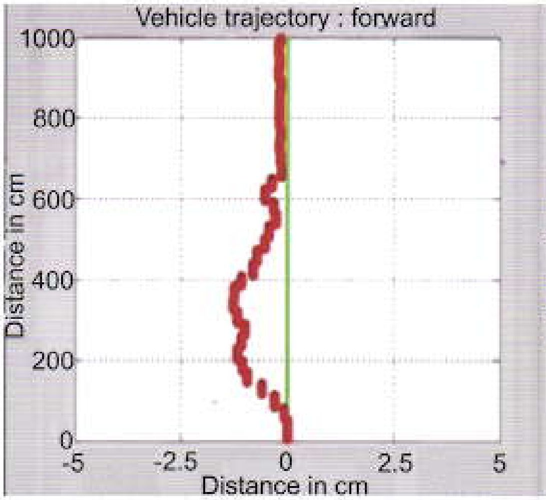


Figure 9: Forward Trajectory of SR

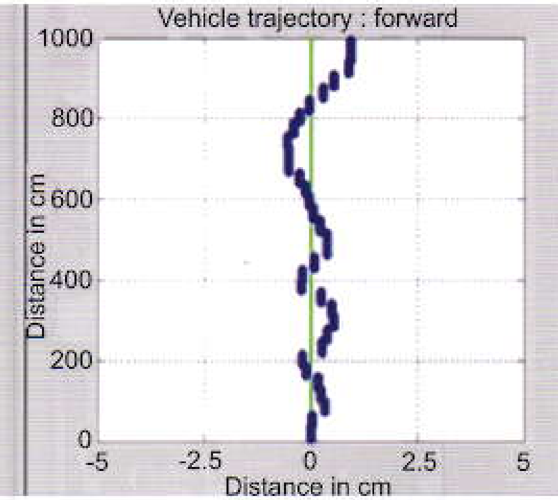


Figure 10: Reverse Trajectory of SR

Various data obtained during the field trials were logged on to the on-board system and downloaded later. After post-processing the motor data for forward and reverse motions were plotted against the traverse, as is depicted in the following two graphs:

Data of tunnel scan obtained during the test at the underground coal mines (Drift-3 at Satgram Project Under ECL) with preset range for up to 5 meter exhibited a clear view of the tunnel after complete scan.

Outcomes

- "Sub-terranean Robot: A Challenge for Indian Coal Mines", Dip N. Ray, R. Dalui, A. Maity & S. Majumder, World Congress on Electrical & Electronics Engineering 2009, Cairo, Egypt, April, 2009
- Copyrights: 2 Nos.

New Initiatives, Planned if any

Primary investigations and the experience of the test results suggest that two separate modules/units, one each for waterlogged tunnels and dry tunnels would be more helpful for system design. The unit meant for moving in tunnel water should have thrusters only for movement and the unit meant for the dry tunnel would be using motors only. This will make

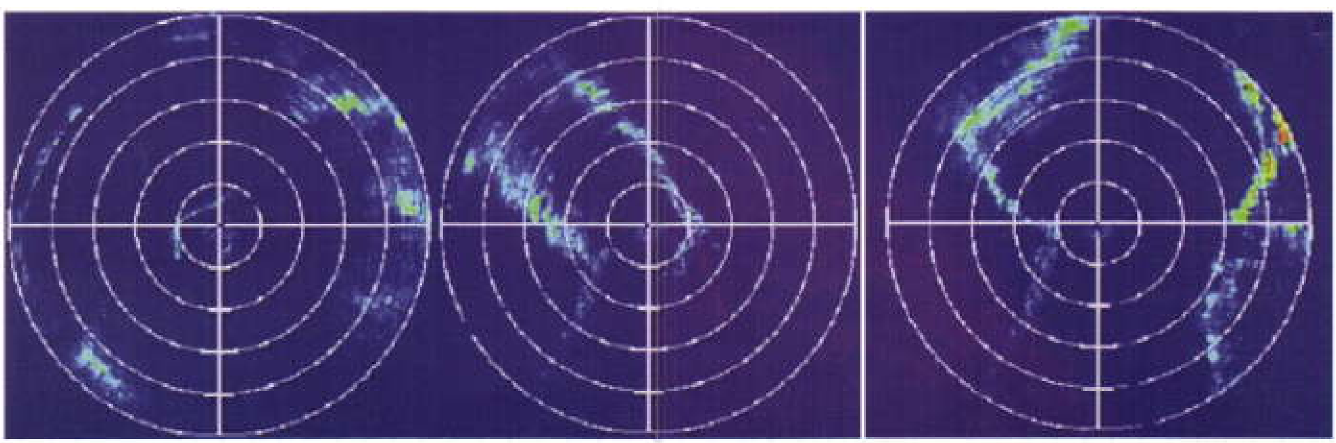


Figure 11(a): Forward Tunnel Scan at Drift -13 showing the existence of an underwater pipe (in centre circle region) and blocked wall of the tunnel at far end

Figure 11 (b): Forward Tunnel Scan showing clear view of the tunnel at Drift -3

Figure 11 (c): Entrance Tunnel Scan showing the walls of the tunnel at Drift -3 both the systems compact and with larger endurance time. Work is in progress for developing a new model of SR in accordance to these findings.

Teleoperated Flying Robot with Autonomous Hovering

Background/Objectives

In recent times, CMERI has ventured into the field of aerial robots which expectedly has opened up a plethora of new possibilities. Flying robots are used primarily for carrying out tasks such as inspection of bridges, aerial survey, observation and mapping, which are not achievable by other type of mobile robots. CMERI initially concentrated 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 behavior of flying robot by stabilizing the non-linear dynamics, with focus 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 different sensors mounted on the flying robot was attempted. Specific sensors used include INS, GPS, compass, altimeter, etc. for state estimation, control and navigation.

Work done & discussion

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 a CrossBow NAV420CA, XSens Mti-G INS with integrated GPS, KVH C-100 compass and this was mounted on a test rig with bending flexibility along all axes. A SICK Laser was mounted for altitude mapping along with a thermal vision FLIR camera for navigation in poor visibility conditions.

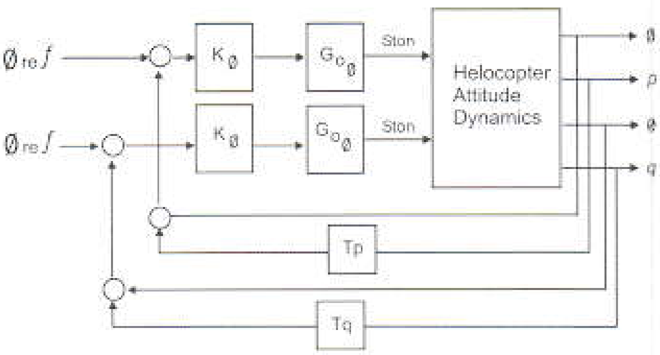
The first task comprised interfacing kinematic and navigational sensors to the system with hybrid communication protocols i.e. RS-232 based serial communication with INS sensors and compass and TCP/IP based communication for SICK laser and thermal vision camera.

Next task consisted of interfacing PC-104+ based high speed digital I/O card with programmable clocks and incremental encoders for controlling each degree of freedom of the aerial robot for controlling throttle/pitch, aileron, elevator and rudder digital servos using PWM based actuation.

Rotorcraft Bergen Turbine Observer on a test rig for experimental data collection

The qualitative behavior 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, it entails dozens of unknown physical parameters that need to be determined. These include, among others, mass and moments of inertia of fuselage and rotor components aerodynamic parameters such as the blade and stabilizer bar lift curve slope and fuselage drag coefficients.

Owing to the limited accuracy of non-linear dynamic model, the model tends towards instability. To address the problem of 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. As the model was strapped to the test rig, the first task was to control the attitude of RWFR simulating a hover condition. 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

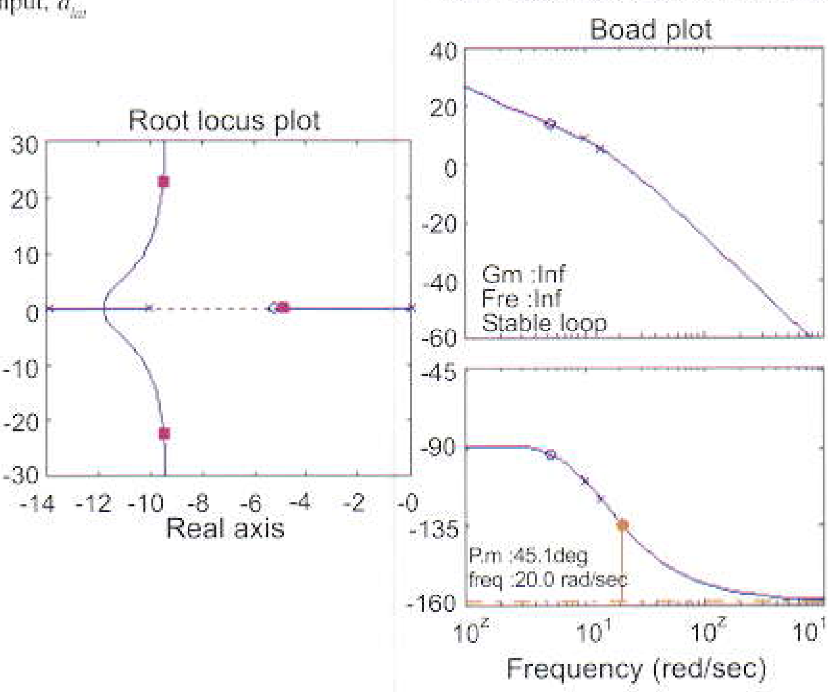
$x = [u, v, w, p, q, r, \phi, \theta, \psi]$

and perturbative input control vector is given as

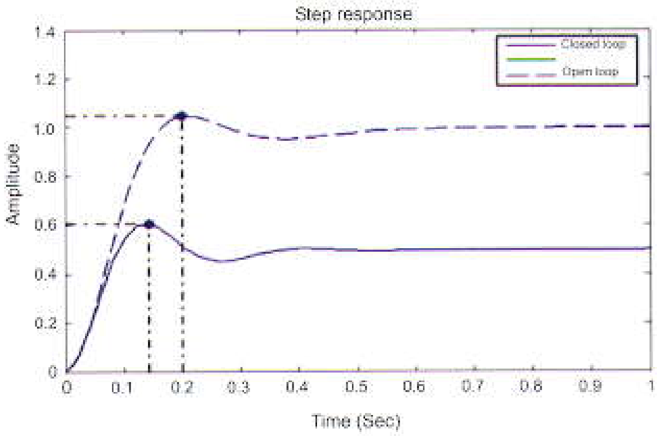
$u = [d_{lat}, d_{lon}, d_{ped}, d_{col}]$

such that in reduced state space model for SISO structure

$Ge_\phi = C_\phi [\, sI - A \,] \text{-}1\, B_{lat}$ and $Ge_\theta = C_\theta [\, sI - A \,] \text{-}1\, B_{lon}$ where - I is the unity matrix, -C_ϕ 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

Outcomes

1. S. Datta, U.S. Patkar, S.Majumder, "Digital Controller for Attitude Control of a Rotary-Winged Flying Robot in Hover", IEEE International Symposium on Industrial Electronics, ISIE 2009.
2. A. Mishra, U.S. Patkar, S. Datta, S. Majumder, "Computational Design of a Rotating Blade of a Tele-Operated Aerial Robot (TOAR)", 22nd National Convention of Aerospace Engineers and National Seminar on Present Status and Technological Challenges of Indian Aerospace Programme, BIT Mesra, Nov. 27-29, 2008.

Design and Development of Vision Guided Mobile Robotic System for Handling Hazardous materials

Background/Objectives

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 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 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) feature 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 taking 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 future operations are performed on image data that has 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 for 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 finding 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 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 sensors readings are used to determine regions where the obstacles are anticipated. The grid locations, near obstacles increased their probability values than 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 done & discussion

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 CMERI dispenses with sonar range sensor and uses a laser counterpart as its primary spatial sensors in order to increase on the accuracy level.

Figure 1: Prototype of Vision guided Robotic System

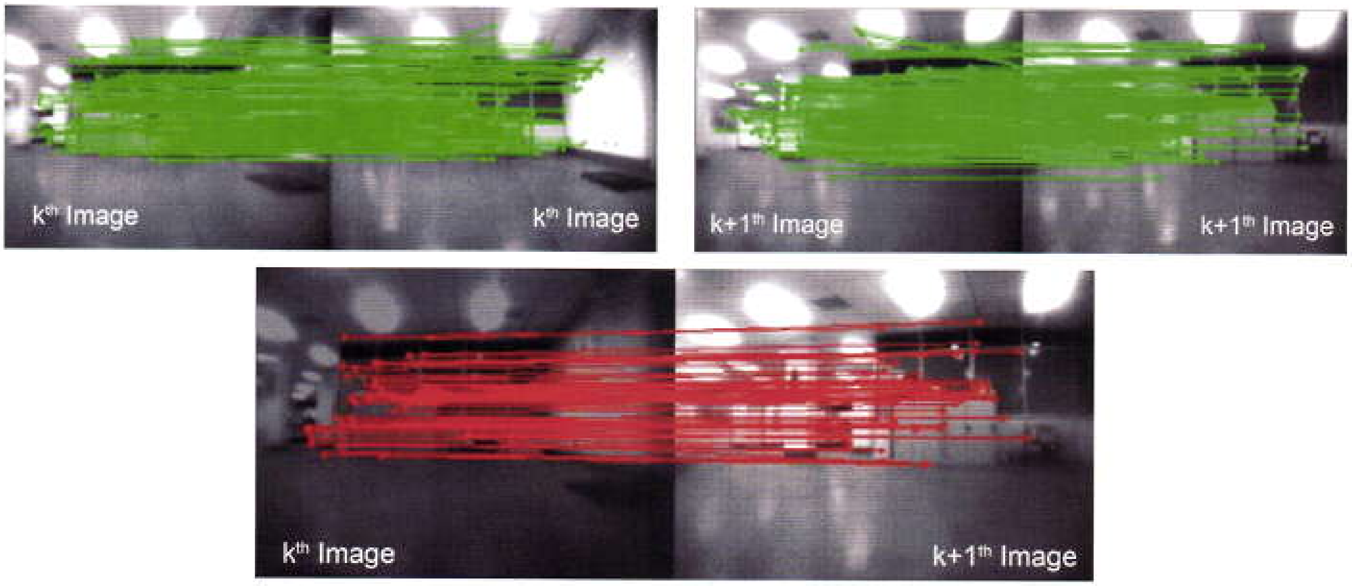


Figure 2: Data association

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 of different features. These are viewed as following:

Map Based Self Localization of Mobile Robot Using Scan Correlation Technique

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 angle 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 250mm 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 a-priori map.

Figure 3: Real environment for conducting the test

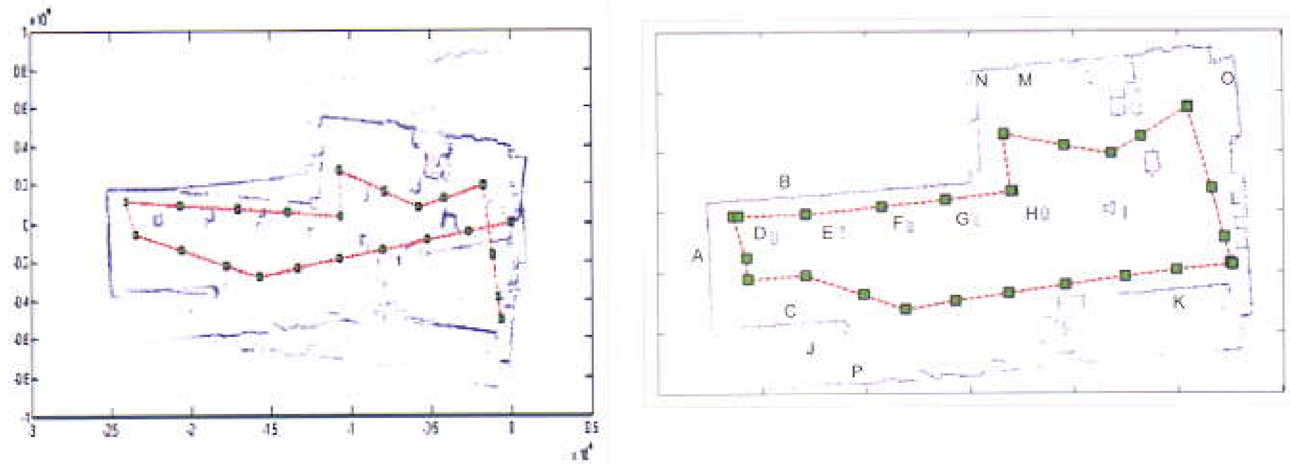


Figure 4: Generation of (i) global map with odometry error and (ii) global map after eliminating the errors

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 got 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 we cannot proceed with this erroneous result. To rectify it, an algorithm has been devolved.

MICRO SYSTEMS TECHNOLOGY

Programme Leader
Dr. Nagahanumaiah

Area Leaders
Ms. Shilpa
B. Ravi

TRIBOLOGY

Programme Leader
N.C. Murmu

Area Leader
Sampath Kumar

The nomenclatures of **Micro Systems Technology** (MST), **Micromachines** and **Microelectromechanical Systems** (MEMS) are used interchangeably in different parts of the world. While MST is more popular in Europe, Japan prefers using Micromachines, and both repose broadly on MEMS. Micro Systems Technology is basically associated with the technology of very small parts, actuators, devices and other MEMS, and at the nano-range this merges seamlessly into nanoelectromechanical systems (NEMS) and nanotechnology.

MST, however, is distinguished from molecular nanotechnology or molecular electronics in that such systems comprise components ranging typically between 0.001 to 0.1 mm in size, while the corresponding devices generally range in size from 20 micrometres to a millimetre. These devices generally consist of a data processing unit and microprocessors and components that communicate with the outside world by means of microsensors. MEMS can now be fabricated using molding and plating, wet etching, dry etching, electro discharge machining (EDM), and other technologies capable of manufacturing very small devices.

Microsystems Development

Background/Objectives

The research program on Micro System Technologies (MST) was initiated in CMERI in 2006, with the primary focus on understanding the manufacturing science in micro-nano scales, and engineering the systems having dimensions in 1 - 500μm scale. The fact that emerging multi-material micro-nano systems technologies are perceived to bring about a total paradigm shift in the ways the people and systems interact has enabled MST to make significant inroads in many sectors including bio-medicine, electronics, process control, space and automotives. Researchers at MST laboratory at CMERI are striving towards developing multidisciplinary scientific knowledge and are working on technologies integrating mechanical and electronic, computational, chemical, optical and biological elements. The broad research objectives of this group include:

- Building capability in fundamental of micro-nano systems engineering including mechanics, heat transfer, fluidics, electronics, chemistry, optics and energy conversion and storage techniques
- Developing a thorough understanding of multi-material micro-manufacturing science
- Development of integrated micro machines, systems and devices
- Training manpower, and providing technical support to researchers in related areas.

The MST laboratory at CMERI is equipped with state of the art micro machining facilities and characterization and testing instrumentation. Micro machining facilities include: Micro-

EDM milling machine, Multipurpose micro machine and Nano second pulsed Nd-YAG laser system. Characterization and testing instruments include Optical microscope, Laser scanning micrometer, Image Analyzer, Mini dynamometer and data acquisition systems.

Micro EDM Milling Machine

The current micro machining capabilities include:

- Micro milling of 3D features
  - Channels: >100μm, holes: >150 μm diameter in 1mm
  - Material: Metals, polymers, green ceramics, metallic glass
- Micro EDM-milling of 3D features
  - Channels and holes : 20μm on Copper, 50μm on aluminum
- Pulsed Laser Ablation
  - 2D features of any geometry > 100μm aspect ratio up to 100.

Work done & discussion

The major work of micro system technologies was carried out as a part of a network project entitled **Modular Reconfigurable**

Multipurpose Micro Machine

Nd-YAG nano second pulsed laser

Multi Material Micro Manufacturing Systems supported by the Planning Commission during the 11th. Five Year Plan. CEERI Pilani, CSIO Chandigarh and NAL, Bangalore were the other networking partners. Within CMERI, the MST Laboratory, the Tribology Group, the Chemistry & Biomimetic Laboratory and the Micro Robotics laboratory collaborated for capability development.

Research attention was focused on the following:

- Micro-EDM-Milling
  - Optical emission spectroscopy of plasma
  - Micro-EDM debris analysis
  - Electro-thermal modeling
  - Parallel spark multi-tool micro-EDM
- Laser Processing
  - Laser ablation in meso-micro-nano scale

- Sintering of <10 μm copper powder
- Direct metal laser deposition

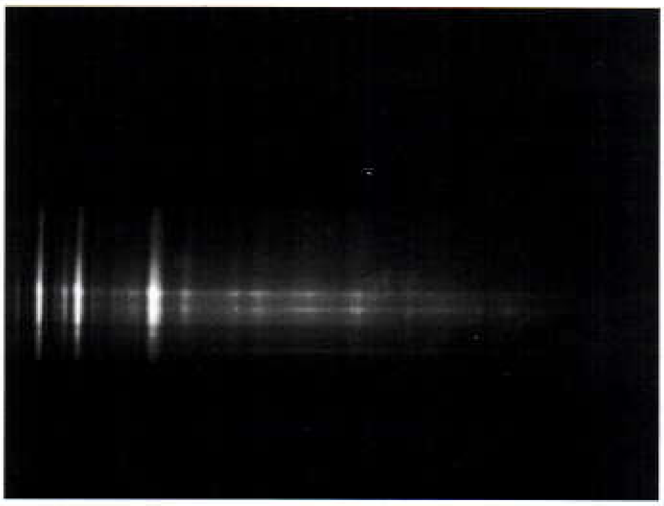
- Micro Injection Molding
  - Development of micro-molding experimental set-up
  - Micro mold design and non-conventional mold materials

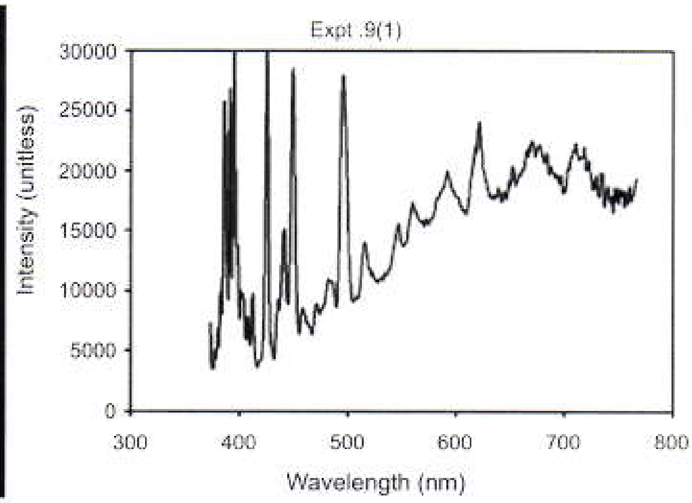
- Micro Factory Concept
  - Development of demonstration test bed of micro-factory with footprint area of 1 m x 1m

- Non-conventional Fabrication Methods for Micro Channels
  - Fabrication of braided micro channels on PDMS

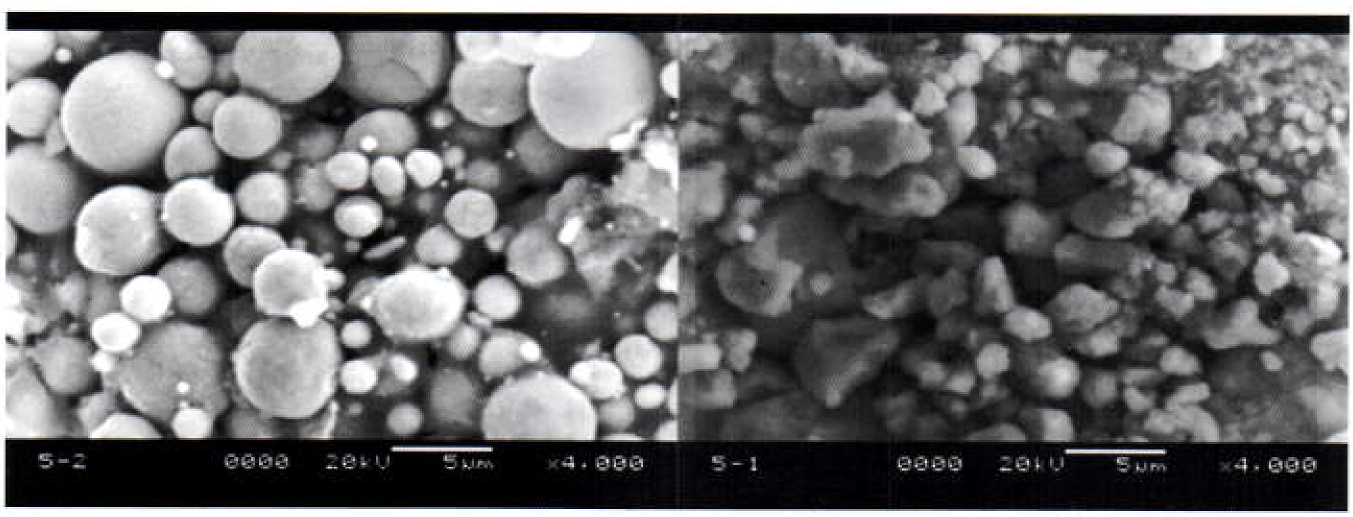
- Micro Devices and Systems
  - Preparation of monodisperse non-spherical micro gel particles in braided fluidic channels
  - Smooth membraneless micro fuel cell
  - Selective Metallization of PDMS polymer

The following images represent the glimpse of research findings obtained from some of the above listed investigations:





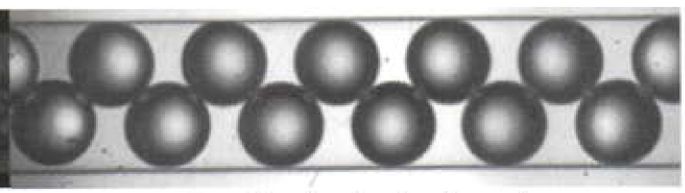
Optical emission spectroscopy of plasma



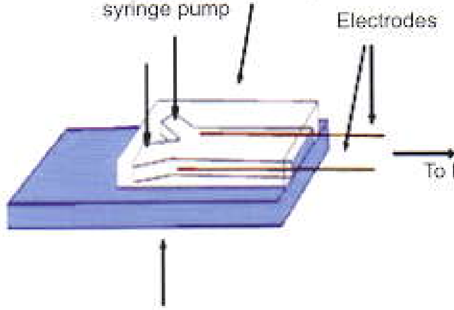
Material removal mechanism in μ-EDM

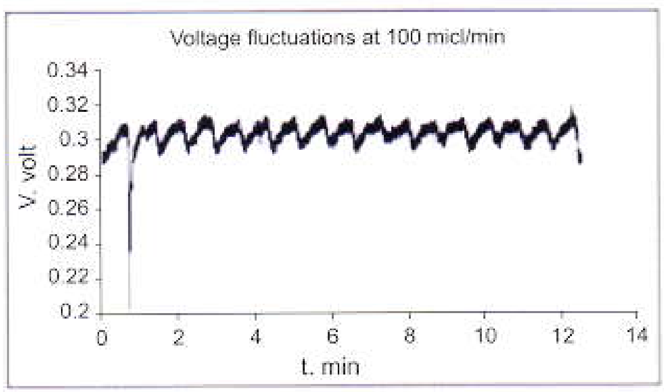
Low pressure micro-injection molding

Emulsions in briaded channel



Emulsions in circular channel





Membrane less micro fuel cell and its pulsed voltage signal

Figure 1: Micro-EDM machine set up demonstration

Micro Machine Prototypes

Micro Electric Discharge Machining (μ-EDM) Machine: This μ-EDM machine test bed developed at CMERI consists of three linear precision positioning stages with travel resolution of 0.1μm and travel length of 150mm. These are mounted to have programmed movements in X, Y and Z axes. A RC circuit based pulse generator has been integrated for low energy discharge power supply. The discharge voltages and currents have been measured using digital oscilloscope. The hardware was interfaced in a synchronized manner and controlled through LabView. The approach and retraction movement of an electrode with respect to the work piece were programmed. The discharge voltage was continuously monitored to compensate electrode and work piece wear resulting from material removal, so that a constant spark gap could be maintained during successive discharges. Figure 1 shows the first generation prototype developed currently and this is being upgraded to incorporate micro milling features, so that systems can be used as a multipurpose micro machine.

Micro Injection Molding System: CMERI is involved in the development of low pressure injection molding system for micro-scale plastic and re-crystalline wax parts. CMERI has previously successfully demonstrated the process of micro-moulding through the experimental μ-injection molding setup developed at CMERI. This injection system employs a miniaturized screw barrel injection as is common in macro size molding machines, the screw injects the polymer melt inside the mold cavity with the help of pneumatic actuation. Figure 2 shows the current micro injection molding setup along with a few sample wax parts which have been produced using the setup.

The injection mold is made in various soft materials including non-metallic materials by micro-milling. Currently, the team has successfully demonstrated injection molding of re-crystalline wax, where the minimum controllable shot capacity was 0.5mg. However, for thermoplastics, technical issues related to the control of the shear rate needs to be addressed through interfacing intelligent control system. The current prototype is deficient on that count.

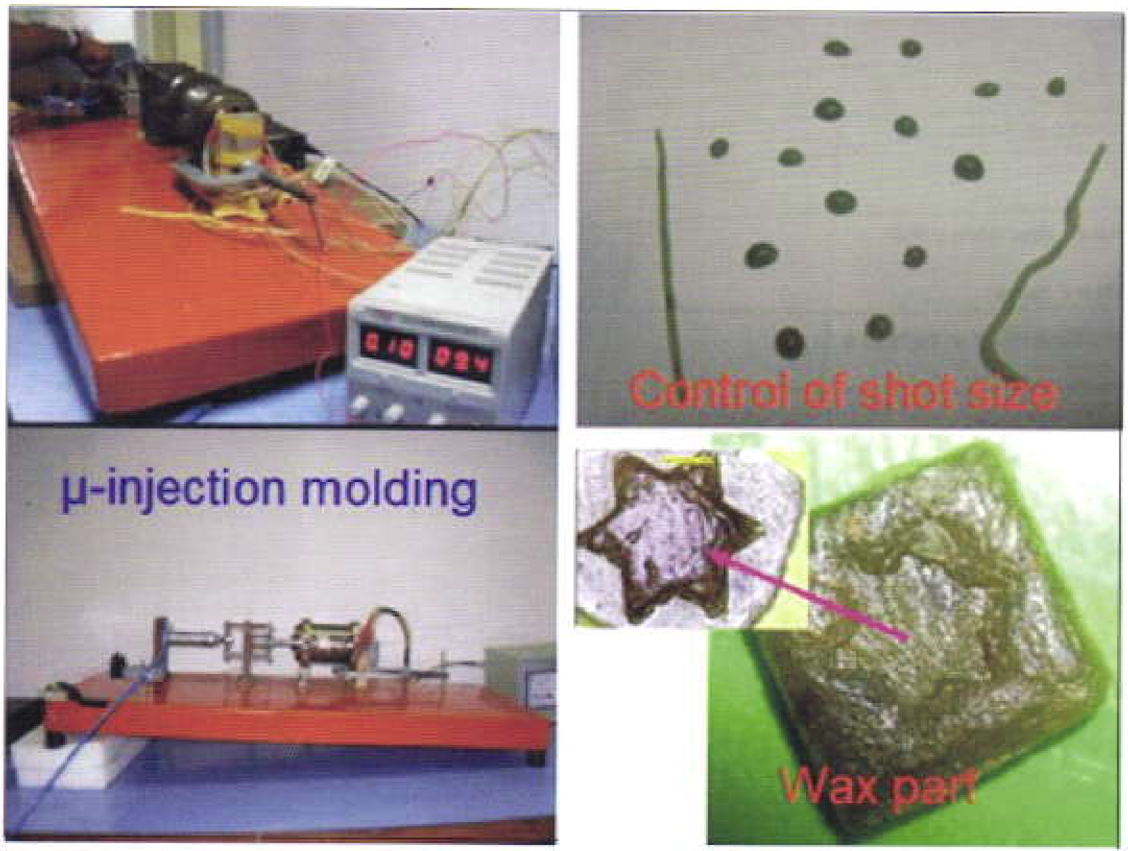


Figure 2: Micro injection molding setup with sample components

machines, barring the low pressure system. The screw is 14 mm in diameter and barrel is 20mm in diameter. A combination of cartridge and band heaters operated by thyristor controllers is used to melt the polymer. The cartridge heaters are mounted inside the holes machined in the barrel and the band heater is wrapped around the barrel. The slow speed screw imparts shearing action required for homogeneous polymerization. The screw has an 18° helix angle. Like in conventional macro size

New Initiatives planned

- A proposal has been submitted to the CSIR for adoption under the NMITLI Programme on design and development of **Fiber Bragg grating based sensor for micro tools health monitoring systems** in collaboration jointly with the Indian Institute of Science, Bangalore and Instrumentation Scientific Technologies Pvt. Ltd.

- A project proposal has been submitted to the Indo-European Call on Solar Energy Systems for undertaking research activities on **Advanced grating for thin films solar cells.**

Development of Five-Axis µ-Milling Machine Tools

Background/Objectives

The rising demand of miniaturised components having higher precision in the field of automotive, aerospace, bio-medical, electronics, environmental, communications etc is drawing attention from reseacrhers worldwide in micro-manfuacturing. Micro channels for lab-on-chips shape memory alloy stents, fludic graphite channels for fuel cell application, sub-miniature actuators and sensors and medical devices are examples of miniaturised components which are promising health care, quality life and economic growth. Numerous researchers have investigated the feasibility of using other fabrication processes such as laser, ultrasonic, ion-beam, EDM, etc. to manufacture comemrically viable micro components. However, majority of these techniques are slow and limited to planner geometries. The broad spectrum of commericailzation of microsystems is inihibited by low productivity and by the inability to manufacture in small batch sizes cost effectively.

Micro machining is suitable for manufacturing a variety of shapes from different materials. In recent times there has been great interest in manufacruring of micro scale components through micro maching process. Parts of the size of 500ìm with holes 125 ìm in diameter and wall thickness of 25-50 ìm are now commonplace. Such components are currently being manufactured on large, ultra-precision machine tools. In general, such manufacturing is taking place using conventionally-sized, specially-fitted ultraprecision machine tools. Given the part size and the cutting forces present during micro-machining, using large machine tools results in inefficient utilization of resources in terms of floor space, energy requirement, and cost. These ultraprecision machines further require expensive and specialized design features to achieve the desired levels of accuracy.

Presence of considerable error in ultra-precision conventional machine tools and the possibility of design simplification for meeting accuracy requirements are leading towards the design and development of function-specific, small and less expensive machine tools. For example, the shorter Abbe, the lesser are amplification of angular errors. This allows the use of components with less stringent geometric tolerances in case of micro-scale machine tools, and, therefore, result in less expensive components. Smaller moving masses mean less inertial effects and less energy required to move the machine components. Less input energy also results in lesser heat dissipation which in its turn results in smaller thermal distortions of the machine structure and this in turn leads simplification of heat dissipators for transporting heat away from critical components. With this objective in mind, an attempt was made to design a five axis micro milling machine that is capable of achieving significantly higher cutting speeds and producing three-dimensional features in metals with higher precision.

Work done & discussion

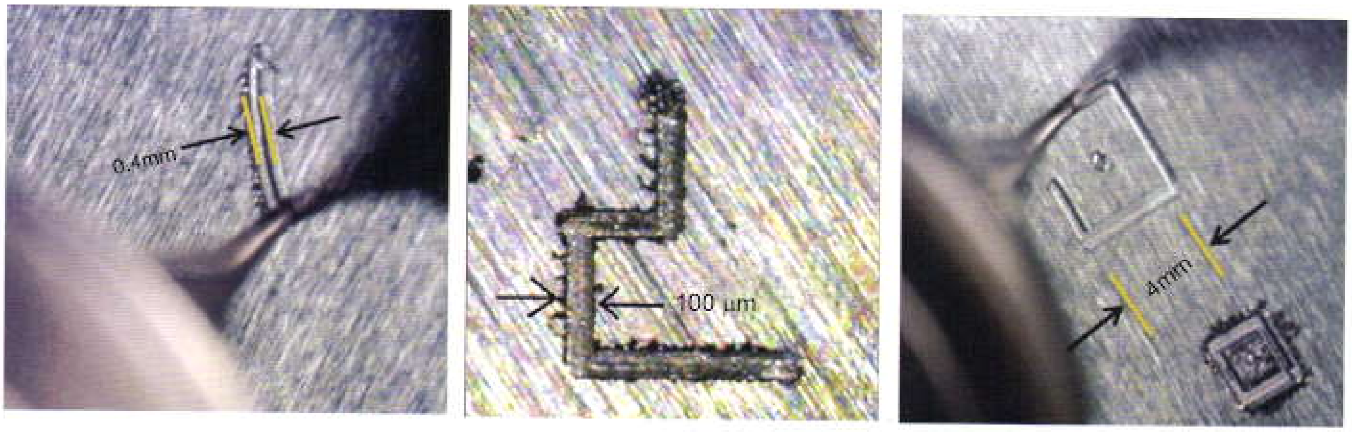
CMERI has developed "***µCNCmill***" - a five axis micro-milling machine of gantry configuration which is useful for efficient, cost effective and high resolution micro-scale milling and drilling operations for small parts of complex three dimensional geometries. Two rotary axes eliminate the error caused by re-clamping and assists in machining of cylindrical shapes without X and Y-axis interpolation that goes on to afford precise and easy machining. Finally, it helps improving materials removal rate and surface finish.

3D CAD Model

µCNCmill at CMERI

Micro-miilling machine

The developed ***μCNCmill*** – has travel volume of 20 mm × 20 mm × 30 mm, linear resolution of about 50 nm, rotational axis resolution of about 0.002° and the spindle speed exceeds 80,000 rpm. The machine has been extensively tested for machining of steel and Al-Alloy. Tests are being conducted for Titanium Alloy, INCONEL and other hard materials.



In-situ microscopic image of micro-cutting of steel using f100 μm and f400 μm

MATERIALS & PROCESSES

Programme Leaders
Dr. B.N. Mandal
Dr. D. Chatterjee
A.K. Chowdhury
S.K. Samanta

Area Leaders
Dr. Biswarup Satpati
Mr. Nilrudra Mandal
Dr. Sujit Kumar Ghosh
Ms. Shrabani Mahata
Mrs. Kasinadhuni Usha
Aditya Lohar

Materials science basically reposes on characterizing the atomic structure and phases in a particular material in relation its desired properties and relative performance for a specific application. Chemical elements constituting a particular material and the manner of processing into its final form determinants the structure of a material and also its properties. The characteristics, taken together and related through the laws of thermodynamics, govern the microstructure and the properties of a material.

Research for the development of new materials and processes are being continually undertaken, and with the advent of nanosciences, the prospects appear to be truly phenomenal. CMERI, which always had a component of R&D directed towards materials and process development, has further broadened its scope to embrace newer ventures. This section relates to some of the activities being undertaken at the Institute.

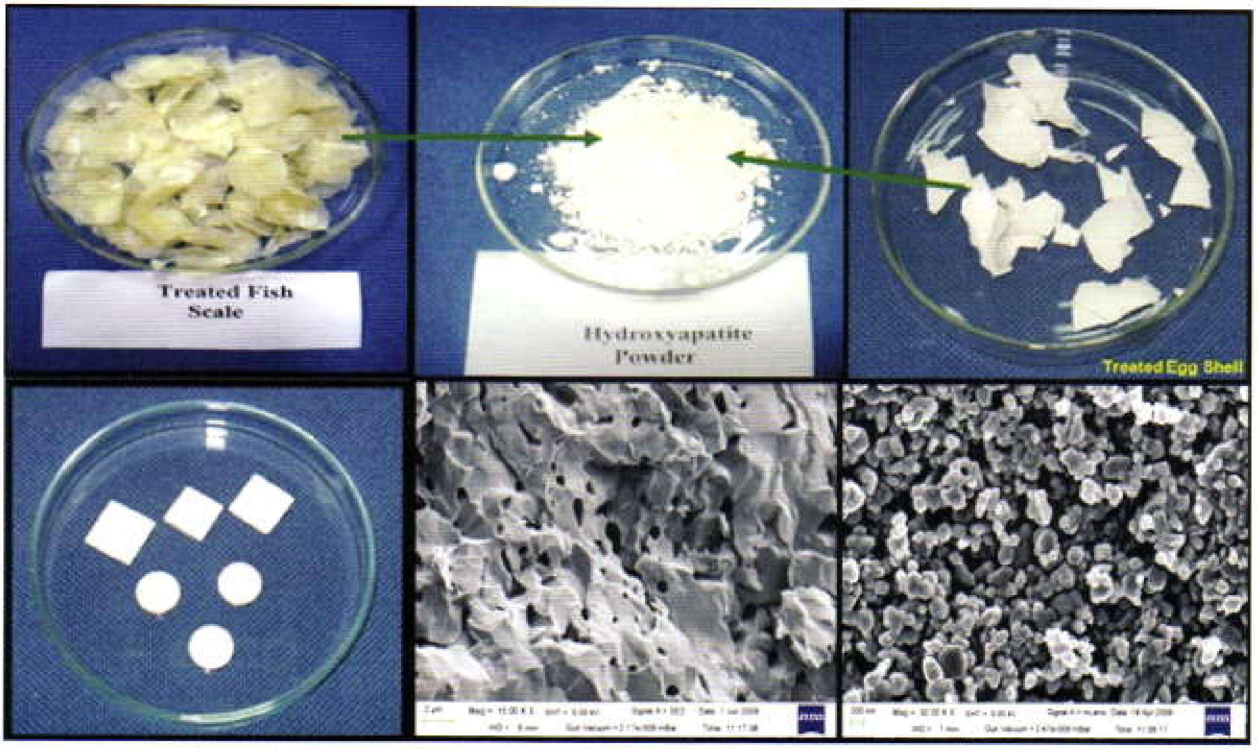
Tissue Engineering Scaffold: Nanomaterials & Process Development

Background/Objectives

The prime objective of the programme is developing suitable biodegradable and biocompatible porous scaffolds for tissue engineering applications. Monolithic or composite scaffolds may be developed by attempting several techniques like rapid prototyping gel casting or combining the gel casting and polymer sponge techniques. There are plans for study of scaffold seeding techniques to realize the concept design and formulation of surface/sub surfaces, with a view to ascertaining and analyzing the behavior of tissue engineering with porous architecture. The project further targets attainment of sufficient mechanical properties before applying the techniques for bone tissue engineering. In vitro investigation on proliferated cells in the designed scaffold materials like TCP/HA, TiO_2, ZrO_2/HA would also be carried out as part of the project.

Work done & discussion

- Hydroxyapatite Nano materials were synthesized from different natural sources like fish scale, egg shell, etc.
- TiO_2 powders were synthesized from different precursors through hydrolysis / precipitation method.
- Nano powders were characterized through X-ray diffraction, Zeta sizer, Thermal analyzer and SEM- EDAX & TEM analysis.
- Study of shape formation of porous biocompatible materials through non-toxic gel casting technique using natural binders like Moringa, Boiling rice extract, etc. is under way.



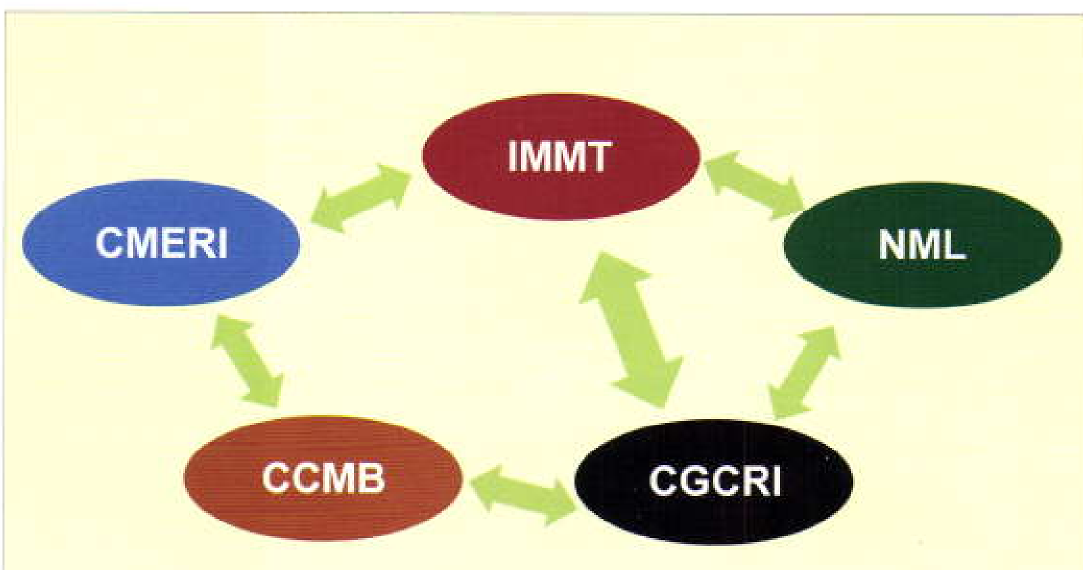
- Condition of slurry preparation with different solid loading and rheological study to optimize suitable shape formation for the production of gel-casting scaffolds is being carried out.

Outcomes

Two papers emanating from the investigations were published in peer reviewed journals, and two conference papers were presented.

New initiatives planned

Further studies would be undertaken for implementation of scaffolds. Interfacial study for in-vivo and in-vitro application would also be undertaken through networking of the CSIR labs involved in tissue scaffold development.



Development of Dye-sensitized Solar Cell and Nano Composite Cutting Tool for High Speed Machining

Background/Objectives

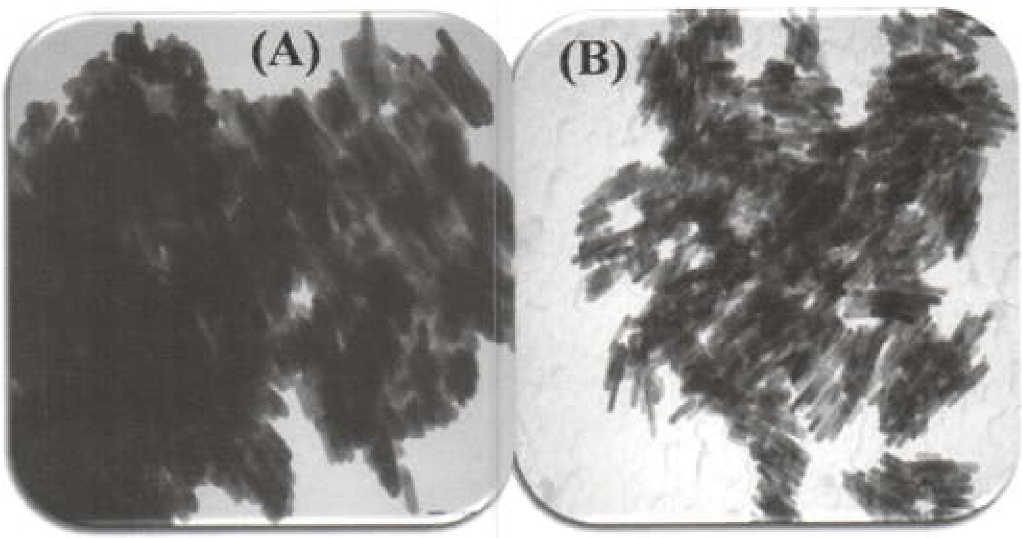
The increasing global demand for energy is spurring the search for environmentally clean and alternative energy resources. The process of photosensitization utilizing the sub-band-gap excitations of semiconductors with dyes that mimic the photosynthetic process has recently attracted academic and industrial interest as regenerative low-cost alternatives to conventional solid state devices. Utilization of the unique physicochemical properties of tailored nanostructures in organic-inorganic hybrid assemblies and modulating their properties in thin-films has enabled the design of high efficiency and economically viable light-energy conversion devices. In this context, CMERI has taken up the task of developing dye-sensitized solar cells under this CSIR Network Project.

Development of new and advanced materials is rapidly changing the manufacturing scenario around the world. Modern Ceramic tools with their remarkable advanced properties and versatile performance are gradually replacing carbide and coated carbide tools, particularly for machining of carbon steel, cast iron and heat-resistant alloys. Hard turning with ceramic cutting tools offers several benefits in the process of grinding by eliminating the necessity for coolants, reducing the processing costs, improving material properties, reducing power consumption and increasing productivity. Zirconia Toughened Alumina (ZTA) Ceramic cutting tool is a recent addition in the era of high performance ceramics, which requires evaluation of the machining parameters for optimization, and this is being addressed through this project.

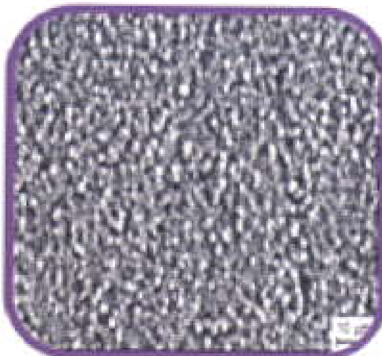
Work done & discussion

Initially the synthesis of mesoporous TiO_2 and ZnO nanorods in the multigram scale enabling the proper modulation of ∂-conjugated photosensitizing dyes is being attempted to fabricate device architectures and measure the efficiency of the solar cells with impedance spectroscopy. Following this, suitable doping techniques with appropriate metals and non-metals will be adopted for the band gap of the semiconductor nanocomposites in the visible region. Finally, ligand modification of a series of light-harvesting ∂-conjugated dyes using supramolecular approach will be undertaken to suppress the interfacial charge recombination and improve the cross-section for light absorption.

The enhanced strength, transverse rupture strength (TRS) and toughness makes ZTAs more widely applicable and renders them more productive than plain ceramics in machining of steels and cast iron. Martensitic transformation of partially stabilized yttria and ceria doped Zirconia in á-Alumina under matrices induces intensive compressive stress ahead of the crack tip resulting in high toughness. The project aimed at development and analysis of the machinability of this non-conventional cutting tool. Also modeled was the stochastic nature of the cutting force and tool-life using FEA & soft computing techniques. The different parameters which affect the life were also optimized to obtain the minimum tool failure and ensure maximum tool life.



Transmission electron microscopic images of (A) TiO_2 and (B) ZnO nanorods



Outcomes

- ➢ Both TiO_2 and ZnO nanorods have been synthesized in the multigram scale
- ➢ Some ∂-conjugated dyes have been modified which grafts satisfactorily to the nanoparticle surface
- ➢ Characterization of nanocomposite cutting tool has been ubdertaken
- ➢ Mathematical Modeling of Tool Life & Force Model is under progress

New initiatives planned

- Electric field induced alignment of dye-semiconductor composites would be tried out at the laboratory scale
- Efficiency of solar cells developed through the project would be measured with impedance spectroscopy
- A proposal entitled **Tool Life and Cutting Force Modeling of Advanced Ceramic Cutting Tool using Finite Element Analysis & Soft Computing Techniques** has been submitted recently to the Department of Science & Technology, Government of India, with SANDVIK Asia as the Industrial partner.

Platinization of Nafion towards the development of Ionic Polymer Metal Composite (IPMC)

Background/Objectives

Making use of biological cells to power ionic polymeric metal composites (IPMC) explores the possibility of biological control of IPMCs in operation as an artificial muscle. This novel technique, which relies on electrical activation of synthetic biocompatible polymeric materials (artificial muscles) by means of biological cells or nerves have the potential to assist patients suffering from ocular malfunctions, cardiac and intestinal paralysis, and various muscular diseases in the near future. IPMCs are highly efficient and research into IPMC based systems is expected to have will have far reaching ramifications in biomedical engineering and medicine.

Work done & discussion

Very recently, CMERI, Durgapur has achieved the success in developing IPMC based actuator (Figure-1) at the demonstrable laboratory scale, and this is perhaps unique in the country. Actuation response of IPMC based actuator is shown in Figure-1.

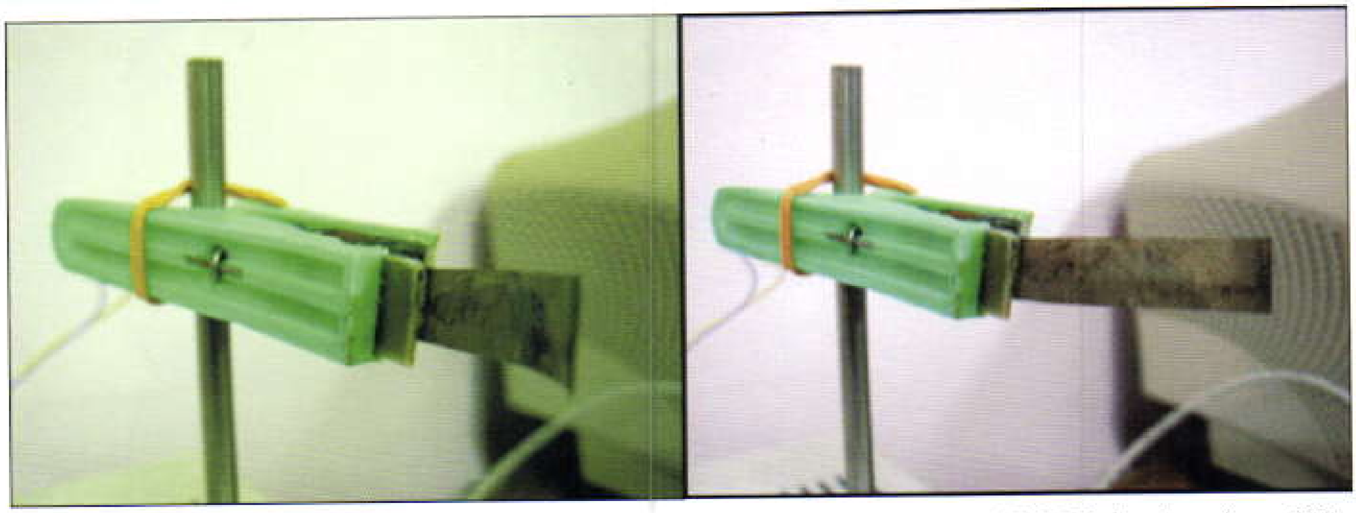


Figure 1: Successive photographs of the IPMC strip showing deformation under time-varied (0.5 Vs^{-1}) voltage from +3.0 to -3.0 V. duration time as a function of applying current -200 to +200 mA. Deflection and relaxation test of actuators also was conducted by chrono-amperometry under constant DC potential of +2 V. The electrochemical behavior of the IPMC exhibits a good electrical response.

The expected yield from the project includes development of biologically powered micro-devices - a technologically and economically feasible reality. The economic implications of such devices lie in an extremely wide range of applications, much broader than presently possible.

Outcomes: A peer-reviewed paper entitled 'Use of $[Pt^{II}(H_2O)_4]^{2+}$ complex towards development of ionic-polymer-metal-composite actuators', and authored by Dr. Debabrata Chatterjee was published in the *Ind. J. Chem (A)*. 48A, 2009, 1201-1203.

Facility for Rheo Pressure Die Casting

Background/Objectives

It was discovered during the early part of 1970s decade 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 (at a temperature which is between the solidus and the liquidus) shows a significantly low viscosity and deforms homogeneously, which leads to a new manufacturing technology christened **Semisolid Manufacturing** (**SSM**). This new technology is now widely accepted for production of commercial components requiring extremely high casting integrity and excellent properties.

One of the popular ways to obtain semi-solid alloy slurry is by introducing forced convection in the melt during solidification. The strong fluid flow arrests the growth of dendrites by detaching them from the solid-liquid interface and carrying them into the mould to form slurry. Subsequently, this semisolid slurry is either cast into parts in a die (the **rheocasting** process) or produced in the form of solidified billets which can be reheated to the semisolid temperature and cast into final parts in a die casting machine in a process known as **thixocasting**. Semisolid manufacturing has several advantages over conventional casting processes, and it is characterized by negligible shrinkage and porosity, ability to produce thin sections, significantly superior mechanical properties and near net-shape manufacturing. Because of the advantages listed above, semisolid forming process is ideally suited for producing a wide range of components for automotive, aerospace, defence and structural applications. However, because of lower production volume and enhanced processing costs (compared to parts made by conventional methods), semisolid forming is generally adopted for some special parts requiring high integrity, consistency in quality, increased strength and/or elongation, increased pressure tightness, thin walled sections and parts which are safely-critical.

In spite of some obvious merits of the thixocasting process, commercialization has not taken place in any significant scale, mainly because of high cost of feedstock material compared to normal foundry alloys. The key to successful thixocasting process is the production of consistent quality non-dendritic microstructure billets. However, there are only few such billet manufacturing facilities around the globe, who generally sells the billets at a much higher cost compared to conventionally cast billets of the same alloy. Although rheocasting is free from the problem of billet manufacturing, the major disadvantage lies in consistency, as the quality of the final product depends directly on the slurry produced, as also on the die casting machine. Hence, for the process to be successful, it is important to develop a process of slurry making which can be easily standardized and commercialized.

The proposed project is aimed towards developing alternative semisolid technology such as direct rheocasting of components. This billet-less semisolid technology is proven to be significantly cheaper than the thixocasting method, but there do remain challenges and drawbacks which need to be overcome. There is a further need for in-situ production of semisolid slurry. Electromagnetic stirring for this purpose has proven to be quite complex and difficult to be adopted for industrial rheocasting. Similarly, other processes such as stress induce melt activated (SIMA) process, liquidus casting, ultrasonic treatment, inert gas purging and single slug process are not industrially viable techniques. Several techniques of semisolid slurry formation are reported in literature. Among these, magneto-hydrodynamics (MHD) technique has received some interest in the industry, though continuous slurry production using MHD to meet industrial requirements is not feasible.

This project proposes the application of the "cooling slope" technique that might prove to be the simplest process of obtaining slurry in-situ. Moreover, this technique can easily be adapted in a conventional foundry. The project proposes design and development of a cooling slope slurry maker for aluminium alloys which would be capable of delivering a controlled quantity of slurry into a "receiver" situated right beside (or above) the shot sleeve of a die casting machine. A metered quantity of slurry at a prescribed temperature will be poured into the slot sleeve for each component casting. The proposed system is quite novel, and has not yet been reported in literature. The whole process of design and development will be carried out with the help of computational modeling tools (CFD), so that the parameters for successful manufacturing are chosen in a scientific manner.

The broad objectives comprise:

- Design and manufacturing of a cooling slope, and experimental investigation of semi solid slurry formation with globular equiaxed grain using the cooling slope.
- Design and manufacturing of holding semi solid slurry and transferring metered quantity to a die casting machine.
- Development of a CFD model for semi solid slurry formation using a cooling slope.
- Integration and synchronization of semisolid slurry formation, holding, transferring and producing final product in the pressure die casting machine, thereby developing rheo pressure die cast components.
- Development of a CFD model for die filling of semisolid slurry, thereby developing die design concepts.

Work done & discussion

A project has been submitted to Technology System Development (TSD) programme of DST-New Delhi in November 2009, with the Indian Institute of Science, Bangalore and the Mahindra & Mahindra as the collaborators, and the proposal is in an advanced stage of funding. Necessary literature survey is under way, and design approaches are being discussed for application.

Development of Process Technology and Manufacturing of ADI Components for Engineering Applications

Background/Objectives

Austempered Ductile Iron (ADI) is a type of the cast iron with exceptional properties imparted through customized metallurgy. ADI is far more superior to cast irons commonly available in the industries. It has an improved strength-to-weight ratio over steel and is potentially less expensive in the production of **Near Net Shape** form in mass quantities. This project was adopted in a bid to develop appropriate manufacturing technology suitable for production of specific engineering components in the NNS form through the ADI route.

In specific, the project objectives are:

- Optimization of composition and austempering parameters to produce ADI as per ASTM / EN standards.
- To develop the process route for production of high quality ADI components for engineering applications.

Work done & discussion

At the onset of the project the components like crankshafts were selected for development through the ADI route. Subsequently, other engineering components like Beater Heads, Swing Hammers, Gears, etc. were also selected for development.

Activities of this project were divided into two segments,

a) Development of specific grade of Austempered Ductile Iron as per international specification (EN/ASTM).

b) Development of process technology to manufacture the engineering components from a specific grade of ADI.

Development of ADI material: The crankshafts which were selected for development from ADI material are currently being made of forged steel equivalent to EN19 in normalized condition.

The mechanical properties of ADI Gr-II (as per EN/ASTM standard) are found to be nearly equivalent to their forged counterparts being used for manufacture of crank shafts. Accordingly experimental activities were focused on the development of ADI Gr-II material. The critical factors which influence the mechanical properties and the quality of final ADI components are:

- Chemical Composition of the alloy
- Melting
- Treatment of Liquid Metal
- Method of casting
- Heat treatment Process

Preparation and testing of ADI samples: The raw material used for preparation of liquid iron consists of low manganese steel scrap, graphite, ferronickel, pure copper, ferromolybdenum and ferrosilicon. A medium frequency Induction melting furnace of 100kg capacity was used for melting of steel scrap and ferroalloys. Liquid iron was tapped at 1450/1500°C and was then treated with Mg alloy by plunging method. After adding Fe Si dust, the molten metal was poured in sand moulds to cast Y blocks as per ASTM standard. Tensile, Impact and K_{IC} test specimens were prepared form specific locations of the SG iron Y block castings and samples were heat treated to produce ADI samples as per the following cycle.

- Austenitising at 880°C-900°C for a period of 60-90 minutes
- Quenching in salt bath
- Austempering at 360°C-380°C for a period of 90-120 minutes
- Air cooling

After final machining and polishing, all the ADI test specimens were inspected by X-ray and good quality samples were cleared for testing. Tensile tests of ADI samples were carried out at SERC, Chennai and CTOD Fracture toughness K_{IC} tests were carried out at NML, Jamshedpur. X-ray tests and Metallographic test were carried out at CMERI. Table 1 shows the nominal chemical composition of the SG iron alloys which were prepared for the experiments. Figure 2 shows the room temperature mechanical properties obtained on ADI samples. Results obtained on the ADI specimens developed at CMERI shows that the specimens conform to the laid-down in international standards. Figure 3 shows the microstructure of ADI Gr. II sample austempered at 350°C.

Table 1: Chemical composition of SG iron

Melt	% C	% Si	% Mn	% Ni	% P	% S	Other Elements
ADI 3	3.2-3.8	2.2-2.8	0.3-0.5	1.0- 1.6	0.02 max	0.02 max	Cu and Mo
ADI 4	3.5-3.7	2.3-2.6	0.2-0.4	0.5-0.75	0.02 max	0.02 max	Cu and Mo

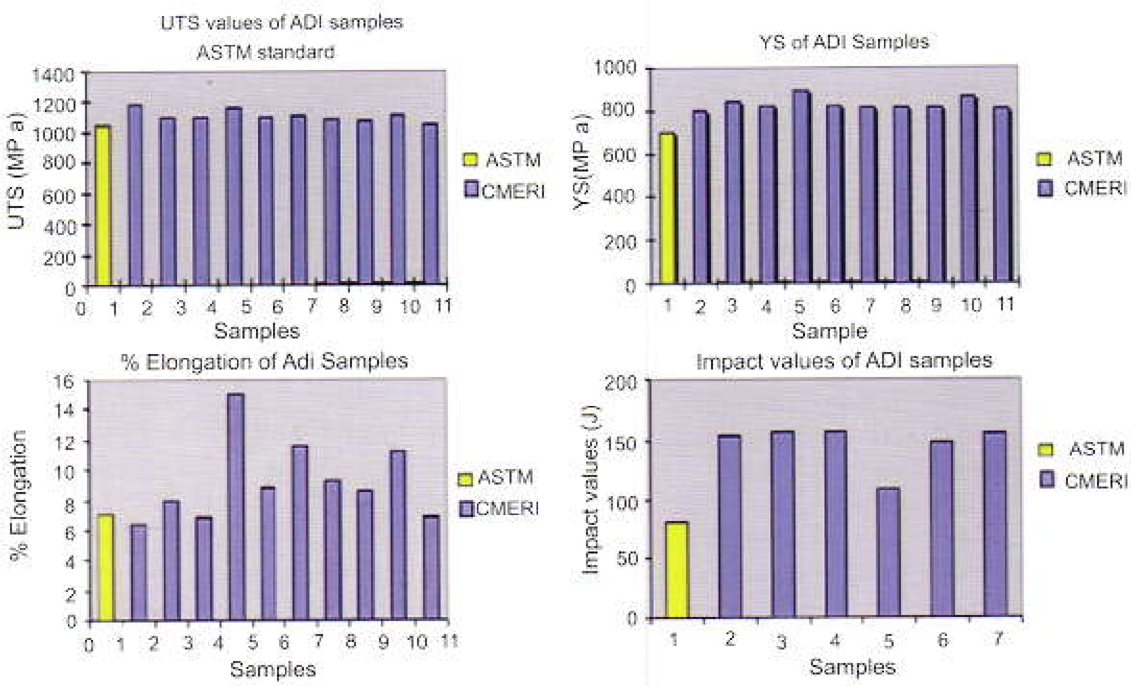


Figure 2: The bar charts show the tensile and impact values of ADI samples developed at CMERI

Table 2: YS, Fracture Toughness and Flaw tolerance of ADI samples (*Source: Ductile Iron Society, US, and ADI 4 Developed at CMERI)

Alloy	YS (MPa)	K_{IC} (MPa$\sqrt{m}$)	K_{IC} / YS (mm)
ADI I*	980	72	5.3
ADI II*	790	74	6.9
ADI 4	820	70	5.9

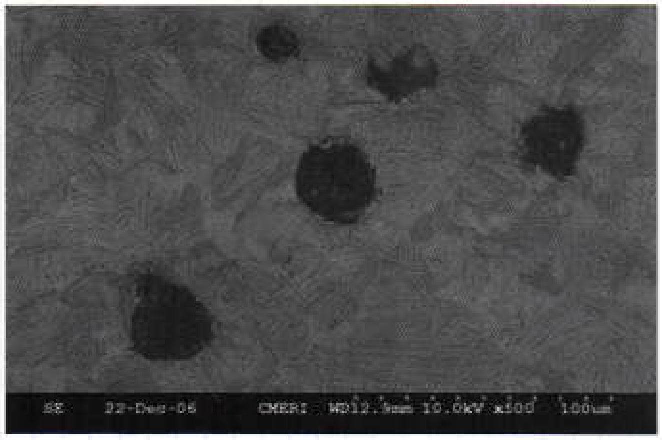


Figure 3: Microstructure (x500) of ADI Gr. II sample austempered at 375°C

Development of ADI Components for engineering applications: The components which had been developed through ADI route at CMERI comprise **Beater Head, Swing Hammer and Gear** and **Crank shafts.** ADI Beater head, Swing hammer and Gear have been developed for M/S McNally Bharath, Kumardhubi. ADI crankshaft has been developed for M/S ITL, Hoshiarpur. There are four grades of ADI which are generally used for engineering purposes. Chemical composition of SG iron melt and subsequent heat treatment parameters were selected based upon the individual component geometry and the type of environment it would encounter in service. However it is essential to manufacture defect-free SG iron castings before the same is transformed in to ADI. To ensure this, computerized methoding were carried out with AFS software for each component to produce shrinkage-free cast components with minimum trials. Computerised methoding also helped to increase the yield from 60% to 85% in case of Swing hammer castings. After fettling and preliminary machining of cast blanks, the gear blanks and crank shafts were austempered to produce ADI Gr-I and ADI Gr-II products. Beater head and Swing hammer cast blanks were heat treated to produce ADI Gr-II, ADI Gr-III, and ADI Gr- IV material. Important factors which have direct influence on the quality and performance of the components are:

1. Chemical composition of raw material
2. Design of in-gate system to ensure non-turbulent flow of liquid metal inside the mould cavities
3. Optimisation of riser geometry and its location
4. Melt treatment technique to produce good quality SG iron castings
5. Optimisation of the heat treatment parameters

ADI **Beater head** samples (Figure 4) were assembled in the reversible hammer mill of a steel plant for field trial in actual environment. Weight of one ADI beater head is 20 kg. In a reversible hammer mill (diameter: 1200mm, length: 1200mm), 52 beater heads are assembled in 13 planes, with 4 beater heads reposing in a single plane. In the hammer mill, 2 ADI beater head samples were assembled with another 2 steel beater head samples in the same plane. In order to assess environmental effects, the ADI beater head samples were developed with different magnitudes of hardness. All the ADI samples could successfully complete 430 hrs of field trials of the hammer mill. Wear pattern of ADI beater heads were compared with steel samples fitted in same location of the reversible mill. Out of four samples, two samples showed superior performance and one sample showed similar wear-out rate like its steel counterpart. Fig 5 shows conditions of the ADI and steel beater head samples after 430 hrs of field trials. SEM analysis were carried out on small specimens taken from the used ADI and Steel beater head samples to study the characteristic of the worn out surface.

Figure 4: ADI Beater head samples

Figure 5: ADI and Steel beaer heads after 430 hours of operation

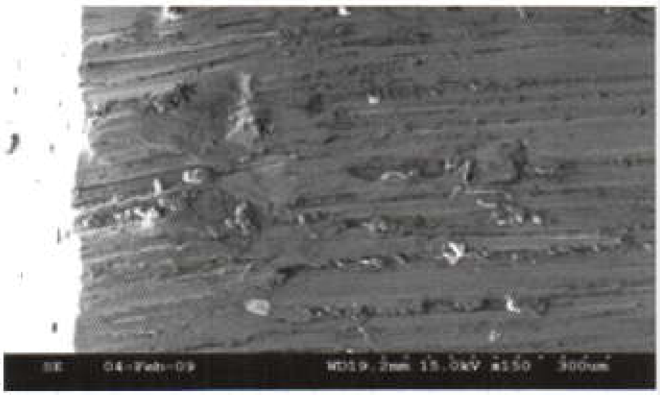


Figure 6: Scanning electron micrograph of steel head (X150)

Figure 7: Scanning electron micrograph of ADI beater head sample

Figures 6 and 7 depict the scanning electron micrographs of the working surfaces of ADI and Steel beater head samples after 430 hrs of operation. The steel sample shows deep marks on the worn out surface whereas the depth of scratch marks on the ADI sample are shallow and uniform indicating the work hardening behavior of ADI, which is a factor contributing to superior wear resistance property of ADI. Figure 8 shows the photograph of AFS computerized methoding for swing hammer indicating the position of shrinkage defect above the riser. Photograph of cast hammers with side risers are shown in Figure 9. Quality of cast component was ascertained by destructive testing and no shrinkage defects were noticed in the neck region of the cast swing hammer as shown in Figure 10. Weight of each hammer is 34 kg. Following the same manufacturing process, 9 ADI Swing hammers (Figure 11) were also developed and deployed in the iron ore crushing plant located at Goa. The hammers were fitted in three consecutive planes in the crusher and were operated continuously for 158 hrs. Total tonnage of material handled by the crusher fitted with ADI hammers was 10128 tons as against 6000 to 7000 tons that was obtained with steel hammers. This field trial results revealed that ADI hammers showed superior performance in adverse environments where each hammer encountered high abrading and impact loads during the crushing operation.

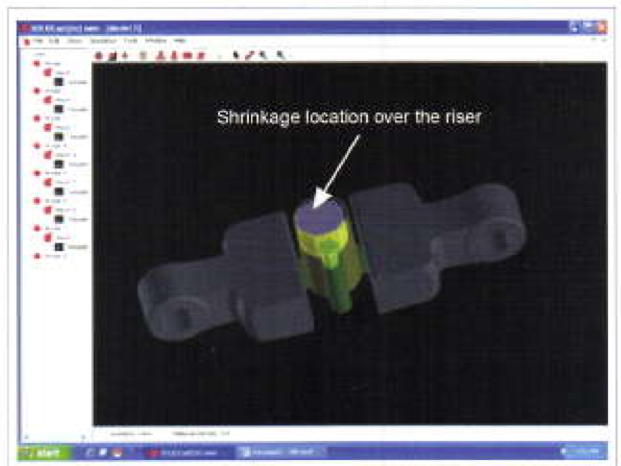


Figure 8: Computerised methoding of swing hammers

Figure 9: Photograph of cast hammers with side risers

Figure 10: Photograph of cut section of neck area of cast swing hammer

Figure 11: Photograph of ADI swing hammers

Other engineering components which have been developed through ADI are Gear for Exciter and Crank shafts for 35 hp tractor engine. Machining of ADI Gr- I and Gr -II material with HSS tools was the major hurdle for development of ADI Gear and ADI crankshaft. After carrying out extensive R&D activities on optimization of composition, heat treatment parameters and hardness of ADI samples, a solution for machining of Gr-I and Gr II ADI material was devised. Fig 12 shows the helical gear which has been developed through the ADI route and supplied to M/S McNally Bharat, Kumardhubi for performance evaluation. Machining of the gear has been carried out by M/S Mc.Nally Bharat Kumardhubi. Weight of forged steel gear is 50kgs.Since the ADI gear has been developed through NNS casting route, it has been possible to reduce the weight of ADI gear to 35 kg, resulting in more than 15% saving of initial material. Two ADI crankshafts (Fig 13) for 35 hp tractor engines have been sent to M/S ITL, Hoshiarpur for final machining, balancing, assembly and short duration field trial. It is expected that field trials of these components will be completed within next few months.

Figure 12: Photograph of ADI gear for exciter

Figure 13: Photograph of ADI crankshaft for 35 hp tractor engine

Outcomes

Process technology for manufacturing of different grades of ADI components have been successfully developed at CMERI. M/S McNally Bharat, Kolkata has shown interest for industrial application of ADI components in the mining sector. Beater head, Swing hammer and Gear have been developed through ADI route and supplied to McNally Bharat for field trials. Periodic technical discussions are taking place between the technical experts of both the organizations to identify suitable avenues to promote wear resistant ADI components on an industrial scale. M/S International Tractor Ltd, Hoshiarpur is interested for ADI technology for manufacturing of crankshafts. There are two small scale industries located at Jamshedpur who have also shown interest for ADI process technology.

New initiatives planned

Austempered Ductile Iron is a new class of material. So far, it has not been regularly used for the manufacture of Industrial components. In order to develop awareness among the industries, it is essential that additional activities be initiated in association with medium scale industries for development and deployment of other types of ADI components. In near future gudgeon pin of compressor piston will be developed through ADI route.

ADVANCED DESIGN & ANALYSIS

Programme Leaders

Avik Chatterjee
Tapas Gangopadhyay

Area Leaders

Abhijit Mahapatra
Anupam Sinha
Bibhuti Bhusan Ghosh
Tapas Sarkar

A specific strength of the Institute lies in a strong back-up in design engineering and design analysis, which enables proper conceptualization, evaluation, cross-check and finalization of designs. Aided by a comprehensive CAD tools environment that supports collaborative design through concurrent consideration of trade-offs, analysis of mechanisms, tolerances, interferences of designated parts and components is carried out to satisfy contrary design requirements. Analysis is further bolstered by simulation of functions and processes leading to design optimization.

Generation and Analysis of Modulated Vane profile for Radio Frequency Quadrupole Linac

Background/Objectives

The high energy Radioactive Ion Beam (RIB) plays an important role in R&D in the field of Nuclear Physics, Nuclear Astrophysics, Material Science, Biology and Medical Science. The technology needed for developing RIB facility is extremely complex and it requires extensive R&D in the field of Particle Accelerations, Ion Sources, Instrumentation and Manufacturing Technology.

The prime example of the use of ion beams in material science is modification of the properties of materials and analyses of the location and chemical nature of their constituents. Beams of radioactive nuclei greatly expand the scope of such applications and the last decade has seen rapid growth and development in the use of low energy (<400 keV) beams of radioactive isotopes to study the properties of solid-state materials. Although on date there is more emphasis on semiconductors, studies on metals, insulators, superconductors, surfaces, interfaces and even complex bio-molecules are also being undertaken.

The Variable Energy Cyclotron Center (VECC) had signed an MOU with CMERI, Durgapur, for fostering such investigations through a collaborative venture in system design, and for the development, fabrication, and commissioning of Radioactive Ion beam facility at VECC. The entire collaborative research work has been planned in three phases, of which the first two phases have been completed and the final phase is under way.

The remarkable outcome of this collaboration in the first two phases has successfully culminated in the indigenous development of Radio Frequency Quadrupole (RFQ) Linac, and this has put India in the Global map with six other nations of the world. The RFQ Linac is a RF cavity (Frequency ~ 33.7 MHz) of very pure cupper that houses four (quadrupole) precisely designed and machined vanes which take care of the acceleration, bunching and focusing of the Ion Beam. RFQ is the optimum choice for accelerating very low energy ions to medium energy.

The third phase comprising the development of Linac Re-buncher is primarily focused on re-bunching and collimating the medium energy level Radioactive Ion beam from RFQ Linac such that it can injected in the Drift Tube Linac for higher levels of acceleration.

The basic design of Linac (RB) ws carried out by VECC Kolkata from the principles of Accelerator Physics and Beam Dynamics for Ion Beam acceleration. CMERI's role was primarily focused on mechanical design and analysis from the inputs of VECC.

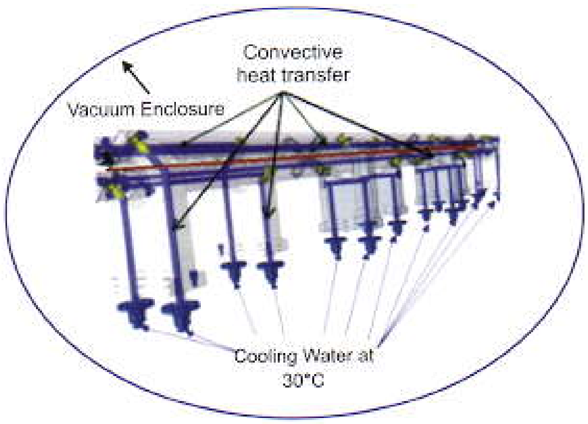


Figure 1: Convective Heat Loss

Work done & discussion

The heat distribution and cooling pattern of the 3.2 m RFQ structure due to the thermal loading and modal response have been investigated with Finite Element Model. The cooling phenomenon has been modeled with convective and radiative Heat loss. The Convective heat loss is due to the flow of the low conductivity cooling water through sub-surface channels in vanes and posts. The thermal heat input in to the system has been modeled as per the input from Variable Energy Cyclotron Center (VECC), calculated from electromagnetic interactions.

The foregoing schematics illustrate the process:

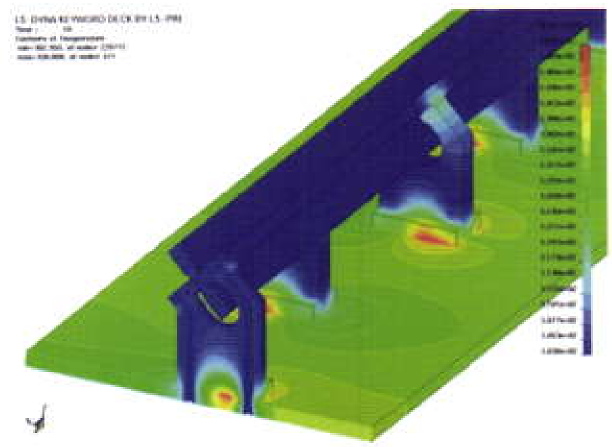


Figure 2: Temperature distribution profile at active posts.

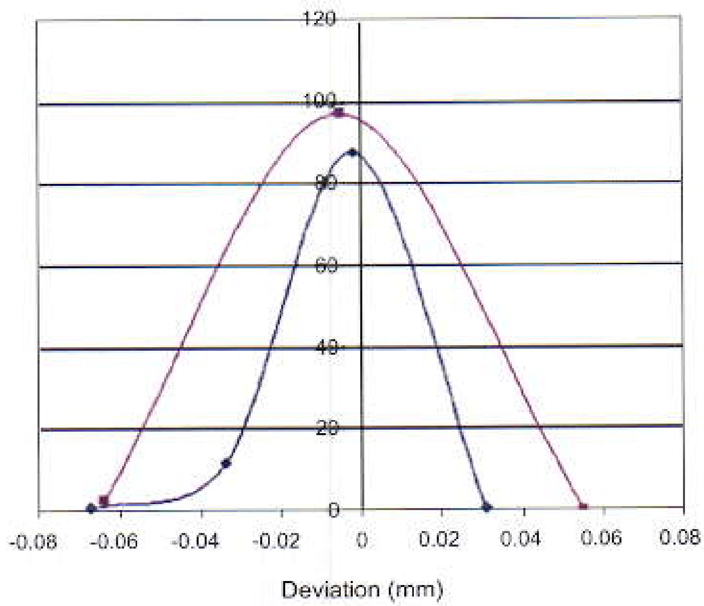


Figure 3: Distribution of Modeling error due to elimination the noise in input data

The analysis of this entire complex system commences with the development of the surface model form the output of the PAMTEQ code, which is basically a grid of spatial coordinates with longitudinal and transverse modulations. This grid also has some in-built noises or erroneous data points, arising due to the numerical solution. These errors are to be filtered maintaining the geometric integrity of the modulated surface. In the noise and error filtering stage of modeling, the distribution of errors (deviation) lies well within $\pm\ \sigma$ ($=0.04$) as shown in the plot Figure 3.

The Heat generation is not uniform and it is estimated from electromagnetic interaction by VECC. The generation can be estimated as for Vane post interface @ $\frac{6}{16}$ kW , Post –Base Plate Interface Cavity Far side @ $\frac{1}{5}\times\frac{6}{8}$ **kW ,** Post -Base Plate interface Cavity Near side @ $\frac{4}{5}\times\frac{6}{8}$ **kW.** The segment sets for

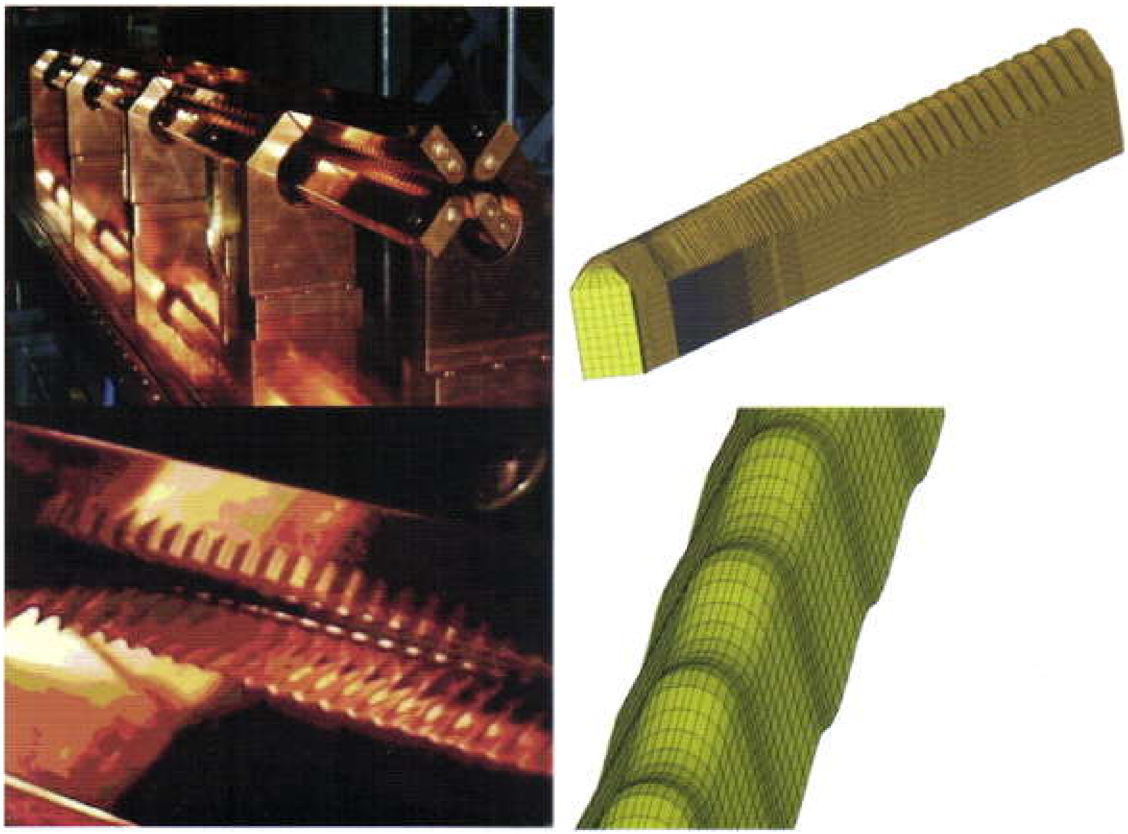


Figure 4: Modulated Vane and its Hex mesh

heat generation and heat dissipation by convection has been modeled as Figure-5.

Meshing is very important to gather the modulated profiles and the state variables. Several advance meshing techniques like Morphing, Solidmap, etc. were used to generate mesh on the longitudinal and transverse curvatures.

It is worth mentioning that the meshing parameters like Jacobian, Skewness, etc. have all been maintained within the prescribed values to minimize chances of errors while solving. The whole model is meshed with regular solid brick elements to catch hold of the modulation and analysis stability (Figure 4). Total no of meshing components is 13 (4 modulated vanes, 8 posts, 1 Baseplate) with total 351352 nodes of 283592 elements.

At the post section, the flow condition estimates the Reynolds Number (R_{eD}) ~ 10000 and fluid properties estimates the Prandtl Number (Pr) ~ 5.4 . For Forced Convection Turbulent Fully Developed Flow, the Dittus-Bolter Empirical Correlation estimates Nusselt Number ($\underline{N}_{ufd}$) ~ 60.46 and Sieder-Tate Empirical Correlation estimates $\underline{N}_{ufd}$ ~69.93. Considering the larger value and after introducing Molki & Sparrow correction for short tubes, the $\underline{N}_{u}$ was found to be in the range of 86.82,

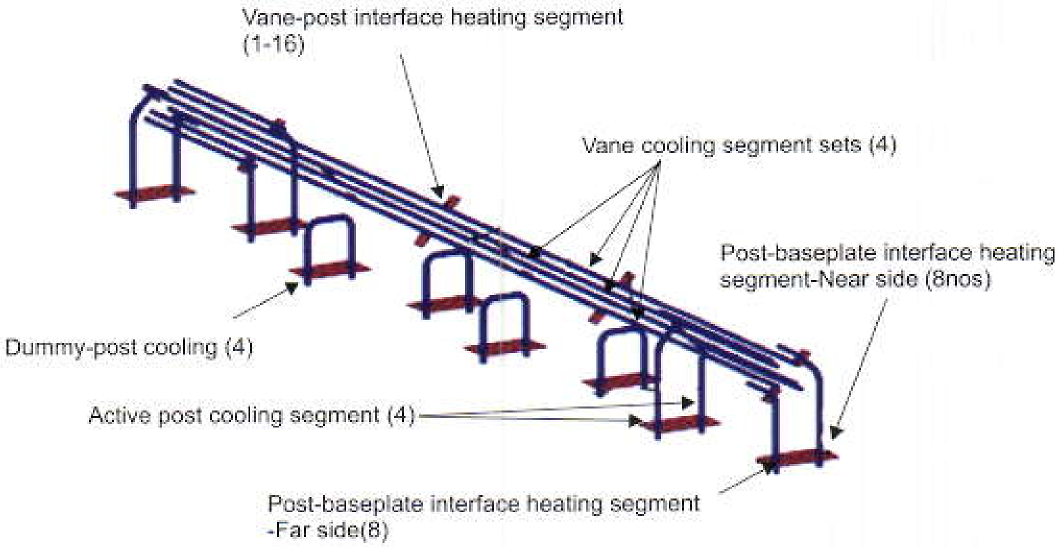
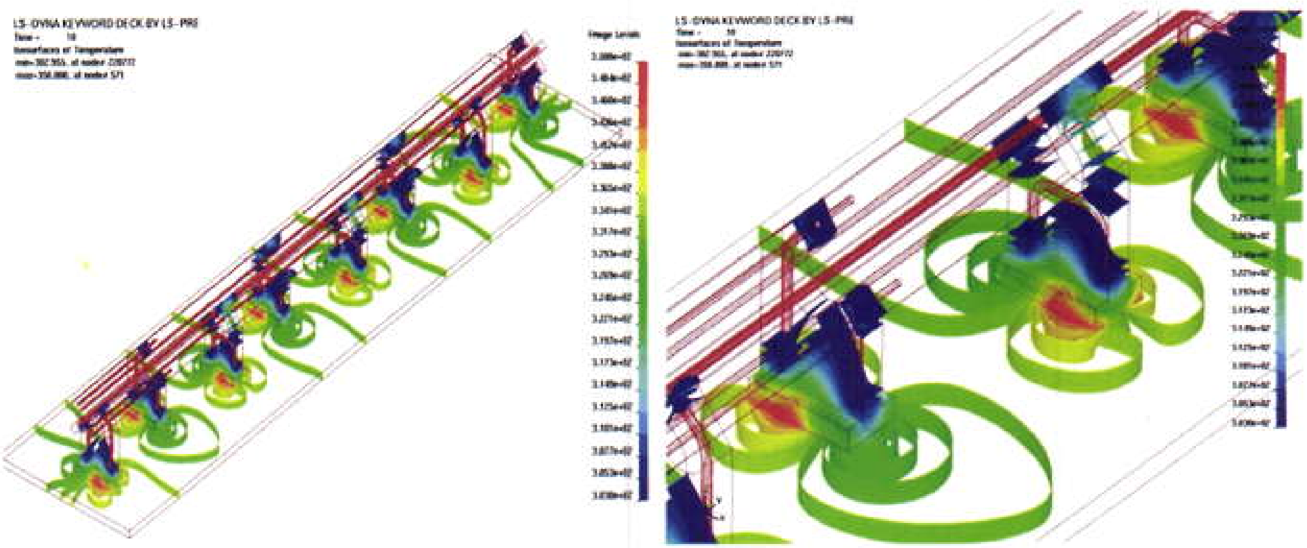


Figure 5: Set-segments for heat generation and convective cooling



Figures 7(a) & 7(b) : Thermal isosurfaces in whole 3.2 RFQ and partial enlarged view

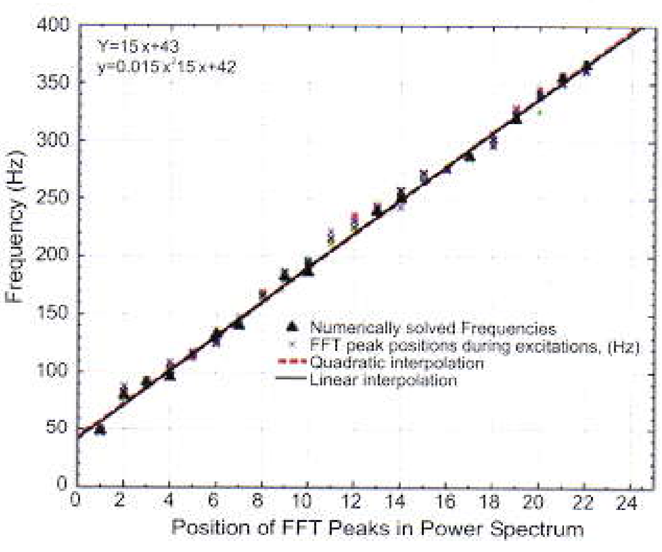
which gives the average heat transfer coefficient ($\underline{h}_c$) to be 3814 W/m^{2}K. Similar consideration at vane section gives the $\underline{h}_c$ to be 5474 W/m^{2}K.

The solution provides very important characteristics of heat distribution and identified the hot spots where particular attention is to be provided in the design. The heat distribution pattern is shown Figure 2, Figure 6 and Figures 7(a) and (b).

The investigation of modal response deals with the analysis and experimental study of natural frequencies of vibration of a 4-rod type Radio Frequency Quadrupole (RFQ) Linear Accelerator (Linac). The eigenvalue analysis of the structure has been done analytically (multi-span beam concept) and also using Blocked Lanczos Eigenvalue Finite Element Solver with an ability to extract the rigid body modes. This has been done in the mechanical design phase to ascertain the level of

Experimental Setup for testing the modal response of RFQ Linac

agreement between the output of simplified analytical analysis results and the output of a commercial FEM solver, since a full scale RFQ structure is too complex to handle analytically. Experimental validation of the analysis results has been done on the physical 1.7m RFQ at the installation site. The experimental data obtained was later analyzed and found to be in close agreement with the predicted frequencies in the lower frequency ranges, although larger deviations are noticed in the higher frequency ranges. Some frequencies not reflected in the Finite Element Analysis (FEA) results were also detected during experimentation. The source of these frequencies is to be further investigated as it may play a predominant role in the design of high Quality Factor Beam Line Cavities for higher operational efficiency.

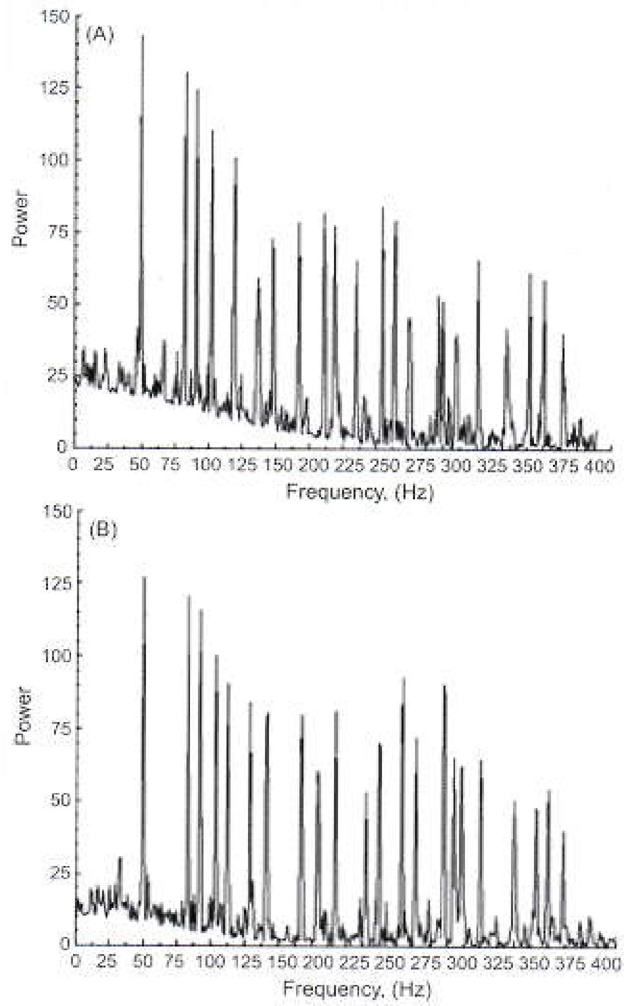


Power spectrum of Model Response Outcomes

Outcomes

SCI Publications

- S.D. Choudhury, 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 and 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*, 81, 23301 (2009). (ISSN online: 1089-7623, print: 0034-6748) [doi:**10.1063/1.3280175**]
- Chatterjee A., Mahapatra A., Mondal M., Chakraborti A., *"Model Response of 4-Rod Type*



Radio Frequency Quadrupole (RFQ) Linac", Review of Scientific Instruments, *American Institute of Physics*, 80, 103303 (2009). (ISSN online: 1089-7623, print: 0034-6748) [doi:**10.1063/1.3247904**]

New Initiatives planned

Planned for design and analysis of High Quality Factor (High-Q) RF Cavities.

Indigenization of Special Purpose Valves of SARAS Aircraft

Background/Objectives

Development of aircraft in India is in a very early state of maturity and India is totally dependent on import of various systems, components and even spare parts to meet the requirements of aircraft being designed in the country. These components form a considerable proportion of the cost of the aircraft. Moreover, the cost of spares is exorbitant, and often these do not match specific requirements. The long delivery time of the components further increases the overall aircraft cost. In addition, due to various protective policies practiced by aircraft manufacturing companies, there might arise situations where the spare would not even be available during the life cycle of the aircraft. Capability building for the development of equipment/sub-systems/systems, ultimately leading to and achieving the capability to manufacture aircraft is to be considered simultaneously for indigenous design of aircraft.

With this in mind, selected critical equipments for small aircrafts are being indigenized under the CSIR network project "Spearheading Small Civilian Aircraft Design, Development and Manufacture" with NAL as the nodal laboratory. CMERI is a participating laboratory in this network initiative and is engaged in developing the following three aircraft valves from the first principles:

- Pressure regulating pneumatic valve
- Ball type motorized fuel shut-off valve
- Butterfly type non return valve.

Work done & discussions

A pressure reducing valve is a sleeve type valve used to regulate the varying inlet air pressure and to maintain constant outlet pressure. A ball-type motorized fuel shut-off valve is used to control fuel flow to the gas turbine engine. Non-return valve is used for allowing air flow in a particular direction only. Valve designs have been completed, and optimization of the design is being carried out using CAE and CFD.

A valve testing facility is being set up at CMERI to prove airworthiness of the designed valves. Design of the test rigs to create actual operating conditions of the valves has been completed. Necessary procurement and fabrication work is going on.

PRODUCT / PROCESS DEVELOPMENT

Programme Leaders

Cdr. V. R. Dahake
Arup Kumar Nandi
Dr. Krishnendu Kundu
Dr. Partha Bhattacharjee
Joydev Roy Chowdhury

Area Leaders

B.B. Ghosh
S. Karmakar
A. Maity
R. Singh
Dr. Pradeep Rajan
Ashwani Kumar
Rajesh. K. Chak
S. Salman Mojiz
B. D. Bansal
Ms. Anjali Chatterjee
Ms. Abhilasa Saxena

Developing new products/processes to suit the market requirements is steadily becoming a fundamental differentiator for the speed and cost with which novel and more efficient products/processes are introduced to the market. Product/Process development is a complex enough process involving a number of stated and inchoate variables, relationships and abstractions. It is quite a difficult task involving multiple inputs from varied sources to convert a concept into a complex multi-technology product or process, and therefore a lot of effort, definition, analysis, investigation of physical processes, verification, tradeoffs and other informed decisions are required.

Converting a concept into a complex, multi-technology product or process involves many steps of refinement. Through its long association with developing engineering products and processes, CMERI has in place a carefully crafted product development routine that embraces all phases of product/process development from initial planning to customer follow-up. Continual improvement of new design methods and incorporation of customer feedback helps CMERI continually reduce iterations of the design cycle, thereby ensuring reduced time to market.

Design and development of Small Hydraulic Tractor

Background/Objectives

Conventional Tractors are used the world over for agriculture and haulage. Advanced countries have already resorted to mechanized farming on large agricultural plots, where powerful tractors exceeding 60HP are commonly used with a large variety of implements.

In developing countries like India, farmland plots are small and fragmented which necessitates the use of a light tractor ideally suited for this application. Such a tractor should also be low cost and within the means of an average farmer with limited disposable income.

This project was undertaken to develop a small tractor having the features of maneuverability, energy efficiency, flexible operation and equal speed reversal. The tractor designed by CMERI incorporates a hydraulic power transmission system to replace the mechanical power transmission system and to overcome drawbacks associated with conventional tractors.

Work done & discussion

The small 12HP hydraulic tractor (PUSHAN) is designed and developed on the basis of a hydro-mechanical power transmission system. In line with the development of three major

CMERI tractors, namely the Swaraj, the Sonalika and the Krishishakti, the advent of PUSHAN TRACTOR is expected to revolutionize again the Indian agricultural scenario. The PUSHAN TRACTOR embodies a new technology that differs significantly from conventional tractors. PUSHAN It is a multi-utility vehicle and possesses many advantages including easy maneuverability and control. The tractor is suitable for irregular terrain profile, various soil conditions and can be used for cultivation of different crops. In

India, the average land holding of majority of the farmers normally does not exceed 4 hectares per farmer. Under such a situation, PUSHAN would be the appropriate and affordable means of cultivation.

With the development of the 12 HP PUSHAN TRACTOR, farm mechanization as applicable to small land holdings will become a reality in India, promising better yield and prosperity for the millions of countrymen.

Outcomes

Papers published:

1. Nandi A.K., Regeneration of power in hydraulic power transmission system, International Conference on Advances in Mechanical Engineering (ICAME 2006). SRM Institute of Science and Technology, Deemed University, 14-16 December 2006, Chennai, 363-367.
2. A.K. Nandi, B.B. Ghosh and S. Karmakar, Regenerative hydraulic power transmission system, International conference on Materials, Mechanics & Management (IMMM2010), Jan 14-16, 2010. College of Engineering Trivandrum, Thiruvananthapuram, India

Patents/copyrights filed:

1. Hydraulic Power Transmission System for Agricultural Tractor, (Ref No. 34/CR/06)
2. Hydro-mechanical Power Transmission System for Agricultural Tractor, (Ref. No. 34/CR/06)
3. Regenerative Power Transmission System, (Ref No. 34/CR/06)
4. Regenerative Power Transmission System for Paddle Operated Tricycle, (Ref No. 34/CR/06)

New initiatives planned

Another prototype of 12 hp small hydraulic tractor is being planned for development, this time utilizing a purely hydraulic power transmission system

Design and development of Semi-Continuous Type Biodiesel Plant suitable for the Rural Sector

Background/Objectives

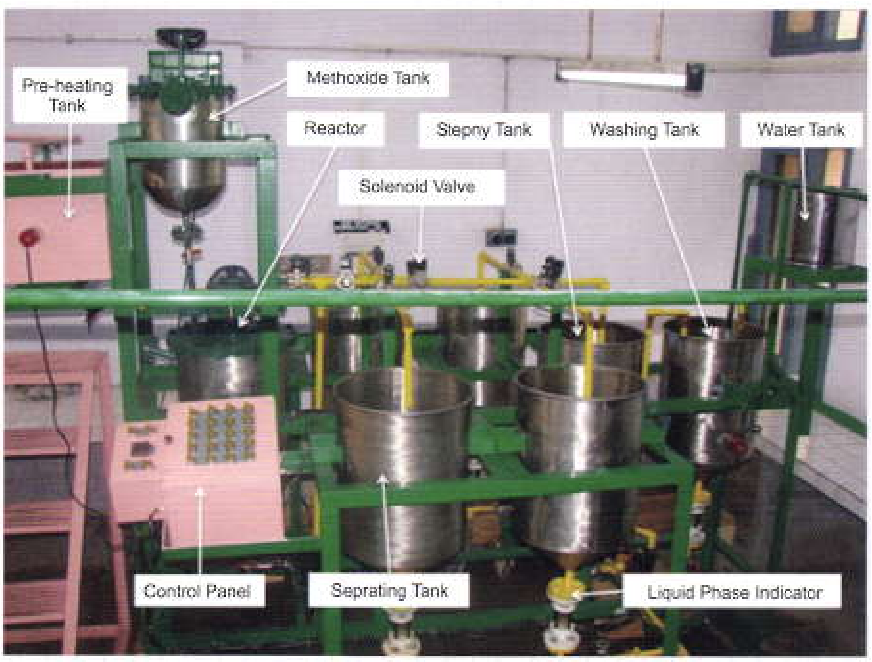
International crude oil price is undergoing daily fluctuations and it will continue to rise in the foreseeable future, in spite of a drop in crude price in the recent past. For a primarily oil importing country like India, every $1 increase in per barrel crude price imposes an extra annual burden of Rs. 3000 crore on the government exchequer. With an annual requirement 114 million tones of oil, the import bill is set for a quantum jump of over Rs. 55000 crore to reach over Rs. 175000 Cr this year. By all indications, India is heading for a major energy crisis.

India has the potential to produce nearly 60 million tonnes of bio-fuel annually. For true energy independence, a major shift in the structure of source-specific utilization pattern is mandated with a gradual shift from the fossil fuels to the renewable sources. The high cost of bio-diesel is at present a major handicap, but considering the ever increasing environmental pollution by the use of petroleum based fuels the use of bio-diesel needs to be encouraged.

Among different alternate fuels, liquid vegetable oils have been proven best. Edible oils, such as those obtained from sunflower, safflower, rice bran, palm, etc. as well as non-edible oils obtained from jatropha, karanja, mahua, neem, sal, etc. can be used to produce biodiesel. India being a net importer of edible oils, the current accent is on the use of non-edible oils as possible bio-diesel sources. A national initiative has already been taken up by the Government of India for promotion of oil obtained from *Jatropha curcas* L., which has the potential to supplement conventional diesel fuels. *Jatropha curcas* plantations are being promoted in 15 states throughout the country, spanning over 13.4 million hectare of wasteland with an investment of Rs 6000 Crore. The present effort is aimed towards the design and development of a low cost semi continuous type biodiesel plant having a capacity of 600 lit/day which will be distributed to the farmers to promote self-reliance and to save the energy crisis and avoid environmental pollution.

Work done & discussion

Two semi-continuous type biodiesel plants have been designed, fabricated, installed and tested at MERADO, Ludhiana. These plants, each having a capacity of 600 litres /day, produces biodiesel from any edible or non edible vegetable oil irrespective of its FFA content. The plants have been designed on consideration of the process timing and simulation so that all the components can work for the designated time and ultimately produce the nominal quantity of biodiesel per day. The plant comprises an oil preheating tank; a methoxide tank with agitator and motor; a reactor vessel with heater, temperature controller, agitator, recirculator, motor and pump; four separating vessels; a washing cum heating vessel; a spare vessel for reaction/separation/washing; pipelines; motors; pumps and mounting frame with wheels for easy movement of the whole system. The solenoid valves, motors and pumps are operated by switches mounted on a single control panel so as to enable minimum manual intervention during biodiesel production process. The maximum power consumption of the plant is only 3 kW at the peak time. Both the plants have been successfully tested with jatropha (non edible oil with FFA content of 3.9) and soybean (edible oil having FFA content of 0.8). The fuel properties of jatropha and soybean biodiesel produced from the plants have been tested and the results obtained are within the limit of ASTM standards.



Outcomes

Technology transferred to

1. M/s Best Engineering Technologies, Hyderabad
2. M/s Fab Con Engineers, Chennai

New initiatives planned

Future plans comprise modifications in the basic design for more energy efficiency. The biodiesel plant needs more automation, and PLC based control will be implemented soon.

Fabrication of Mobile Bridge Inspection Unit

Background/Objectives

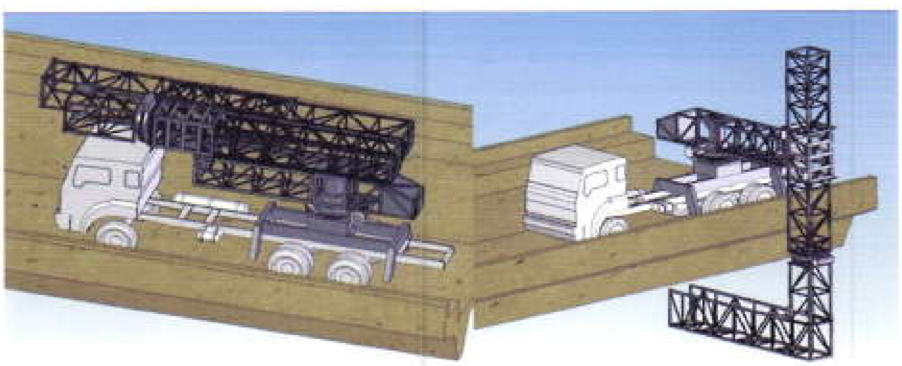
The primary objective of this project is the creation of visual Non-Hydraulic (Electro-Mechanical) inspection facility in the form of an aerial platform to inspect the bridges from various sides. The inspection unit is required to be of folding type and is mounted on a truck / trolley, and should have structures and joints and as well as an independent drive mechanism to drive joints.

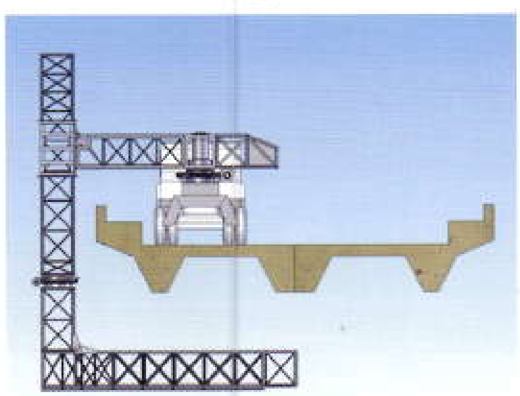
During the last 50 years, a number of Reinforced Cement Concrete (RCC) and Pre-stressed Cement Concrete (PCC) bridges were built across the country and it is estimated that the state of health of about 25% is rather poor. Maintenance of bridges in India, save a few important bridges of high visibility, leaves much to be asked for. Considering that the number of bridge assets is increasing quite rapidly, there is a need to develop a scientifically designed Bridge Management System policy and infrastructure in the country.

Pressing demand by user agencies like the PWDs/ NHAI and controlling agencies like MORTH prompted MERADO, Ludhiana to take up the task of designing a suitable bridge inspection system so that a critical infrastructure for proper inspection is created as part of the drive to evolve a suitable bridge management system in the our country.

Work done & discussion with Figures

Fabrication of the unit structural members and joint members has been completed. All Imported components have been purchased and are now being assembled. Purchase of a suitable vehicle for accommodating the suspension unit is under progress. The RCC structure forming part of the ramp for functionality testing of joints is in the final stage. Functioning of individual joints has duly been tested. Automation process design has been finalized and order will be placed after full assembly of the MBIU unit over the test ramp.





Outcomes

Indigenously development of Mobile Bridge Inspection Unit, which facilitates quick inspection of road bridges and enables physical study of the intricate bridge spans along with NDT equipment.

Design and development of equipment with appropriate and adaptable automation for hygienic and safe production of processed and semi-processed foods in large scale

Background/Objectives

This project aims at developing semi-automated machinery large scale production of low cost hygienic food. 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.

Work done & discussion

The Sigma-mixer is required for preparing through proper mixing 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. This machine has already been developed. The Extruder for drawing long bars of cereal cake has also been designed and developed. A horizontal flow wrap machine has been procured to facilitate packaging, and this is being suitably integrated. A machine for grating coconut has been designed and fabricated for making laddo out of the 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 minor axis to 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 that 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).

Outcomes

The machine has been designed and developed, and will be demonstrated soon.

New initiatives planned

- Design and development of the Laddo making machine
- Filing of patent

Development of embedded processor based tactile image sensor for object recognition in real time

Background/Objectives

The primary objective is to develop an embedded processor based object recognition system through tactile imaging technique. By means of tactile sensing a great many properties of an object can be perceived in the absence of vision.

The project would involve development of a methodology for determining the characteristics of an object through distributed tactile imaging technique. This in its turn would require considerable processing of tactile database and subsequent description of the object contour as extracted from the data related to the shape and other associated parameters. Tactile images be accessed through embedded processor and the associated parameters interpreted through a graphical display unit. A fuzzy logic based approach will be adopted for discriminating materialistic properties associated with the object.

Work done & discussion

The steps to be undertaken in recognizing a predefined shape consists of:

1. Formation of the 'SHAPE LIBRARY' where various common shapes would be stored. These shapes will be calibrated against the shape provided by a user and checked for possible matches, and the nearest approximation identified.
2. Acquisition of user data: In this step, the pressure data of the shape provided by a user is taken for identification with members of shape library.
3. Matching: As obvious, this is the most crucial part of the overall process. This is the step where a computer program will perform the matching of user given shape with the best one from the 'SHAPE LIBRARY'.

Tactile sensors are devices which measure the parameters of contact between the sensors and the object. Technically, an array of tactile sensors emulates the distributed sensory arrangement of the human skin. A touch sensor provides binary information as to whether or not there is a touch. Tactile sensing however provides the measurement of the distribution of forces applied on the sensory area. Presence of atmospheric pressure however can indicate a low reading at the no load condition, which contributes to noise even in the absence of any applied pressure from the user.

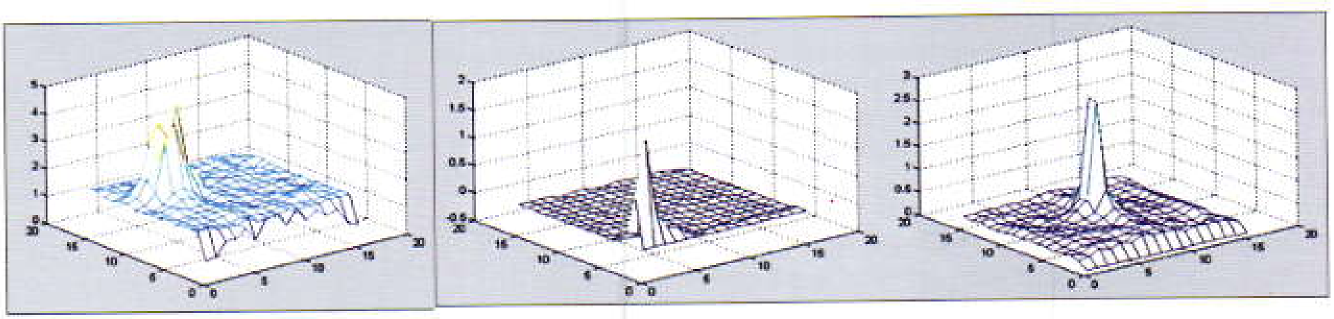
Problem with the presence of noise is very common and affective for the experiment because here the system does not work with a single pressure sensor but employ as many as 256 individual pressure sensors which, once again, are interconnected. As a result a given pressure on a particular sensor is also experienced partly by its neighboring sensors because of the cushioning of the interconnecting material and in most cases these create noise. Study of the pressure profile therefore needs to be combined with noise elimination to have an idea of the actual contour of the object which is in contact with the sensors.

Outcomes

Demonstration of Edge detection of an objects using distributed pressure sensor array in the MEMS Innovation Feast 2007 at Bangalore

New initiatives planned

Project proposals based on this preliminary study has been submitted to various agencies for funding for development of intelligent glove to train students with vision impairment.



Cylindrical object impression as gathered by a tactile sensor array

SOCIETAL PROGRAMMES

Programme Leaders
Dr. P.K. Chatterjee
Joydev Roy Chowdhury
Amit Jyoti Banerjee
Partha Sarathi Banerjee
Palash Kumar Maji

Area Leaders
Ashok Prasad
Ms. Abhilasa Saxena
Biplab Choudhury

Through the years, CMERI's commitment to society has been manifested in different forms through extension of its expert guidance and services for mitigating different technological needs for weaker sections of the society, or for the artisans of the handicrafts sector, for ensuring proper returns for the farmers the north-eastern region, etc. Such support was extended through adoption of different projects for that have a direct impact on the society.

CMERI has made significant contribution to the **CSIR 800** initiative for providing a better life to 800 million people in the country through the provision of appropriate technological solutions in the area of agriculture, energy and other domains. Keeping in mind the promise India holds in emerging as a global innovation hub, CMERI has dedicated its efforts for promoting innovations at the non-formal and formal sectors.

Technology Demonstration on Pedicab for the Promotion of Eco-friendly Urban Transport (SOLECKSHAW) System in India

Background/Objectives

In the busy streets of cities, mainly in Asian subcontinent, we find many tricycles and auto rickshaws. Auto rickshaws are driven by fossil fuel, which produces considerable pollution. On the other hand tricycle or cycle rickshaws are used to carry two passengers and are suitable for narrow streets at speeds below 15 Km/hr and do not contribute to pollution since these do not use fossil fuels. But driving cycle rickshaws proves to be quite demanding for the driver, as the rickshaw has to be driven solely by manual power. Considering the climatic changes caused by environmental pollution, introduction of green vehicles has become very important. Especially in busy streets of cities, pollution is at alarmingly high levels due to very slow movement of automobile vehicles. Keeping these in mind, solar powered motor assisted tricycle (**SOLECKSHAW**) has been developed. The Soleckshaw is mainly pedal driven and is assisted by an electric motor drawing energy from a resident battery, which can be charged at a solar power charging station. This vehicle provides driving comfort to the driver and can run for longer distances compared to manual driven cycle rickshaws, resulting in higher earning of rickshaw pullers. An override mechanism has been used at the center of rear axle resulting in proper turning and better dynamic stability of the vehicle. Its power source is solar energy, which eliminates the problem of environment pollution that lies with other automobile.

The SOLECKSHAW has the following salient features:

- Dual Drive: Manual & Solar Power Assisted

- Minimum manual effort, leading to reduction of drudgery for rickshaw puller
- Batteries charged from solar charging station
- Zero Carbon Urban Transport

Work done & discussion with Figures

The SOLECKSHAW has been designed with following specifications.

- Power source : Electric and manual
- Type of Drive : Electric Motor assisted pedal driven
- Electric Motor : 240W, 36 V Brushless DC (BLDC) Hub Motor
- Manual drive : Sprocket and chain drive by pedaling to rear axle
- Pay load : 210 Kg, considering two passengers and one driver
- Average speed : 15 Km hr-1
- Motor mounting : On front wheel
- Brake : On all 3 wheels (disc or drum brakes)
- Weight : 100 Kg

Some prototypes conforming to the above specifications have been fabricated at CMERI, Durgapur for trial run and testing. Different models of the prototype have been built for sitting capacity of two passengers, driven by one driver. To make it appealing to the passengers, the vehicle body has been aesthetically designed. The product has been developed with two types of wheels. Figure 1 shows prototypes with smaller and wider wheels, providing better traction and stability. It is also equipped with better suspension and lighting system, but involves a higher cost. Figure 2 on the other hand shows the same pedicab with conventional bigger wheels like those used in normal cycle rickshaws, and these are produced at a lower cost to ensure ownership my poor rickshaw pullers. These two models are to be charged from a solar charging station. Figure 3 represents the pedicab with overhead solar panel, which can charge the battery of vehicle and it is not dependent on a separate charging station.

Outcomes

- Technology development for electric motor assisted tricycle
- Prototype development and conduction of successful road trials
- Technology transfer to three entrepreneurs
- Filing of two patents and one trade-mark application
- One paper accepted in the International Journal of Electric and Hybrid Vehicle, Inderscience publishers

Design and development of variable speed DC driver for Hybrid Solar Rickshaw

Background/Objectives

BLDC motors offer a lot of advantages for automotive applications. BLDCs are lighter in weight, more durable, and consume less power than their brushed cousins. They have an excellent low end torque capability and offer a very wide speed range. There are many microcontrollers that can easily control

Figure 1

Figure 2

Figure 3

a brushless motor. While some are more elegant and efficient than others, a lot has to do with the peripherals. Some have the right kind of analog to digital converter controls allowing synchronous sampling of an analog voltage. A brush-type permanent magnet motor has the magnets in the stator, or the stationary part of the motor, and the windings in the rotor. As the rotor rotates between the brushes, the commutation, or switching from one phase to the next, takes place naturally. BLDCs offer a simple and reasonably reliable solution over brushed DC motors since brushes are the weakest link in the durability chain. Brushless motors commutate the windings by electronic means, thereby dispensing with brushes and commutator bars.

The primary objective of the project is to design and develop a reliable controller for speed control of BLDC motors being used as a prime mover for the Soleckshaw – a pedal operated, motor driven (on demand) pedicab being developed at CMERI.

Work done & discussion

The system is implemented developing the hardware using a Phillips 8051 based microcontroller (P89C51RD2), which is programmed with sensor-less control for BLDC motor. The implementation through 'C' and assembly language programming of DSP has resulted in reduced hardware and fast response of the controller. The high performance of controller minimizes the control loop delays. The basic scheme allows further modifications in the control structure, implemented by rewriting the software. The implemented hardware can support a speed range up to 3500 rpm with reduced back EMF noise. The validity of the proposed BLDC motor drive system is verified through testing on hardware results such as phase current, back EMF signal waveforms and speed. The experimental results on a 3-phase, 24 V, 120 W BLDC motor using Phillips 8051 based microcontroller (P89C51RD2) based digital controller closely agree with the desired results.

Hardware was developed using a Phillips 8051 based microcontroller (P89C51RD2), Motor driver hardware is designed using 6 – MOSFET which are fed by PWM signals generated by the microcontroller. Only two MOSFETs are switched at a time. The sequence of MOSFET on-off depends on Hall Sensor Input fed to microcontroller.

The commutation sequence for BLDC motors has one of the windings energized to positive power (current enters into the winding), the second winding is negative (current exits the winding) and the third is in a non-energized condition. The interaction between the magnetic field generated by the stator coils and the permanent magnets creates the required torque. Ideally, the peak torque occurs when these two fields are at 90° to each other. In order to keep the motor running, the magnetic field produced by the windings should shift position, as the rotor moves to catch up with the stator field. The motor construction with star connection consists of three electromagnetic circuits connected at a common point, also referred to as neutral point. Each electromagnetic circuit is split in the center, thereby permitting the permanent magnet rotor to move in the middle of the induced magnetic field. The key to electronic commutation is to sense the rotor position, and then energize the correct winding phases to keep the rotor rotating.

Establishment of Centre for Post Harvest Technology in the North East

Background/Objectives

Thermal Engineering is one of the core activities of 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. 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, 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.

Tribal youths of Mizoram working in CSIR Rural Centre, Tuirial

Work done & discussion

As a part of the North East initiative, CMERI established post harvest processing centers at Mizoram and Arunachal Pradesh for processing ginger, turmeric, chili and other spices. The centers, along with its 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.

The drying system developed and installed by CMERI utilizes a source of hot air as drying media. The air, whose temperature is controlled by a thermostat, enters the drying system and gradually makes its passage through trays of produce being dried, and exits through an exhaust vent.

The drying system is equipped with the trays, where hot air is circulated to follow a longer zigzag route, which, in its turn, increases the gas/solid contact time resulting in enhanced system efficiency.

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, CMERI proposes the establishment at local level in each of the districts of Mizoram and Arunachal Pradesh, which shall be run and maintained by NGOs / SHGs, and later extending the scope to cover the entire state. 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.

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


Driers for Ginger / Turmeric / Chili

Ginger / Turmeric Washing Unit

Ginger / Turmeric Slicing Unit


Construction of CMERI Rural centre at Aizwal, Mizoram

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

Centre for Post Harvest Processing and Research, Aizwal

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

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

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

Tribal youths 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 youths 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, 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.

TePP Outreach Centre

The mandate of the 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, 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 CMERI was established in September 2008.

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 five innovations, namely:

- Portable Microscope Slide Projector (Teaching Aid)
- Self-propelled three row potato seeding device
- Solar powered DC/BLDC motor operated kerosene dispensing unit with biometric/bar-code access control
- Low specific-cost solar parabolic dish concentrator system
- Electricity from tidal waves.

The projects are in various stages of completion now.

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 the scheme in 2005, 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, 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)

Details of the work done

Manually operated pulse thresher

- Improvement in the mode of operation by replacing the hand operation with an ergonomically designed pedal mechanism
- Design optimization to enhance the working capacity and minimize the torque input to the system
- Introducing compactness in the design facilitating ease of assembly
- Standardization of the components
- Introduction of safety attachment
- Providing for sieves of different mesh sizes for different applications

Shivraj Multipurpose Agricultural Equipment

Design optimization

Standardization of all components except the tyre

Provision for varying the speed of the ground wheel for seed drilling pitch vise

Provision of ratchet mechanism replacing extant levers for better belt tensioning

Provision to adjust the tine depth for ploughing

Obviation of residual seeds in the seed box

Provision of dividers to properly guide the seeds directly into the delivery conduit

Hand Operated Water Lifting Device

- Improvement of discharge rate,
- Weight reduction
- Increase in the gear ratio,
- Ease of operation,
- Ease of assembly of the prototype with foldable option

Siddhant Self Propelled Windrower Reaper (Attachment part)

- Design optimization to minimize the torque input to the system and enhance the working capacity
- Standardization of the components

SERVICE INTERFACES

Inspection, standardization and quality assurance are the primary aspects integrally associated with product development, as the product must conform to the laid-out standards in respect of dimension, material composition, soundness, safety aspects, etc. CMERI manifests a strong attitude towards quality assurance through testing, evaluation, calibration and standardization – along with the requisite infrastructure and human resource – which user industries have exploited and have benefitted in the process.

Excellent testing and calibration facilities exist in the areas of Metrology, Mechanical testing, Material Testing, Metallurgical testing, Non-destructive Testing, Vibration & Noise Analysis, Thermal Evaluation, Bearing Testing, etc. A few areas of importance are projected in this section.

RESIDUAL LIFE ASSESSMENT

Most of the critical components in process and power plants operate at extreme environments in creep regimes and are subjected to conditions that degrade the components gradually. This may be due to one or a combination of time-dependent damage mechanisms such as creep, fatigue, corrosion, erosion etc.

Critical components are therefore designed with respect to a target life usually based on a degree of allowable strain accumulated in a specified period of operation. A further factor of safety is then applied in selecting the stress. This, once again, translates into an expected life of 25 to 30 years for the components.

In actual conditions the useful life of components in service may well exceed or fall short of the design life due to design, operational, environmental and metallurgical factors. Considerable reserve strength and ductility even after the end of design life may be expected because of the conservatism of the original design. On the other hand, the components may fail prematurely due to operation under conditions not envisaged in the design stage.

It is therefore necessary to assess the residual life of different vital components of a process unit approaching the design life, and especially when it is planned to run an old plant beyond its design life with an acceptable level of safety and reliability.

Residual Life Assessment (RLA) is the most important step in knowing the present status of the components and taking remedial actions for the life extension of process plants. The purpose of life extension activities is not to continue the operation of a plant beyond its usual life but to ensure full utilisation up to its residual life.

RLA helps in preventing the premature retirement of process plants and their components, which in turn has important ramifications on the operational and financial aspects of plant performance. RLA has now emerged as a full-fledged discipline embracing development and incorporation of methodologies that help in decision making in run, repair, retirement and life extension of critical process plant components.

In fact, the very concept of RLA embodies a set of values and a particular philosophical approach, stressing on scientific identification of the causality with regard to damage and deterioration and ensures optimal utilisation of a process plant.

It is evident that for conduction of activities related to RLA, a base level of competence in such disciplines as material science, metallurgy, heat power & engineering, machine design, condition monitoring & failure analysis is required. CMERI is ideally posed to cater to these requirements, as a common pool of exists in the Institute with contributions from experts in all the areas of specialization. The distinctive features of the services extended by CMERI in this discipline are:

- Collateral strength in all the requisite disciplines related to RLA
- Over two decades of strong presence in the field.
- Best-of -the-class intellectual capital.
- A strong background of exhaustive engineering research.
- Regular supplementing of acquired skills with state-of-the-art developments.
- Thorough in-depth scientific analysis for determining the best preventive action.
- Appropriate, innovative and cost-effective solutions.
- Over two hundred successful case studies.

METROLOGY

Metrology is the science and art of precision measurement and is one of the most essential components needed for ensuring quality of industrial products. In the prevailing atmosphere of commitment to quality, metrology is an imperative tool that helps in raising the quality and accuracy of measurements, thereby leading to product quality improvement. In fact, metrology is the mother science for appraisal, communication and decision-making in industries and also in research and development. Accuracy in measurements is essential at all stages of product development and covers the entire gamut covering research, design, production, testing & evaluation, quality assurance, standardisation, on-line control, operational performance appraisal, reliability estimation, etc.

Technological advancements in automation, robotics, space ventures, satellite communication, precision medical application, etc. the need for dimensional accuracy of functional parts has assumed paramount importance. So much so, that the level of industrial development of a country can now be gauged by its excellence and degree of sophistication in metrological capabilities. A close study of ISO 9001, ISO 9002 and ISO 9003 clearly show how important the element "Inspection, Measurement and Test Equipment" is in the context of these international standards. These are essential requirements that decided whether or not an applicant for ISO 9000 series accreditation does qualify for the certification. Clause 4.10 of ISO 9002, Clause 4.11 of ISO 9001 and Clause 4.6 of ISO 9003 require manufacturers to maintain appropriate records, quality plans and documented procedures for product testing according to specified and clearly laid down standards. ISO 9000 also requires on part of the successful applicant to establish and maintain a system for periodic calibration of measuring standards. In addition, all testing and calibration activities need to be documented so as to provide documentary evidence of satisfactory operation of all testing and calibration equipment.

CMERI happens to be the leading laboratory recognised by the Bureau of Indian Standards (BIS) in so far as mechanical measurements are concerned. CMERI has traceability to national standards of the National Physical Laboratory, the custodian of measurement standards as regards length. A high echelon of individual professional competence, long familiarity with the ground rules of precision measurement and an atmosphere of stringent procedural adherence adds excellence to the service provided by CMERI in the field of dimensional metrology that guarantees the customer not only perfect services, but also value addition.

Activities at the core of metrological services are:

- Calibration of master gauges and measuring instruments
- Precision measuring assistance in product development activities
- Customized training for defined technical levels.

The laboratory is equipped with standard calibration facilities for the following parameters:

- Length & form measurements
- Angle measurement
- ·Surface roughness characterization
- ·Pressure measurement
- Vacuum measurement.

Facilities available for calibration

- Micrometers with Setting Pieces
- Vernier Calipers, height & Depth Gauges, Height Master
- Dial Gauge, Test Indicator & Snap Dial Gauge
- Screw Plug & Ring Gauges (Parallel & Taper upto 100 mm nominal diameter except square thread)
- Straight Edge, Surface Plate & Table, Precision Block Level
- Slip Gauges (Grade 2, Grade 1 & Grade 0)
- Length Bars, Angle Gauges, Steel Tape & Scales,
- Pitch Gauge, Radius Gauge & Filler Gauge
- Engineer's Square, Bevel Protector, Combination Set, Sine Bars & Clinometers
- Plane Plug, Ring Gauges (Parallel & Taper) & Morse Taper
- Pressure Gauge, Load Measuring Gauge & Vacuum Gauge
- Dead-weight Pressure Gauge Tester / Calibrator.

Additional services for Precision Inspection / evaluation of:

- Ground or Generated Gears, Spur, Helical & Bevel
- Gear Hubs & Worm Gears
- Cam Shafts & Templates
- Roundness & Form Errors
- Surface Roughness Characterization
- Lead Screws of Machine Tools
- Machine Bed Alignment
- Ball & Roller Bearings
- Gas Cylinder Valves
- Viscosity Flow Cup.

Importance

- Application in areas like Automation, Robotics, Space, Satellite Communication, Precision Medical Applications are of paramount importance.
- Metrological accuracy is an essential requirement for any quality series accreditation.
- In addition, all testing and calibration activities need to be documented so as to provide documentary evidence of satisfactory operation of all testing and calibration equipment.

FACILITY AVAILABLE	CAPACITY / SPECIFICATIONS	APPLICATIONS
Co-ordinate Measuring Machine F 1006	Measuring Range: X = 1000mm Y= 650mm Z= 600mm Resolution: 1µm Accuracy: 03±4L/1000µm	Measurement of linear dimensions, point locations and hole-centres contour on single or multiple planes externally or internally. CMM upgraded from Micropak 210 to Geopak (3) and Scanpak (3) software integrated to compute contour and profiles.
Internal Diameter Measuring Machine	Measuring Range: 6.35mm – 150mm to a maximum depth of 50mm Resolution: 0.2µm Accuracy: 1µm	Measurement of: 1. Internal Plain Diameters (parallel) 2. Internal screw thread diameters (parallel) 3. Internal plain diameters (taper) 4. Internal screw thread diameters (taper) having threads square to the axis.
Perthometer (S6R)	Magnificance: Horizontal: 1000X Vertical: 10000X Resolution: 0.1µm	Measurement of surface roughness on components like spindles, bearings, gauges, etc. and characterization through statistical technique with strip profile recording.

(Contd.)

FACILITY AVAILABLE	CAPACITY / SPECIFICATIONS	APPLICATIONS
Floating Carriage Diameter Measuring Machine	Measuring Range: 0 – 100mm Resolution: 0.2µm Accuracy: 1µm	Measurement of: 1. External plain diameters (parallel) 2. External screw threads (parallel) 3. External screw threads (taper) having threads square to the axis.
Universal Profile Projector	Magnifications: 10X, 25X & 50X; Capacity: Linear: 0 – 25 mm Angular: 0 - 360^0 Resolution: Linear: 0.001mm; Angular: 1 min of arc	Inspection of profiles, templates, precision measurement of length and angle.
Universal Measuring Machine	Measuring Range: X= 400mm Y= 100mm Resolution: 0.5µm	Measurement of linear dimensions, point locations and hole centres externally and internally.
Dead Weight Pressure Gauge Tester	Capacity: Maximum 50000psi in steps of 5 psi	Calibration of Pressure Gauges and Load Measuring Gauges.
Electro Limit Comparator (Talymin Gauge series 2)	Capacity: 0 – 170mm Resolution: ±0.2µm ±0.5µm	Inspection of tools and gauges.
OMT Vertical Omtimeter	Capacity: 0 – 250mm Range: ±0.120mm Resolution: 1µm	Measurement of length, thickness, diameter, standard end cylindrical gauges and precision steel balls.
OMT Vertical Omtimeter	Capacity: 0 – 250mm Range: ±0.120mm Resolution: 1µm	Measurement of length, thickness, diameter, standard end cylindrical gauges and precision steel balls.
Vacuum Gauge Tester	Capacity: 0 – 76cm Hg. Graduation: 1cm Hg of scale	Calibration of Vacuum Gauges up to 70cm of Hg.
Taper Diameter Measuring Machine	Capacity: 0 – 100mm Length: 0 – 330mm Resolution: 0.2µm	Inspection of external taper.
Slip Gauge Calibrator 826E	Capacity: 0 – 170mm Accuracy: 0.01µ	Calibration of Slip Gauges.
Numerical Precision Balance	Capacity: 100gm Accuracy: 0.1mg	Calibration of precision masses.
Common Balance Class B	Capacity: 10kg Accuracy: 1mg	Calibration of precision masses. *(Contd.)*

FACILITY AVAILABLE	CAPACITY / SPECIFICATIONS	APPLICATIONS
Roundness Measuring Machine (Talyrond Model 2)	Capacity: a. External & internal diameters: 350mm b. Maximum height: 700mm c. Resolution: 0.2μm d. Magnification: 1000X	Measurement of: a. Errors of roundness b. Concentricity c. Squareness d. Flatness e. Parallelism
Vertical Meteroscope	Capacity: 0 – 200mm Resolution: 1μm	Measurement of external dimensions of work pieces with flat parallel gauging surfaces, cylindrical work pieces, balls or work pieces with spherical gauging surface.
Millionth Comparator	Suitable for comparing Slip Gauges up to 25mm length with a direct scale reading of 0.0001mm	Calibration of Slip Gauges.
Level Comparator (Wall Type)	Capacity: 0 – 1000mm; Accuracy: 0.2μm	Calibration of Length Bars.
Auto Collimator	Measuring range up to 10m; Resolution: 0.2 sec. of arc; Accuracy: ±1 sec. of arc	Measurement of straightness, flatness, squareness of machine tables, cast iron and granite surface plates / tables.
Microoptic Angle Dekkor	Maximum working distance: 12m, Accuracy: 6 sec. of arc Resolution: 0.5 sec. of arc	Any angle can be measured by comparison with a standard angle or any change of angle can be observed instantly and accurately.
Optical Dividing Head	Diameters up to 200mm Resolution: 30 sec. of arc	Measurement of index plates, spline shafts, keyways, angular measurements of parts having centres at both ends and throw of cam shafts.

NEW FACILITY IN THE DIMENSIONAL METROLOGY

CMERI has augmented its strength and service interface in Dimensional Metrology through the induction of two new facilities.

The first instrument, a state-of-the-art CNC Co-ordinate Measuring Machine (Model – Spectra) has been inducted recently. This instrument has a measuring range of X = 600 mm, Y = 800 mm and Z = 500 mm, a Resolution of 1 mm, Repeatability (CNC): 2 mm and Volumetric Accuracy: 0.004+L/300 < 6 mm. CNC Control in the machine facilitates probing in standard and continuous modes. A VDMIS Software platform is further provided for geometric measurements, surface measurement and CAD comparisons. Reverse engineering applications as well as non-contact measurements using Nexter Laser attachment scanner has rendered this machine more versatile. A ML 10 Gold Standard Laser (Make: Revishew, UK) has further been added to the existing facility in Dimensional Metrology. This instrument uses a Helium-NeonLaser source and employs a Class 2 Tube. It can perform linear measurements up to the range of 40mm with an accuracy of ± 7 ppm and with a resolution of -0.001 mm. In addition to linear measurements, Angular, Rotary, Flatness, Squareness and Straightness measurements can be performed with this equipment. Automatic environment compensation, data capture and analysis with Laser 10 software are added features.

Pressure equipment like gauges and transducers form the major components of modern development and production processes. Most of the industries, including power generation utilities, fertilizer plants, chemical and petrochemical plants, automobile plants, the aviation industries, etc. are totally dependent on accurate measurements of pressure for different process controls. Moreover, pressure measurements are essential for human safety against hazards. To cater to the growing need of calibration in pressure testing equipment, the Dimensional Metrology Lab at CMERI has established a High Pressure Laboratory that offers an accuracy of ± 0.005% in calibration of pressure testing equipment. A Pressure Balance including a Class S2 Mams set (100 kg) has been installed, which can perform pressure calibrations upto 500 mpa with a 5000 bar constant volume valve. The instrument further incorporates interface terminals and has the ability to support two pressure balances for easy cross floation and automatic compensation for environmental influences. This instrument can further derive true pressure with an uncertainty of less than ± 0.005/ reading.

In addition to this, an accurate comparator in the range of 0 – 1200 bar has been installed in the High Pressure Laboratory for use with oil and which is ideally suited for shop-level environment. It provides a complete measurement solution including generation, control and measurements of pressure and also singular readings from instruments under test. It has accuracy of 0.05 / of full scale, including temperature compensation 0^0 to 40^0 C.

IMMERSIVE VISUALIZATION FACILITY

Virtual Prototyping (VP) programs provides a means of rapidly developing system concepts and analyzing them for form, fit, function, logistics, human factors integration, and general feasibility analysis. The resulting models can be studied, viewed from different angles, and even "entered" (Integrating with Virtual Reality) by multidisciplinary design teams working in an integrated product development environment.

CMERI has a rich working background in Computer Aided Design (CAD) and Computer Aided Engineering (CAE), and its expertise in visualization is being augmented with the induction of state-of-the-art facilities in Virtual Prototyping and Virtual Reality, which facilitates working in the full 1:1 scale assembly level rather than at the conventional component level.

Simulation of the functional behavior of the full scale digital prototypes help in identifying the design flaws at the early stage of product development and has the direct effect on reducing the number of development of actual physical prototypes, which, in its turn, reduces the lead time for product development and the time to market the product.

Salient Features

The Advance Simulation and Immersive Visualization Facility is equipped with very powerful computing platform for full-scale multi-physics analysis (fluid, structural or thermal) with integrated multi-piped graphics subsystem for real time rendering and visualization of large datasets. Silent features of the facility are:

- Computing power of the order of 20–24 peak GFLOPS. (12xR16000x1GHz MIPS processors)
- 4 parallel SG2 graphics pipelines with graphics compositing facility for rendering very large data sets.
- 24 GB RAM on shared memory architecture required for holding large datasets in memory.
- 1TB of storage.
- Large wall format display (8'x6') with high resolution BARCO CRT projector to work in mono and stereo modes.
- Software codes like CATIA V5, LS-DYNA, ADAMS, ENSIGHT GOLD, etc.
- Compilers & Libraries for development applications in C, C++, FORTRAN, OpenGL Performer.
- Xeon processor based Windows / Linux workstations for data preprocessing.
- High-speed internal network for data transfer.

Working Areas

- Rigid body dynamics for functional simulation of full-scale prototypes
- Nonlinear high-rate dynamics for functional simulation of a range of materials and environment
- Post processing of analysis / simulation data for immersive visualization and interaction

CENTRE FOR ADVANCED MATERIAL PROCESSING

A **Center for Advanced Materials Processing (CAMP)** has been established at CMERI for dedicating research efforts for the development of high-technology materials processing relevant to manufacturing aspects and is focused on industrial concerns and meeting industrial needs.

The mandate of CAMP is to bring about innovations in advanced materials processing and to transfer this technology to industry for application. Towards this end, CAMP is receiving support from CMERI, CSIR networked projects, DST and other industrial R&D services.

Objectives

- The goal and objectives of the Center for Advanced Materials Processing are:
- To create a center of expertise in advanced materials processing
- To provide R&D and material testing services to government groups and private industry through funded research projects
- To facilitate training, research opportunities, and assistance to graduate and undergraduate students
- To enhance the knowledge and productivity of manufacturers & to provide financial and research opportunities for faculty
- To strive for national and international prominence in the field of materials processing and manufacturing of advanced components.

The presently CAMP involves in developing capabilities of Advanced Materials Processing Technology for manufacturing of engineering and biocompatible components through different materials processing techniques. It caters to present scope of activities with future developmental work in the advanced materials processing in the following areas:

- Metals, alloys, and metal matrix composites through Investment casting / Rapid Prototype Integrated Investment Casting (RPIC)
- Ceramics, ceramic matrix composites, cermets etc for structural, cutting tools & other engineering applications.
- Net Shape processing of advanced ceramic engineering components / bio- implants through RPIC / Gel Casting & Sol-gel process
- Sol-gel processing for coating application
- Synthesis of ultrafine / nano-powders through wet chemical processing for development of advanced engineering and bio-medical components.
- Smart Materials Processing for self-adjustment of humidity and temperature

Major facilities with CAMP

- Planetary Mill (2x 500ml)
- Wax injection Press
- Ceramic shell making facilities including slurry mixer, fluidized bed systems for stuccoing
- De-waxing autoclave
- Ceramic shell baking furnace
- Melting & pouring facilities for non-ferrous alloys /MMC
- High temperature sintering furnace (Air, 1700C)

Post Processing Equipment

- Lapping & Polishing Machine
- Ultrasonic cleaner
- Abrasive cut-off machine
- Characterization Equipment
- 4-Component Dynamometer (Kistler)
- Scratch tester (1 to 200 N)
- Reciprocating Wear & Friction
- Air Jet Erosion (max. 120m/sec)
- Microscope (inverted stage) with Image analysis system

NATIONAL TESTING FACILITY FOR BEARINGS

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, 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 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.

The National Test Facility for General Purpose Rolling Element Bearings was inaugurated by Prof. D.V. Singh on 27th September 2005. Dr. G. P. Sinha, Director CMERI, Shri. S.S. Kohli and Dr. A.K. Mallik, Head R&D, Tata Bearings, witnessed the demonstration and appreciated the efforts of the CMERI scientists.

Technical Specifications

Radial Load	40kg - 2000kg
Rotational Speed	Upto 1500 rpm
Bearing Inner Diameter	20mm - 40mm
Bearing Outer Diameter	45mm - 90mm
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 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 to 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 of a 10liter capacity 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 150bar. 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 5liter capacity 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 AC 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.

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:

- *gSE* values (IRD Instrument)
- Total revolution counts

The test rigs are stopped for further analysis as soon as the abovementioned parameters approach the predefined threshold

Test Monitoring

values. The oil from the test rig is taken out and wear debris analysis is utilizing Ferrography methods. The life of a particular bearing is determined based on these results.

Scope for future work

The establishment of National Testing Facility for General Purpose Rolling Element Bearings at CMERI is 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.

RESEARCH & TRAINING FACILITY IN EMBEDDED SYSTEMS

India represents immense potential and promises a very strong market after China and Japan in so far as embedded systems based applications are concerned.

Presently India has approximately 50 million smart cards users with around 30% usage in cell phone SIM cards. There are around 3 million mobile phone users in this country, and the figure may well exceed 12 million users quite soon.

Indian smart card industry is growing @ 45% per annum.

The requirement of smart cards as identity cards and in the municipal, welfare, healthcare and transportation sectors is expected to grow phenomenally.

CMERI is fast growing in stature as a solution provider in Embedded Technology Systems by virtue of the services it is

Smart Fuel Dispensing system developed at CMERI

extending through the Integrated Research & Training Centre in Embedded Systems.

For facilitating demands for design and development of products tailored to commercial and industrial requirements in India, this centre is equipped with state-of-the-art facilities like:

- Embedded systems development tools for real-time application
- Fuzzy logic based application-specific product development tools
- Matlab software & simulator
- Digital signal processing hardware and software
- Smart-card based product design facility

This centre is already offering application-specific training courses in Embedded Systems Technology and has further started functioning as a technology support centre for embedded systems based product development. To emerge as a competence centre in embedded systems, the Centre has initiated industry-driven need-based research in the following focus areas:

- Embedded Fuzzy Control in Energy Management
- Hardware Optimisation through FPGA
- Smart-card based application specific research
- Embedded web-server based technology development.

In addition to developmental work, the Centre shall act as a nodal body for **research, human resource development** and **entrepreneurship promotion** in this emerging and very promising cutting-edge technology area.

HUMAN RESOURCE DEVELOPMENT

The Human Resource Development Group of the Institute organized a number of training programmes for augmenting the knowledge base of CMERI personnel, the details of which are as follows

IN-HOUSE TRAINING PROGRAMMES ORGANISED FOR CMERI PERSONNEL

SL.	TRAINING PROGRAMME ON	PARTICIPANTS
1.	Basic Computing	1
2.	Electrical Maintenance	3
3.	Tolerance Chatting & Stack Analysis	7
4.	Tool Design	5
5.	Cutting Tool Materials & Theory	6
6.	Testing Of Pressure Vessels & Cylinder	5
7.	FEM/ANSYS	8
8.	National workshop on Condition Monitoring	15
9.	Workshop cum Training programme on Engineering	14
10.	Short term course on design	2
11.	FEM	10
12.	CNC Machining	8
13.	Process Planning	6
14.	Metrology	3
15.	Modeling & Surfacing Using CATIA	4
16.	Fitting & Assembly	9
17.	SPC	3
18.	Conventional Machining	4
19.	Application of Bar Coding on Library	1
20.	Quality Control	5
21.	Engineering Drawing	9
22.	Patent Drafting	22
23.	FEM/ANSYS	10
24.	Mechanical Design	4
25.	Process Plant Engineering	5
26.	Fitting Assembly	4
27.	Metrology	6
28.	ISO	4
29.	Six Sigma	4
30.	Heat Transfer	15
31.	Theoretical Approaches for Turbulent Flows	15
32.	Vibration Analysis	20
33.	Mechanism	43
34.	IDEAS	3
35.	GD & T + Stack Analysis	3
36.	Quality Control	1
37.	Theory of Cutting Tool Materials	2
38.	CNC Machining	2
39.	Process Planning	3

OUTSIDE TRAINING SCHEDULES ATTENDED BY CMERI PERSONNEL

SL.	TRAINING PROGRAMME ON	PARTICIPANTS
1.	Entrepreneurial 2007	3
2.	Non-Destructive Testing & Evaluation of Concrete Structures	1
3.	Analysis & Design for Wind And Seismic Loads	1
4.	Technology Led Entrepreneurship	4
5.	Internal Auditor ISO 9001:2000	2
6.	Enhancement of Management Efficiency for Scientists	2
7.	E – Journals Consortium	2
8.	Induction Training Programme for Newly Recruited Scientist B & C	3
9.	Enhancement of Managerial Efficiency for Scientists	1
10.	Micromachining	1
11.	Welding & Inspection	1
12.	Crafting Effective S & T Communication	2
13.	Leveraging Intellectual Property For Business Development	2
14.	Induction Training Programme For Newly Recruited Scientist B & C	3
15.	Research Methodology And Statistical Methods	2
16.	Leadership Development	2
17.	Project Management Techniques and Practices	2
18.	Leadership Development Programme	3
19.	Condition Based Maintenance	1
20.	Planning Process For Post Retirement Life	3
21.	E-Procurement	1
22.	Industrial Corrosion: Evaluation And Mitigation	1
23.	Patent Issues Related To Electronics, Software, Electrical & Mechanical	2
24.	Diagnostic Maintenance & Machine Condition Monitoring	1
25.	Refresher Programme for the Section Officers	
26.	Mentoring as A Management Tool	3
27.	Enhancement of Managerial Efficiency for Scientist	1
28.	Robotics	12
29.	Advanced Course for Private Secretaries	3
30.	Leadership Development	3
31.	Patents for IP Professionals, Attorneys & Lawyers	1
32.	CEP Short Course on Delivering High Quality Services In Guest House	3
33.	Refresher Programme for Assistants Gr-I(Admin)	3
34.	Leadership Development	1
35.	Science Audit for Senior Scientists and Senior Administrators	2
36.	Enhancement of Managerial Efficiency for Scientists	2
37.	ANSYS Workbench Modeling & Simulation Introduction	1
38.	Planning for Life After Retirement	2
39.	Flow meter and Calibration Technique	2
40.	Refresher Programme for Stores & Purchase Assistants	3
41.	Training Programme for Security Officers	1
42.	Project Management	2
43.	Mentoring as A Management Tool	2
44.	Awareness Programme on RTI Act for Appellate Authorities	1
45.	TRIZ Methods	3
46.	Computational Fluid Dynamic	1
		Contd..

OUTSIDE TRAINING SCHEDULES ATTENDED BY CMERI PERSONNEL

SL.	TRAINING PROGRAMME ON	PARTICIPANTS
47.	Knowledge Management	1
48.	17th Induction Training Programme	2
49.	Self-Effectiveness at Work Place	2
50.	Leadership Development	1
51.	Ultrasonic Testing Course (Level-II)	1
52.	Skill Development Programme for Section Officers	1
53.	Crafting Effective S &T Communication	2
54.	Red Hat Linux Training with Global Certification	1
55.	Probability, Statistics and Optimization Method with Application	1
56.	Practical Vibration Analysis with SKF Microlog-70S	1
57.	Science Communication: The Emerging Scenario	3
58.	Computational Thermal & Fluid Science & its Engineering Application	2
59.	Application of S/W in Analysis and Design of Structure	2
60.	Web of Science	2
61.	Advanced Executive CDM Training Programme	1
62.	Design And Development of Digital Libraries Using Dspace	2
63.	Flow Meters & Calibration Techniques	2
64.	Power Electronics	1
65.	Residential Workshop on LDP 0904 & 0905	2
66.	Project Management	2
67.	ASTM Standards & Digital Library	2
68.	Project Management Techniques & Practices	2
69.	Renewal of UT Level II Certificate	1
70.	Information Security and Advanced Computing for Support Staff of Scientific Organizations	1
71.	Patent Strategies	1
72.	Power Electronics Application in Industry	1

TRAINING ORGANISED BY CMERI FOR OUTSIDERS

SL.	NAME OF PROGRAMME	PARTICIPANTS
1.	Training on Embedded System	16
2.	Training on Engineering Metrology and NABL Accreditation	10
3.	Training on Thermal, Vol. , Density Mass & Pressure	8
4.	Training on Calibration Technique for Mass, Vol. & Density	10
5.	Training on Course Engineering Tolerancing and stacking	6
6.	Training on Embedded system	15
7.	Training on Embedded system	15
8.	Training program on CNC Machining	30
9.	Hands on Training on Vol. tric calibration	5
10.	Training on Engineering metrology & measurement uncertainty	5
11.	Training programme on ANSYS	20
12.	Training on CNC Machining	31
13.	Training on Coordinate measuring machine	20
14.	Short-Term Training Course on Embedded Systems for Faculty Members	20
15.	Training Courses on CNC Machine	30
16.	Training Programmes on Pressure, Mass, Vol. & Dimension Parameter	5
17.	Training Programme on Embedded Systems	17

PARTICIPATION ON WORKSHOPS / SEMINARS / CONFERENCES

SL.	NAME OF PROGRAMMES	PARTICIPANTS FROM CMERI
1.	Conference on Factory Automation Robotics & Soft Computing	1
2.	Seminar on Achieving Technological Excellence in the New Millennium	1
3.	8th International Conference on Vibration Problems	1
4.	Indo-US workshop & Tutorial on Advances of Computational Optimization & Analysis	1
5.	Symposium on Physics ion the 21st century	20
6.	Conference on Current Trends In Remote Sensing and GIS application	1
7.	Workshop on Engineering Metrology & Quality for Growth	3
8.	International Conference on Emerging Mechanical Technology Macro to Nano	2
9.	Conference on Trends and Advances in Computer Aided Design and Engineering	1
10.	Workshop on Application of Renewable Energy	1
11.	Conference on Environmental Challenges and Management	1
12.	Seminar on Mechanized Cultivation of Sugarcane	1
13.	CSIR E-Journals Consortium-Nodal Officer Meet	1
14.	Workshop on towards a more Customer Responsive CSIR	1
15.	International Conference on Global Conference on Production and Industrial Engineering	1
16.	Workshop on Biofuels: Production Methodologies, Utilization & Challenges Ahead	2
17.	Seminar on Processing of Coals with reference to Indian Industries	1
18.	Workshop on Power Sector Reform-Learning through Experience	1
19.	PLACER-2007	13
20.	NWMMAM-2007	6
21.	Symposium on Advances in Stainless Steel	1
22.	Workshop on Industrial pollution and Environmental Issues in Durgapur	1
23.	Eastern India Energy Summit 2007	1
24.	Workshop on Current Manufacturing Technology	3
25.	Workshop on Condition Monitoring	15
26.	Seminar on Machinery Health Management	1
27.	Workshop on Engineering Tolerancing and Stacking	14
28.	Manufacturing Design & Analysis	1
29.	Symposium on Metrology & Quality Management	2
30.	Workshop on DMI for Dimensional Metrology	3
31.	CSIR e-journals consortium	2
32.	Workshop on Effluent Treatment using fly ash-prospects & potential	10
33.	National Seminar on Environmental Management	1
34.	Seminar on Agri-Biotechnology: Opportunities and Challenges	4
35.	International Conference on Engineering Design	2
36.	International Conference on Modeling & Simulations	2
37.	Metrology for Quality Assurance and Product Development	12
38.	Workshop on Metrology for quality assurance and product development	46
39.	Training on Programming and Operating CNC Machines	38
40.	National Workshop on Investment Casting	10
41.	Conference on Advances in Materials & Manufacturing Technology	3
		Contd.

PARTICIPATION ON WORKSHOPS / SEMINARS / CONFERENCES

SL.	NAME OF PROGRAMMES	PARTICIPANTS FROM CMERI
42.	Workshop on Metallurgy of Iron & Steel	1
43.	International Conference (Team Tech 2007)	2
44.	Workshop on Renewable Energy Systems	4
45.	Workshop on Strategic Management of Human Capital	1
46.	International Seminar on Clean Energy	12
47.	ICAMC 2007	1
48.	Workshop on Manufacturing of Automotive Components from Cast	3
49.	Workshop on US patent law and Practice	1
50.	Conference on MEMS, Microsensors, Smart Materials, Structures & Systems	1
51.	Seminar on Role of R & D and Testing in Promoting small and Medium Industries	2
52.	International symposium on Measurement and Quality Control	1
53.	Workshop on Healthy and Wealthy Society by use of Herbal Science	1
54.	ICAMT-2007	42
55.	Workshop on Digital Image Processing and Application	4
56.	International Conference on Humanizing Work and Work Environment	1
57.	International Conference on Advance in Energy Research	1
58.	Symposium on Peaceful uses of Atomic Energy	12
59.	Creativity and Innovation-a two day programme	2
60.	International Conference on Theoretical, Applied Computational & Experimental Mechanics	1
61.	ISHMT-ASME Conference on Heat and Mass Transfer	1
62.	71st Annual Session of the Indian Ceramic Society	1
63.	NGMS2008	1
64.	Seminar on Engineering Software Products: Requirement to Deliverables	1
65.	Technical seminar on Advance in Steam Generation Technology	3
66.	Seminar on Indian Electricity Act & Rules-Experiences & Way forward	2
67.	Conference on EMT-India 2020	1
68.	International Conference on Nanomaterial Toxicology	1
69.	Seminar on Data Analysis Using SPSS	1
70.	Seminar on The Electricity East 2008	1
71.	Conference on Quality for National Well-Being	1
72.	Conference of Indian Scientists Showcasing Science by Indian Women Scientists	4
73.	Symposium on Bionano Technology & Pharmaceuticals	2
74.	Nomination in SERC school on Texture and Microstructure	2
75.	Seminar on RREST and workshop on Solar Photovoltaic Systems	2
76.	Workshop on Recent Advance in Internal Combustion Engines	2
77.	Seminar on Wireless Communication and Networking	1
78.	Seminar on Environment Management & Pollution Control	2
79.	Seminar on Evolution in Electrical Systems	1
80.	FICCI Environmental Conclave	1
81.	Hindi seminar	1
82.	Workshop on Stimulating Attitudinal Excellence in Science	1
		Contd.

PARTICIPATION ON WORKSHOPS / SEMINARS / CONFERENCES

SL.	NAME OF PROGRAMMES	PARTICIPANTS FROM CMERI
83.	International conference on Aerospace Science & Technology	2
84.	Seminar cum Workshop on Colposcope	35
85.	Workshop on Modeling and Simulation of Dynamic System (MSDS-08)	4
86.	National seminar on Solar Energy	2
87.	Fuel –Cell –Technology, Standard s& Testing	2
88.	Energy Conclave 2008	2
89.	Seminar on Micro Machining and Nanofabrication	2
90.	National seminar (CCST)	1
91.	Workshop on Risk Based Inspection (WI & LP)	2
92.	International Conference on Creep, Fatigue and Creep Fatigue Interaction	1
93.	Seminar on Frontiers in Electronics Communication	1
94.	International Conference on Industrial Tribology	1
95.	DRDO Golden Jubilee Symposium on Robotics & Autonomous	2
96.	Seminar on Nanosikkim-III, Machining & Fabrication at the Nano-scale	2
97.	International conference on PLMMS-2008	4
98.	International conference on PLMMS-2008	1
99.	NIM-2008	2
100.	R & D Management Conference -2008	2
101.	Conference on ICON -2008	1
102.	2nd International & 23rd AIMTDR conference	4
103.	National Meet on Tractor & Allied Machinery Manufactures	2
104.	Seminar on Technical Education in India Challenges Ahead	2
105.	96 th Indian Science Congress	2
106.	International Conference on MEMS -2009	1
107.	Indo-US workshop on Microfluidics & Fabrionics	3
108.	International Food Processing Conference-2009	2
109.	National seminar on Engineering of S/w products : Perspective of Research & Development	3
110.	Workshop on Quality Assurance though Measurement Science	18
111.	Workshop on Ductile and Iron Castings	3
112.	57th Indian Foundry Congress	3
113.	57th Indian Foundry Congress	2
114.	57th Indian Foundry Congress	2
115.	National Conference on Scientific Achievements of SC/ST Scientists & Technologists	7
116.	Conference on Genital Infection & Neoplasia	1
117.	Nodal Officer's meet of CSIR e-Journals Consortium	1
118.	Symposium on Deformation Behavior & Process Modeling of Materials (DBPMM)	2
119.	Workshop on Production of Ductile Iron Casting using Stream Treatment & In-Mould Treatment Technique	2
120.	Renewable Energy India 2009	2
121.	IIP Golden Jubilee Symposium on Fossil Economy to Biomass Economy Opportunities & Challenges	1
122.	Environment & Energy Conclave 2009	1
		Contd.

PARTICIPATION ON WORKSHOPS / SEMINARS / CONFERENCES

SL.	NAME OF PROGRAMMES	PARTICIPANTS FROM CMERI
123.	Eastern India Clean Energy & Climate Changes Summit 2009	1
124.	Workshop on Advances in Technology & Sustainable Development	2
125.	Workshop on Bioinformatics in Genomics & Proteomics	2
126.	National Conference on Renewable Energy 2009	5
127.	Roving Seminar on Industrial Lubrication Management	2
128.	National Conference on Workshop on Technology & Innovation Management	1
129.	47th National Metallurgists Day	4
130.	Workshop on Metrology, Quality Assurance, Conformity Assessment & Proficiency Testing	5
131.	National Conference on Condition Monitoring	2
132.	Internal Auditor Training on ISO9001 :2008	1
133.	National Seminar on Non-Destructive Evaluation	2
134.	International Conference & Exhibition on Advances in Energy Research	1
135.	8th International Conference on Computer Information System & Industrial	1
136.	6th International Conference on Precision Meso, Micro & Nano Engineering	3
137.	International Conference on Computers & Devices for Communication	1
138.	5th IEEE Conference on Wireless Communication & Sensor Networks	1
139.	2nd International Conference on Emerging Trends in Engineering & Technology -09	1
140.	14th National Conference on Machines & Mechanics	9
141.	International Conference on Food Security & Environmental	2
142.	International Symposium on Biologically Inspired Computing & Applications	1
143.	Science & Administrator Interface Training Programme	1
144.	International Conference on Workshop on Application of Laser Mechanical Industries	3
145.	International Conference on the theme Mother Earth: Save It for Future Generations	2
146.	International Conference on Materials Mechanics & Management	2
147.	National Conference on Advance in Manufacturing Technology & Management	1
148.	International Conference on Recent Advances in Manufacturing Technology & Management	2
149.	International Conference on Investment Casting	8
150.	International Conference on Systems, Cybernetics & Information	1
151.	Indo -Australian Solar Energy Workshop	2
152.	Third North East & East Power Summit 2010	3
153.	Seminar on Total Solution of Chromatography	2
154.	Workshop on MEMS Capacitive Accelerometer & Training Programme on MEMS Design Tools	1
155.	25th AICC RCOG Annual Conference"	1

Contd.

PARTICIPATION ON WORKSHOPS / SEMINARS / CONFERENCES

SL.	NAME OF PROGRAMMES	PARTICIPANTS FROM CMERI
156.	Indo–German Seminar on Future Mobility	1
157.	Indo–Dutch Seminar & Training Programme on Process Safety	2
158.	National Conference on Challenges & Applications of Mathematics in Science & Technology	2
159.	Metallurgists Day Award	1
160.	Workshop on Development of Technology Commercialization & Transfer Specialist	1
161.	Workshop on Fracture Mechanics: A Modern Perspective	2

TWO YEAR M. TECH PROGRAMME IN MECHATRONICS

Collaboration	Objectives	Eligibility
BESU, Shibpur CEERI, Pilani CSIO, Chandigarh CMERI, Durgapur	To create skilled multidisciplinary manpower so as to cater to the growing demand of professionals in emerging areas of SW&T	B.Tech students from various disciplines with preferable GATE score can apply.
	To provide real-life experience across disciplines to the students on running projects at the CSIR laboratories for their project and thesis work	• Intake limited to 20 students per batch • The level of instruction comparable with any standard national level institute.

FOREIGN DEPUTATION OF CMERI PERSONNEL

SL.	DEPUTATION	TO	PARTICIPANTS
1.	Shri Arup Kumar Nandi	USA for attending **FAIM 07** at Philadelphia, USA	18/06/07 to 20/06/07
2.	Dr. Nagahanumaiah	USA under **BOYSCAST** fellowship	18/06/07 to 17/06/08
3.	Shri Deep Narayan Ray	South America for attending **23rd International Conference on CAD/CAM** at Colombia, South America	16/08/07 to 18/08/07
4.	Shri G. Balamurgan	South America for attending **23rd International Conference on CAD/CAM** at Colombia, South America	16/08/07 to 18/08/07
5.	Dr. D. Chatterjee	Sydney University, Australia as a visiting scholar for collaborative research work with Prof. Peter Lay's group on a scholarship awarded by Royal Society of Chemistry, UK	6/10/07 to 04/10/07
6.	Shri Palash Kumar Maji	Sri Lanka for attending the Seminar on **Best Practices in Agricultural Technology Transfer**	5/11/07 to 09/11/07
			Contd.

FOREIGN DEPUTATION OF CMERI PERSONNEL

SL.	DEPUTATION	TO	PARTICIPANTS
7.	Dr. Krishnendu Kundu Bangkok, Thailand	Bangkok, Thailand for presenting a paper in the **International Agriculture Engineering Conference** held at the Asian Institute of Technology, Bangkok	3/12/07 to 06/12/07
8.	Shri Biswajit Ruj	Stony Brook University, New York, USA for presenting a paper in the International Seminar on **Dangerous trade: Histories of Industrial Hazards across a Globalizing World**	13/12/07 to 15/12/07
9.	Mr. Naresh Chand Murmu	South Africa to participate in the **9th International Tribology Conference**	02/04/08 to 04/04/08
10.	Mr. Ranjit Roy	Thailand, Bangkok for obtaining training in 20Sim software package	04/05/08 to 11/05/08
11.	Mr. Sambhu Nath Nandi	Thailand, Bangkok for obtaining training in 20Sim software package	04/05/08 to 11/05/08
12.	Dr. D. Chatterjee	Germany for **DST-DAAD** project	11/05/08 to 07/06/08
13.	Dr. D. Chatterjee	USA for Platinization of nafion towards the development of ionic polymer metal composite (IPMC)	15/06/08 to 22/06/08
14.	Mr. Subrata Kumar Mandal	Greece for presentation of paper in the **Agricultural Engineering 2008 Conference and Industry Exhibition**	23/06/08 to 25/06/08
15.	Ms. Abhilasha Saksena	Japan under the **Hindu-Hitachi Scholarship**	01/07/08 to 31/12/08
16.	Mr. Partha Bhattacharjee Thailand	Thailand for attending the **9th ACIS International Conference on Software Engineering, Networking & Parallel / Distributed computing**	06/08/08 to 08/08/08
17.	Shri Arup Kumar Nandi	Finland under **BOYSCAST** Fellowship 07-08	15/09/08 to 28/02/09
18.	Dr. B.N. Mondal	Ankara, Turkey for participating in the **5th International Conference on Power Metallurgy**	08/10/08 to 12/10/08
19.	Dr. D. Chatterjee	University of Dhaka, Bangladesh under the project entitled **Kinetic Mechanistic and pharmaceutical studies on Ru-pac (Pac-Polyamino-carboxylate) complexes towards development of Ruthenium pharmaceuticals**	30/01/09 to 01/02/09
20.	Mr. Rudra Prasad Chatterjee UK	United Kingdom for participation in the **8th WSEAS International Conference**	30/01/09 to 01/02/09
21.	Mr. D.N. Ray, Sct-B Cairo, Egypt	**World Congress of Electrical & Electronics Engineering 2009**	05/04/2009 to 09/04/2009
			Contd.

FOREIGN DEPUTATION OF CMERI PERSONNEL

SL.	DEPUTATION	TO	PARTICIPANTS
22.	Mrs. Anjali Chatterjee Sct-EII	**8th. WSEAS International Conference**, University of Houston, USA	30/04/2009 to 02/05/2009
23.	Dr. B. Ruj, Sct-EI	**Raman Research Fellowship**, McMaster University, Canada	01/05/2009 to 31/07/2009
24.	Mr. M. Karmakar, Sct. E I	**Raman Research Fellowship**, Columbia	12/05/2010 to 15/07/2010
25.	Dr. K.P. Roysarkar, Sct-G	**International Conference on Computers & Industrial Engineering**, University of Technology, Troyes, France	06/07/2009 to 08/07/2009
26.	Dr. D. Chatterjee, Sct-EII	University of Erlangen, Germany	05/08/2009 to 04/10/2009
27.	Dr. Gautam Biswas, Director, CMERI	USA and Czech Republic as a member of CSIR delegation	11/09/2009 to 18/09/2009

PAPERS PUBLISHED

	2009
1.	Debabrata Chatterjee, C. Hariharan, M. Chatterjee, A. Mitra. Ru-edta (ethylenediaminetetraacetate) induced cleavage of DNA. **J. COORD. CHEM., January 2009, Vol. 62, Issue 10, pp. 1719-1724**
2.	R.K. Jain, U.S. Patkar & S.Majumder. Micro gripp.er for micro manipulation using IPMCs. **Journal of Scientific & Industrial Research, January 2009, Vol. 68, pp. 23-28**
3.	H. Roy, D. Ghosh, P. Roy, A. Saha, A.K. Shukla and J. Basu. Failure investigation of Platen Superheater Outlet Header. **International Journal for Manufacturing Science & Production, February 2009, Vol. 10, No. 1, pp. 17-24**
4.	H. Roy; D. Ghosh. Failure analysis of a Spring for a free pump Bracket Assembly. **Indian Journal of Engineering & Material Science, February 2009, Vol. 16, pp. 33-36**
5.	Subhendu K. Mukhopadhyay; Himadri Roy; Amitava Roy. Development of Hardness-Based Model for Remaining Life assessment of Thermally loaded Components. **International Journal of Pressure Vessel & Piping, April 2009, Vol. 86, No.4, pp. 246-251**
6.	Debabrata Chatterjee. Olefin epoxidation catalysed by [Ru(TDL)(tmeda)H_2O] complexes (TDL = tridentate Schiff-base ligands; tmeda = tetramethyethylenediamine). **Jornal of Molecular Catalysis A - Chemical, June 2009, Vol. 30, pp. 174-179**
7.	Debabrata Chatterjee. Hydrocarbon oxidation catalysed by [Ru(TDL)(XY)Z] complexes (TDL = tridentate ligands; XY = bidentate ligand and Z = H_2O or halide). **Catalysis Survey Asia, June 2009, Vol. 13, No.2, pp. 132-142**
8.	A. Saha, H. Roy, S. Ray, M. Maiti, K.K. Chowdhury, A.K. Shukla, J. Basu. Investigation of probable cause of damage of steam drum of naphtha cracking furnace. **Engineering Failure Analysis, July 2009, Vol. 16, Issue 5, pp. 1387-1396**
9.	H. Roy, S. Sivaprasad, S. Tarafder, K.K. Ray. Monotonic vis-à-vis cyclic fracture behaviour of AISI 304LN stainless steel. **Engineering Fracture Mechanics, August 2009, Vol. 76, Issue 12, pp. 1822-1832**
	Contd.

PAPERS PUBLISHED

	2009
10.	G. Balamurgan; BN Mondal. Taguchi Method & ANOVA: An app.roach for Process Parameters Optimizations of Hard Machining while machining with Harden Steel. **Journal of Scientific & Industrial Research, August 2009, Vol. 68, pp. 686-695**
11.	G. Balamurgan; BN. Mondal. Investigation on hard Machining of IMPAX Hi-hard Tool Steel. **International Journal of Material Forming, September 2009, Vol. 2, No. 3, pp. 145-165**
12.	A. Chatterjee, A. Mahapatra A. Mondal M. Chakraborti. Modal Response of 4-Rod Type Radio Frequency Quadrupole (RFQ) Linac, **Review of Scientific Instruments, American Institute of Physics, *October 2009*, Vol. 80, Issue 10, pp. 103303-103303-7**
13.	A.K. Lohar, B. Mondal, D. Rafajab, V. Klemmb, S.C. Panigrahi. Microstructural investigations on as-cast and annealed Al–Sc and Al–Sc–Zr alloys. **Materials Characterization, November 2009, Vo. 60, Issue 11, pp. 1387-1394**
14.	G. Balamurgan; B.N. Mondal. Optimization of Machining Parameters for Hard machining: grey relation Theory & ANOVA. **International Journal of Advanced Manufacturing Technology, December 2009, Vol. 45, Nos. 11-12, pp. 1068-1086**
15.	D. Ghosh, H. Roy, A. K. Shukla. Investigation of Probable Cause of Premature Cracking of Downcomer Nozzle of Heat Recovery Steam Generator. **Journal of Failure Analysis & Prevention, December, 2009, Vol. 9, No. 6, pp. 517-521**
16.	Swati Ghosh, V. Kain, A. Ray, H. Roy, S. Sivaprasad, S. Tarafder, K.K. Ray. Deterioration in Fracture Toughness of 304LN Austenitic Stainless Steel Due to Sensitization. **Metallurgical & Materials Transactions, December 2009, Vol. 40, No. 12, pp. 2938-2949**
17.	Nagahanumaiah, B. Ravi. Effects of Injection Molding Parameters on Shrinkage and Weight of Plastic Part Produced by DMLS Mold. **Rapid Prototyping Journal, 2009, Vol. 15, Issue. 3, pp. 179 – 186**
18.	Arup Kumar Nandi, J. Paulo. Optimisation of Surface Roughness in Hard Turning AISI D2 Steel using TSK-Type Fuzzy Logic Rules **International Journal of Materials & Product Technology, 2009, Vol. 35, No. ½, pp. 167-183**
19.	**Arup Kumar Nandi , J. Paulo Davim.** A study of drilling performances with minimum quantity of lubricant using fuzzy logic rules. **Mechatronics, March 2009, Vol. 19, Issue 2, pp. 218-232**
20.	Biswajit Ruj, P.K. Chatterjee, I. Rehman, B.C.Ray. Consequence of hazards on some petroleum storage tanks and model for off-site emergency plan. **Disaster Advances – an International Journal, Vol. 2 (2), pp. 36-40**
21.	Biswajit Ruj, S.N. Maity, P.K. Chaulia. Utilisation of Flyash as Gainful Resource Material for Green Brick Making. **Research Journal of Chemistry & Environment, December 2009, Vol. 13 (4), pp. 10-12**
22.	R. P. Chatterjee, B. Sutradhar, Uma Dutta. Remote control technique with OFDMA based app.roach for biologically inspired robots in a mobile ad hoc network (MANET). **WSEAS Transactions on Communications, May 2009, Vol. 8, Issue 5, pp. 437- 446**
23.	Anubhuti Saha, R. P. Chatterjee, Sarbari Datta. Active cord mechanism (ACM) controller for biologically inspired robots designed with frequency response app.roach. **WSEAS Transactions on Systems & Control, July 2009, Vol. 4 , Issue 7, pp. 316-328**
24.	A. Mahapatra, S.S. Roy. An App.lication of Computational Intelligence Technique for Predicting Surface Roughness in End Milling of Inconel-718 **International Journal of Recent Trends in Engineering, Nov 2009, Vol. 2(2), pp. 43-47**
25.	A. Mahapatra, S.S. Roy. Computer Aided Dynamic Simulation of Six-Legged Robot. **International Journal of Recent Trends in Engineering, Nov 2009, Vol. 2(2), pp. 146-151**
	Contd.

PAPERS PUBLISHED

	2009
26.	Nagahanumaiah, J. Ramkumar, N. Glumac, S.G. Kapoor, R.E. Devor. Characterization on plasma in micro EDM discharge using optical spectroscopy. **Journal of Manufacturing Process, July 2009, Vol. 11, No.2, pp. 82-87**
27.	P. Bhattacharjee, G. Sanyal. Design and dimensioning of an edge router using Markov model. **International Journal of Communication networks & Distributed Systems, Vol. 3, No. 2, pp. 146-158.**
28.	Anjali Chatterjee, Dr. N.K. Roy. Applying Grey Theory Prediction Model on the DGA Data of the Transformer Oil and using it for Fault Diagnosis. **WSEAS Transactions on Power Systems, February 2009, Vol. 4, Issue 2, pp. 43-52**
	2008
1.	D. Chatterjee. Asymmetric epoxidation of unsaturated hydrocarbons catalyzed by .ruthenium complexes. **Coordination Chemistry Reviews, January 2008, Vol. 252, Issue 1-2, pp. 176-198**
2.	S.K. Samanta, H. Chattopadhyay, H. Pustal, B. Berger, R. Godkhindi, M.M. Polaczek. A Numerical Study of Solidification in Powder Injection Molding Process. **International Journal of Heat & Mass Transfer, February 2008, Vol. 51, Issue 3-4, pp. 672-682**
3.	P.K. Maji, P.S. Banerjee, A. Sinha. App.lication of rapid prototyping and rapid tooling for development of patient-specific craniofacial implant: an investigative study. **International Journal of Advanced Manufacturing Technology, March, 2008, Vol. 36, No. 5-6 , pp. 510-515**
4.	D. Chatterjee, A. Mitra. Kinetics and catalysis of oxidation of phenol by ruthenium(IV)-oxo complex. **Journal of Molecular Catalysis A-Chemical, March 2008, Vol. 282, Issue 1-2, pp. 124-128**
5.	Nagahanumaiah, K. Subburaj, B. Ravi. Computer aided rapid tooling process selection and manufacturability evaluation for injection mold development. **Computers in Industry, March 2008, Vol. 59, Issue 2-3, pp. 262-276**
6.	P.K. Chaulia, Reeta Das. Process Parameter Optimzation for Fly Ash Based by Taguchi Method of Parameter Design. **Journal of Materials in Research, April 2008, Vol. 11, No. 2, pp. 159-164**
7.	Lanjewar, RW; Saha, P; Datta, U; Banerjee, AJ; Jain, S; Sen, S; "Evaluation of machining parameters for turning of AISI 304 austenitic stainless steel on auto sharpening machine. **Journal of Scientific & Industrial Research, April 2008, Vol. 67, Issue 4, pp. 282-287**
8.	Himadri Roy, Debashis Ghosh, A.K. Shukla, Jhankar Basu. A Case Study on the premature Failure of a Cooling Water Pump Shaft. **International Journal of Manufacturing Science & Production, June 2008, Vol. 9, Nos. 1-2, pp. 99-106**
9.	D. Chatterjee. Kinetics and mechanism of epoxidation of olefins by a novel ruthenium(IV)-oxo complex **Inorginica Chimica Acta, June 2008,Vol. . 361, Issue 8, pp. 2177-2182**
10.	H. Roy, N. Parida, S. Sivaprasad, S. Tarafder, K.K. Ray. Acoustic emissions during fracture toughness tests of steels exhibiting varying ductility. **Materials Science & Engineering A – Structural Materials Properties & Microstructures, July 2008, Vol. 486, Issue 1-2, pp. 562-571**
11.	D. Chatterjee, A. Mitra, A. Levina, P.A. Lay, .A potential role for protein tyrosine phosphatase inhibition by a Ru-III-edta complex (edta = ethylenediaminetetraacetate) in its biological activity. **Chemical Communications, July 2008, Issue 25, pp. 2864-2866**
12.	S. Dutta, R. Ray, D. Banerjee. Development of Autonomous Mobile Robot with Manipulate for Manufacturing Environment. **International Journal of Advanced Manufacturing Technology, August, 2008, Vol. 38, No.s 5-6, pp. 536-542**
	Contd.

PAPERS PUBLISHED

	2008
13.	D. Chatterjee, V.R. Patnam, A. Sikdar, P. Joshi, R. Misra, N.N. Rao, NN. Kinetics of the decoloration of reactive dyes over visible light-irradiated TiO2 semiconductor photocatalyst. Journal of Hazardous Materials, **August 2008, Vol. 156, Issues 1-3, 15, pp. 435-441**
14.	D. Chatterjee, A. Sikdar, V.R. Patnam, A. Theodoridis, R. van Eldik. Kinetics and mechanism of O-O bond cleavage in the reaction of [Ru-III(edta)(H2O)](-) with hydroperoxides in aqueous solution **Dalton Transactions, August 2008, Issue 29, pp. 3851-3856**
15.	B.N. Mondal, P.K. Das, S.K.Singh. Advanced WC-Co cermet composites with reinforcement of TiCN prepared by extended thermal plasma route. **Materials Science & Engineering: A. December 2008, Vol. 498, Issues 1-2, pp. 59-64**
16.	B.N. Mondal, S. Kundu, A.K. Lohar. Net-Shape manufacturing of intricate components of A356/SiCp composites through rapid-prototyping-integrated investment casting. **Materials Science and Engineering: A, December 2008, Vol. 498, Issues 1-2, pp. 37-41**
17.	S.N. Shome, S. Nandy, S.K. Das, D.K. Biswas, D. Pal. AUV for Shallow Water App.lications - some design aspects. **Proceedings of the 18th. International Offshore & Polar Engineering, pp. 429-435**
18.	P. Bhattacharjee, G. Sanyal. Mathematical modelling for the design of an edge router. **Proceedings of the Ninth ACIS International Conference on Software Engineering 2008, pp. 212-217**
	2007
1.	D. Chatterjee, A. Sikdar, G. Ghosh. Ru-edta complex catalysed degradation of orange II (edta(4-) = ethylenediaminetetraacetate). **Chimica Oggi – Chemistry Today, 2007, Vol. 25, Issue 4, pp. 32-34**
2.	D. Chatterjee, S. Basak, A. Riahi, J. Muzart. Asymmetric epoxidation of alkenes with tert-butyl hydroperoxide catalyzed by a novel chiral complex of manganese(III) containing a sugar based tridentate Schiff-base ligand. **Catalysis Communications, 2007, Vol. 8, Issue 9, pp. 1345-1348**
3.	D. Chatterjee, S. Basak, J. Muzart. Asymmetric epoxidation of alkenes with aqueous t-BuOOH catalyzed by novel chiral complexes of chromium(III) containing tridentate Schiff-base ligands. **Journal of Molecular Catalysis A – Chemical, 2007, Vol. 271, Issue 1-2, pp. 270-276**
4.	D. Chatterjee, A. Mitra, R. van Eldik. Reaction of [Ru-III(edta)(H2O)](-) with H2O2 in aqueous solution. Kinetic and mechanistic investigation. **Dalton Transactions, 2007, Issue 9, pp. 943-948**
5.	D. Chatterjee, A. Sengupta, A. Mitra. Synthesis, characterization and reactivity of a novel ruthenium(II) complex containing polypyridyl ligand. **Polyhedron, 2007, Vol. 26, Issue 1, pp. 178-183**
6.	Y.M. Prasad, A.K. Shukla, A. Roy. Analysis of transient thermal cycling for life assessment of steam turbine rotors **Journal of Scientific & Industrial Research, 2007, Vol. 66, Issue 7, pp. 536-544**
7.	V.K. Khanna, M. Prasad, V.K. Dwivedi, C. Shekhar, A.C. Pankaj, J. Basu. Design and electro-thermal simulation of a polysilicon microheater on a suspended membrane for use in gas sensing **Indian Journal of Pure & Applied Physics, 2007, Vol. 45, Issue 4, pp. 332-335**
8.	R.W. Lanjewar, G. Balamurugan, N.P. Mukherjee, P. Saha, J. Roy Chaudhury, S.S. Roy. Design and development of an ingenious cricket ball decorative stitching machine. **Journal of Scientific & Industrial Research, 2007, Vol. 66, Issue 3, pp. 231-234**
9.	S. Singh, R. Singhal, B.D. Malhotra. Immobilization of cholesterol esterase and cholesterol oxidase onto sol-gel films for app.lication to cholesterol biosensor. **Analytica Chimica Acta, 2007, Vol. 582, Issue 2, pp. 335-343**

Contd.

PAPERS PUBLISHED

	2007
10.	S.K. Samanta, H. Chattopadhyay, B. Pustal, R. Berger, M.M. Godkhindi, A.B. Polaczek. A Numerical Study of Solidification in Powder Injection Molding Process. **International Journal of Heat & Mass Transfer, February 2008, Vol. 51, Issue 3-4, pp. 672-682**
11.	S. Dutta, R. Ray, D. Banerjee. Development of Autonomous Mobile Robot with Manipulate for Manufacturing Environment. **International Journal of Advanced Manufacturing Technology, Web published, May 23, 2007**
12.	H. Chattopadhyay. Simulation of transport processes in squeeze casting. **Journal of Materials Processing Technology, 2007, Vol. 186, Issue 1-3, pp. 174-178**
13.	H. Chattopadhyay. Augmentation of heat transfer in a channel using a triangular prism. **International Journal of Thermal Sciences, 2007, Vol. 46, Issue 5, pp. 501-505**
14.	H. Roy, N. Parida, S. Sivaprasad, S. Tarafder, K.K. Ray. Acoustic emIssueions during fracture toughness tests of steels exhibiting varying ductility **Materials Science & Engineering A, Web published, September 2007**
15.	P. Bhattacharjee, G. Sanyal. Design Tool For An Edge Router Using App.ropriate Mathematical Model **International Journal of Systemics, Cybernetics & Informatics, pp. 56-57.**
	2006
1.	D. Chatterjee, A. Sengupta, A. Mitra, S. Basak, S. Oxidation of catechol and L-ascorbic acid by [Ru-III(tpy)(pic)(OH)](+) (tpy=2,2'6'2"-terpyridine; pic(-) = picolinate): Kin. **Inorganic Chemistry Communications, 2006, Vol. 9, Issue 12, pp. 1219-1222**
2.	D. Chatterjee, S. Dasgupta, R.S. Dhodapkar, N.N. Rao. Simultaneous degradation of non-emIssueive and emIssueive dyes on visible light illuminated TiO2 surface. **Journal of Molecular Catalysis A – Chemical, 2006, Vol. 260, Issue 39084, pp. 264-268**
3.	B. Ruj, I. Rehman, A.K. Bandyopadhya. Off-site emergency scenario, a case study from a LPG Bottling Plant. **Journal of Loss Prevention in the Process Industries, 2006, Vol. 19, Issue 6, pp. 645-647**
4.	H. Chattopadhyay. Effect of surface motion on transport processes due to circular impinging jets - A numerical study. **Drying Technology, 2006, Vol. 24, Issue 11, pp. 1347-1351**
5.	B. Mondal, S. Kundu. Novel synthesis of advanced composites of alpha-Al2O3 reinforced with Ce TZP through co-precipitation process. **Advances in Applied Ceramics, 2006, Vol. 105, Issue 5, pp. 222-227**
6.	D. Chatterjee, A. Mitra, R. van Eldik. Kinetics and mechanism of the reaction of [Ru-III(edta)(H2O)](-) with HOBr to form an intermediate Ru-V=O complex in aqueous solution. **Dalton Transactions, 2006, Issue 39, pp. 4691-4695**
7.	V.K. Meena, Nagahanumaiah. Optimization of EDM machining parameters using DMLS electrode. **Rapid Prototyping Journal, 2006, Vol. 12, Issue 4, pp. 222-228**
8.	A.K. Nandi. TSK-type FLC using a combined LR and GA: Surface roughness prediction in ultraprecision turning. **Journal of Materials Processing Technology, 2006, Vol. 178, Issue 39085, pp. 200-210**
9.	D. Chatterjee, S. Basak, A. Riahi, J. Muzart. Highly efficient asymmetric epoxidation of alkenes with a novel chiral complex of ruthenium (III) containing a sugar based ligand **Journal of Molecular Catalysis A – Chemical, 2006**, Vol. 255, Issue 39084, pp. 283-289
10.	A.N. Ajjou, A. Riahi, D. Chatterjee, J. Muzart. Chromium-catalyzed oxidation of benzylcyclopropane with tert-butyl hydroperoxide. **Catalysis Communications, 2006, Vol. 7, Issue 8, pp. 563-565**
	Contd.

PAPERS PUBLISHED

	2006
11.	K. Chockalingam, N. Jawahar, K.N. Ramanathan, P.S. Banerjee, PS. Optimization of stereolithography process parameters for part strength using design of experiments. **International Journal of Advanced Manufacturing Technology, 2006, Vol. 29, Issue 39084, pp. 79-88**
12.	D. Chatterjee, A. Mitra, A. Sengupta, P. Saha, M. Chatterjee, M. [Ru-III(medtra)(H2O)] (medtra = N-methyl.ethylenediaminetriacetate) complex - A highly efficient NO inhibitor with low toxicity. **Inorganica Chimica Acta, 2006, Vol. 359, Issue 7, pp. 2285-2290**
13.	S.S. Roy. Design of genetic-fuzzy expert system for predicting surface finish in ultra-precision diamond turning of metal matrix composite. **Journal of Materials Processing Technology, 2006, Vol. 173, Issue 3, pp. 337-344**
14.	H. Chattopadhyay, F. Durst, S. Ray, S. Analysis of heat transfer in simultaneously developing pulsating laminar flow in a pipe with constant wall temperature. **International Communications in Heat & Mass Transfer, 2006, Vol. 33, Issue 4, pp. 475-481**
15.	D. Chatterjee, S. Dasgupta, N.N. Rao, NN. Visible light assisted photodegradation of halocarbons on the dye modified TiO2 surface using visible light. **Solar Energy Materials & Solar Cells, 2006, Vol. 90, Issue 39271, pp. 1013-1020**
16.	D. Chatterjee, S. Basak, A. Mitra, A. Sengupta, J. Le Bras, J, Asymmetric epoxidation of alkenes using a mixed-ligand complex of ruthenium (III) containing a sugar-based ligand. **Inorganica Chimica Acta, 2006, Vol. 359, Issue 4, pp. 1325-1328**
17.	S.S. Roy, S. Karmakar, N.P. Mukherjee, U. Nandy, U. Datta. Design and development of indigenous cricket bowling machine. **Journal of Scientific & Industrial Research, 2006,Vol. 65, Issue 2, pp. 148-152**
18.	Nagahanumaiah, B. Ravi. Rapid tooling form accuracy estimation using region elimination adoptive search based sampling technique. **Rapid Prototyping Journal, March 2007, Vol. 13, No.3**
19.	Nagahanumaiah, K. Subburaj, B. Ravi. Computer aided rapid tooling process selection and manufacturability evaluation. **Special Issue on Product Lifecycle Modeling, Analysis and Management (PLAMAM), Computers in Industry Journal, February 2007, Vol. 57**
20.	Suman Singh. Sensors – An Effective App.roach for the Detection of Explosives. **Journal of Hazardous Material, Web published, February 2007**
21.	Nagahanumaiah, B. Ravi, N.P. Mukherjee. Rapid Tooling Manufacturability Evaluation Using Fuzzy AHP Methodology **International Journal of Production Research, 2007, Vol. 45, No. 5, pp. 1161-1181**
22.	Palash Kumar Maji, P.S. Banerjee, Anupam Sinha. App.lication of Rapid Prototyping and Rapid Tooling for Development of Patient Specific Craniofacial Implant - An Investigative Study. **International Journal of Advanced Manufacturing Technology, Published online January 2007**
23.	Amslesh Sarkar, Tapas Sarkar. Managing the Quality of R& D organization through ISO Certification. **Journal of Scientific & Industrial Research, February 2007, Vol. No. 66, pp. 124-127**

PATENTS FILED & GRANTED

Indian Patents Filed

SL.	REFERENCE NO.	TITLE	AUTHORS
1.	IPMG/Patent/2009/3 **0064NF2009**	An Improved Tricycle assisted by Electric Motor energized by built-in overhead Solar panel	Sibnath Maity Palash Kumar Maji Amit Jyoti Banerjee Partha Sarthi Banerjee
			Contd.

PATENTS FILED & GRANTED

Indian Patents Filed

SL.	REFERENCE NO.	TITLE	AUTHORS
2.	IPMG/Patent/2009/4 **0130NF2009**	An improved device useful for safest flying of balloon by Hydrogen gas	Sibnath Maity Palash Kumar Maji
3.	IPMG/Patent/2009/5 **0090NF2009**	Cabinet Dryer for Ginger and Turmeric	Pradip Kumar Chatterjee Chanchal Loha Biplab Choudhury Prakash Chandra
4.	IPMG/Patent/2009/6 **0102NF2009**	An Improved Device for Holding Solar (PV) Panel Flexibly on a Stem/Long Pole an Adjustable required angle	Dr. Sibnath Maity Mr. Atanu Maity Mr. Subrata Kumar Mandal
5.	IPMG/Patent/2009/7 **0101NF2009**	Prepaid Smart Card Based Petrol Dispenser With Inbuilt Smart Card Re-Filler With System Check And Online Error Detection	Joydeb Roychowdhury Abhilasha Saksena
6.	IPMG/Patent/2009/8	Rotary Drum Washer for ginger and turmeric	Pradip Kumar Chatterjee Chanchal Loha Biplab Choudhury Prakash Chandra
7.	IPMG/Patent/2010/1 **0048NF2010**	An Improved Binder for Metal Injection Moulding Process	Sudip Kumar Samanta D. P. Chattopadhyay Siddhartha Kumar Sukanta Sinha Roy Asish Kumar Choudhury Shah Jaidev

Foreign Patents Filed

SL.	NFNO	TITLE	PROJECT FROM WHICH FILED
1	**0127NF2006/ZA APPLICATION NO.** 2009/03660	Prepaid Smart Card Operated Electronics Energy Meter with Online Load Optimizer for Solar Power Application	Development of Prepaid Energy meter for solar power plant
2	0191NF2006/US **APPLICATION NO.** 12/593589	Magnifying Instrument for Wide Object	Development of a magnifying Instrument for wide object

Patents Granted

SL.	REFERENCE NO.	TITLE	COUNTRY
1.	Patent No. 080NF2007 Application No. 1973DEL2007	Intelligent Early Fault Detection System using Embedded Processor	Indian
2.	Patent No. 2005/2352	A Novel Sewing Machine for Decoratively Stitching a Cricket ball	South Africa
3.	Patent No. 538577	A Novel Sewing Machine for Decoratively Stitching a Cricket ball	New Zealand
4.	Patent No. US 7239638 B2	Orientation Unit for fruit sorting and grading machine	USA

Contd.

PATENTS FILED & GRANTED

Patents Granted

SL.	REFERENCE NO.	TITLE	COUNTRY
5.	Patent No. 197230	An improved Induction Motor	India
6.	Patent No. 210335	A Process of manufacturing Crankshaft like Machine part through casting of Ductile Iron	India
7.	Patent No. 0241NF2000/AU	A Novel Sewing Machine for Decoratively Stitching A Cricket Ball	Australia

AWARDS & RECOGNITION

SL.	Awards/Recognition	Awardee(s)
1.	Hon'ble Minister of Human Resources Development, Shri Kapil Sibal released a book entitled **Profile of Engineering Education in India: Status, Concerns and Recommendations** authored by Gautam Biswas, K L. Chopra, C.S. Jha & D.V. Singh in a ceremony at the India International Centre, Lodhi Estate, New Delhi on 22nd January, 2010	Prof. Gautam Biswas, Director, CMERI
2.	Fellow of the **Indian Academy of Sciences**	Prof. Gautam Biswas, Director, CMERI
3.	Member of **Central Boilers Board** under the Ministry of Commerce & Industry, Government of India for the year 2009 – 2012	Mr. A.K. Shukla, Scientist F
4.	**RSC Dalton Delegate Award** for participation in INORG 2009 held at free state, Bloemfontein, South Africa	Dr. Debabrata Chatterjee, Scientist EII
5.	**Raman Research Fellowship Award (2009-2010) 2009)**	Dr. Biswajit Ruj, Scientist EII
6.	Selection as **Member** of the **Editorial Board of *Disaster Advances Journal* 2009**	Dr. Biswajit Ruj, Scientist EII
7.	**CSIR Raman Research Fellows for 2010-2011**	Malay Kumar Karmakar, Scientist C
8.	The Silver **Lockheed Martin Outstanding Innovation Award** for Smart Card Pre-paid Energy Meter	J. Roy Chowdhury, Scientist F
9.	Best Paper Award in AICTE sponsored **National Seminar on Environmental Management**	Dr. Biswajit Ruj, Scientist EII
10.	Selection as reviewer for the Elsevier Editorial System for the **Journal of Food Engineering**	Dr. Partha Bhattacharjee, Scientist F
11.	Recipient of **Royal Society of Chemistry Journal Grants Award** for International Authors and has been honored as a	Dr. Debabrata Chatterjee, Scientist EII
12.	Selection as **Member** of the **Editorial Board** of the **Journal of Molecular Catalyst**	Dr D. Chatterjee, Scientist EII
13.	Recipient of **Letter of Appreciation** for valuable suggestions for carrying out the repair work of LD steel melting vessels by Durgapur Steel Plant (DSP), Durgapur.	Shri A.K. Shukla, Scientist F and his team
14.	Recipient of **Letter of Appreciation** from various Indian Industries like NTPC, IOC, NALCO for enhancement of production and reduction of down time.	Shri Abhijit Chatterjee, Scientist F and his team
15.	Merit Certificate in CSIR LDP Module	Dr. Debabrata Chatterjee, Scientist EII
16.	Recipient of **Young Engineer Award, 2008** of the Institution of Engineers for significant contribution in the field of Agricultural Engineering for last 5 years	Dr. K. Kundu, Scientist EI
		Contd.

DATELINE CMERI

SL.	DATE	PROGRAMME
1.	May 10, 2007	Inter-School and Inter-College **Science & Technology Quiz**
2.	May18-19, 2007	National Workshop on **Condition Monitoring**
3.	June 22-23, 2007	National Workshop on Development of **Precision Ear Mould**
4.	July 18, 2007	Workshop on **Effluent Treatment using Fly Ash-Prospects & Potential**
5.	September 5-7, 2007	Workshop on **Quality Assurance & Product Development**
6.	September 17-20 2007	National workshop on **Investment Casting**
7.	October 5, 2007	National Workshop on **NDT for Health Survey of Structures**
8.	October 15-16,2007	International Seminar on **Clean Energy**
9.	November 16, 2007	Workshop on **Fluidised Bed Combustion and Gasification**
10.	November 29-30, 2007	International Conference on **Advanced Manufacturing Technologies**
11.	December 19- 20, 2007	National Conference on **Enhancement of Plant Availability by Life Assessment and Condition Monitoring**
12.	February 26-27, 2008	National Conference on **Farm Mechanization & Workshop on reinvigorating Indian agriculture**
13.	February 26, 2008	Valedictory programme of **CMERI Golden Jubilee Celebrations**
14.	May 7, 2008	Workshop on **Semi-Continuous Bio-Diesel Plant**
15.	August 17, 2008	**Flag-off Ceremony of SOLECKSHAW**
16.	September 26, 2008	**CSIR Foundation Day**
17.	October 2, 2008	**SOLECKSHAW LAUNCH** at Chandani chowk, New Delhi
18.	February 26, 2009	**CMERI FOUNDATION DAY** Celebration
19.	February 28, 2009	**National Science Day** Celebration
20.	January 20-21, 2009	National Workshop on **Quality Assurance through Measurement Science and Launching of MSI**
21.	March 20, 2009	Workshop on **Bio-gas through bio-methanation of de-oiled Jatropha cake**
22.	March 25-27, 2009	**Innovators' Meet 2009**
23.	August 15, 2009.	**Hydraulic Tractor** developed at CMERI was dedicated to the Nation
24.	September 7-14, 2009	**Hindi Week Celebration**
25.	October 5, 2009	**CSIR Foundation Day Celebrations**
26.	December 3-5, 2009	MERADO, Ludhiaha exhibited 1TPD oil expeller in the International exhibition organized by **Federation of India Chambers of Commerce & Industry** at New Delhi
27.	December 8-9, 2009	Symposium on **Transport Phenomena and its impact on Advanced Material Processing Technologies**
28.	December 31, 2009 - January 1, 2010	CSIR Programme for **Leadership of Youth in Science**
29.	January 22-24, 2010	International Conference on **Investment Casting (ICIC- 2010)**
30.	February 28, 2010	**CMERI Foundation Day Programme**

REMINISCENCES

Inaugural Programme of CMERI Golden Jubilee Celebrations
February 26, 2007

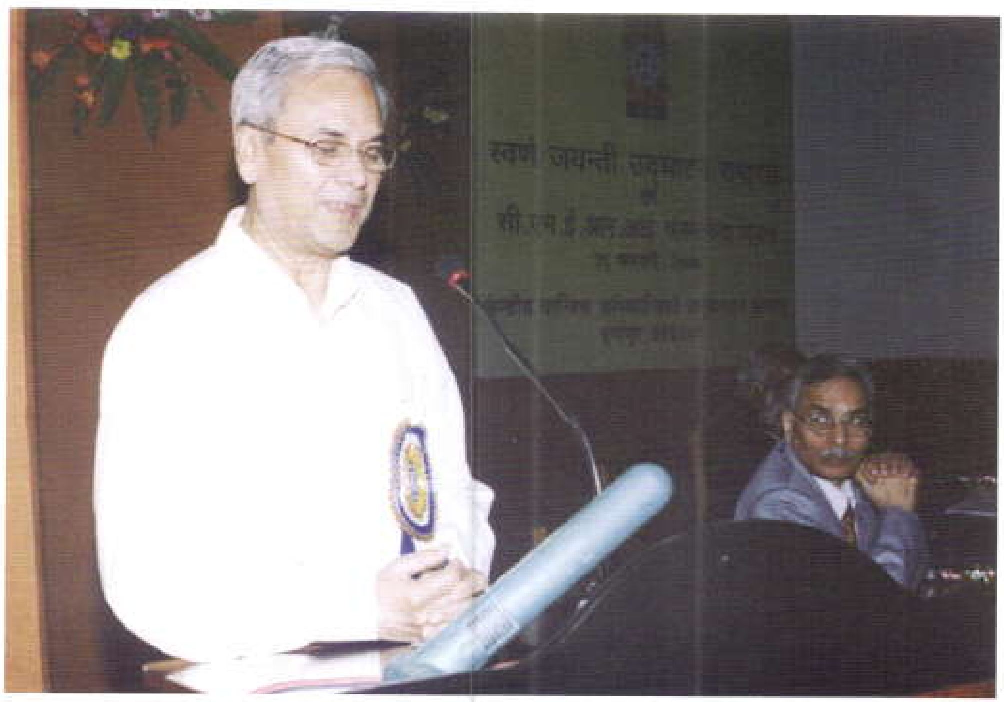
Dr. G. P. Sinha, Director, CMERI delivering the welcome address on the occasion of Inaugural programme of CMERI Golden Jubilee Celebrations

Prof. S.K. Basu, Former Director, delivering the CMERI Golden Jubilee Eminent Lecture on Recent Trends in Design & Manufacturing in Nanotechnology and Bio Applications

Dr. S.K. Basu, Former Director, releasing the CMERI Golden Jubilee Celebration Calender

Dr. Jhankar Basu, Scientist, CMERI presenting a small capsule on the five decades of proud presence and leadership of CMERI in Mechanical Engineering

A view of Auditorium during the Inaugural programme of the Golden Jubilee Celebrations



Prof. Amitabh Ghosh, Professor, IIT, Kanpur delivering the lecture on the occasion of CMERI Golden Jubilee Inaugural Programme

A view of Auditorium during the Inaugural programme of the Golden Jubilee Celebrations

Prof. Amitabh Ghosh, Professor, IIT, Kanpur Inaugurating the Technology Treasure of CMERI

Dr. N.R. Banerjea, VC, BESU, Dr. G. P. Sinha, Director, CMERI

National Workshop on Biofuels: Production Methodologies, Utilization Techniques and Challenges Ahead
March 22-23, 2007

Dr. K. S. Aulakh, V.C., PAU, Ludhiana Inaugurating Bio-fuel workshop with MERADO Scientists

National Seminar on Exploration, Exploitation, Enrichment & Environment of Coastal Placer Minerals March 25-26, 2007

Dr Jhankar Basu, Scientist, CMERI, delivering the welcome address in the Inaugural function

A lecture session of PLACER2007 in progress

National Workshop on Machining and Machiniability of Advanced Materials
March 29-30, 2007

Dr. G. P. Sinha, Director, CMERI

Prof. S.K. Basu, Former Director, CMERI & Prof. A.B. Chattopadhyay, IIT Kharagpur enjoying the lecture session

National Workshop on Condition Monitoring
May 18-19, 2007

Dignitaries present on the dias in the Inaugural sesion of NWCM

Mr. P. P. Agarwal, GM (Design) Renusagar Power Division, Hindalco Industries addressing the delegates of NWCM2007

Science Education Programme on Mathematics and its Application
June 9-14, 2007

Dr. J. K. Bhattacharya, Indian Association for the Cultivation of Sciences, Kolkata, delivering key note address

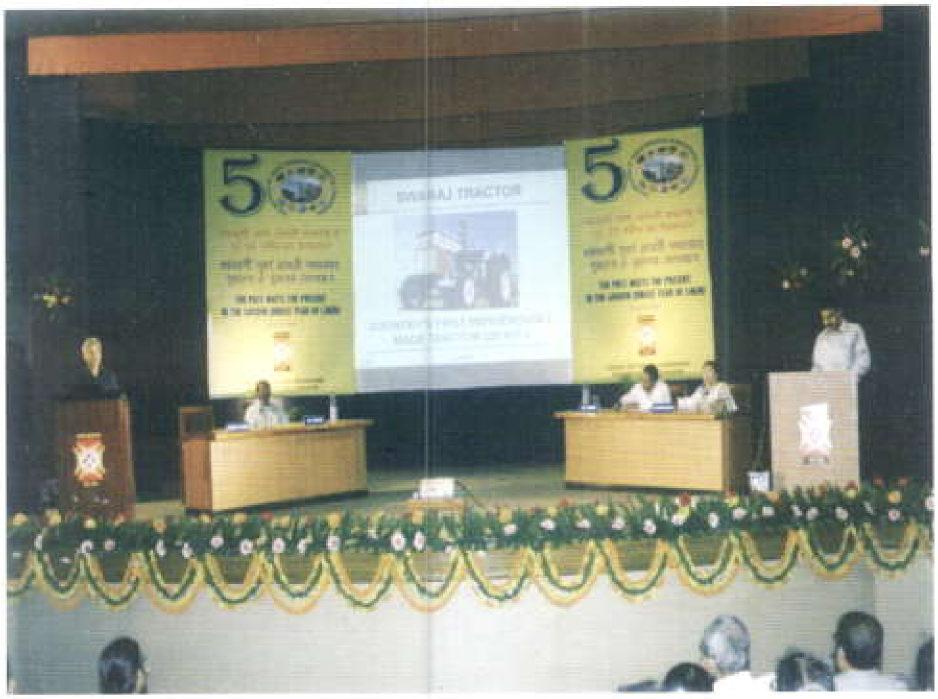
A view of lecture session of Science Education Programme on Mathematics & Its Application

Workshop on Precision Ear Mould Development
June 22-23, 2007

A view of dignitaries present on the dais in the Inauguration Programme of the Workshop

A view of lecture session

Get-together of Past and Present Employees
June 29, 2007



Dr. G.P. Sinha, Director, CMERI delivering the welcome address on the occasion of Get-together of Past and Present Employees

A view of the auditorium on the occasion of Get-together of Past and Present Employees

Course on Manufacturing Drawing, Design and Analysis using High End CAD Software
July 11-13, 2007

View of a lecture session during the Course on Manufacturing Drawing, Design & Analysis using High End CAD Software

Dr. S. Majumdar, Scientist, CMERI distributing the certificates to the delegates of the programme

National Workshop on Metrology for QA & Product Development
September 5-7, 2007

Dr. G. P. Sinha, Director, CMERI distributing the certificate to the delegates of National Workshop on Metrology for QA & Product Development

A view of delegates present during the lecture session

Hands on training on Programming and operating on CNC Machines September 10-14, 2007

Dr. G. P. Sinha, Director, CMERI delivering the Inaugural Address of the programme

Dr. G. P. Sinha, Director, CMERI distributing the certificates to the delegates

Workshop on NDT for Health Survey of Structures
October 5, 2007

A view of the dais in the Inaugural Programme of the Workshop on NDT for health survey of structures

Photograph of the participants of the Workshop on NDT for health survey of structures

International Seminar on Clean Energy
October 15-16, 2007

Dr. P. K. Chatterjee, Scientist, CMERI welcoming the delegates in the Inauguration Programme of International Seminar on Clean Energy

A view of Valedictory Programme of ISCE2007 in progress

International Conference on Advanced Manufacturing Technology
November 29-30, 2007

Hon'ble Professor APJ Abdul Kalam lighting the Inaugural Lamp during the Inaugural Programme of ICAMT 2007

Hon'ble Professor APJ Abdul Kalam delivering the lecture on "Virtual Collaborative platform for large manufacturing mission" at Inaugural Programme of ICAMT 2007

International Conference on Advanced Manufacturing Technology November 29-30, 2007

Dr. T. Ramasami, Secretary , DST delivering the lecture during the Inaugural Programme of ICAMT 2007

Delegates present during the lecture session of ICAMT 2007

National Conference on Enhancement of Plant Availability by Life Assessment and Condition Monitoring December 19-20, 2007

Shri A. N. Mishra, Chief Engineer, Bokaro Thermal Power Station lighting the Inaugural Lamp during the Inaugural Programme of LACOM 2007

Shri A. N. Mishra, Chief Engineer, Bokaro Thermal Power Station delivering Inaugural Address on the occasion of LACOM 2007

Workshop-cum-Training Programme on Robotics
February 5-7, 2008

Dr. G. P. Sinha, Director, CMERI delivering the Inaugural Address of the workshop-cum-training programme

A view of the lecture session in progress

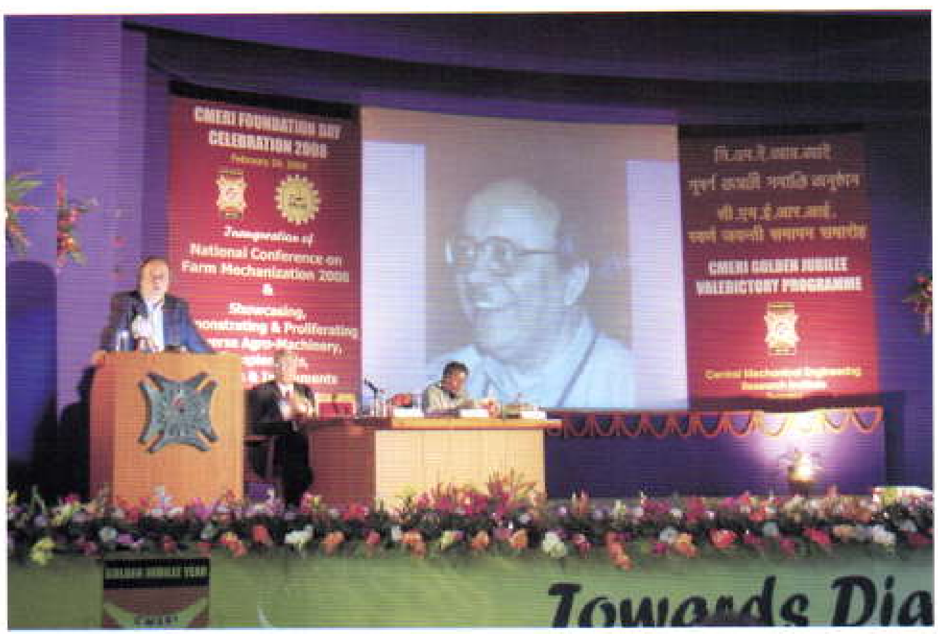
CMERI Golden Jubilee Valedictory Programme
February 26-27, 2008

Dr. G. P. Sinha, Director, CMERI delivering the welcome address on the occasion of CMERI Golden Jubilee Valedictory programme

The beginning of the end......
The valedictory session being inaugurated

CMERI Golden Jubilee Valedictory Programme
February 26-27, 2008

Prof. S. K. Brahmachari, Director General,CSIR releasing the book of abstracts of the NCFM 2008



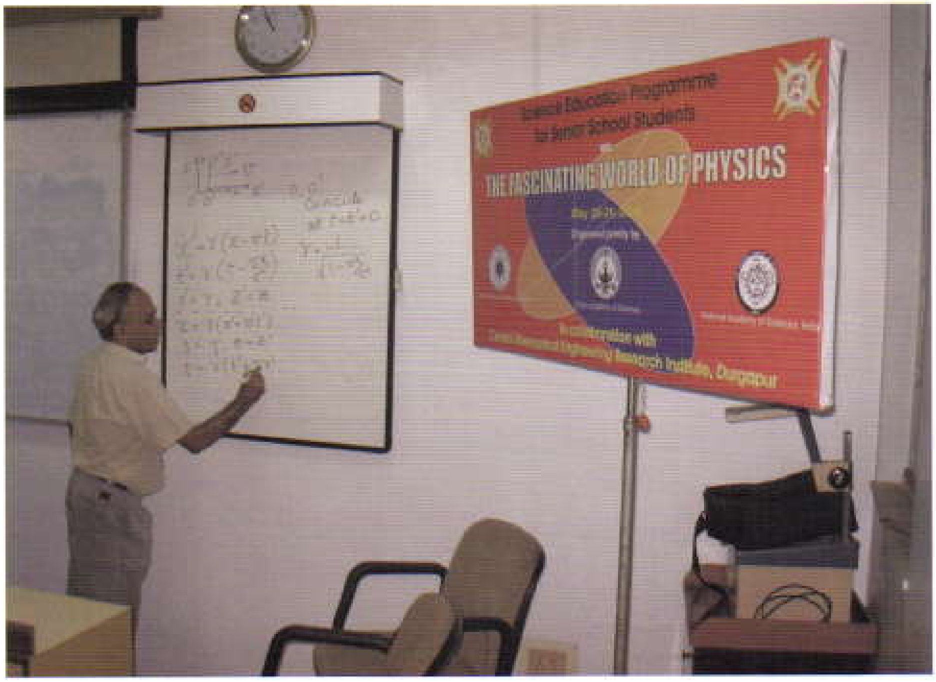
Prof. S. K. Brahmachari, Director General,CSIR delivering the CMERI Foundation Lecture

Science Education Programme on The Fascinating World of Physics
May 26-31, 2008

Dr. J. K. Bhattacharya, Course Director, speaking on the occasion of the Inaugural programme of Science Education Programme 2008 on The Fascinating World of Physics

Dr. Jhankar Basu, Programme Coordinator, welcoming the participants during the Inaugural Session of Science Education Programme 2008

Science Education Programme on the Fascinating World of Physics
May 26-31, 2008



Professor H. S. Mani addressing the participants during a lecture session

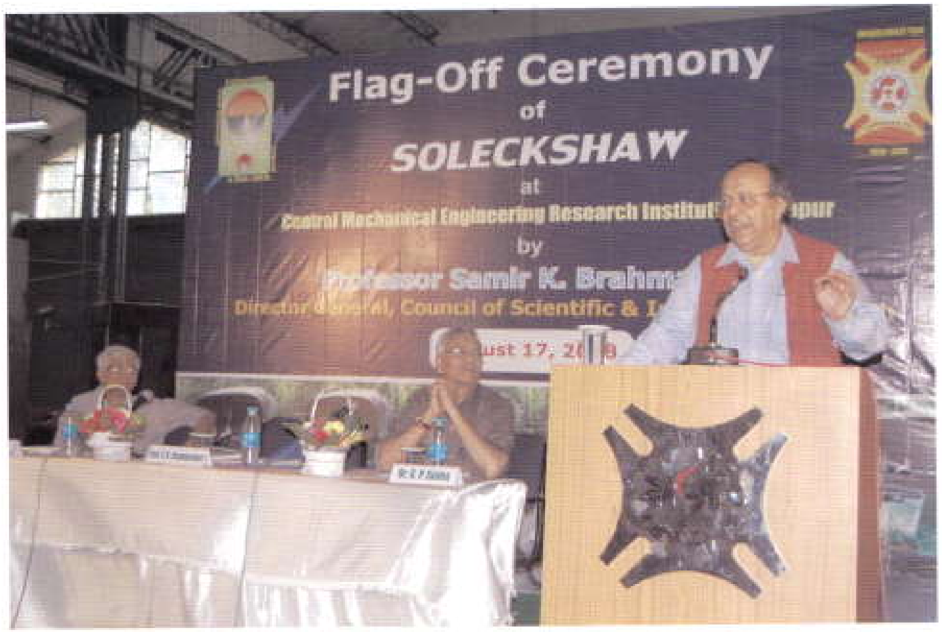
Dr. G.P. Sinha, Director, CMERI addressing on the occasion of valedictory session of the Science Education Programme on the Fascinating World of Physics

Innovators' Meet 2009
March 25-27, 2009

Dr. A.S. Rao addressing the innovators during the Inaugural Programme of the innovators' Meet 2009

A view of presentation session of the innovators' Meet 2009

Flag-off Ceremony of SOLECKSHAW
August 17, 2008

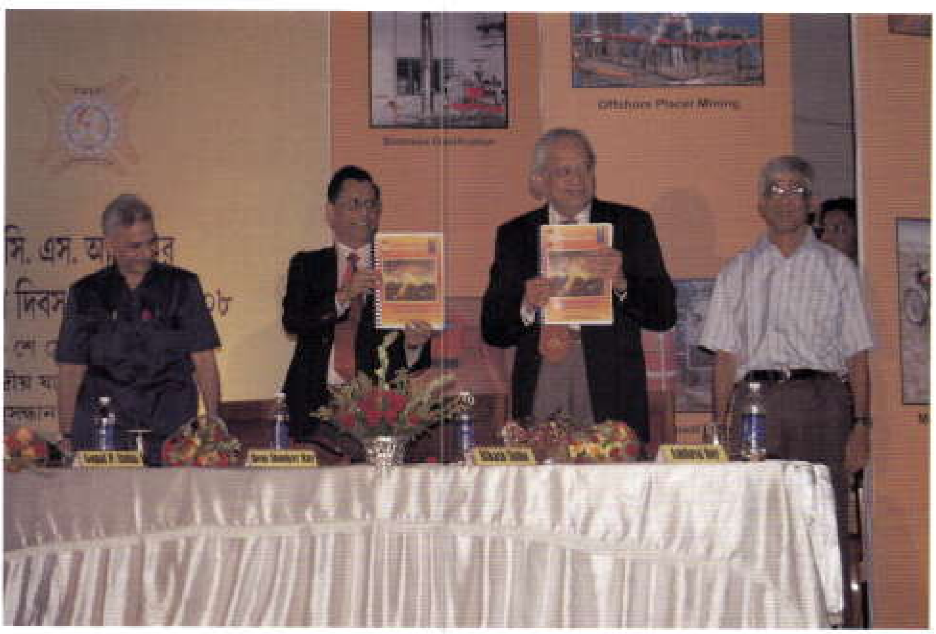


Prof. S. K. Brahmachari, DG, CSIR addressing the audience on the occasion of flag-off ceremony of SOLECKSHAW

A close shot of flag-off of SOLECKSHAW

CSIR Foundation Day 2008
September 26, 2008

Dr. Bikash Sinha, Director, Variable Energy Cyclotron Centre & Saha Institute of Nuclear Physics, Kolkatta, delivering his Foundation Day Lecture on "The Cosmoic Journey through the Universe from the Big Bang to now, man and beyond"



A view of dignitaries present on Dais: Releasing CMERI GOLDEN Jubilee Souvenir on the occasion of CMERI Foundation Day

National Workshop on Engineering Metrology & Quality for Growth
February 15-16, 2007

A view of dignitaries present on the dais on the Inaugural Programme of National Workshop on Engineering Metrology & Quality for Growth

CMERI Foundation Day 2010
February 28, 2010

Prof. Samir Kumar Brahmachari, Secretary DSIR and DG CSIR, Lighting the Ceremonial Lamp

Prof. Gautam Biswas, Director CMERI delivering the Inaugural Speech

Prof. Samir Kumar Brahmachari, Secretary DSIR and DG CSIR delivering the Foundation Day Lecture

Dr. Gangan Pratap, Director NISCAIR delivering the Eminent Lecture

Prof. Suman Chakraborthy, IIT Kharagpur delivering the Invited as well as National Science Day Talk

Scientific Manpower Profile

Scientists [Group IV(1)]

Sl. No.	Name	Group Affiliation
1.	Shri Rajesh Prasad Barnwal	
2.	Shri Subhra Kanti Das	Robotics & Automation
3.	Shri Chanchal Loha	Thermal Engineering
4.	Shri Rudra Prasad Chatterjee	Electronics & Instrumentation
5.	Shri Binod. Kr. Saha	Product Design & Simulation
6.	Shri Pabitra Haldar	Simulation & Modeling Laboratory
7.	Shri Samik Dutta	Metrology
8.	Shri Vineet Kr. Saini	Technology, Publication & Patents
9.	Shri Himadri Ray	NDT & Metallurgy
10.	Shri Man Singh Azad	Microsystems Technology Laboratory
11.	Shri Priyabrata Chattopadhyay	Product Design & Simulation
12.	Shri Satanand Mishra	Information Technology
13.	Shri Jagdish M, M/L	MERADO, Ludihiana
14.	Shri Srinivasan. N	Cybernetics

Scientists [Group IV(2)]

Sl. No.	Name	Group Affiliation
15.	Shri R. K. Bharilya	Design of Mechanical Systems
16.	Shri Rajpal Singh	Manufacturing Technology
17.	Shri U. S. Patkar	Design of Mechanical Systems
18.	Dr. Debashis Das	Material & Structural Evaluation
19.	Shri Virendra Kumar	Robotics & Automation
20.	Shri Lalgopal Das	Process Plant Engineering
21.	Dr.Malay Kr. Karmakar	Thermal Engineering
22.	Shri Abhijit Mahapatra	Virtual Reality & Virtual Prototyping
23.	Shri Dibyendu Pal	Robotics & Automation
24.	Shri Dip Narayan Ray	Surface Robotics
25.	Shri Nilrudra Mondal	Research Planning & Business Development
26.	Shri Ajay Yadav M/L	MERADO, Ludhiana
27.	Dr. T. Murugan	Thermal Engineering
28.	Shri Hanumath Prasad Ikkurti	Drives & Control Systems

Sl. No.	Name	Group Affiliation
29.	Shri Suman Saha	Drives & Control Systems
30.	Dr. Pabitra Ranjan Basu Mandal	Product Design & Simulation
31.	Dr. Priyabrata Banerjee	Chemistry & Biomimetics
32.	Dr. SivaprakaShri S	Process Plant Engineering
33.	Shri Santu Kumar Giri	Electronics & Instrumentation
34.	Dr. Pranab Samanta	Surface Science & Tribology
35.	Shri Swarup Kumar Laha	Condition Monitoring
36.	Dr. Ranajit Ghosh	Centre for Advanced Materials Processing
37.	Shri Manoj Kr. Rawat	Process Plant Engineering
38.	Dr. Bittagopal Mondal	Simulation & Modeling Laboratory

Scientists [Group IV(3)]

Sl. No.	Name	Group Affiliation
39.	Ms. Manju Singh	Foundry & Heat Treatment
40.	Shri Naresh Chandra Murmu	Surface Science & Tribology
41.	Shri Biplab Choudhury	Thermal Engineering
42.	Shri Swapan Barman	Metrology
43.	Shri Sudip Kr. Samanta	Foundry & Heat Treatment
44.	Shri Debashis Ghosh	NDT & Metallurgy
45.	Shri Sankar Karmakar	Manufacturing Technology
46.	Shri Amit Ganguly	Horticulture & Institute Housekeeping
47.	Shri B. Sampath Kumar	Manufacturing Technology
48.	Shri Kamalkishor J. Uke	Condition Monitoring
49.	Shri Atanu Saha	NDT & Metallurgy
50.	Shri Ashok Kr. Prasad	Manufacturing Technology
51.	Shri Aditya Kr. Lohar	Foundry & Heat Treatment
52.	Shri S. R. Debbarma	Research Planning & Business Development
53.	Shri Dilip Kumar Biswas	Technology Innovation Centre
54.	Dr. Asit Kr. Batabyal	ISO Secretariat
55.	Shri Kalyan Kumar Mistry	Surface Robotics
56.	Dr. Prakash Chandra	Thermal Engineering
57.	Dr. Satya Prakash Singh	Simulation & Modeling Laboratory
58.	Dr. Sudipta De	Simulation & Modeling Laboratory
59.	Dr. Dipankar Chatterjee	Simulation & Modeling Laboratory
60.	Dr. Krishnendu Kundu	MERADO, Ludhiana
61.	Shri Siva Ram Krishna Vadali	Robotics & Automation

Sl. No.	Name	Group Affiliation
62.	Dr. Rashmi Ranjan Sahoo	Surface Science & Tribology
63.	Shri Arup Kumar Nandi	Advanced Design & Optimization
64.	Shri Subrata Mondal	Advanced Design & Optimization
65.	Shri B. B. Ghosh	Advanced Design & Optimization
66.	Shri Ravi Kant Jain	Design of Mechanical Systems
67.	Dr. Ranjit Ray	Robotics & Automation
68.	Shri Anupam Sinha	Product Design & Simulation
69.	Shri Palash Kr. Maji	Product Design & Simulation
70.	Shri Pradeep Rajan	MERADO, Ludhiana
71.	Ms. Abhilasha Saksena	Embedded Systems Laboratory

Scientists [Group IV(4)]

Sl. No.	Name	Group Affiliation
72.	Shri U. Nandi	Technology Innovation Centre
73.	Shri S. S. Mojiz	MERADO, Ludhiana
74.	Dr. Arup Mitter	Research Planning & Business Development
75.	Ms. Maw Nandi Sarkar	Process Plant Engineering
76.	Dr. D. Chatterjee	Chemistry & Biomimetics
77.	Ms. Anjali Chatterjee	Cybernetics
78.	Shri U. S. Ghosh	Human Resource Development & Library
79.	Shri Avik Chatterjee	Virtual Reality & Virtual Prototyping
80.	Shri P. S. Banerjee	Advanced Design & Optimization
81.	Shri B. N. Singh	NDT & Metallurgy
82.	Ms. Sarbari Dutta	Surface Robotics
83.	Shri Pankaj Roy	NDT & Metallurgy
84.	Shri Atanu Maity	Advanced Design & Optimization
85.	Shri Ashwani Kumar	MERADO, Ludhiana
86.	Dr. Somenath Mukherjee	Simulation & Modeling Laboratory
87.	Dr. Mrinal Pal	Centre for Advanced Materials Processing
88.	Shri S. N. Nandi	Robotics & Automation
89.	Shri Tapas Gangopadhyay	Product Design & Simulation
90.	Shri Rajesh Kr. Chak	MERADO, Ludhiana
91.	Shri B. D. Bansal	MERADO, Ludhiana
92.	Dr. Biswajit Ruj	Thermal Engineering
93.	Dr. Surendra Kumar	Product Design & Simulation
94.	Dr. Reeta Das	Thermal Engineering

Sl. No.	Name	Group Affiliation
95.	Shri G. S. Reddy	Materials & Structural Evaluation

Scientists [Group IV(5)]

Sl. No.	Name	Group Affiliation
96.	Dr. Ranjan Sen	Metrology
97.	Shri A. K. Shukla	NDT & Metallurgy
98.	Ms. Uma Dutta	Electronics and Instrumentation
99.	Dr. B. N. Mondal	Centre for Advanced Materials Processing
100.	Shri R. K. Biswas	Condition Monitoring
101.	Shri Amitjyoti Banerjee	Manufacturing Technology
102.	Shri A. K. Chowdhury	Foundry and Heat Treatment
103.	Shri Abhijit Chatterjee	Material & Structural Evaluation
104.	Shri Tapas Sarkar	ISO
105.	Shri Soumya Sen Sharma	• Technology, Publication & Patent • Drives & Control Systems Technology • TePP Outreach Centre
106.	Shri P. K. Sen	Process Plant Engineering
107.	Dr. Nagahanumaiah	Microsystems Technology
108.	Shri Debojyoti Banerjee	Robotics and Automation
109.	Shri Tapan Kr. Paul	Condition Monitoring
110.	Dr. Partha Bhattacharjee	Cybernetics
111.	Joydev Roy Chowdhury	Embedded System

Scientists [Group IV(6)]

Sl. No.	Name	Group Affiliation
112.	Dr. Samajyoti Majumdar	• Surface Robotics • Design of Mechanical Systems • Information Technology
113.	Shri S. N. Shome	• Robotics and Automation • School of Mechatronics
114.	Shri Shibnath Maity	Technology Innovation Centre
115.	Shri V. R. Dahake	MERADO, Ludhiana
116.	Dr. K. P. Ray Sarkar	Product Design and Simulation Division
117.	Shri P. K. Chaulia	Technology Innovation Centre
118.	Dr. P. K. Chatterjee	Thermal Engineering

The frontier of mechanical engineering is changing rapidly and is fast merging with other branches of science and engineering. Contrary to the general perception one holds about this discipline as dealing only with machines and mechanisms in isolation, mechanical engineering in the next decade is poised to evolve as a thoroughly collaborative discipline through a shared vision to develop engineering solutions for fostering a cleaner, healthier, safer and sustainable world. Acquiring new knowledge and skills to implement systems engineering approaches across multi-scale systems will be an essential element for the mechanical engineering of tomorrow. New simulation software designed to mimic the emergent properties of complex systems will further assume a vital role in enabling mechanical engineers anticipate system requirements and outcomes. Mechanical engineering, as a broad discipline would further have to face a future characterized by engineering systems in both the nano, micro and mega scales concurrently by utilizing the competitive edge of cutting-edge knowledge and embracing various collaborative advantages, by fostering and controlling global innovation, and by preparing for the technological capabilities of the Nano-Bio future and microfactories, or concurrent design-at-home. In general, the mandate of mechanical engineers of the future would be to:

- Develop sustainably through new technologies and techniques, and respond to the global environmental pressures brought about by economic growth;
- Be at the forefront of implementing a system design approach across large and small-scale systems;
- Engage in international collaboration around our critical knowledge and competencies;
- Work in the emerging Bio-Nano technologies to provide solutions in such diverse fields as healthcare, energy, water management, the environment and agriculture management, and
- Create engineering solutions for the other 90 percent that live on less than two dollars a day.

With this vision in mind, CMERI in the last year underwent a thorough revamping of the R&D areas and the R&D mandates, and a new pool of talented young Scientists was inducted into the Institute to embrace, regulate and guide the desired direction of change. About half of the new inductees are from the top echelon science and technical Institutes, like the IITs, Jadvapur University, etc. having significant post-doctoral exposure into their individual disciplines, and having to their credit substantial publications in peer-reviewed journals. Others who have joined CMERI in the capacity of Scientist Fellows have already made their marks or have the potential of making significant inroads into their specializations.

Newly Inducted Scientists

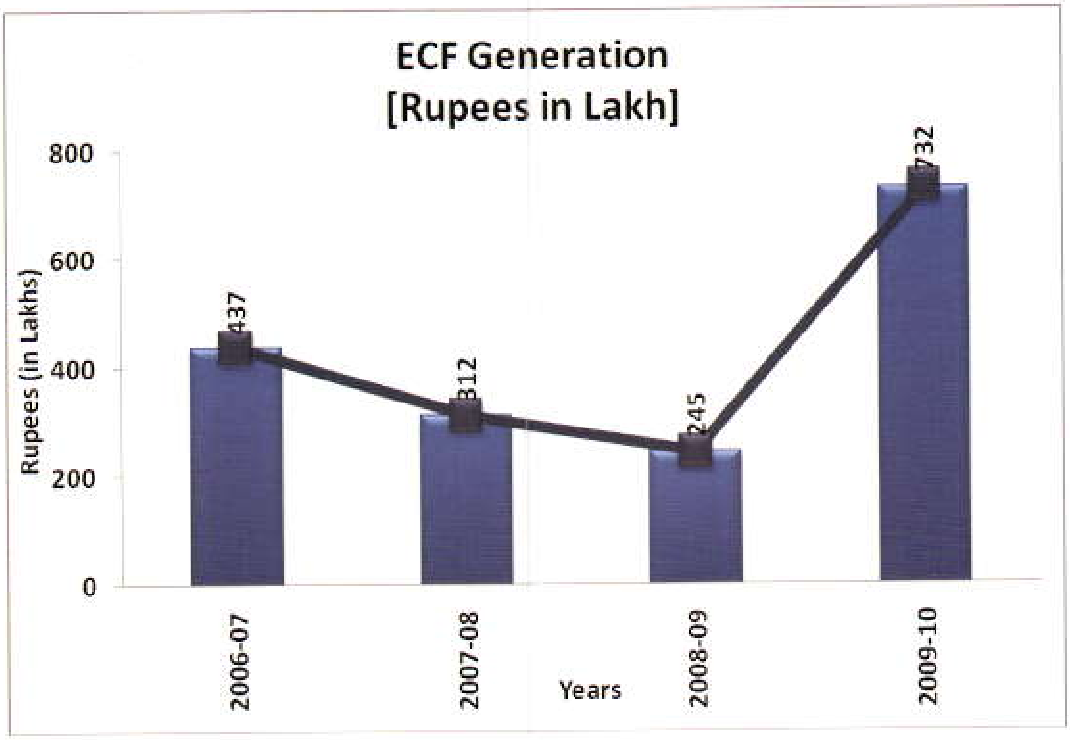
Sl. No.	Name	Group Affiliation
1.	Shri Priyabrata Chattopadhyay	Product Design and Simulation Division
2.	Shri Satanand Mishra	Information Technology
3.	Shri Jagdish M	CMERI-MERADO
4.	Shri Srinivasan. N	Cybernetics
5.	Shri Ajay Yadav M/L	CMERI-MERADO
6.	Dr. T. Murugan	Thermal Engineering
7.	Shri Hanumath Prasad Ikkurti	Drives & Control
8.	Shri Suman Saha	Drives & Control
9.	Dr. Pradipta Ranjan Basu-Mandal	Product Design and Simulation Division
10.	Dr. Priyabrata Banerjee	Chemistry and Biomimetics
11.	Dr. SivaprakaShri S	Process Plant Engineering

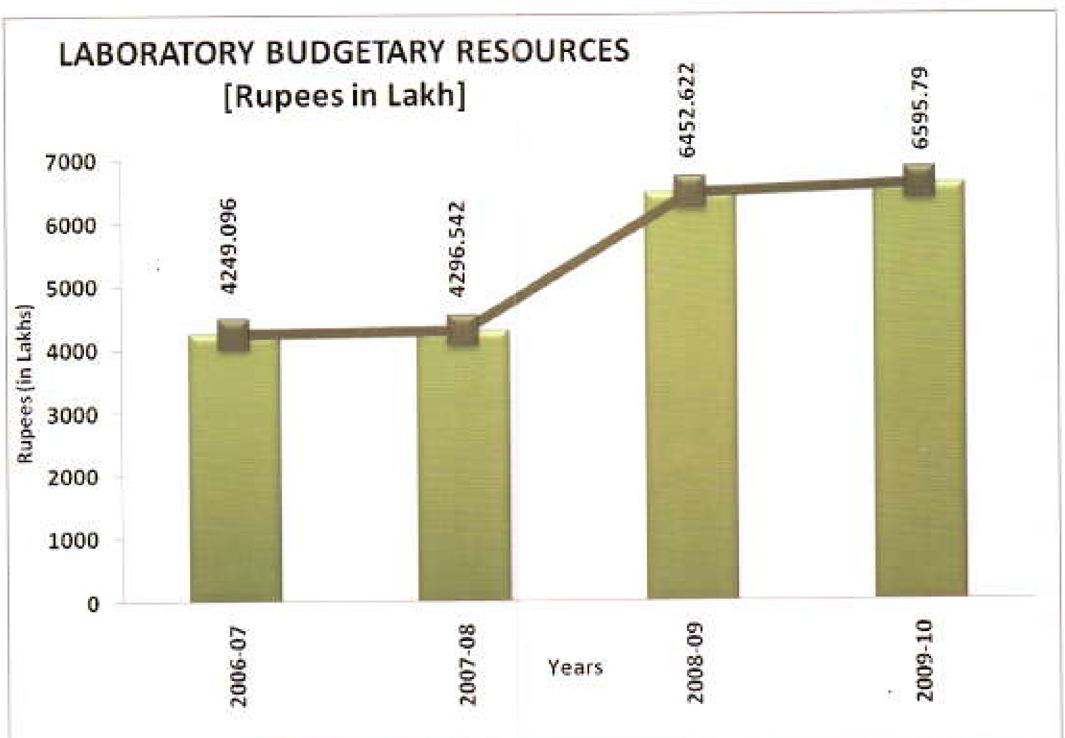
Sl. No.	Name	Group Affiliation
12.	Shri Santu Kumar Giri	Electronics and Instrumentation
13.	Dr. Pranab Samanta	Surface Science & Tribology
14.	Shri Swarup Kumar Laha	Condition Monitoring
15.	Dr. Ranajit Ghosh	Centre for Advanced Materials Processing
16.	Dr. Bittagopal Mondal	Simulation and Modeling
17.	Dr. Satya Prakash Singh	Simulation and Modeling
18.	Dr. Sudipta De	Simulation and Modeling
19.	Dr. Dipankar Chatterjee	Simulation and Modeling
20.	Shri Siva Ram Krishna Vadali	Robotics and Automation
21.	Dr. Rashmi Ranjan Sahoo	Surface Science & Tribology
22.	Dr. Somenath Mukherjee	Simulation and Modeling
23.	Dr. Mrinal Pal	Centre for Advanced Materials Processing

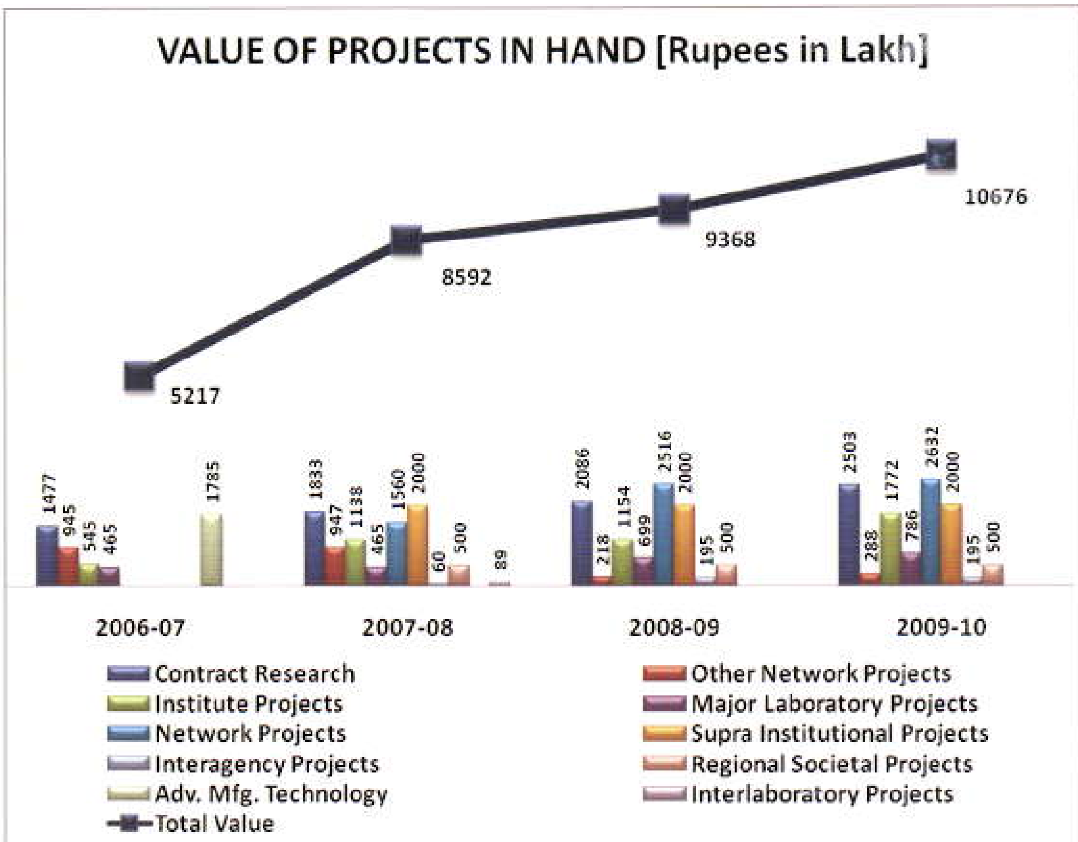
Newly Inducted Quick Hire Scientists

24.	Dr. Souman Sen	Robotics and Automation
25.	Dr. Ujjawal Pal	Chemistry and Biomimetics
26.	Dr. Sarita Ghosh	Chemistry and Biomimetics
27.	Ms. Shilpa	Microsystems Technology
28.	Sh. Ravi Kumar Arun	Microsystems Technology
29.	Sh. Praveen Kumar Singh	MERADO, Ludhiana
30.	Mrs. Arpita Mukherjee	Electronics and Instrumentation
31.	Mrs. Sarika Bharilya	Advanced Design and Optimization
32.	Ms. Sikha	Robotics and Automation
33.	Sh. M.Phani kumar	Surface Science & Tribology
34.	Sh. Amit Kumar	Virtual Reality & Virtual Prototyping
35.	Sh. Abhiram Hens	Microsystems Technology
36.	Sh. Prosenjit Das	Foundry and Heat Treatment

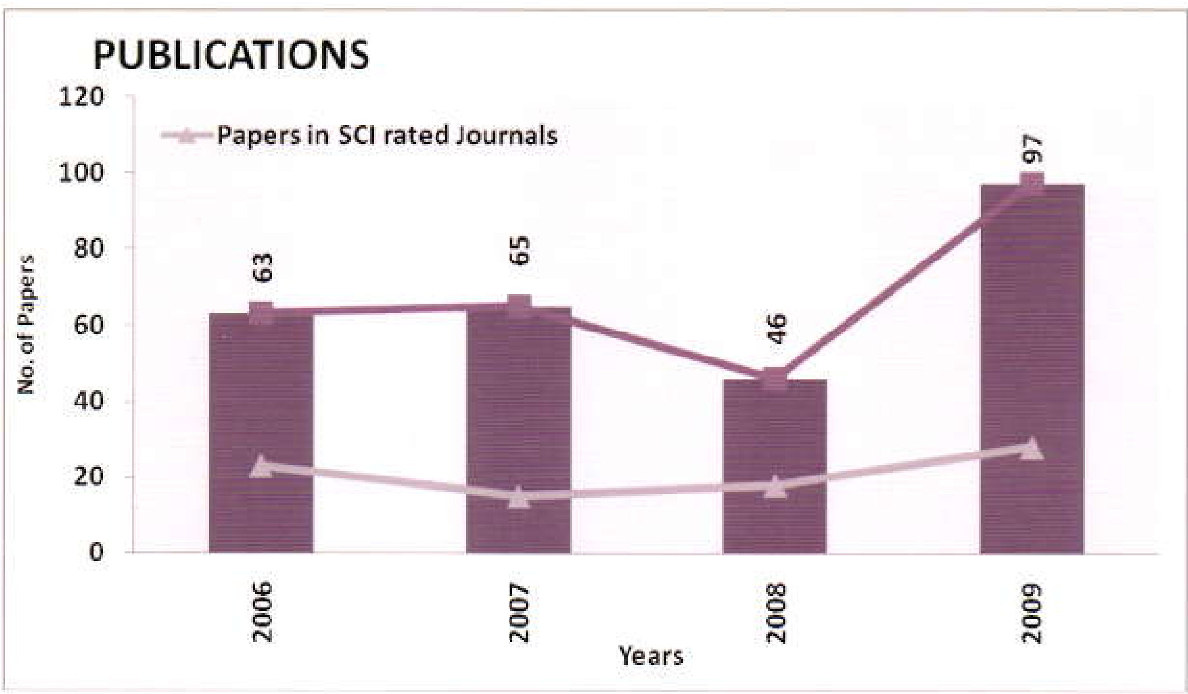
Performance Indices







VALUE OF PROJECTS IN HAND [Rupees in Lakh]
5217
8592
9368
10676
1477
945
545
465
1785
1833
947
1138
465
1560
2000
60
500
89
2086
218
1154
699
2516
2000
195
500
2503
288
1772
786
2632
2000
195
500
2006-07
2007-08
2008-09
2009-10
Contract Research
Other Network Projects
Institute Projects
Major Laboratory Projects
Network Projects
Supra Institutional Projects
Interagency Projects
Regional Societal Projects
Adv. Mfg. Technology
Interlaboratory Projects
Total Value



PUBLICATIONS
120
100
80
60
40
20
0
No. of Papers
Papers in SCI rated Journals
63
65
46
97
2006
2007
2008
2009
Years

Designed and Printed At:
National Institute of Science Communication And Information Resources (NISCAIR), New Delhi