ENGINEERING SCIENCES CLUSTER

Technology Developed

Five Seat General Civil Aviation aircraft (CNM-5)-the country's first Public-Private Partnership in the development of civil aircraft

CNM-5, the five seat aircraft, has the distinction of being the country's first Public-Private Partnership (PPP) for development of civil transport aircraft. It has been developed by CSIR-NAL in collaboration with M/s Mahindra Aerospace Pvt. Ltd (MAPL), Bengaluru. CNM-5 had its first test flight on the 1st September 2011 in Australia. CNM-5 is powered by a 300HP piston engine driving a 3-blade propeller cruising at a speed of 160 knots with a maximum AUW (All Up Weight) of 1525 kg; glass cockpit is a customer option. It is an ideal aircraft for air taxi, air ambulance, training, tourism and cargo. It is proposed to be certified first under the Australian Authority CASA. With the MAPL as a partner organization, there are ample opportunities to capture the global market.

Fig. 1.71 CNM-5 taking maidan flight

Tejas Flight Simulation

The encounter of modern combat fly-by-wire aircraft with the wake of another aircraft during combat, formation flying or refueling is fraught with hazards. A simulation model of the fighter aircraft has been developed by CSIR-NAL incorporating the rigid body dynamics (airframe split into seven components for computing the forces and moments), air data system and flight control laws to clear Tejas for wake penetration trials. The flight model was also incorporated into the ELS to enable the pilots to practice the wake penetration flight test profiles.

The ELS simulator was also used for evaluation of the auto-throttle mode, and for the Autopilot design and high-Angle-of-Attack studies. The figure shows the
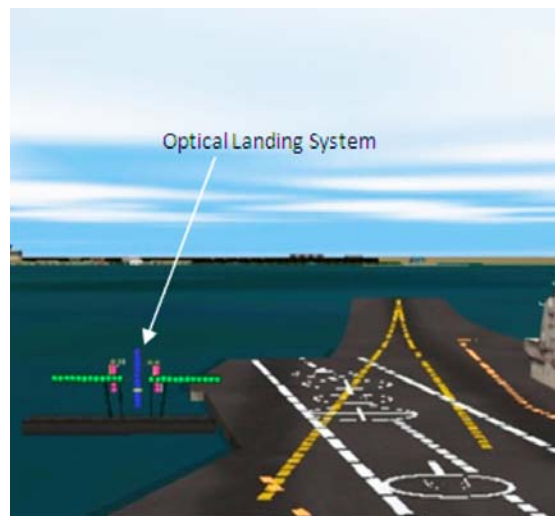

Fig. 1.72 Naval Out–of-Window visuals with Optical Landing System

Fresnel Lens Optical Landing System incorporated in the visuals for LCA Navy (Light Combat Aircraft Navy version).

SARAS Display System Suite

SARAS display system developed by CSIR-NAL consists of four Active Matrix Liquid Crystal Displays (AMLCD) with 1024 x 768 pixel resolution and state-of-the art symbology approved, certified and Technical standard ordered (TSO'd) by Federal Aviation Administration. Each display is capable of functioning as primary flight display, navigation display and EICAS on-pilot selection; there is also an auto reversion feature in case of critical failures. The preliminary and critical Design Reviews and the engineering software build has been released. The electronic flight instrumentation system symbology testing has been carried out using the bench test facility and avionics suite. The performance of the bench test was satisfactory. The bench test set up and the avionics ground integration test rig is shown in Fig. 1.74

Fig. 1.73 SARAS display system symbology test stations (Bench test rig and avionics ground integration test rig)

Manufacturing Technology for Advanced Composites

Composites offer a very attractive option in modern aircraft development because they are lighter than metal and just as strong. Tejas airframe is 45% composites (mostly carbon-epoxy) by weight contributing to its reputation as the world's smallest light weight fighter aircraft. CSIR-NAL has successfully led the National Team for the composite wing development for Tejas and has pioneered the development and fabrication of 13 complex composite structural components for the Tejas (LCA) aircraft using innovative and cost-effective fabrication technologies including co-curing / co-bonding construction.

The manufacturing technology for composites for military aircraft has been earlier transferred to Hindustan Aeronautics Ltd. (HAL) and Aeronautical Development Agency (ADA). During the year CSIR-NAL has received a formal order from HAL, Bengaluru amounting to `60 crore for the supply of twenty sets of critical CFC component (13 types) and a set of composite tools for series production program of Tejas (LCA) aircraft. M/s Tata Advanced Materials Ltd. (TAML), Bengaluru is the production partner in this endeavour.

Radome (MKII) for 13m diameter Doppler Weather Radar

CSIR-NAL has developed and transferred the technology to Bharat Electronics Ltd. (BEL) on December 13, 2011 against payment `1.95 crore. Director, BEL appreciated the quality of the product and congratulated the CSIR-NAL design and fabrication team. BEL team from Mumbai had undergone hands-on training at CSIR-NAL in connection with the fabrication of the fifth set of radome panels.

Jaguar Aircraft Nose Radome - TOT for manufacturing

A team of HAL had undergone training for two months at CSIR-NAL in the manufacturing technology of the composite nose cone Radome of Jaguar maritime aircraft. The HAL team jointly worked with CSIR-NAL and hands-on training was provided in the activities like tool preparation, handling, E-glass preforms loading on core, tool assembly, preconditioning of resin system, liquid resin system injection using RTM machine, oven curing, de-moulding, post curing, trimming and surface preparation operations.

During the training period, two numbers of nose cone radomes were manufactured and bare radomes were also subjected to NDE and forwarded to HAL for integration / assembly with metallic parts like base ring, nose bullet and lightening strips. HAL has an order of 50-60 radomes for Jaguar aircraft from Indian Air Force (IAF) for which this training as part of TOT was of significant importance. CSIR-NAL is also helping HAL in equipping itself with the necessary facility to gear up for the production. CSIR-NAL has received a technology transfer fee of `1.18 crore.

Steel Plant Skelp Mill Mechanization

Skelp Mill at Durgapur Steel Plant, commissioned in 1968, is a continuous type of mill with roughing mill and finishing mill trains. There was a need to design and develop a system for automated fixing of the hot skelp coil tip in the CPR (skelp feeding) and automated fixing the clip for increasing productivity and augmenting human safety in the current working condition.

CSIR-CMERI conceptualized the design of novel and unique automatic system for feeding hot skelp coil tip in CPR with vertical axis coiler covering all the engineering aspects, right from conceptual designs, system analysis to detail design. The conceptual schemes were jointly evaluated by Durgapur Steel Plant and CSIR-CMERI. Conceptual design of the proposed system was done in solid modeling software and simulated in ADAMS (scale 1:1) to analyze its dynamics including all its drives. The five drives are (i)The Linear Guide drive (Motor M1), (ii) Cross Slide Drive (Motor M2), (iii) Vertical Drive (Motor M3), (iv) Gripper Rotation Drive (Motor M4) and (v) Transporter Drive (Motor M5).
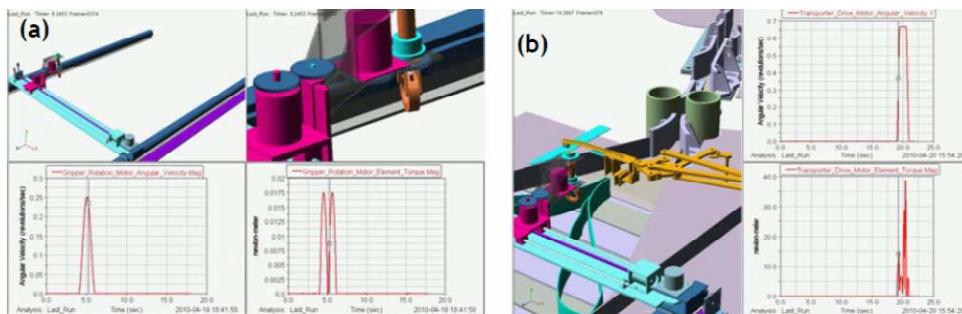

Fig. 1.74 Multibody dynamic simulation (a) Gripper Rotation Drive (b) Transporter Drive

Five Axis µ-CNC Milling Machine

CSIR-CMERI has developed five axis micro milling machine tools with gantry configuration which is useful for micro- scale milling and drilling machining operations to generate small sized three dimensional complex geometries efficiently with reduced costs as well as with high resolution. Two rotary axes eliminate the error caused by the re-clamping and also useful for machining cylindrical shapes without X and Y-axis interpolation; therefore, precise

machining can be easily performed. It also helps to improve materials removal rate and improve surface finish.
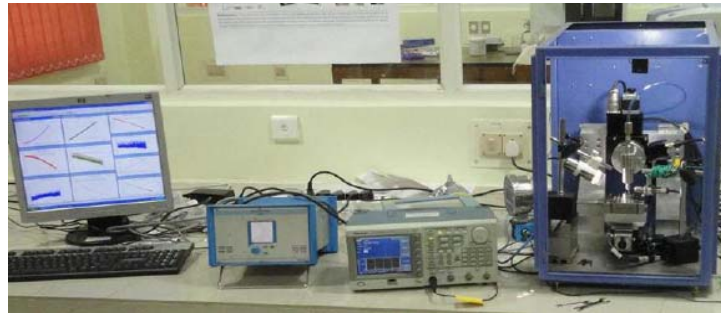

Fig. 1.75a Five axis Micro µCNC mill in operation

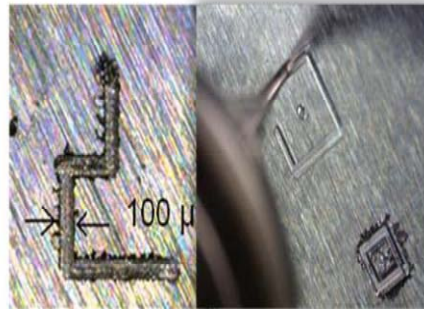Fig. 1.75b GUI of µCNC mill Control System

Fig.1.75c Micro Milling experiments

Autonomous Intelligent Robotic Wheel Chair

CSIR-CMERI has developed an Autonomous Intelligent Robotic Wheel Chair which is differentially driven model where two of the central wheels are used for power and other four are active suspension mounted casters. This design provides enhanced mobility and stability and capability to turn full 360° in any narrow corridor. It can also go up slant pavements, maintaining stability over all terrains, offers enough maneuverability to navigate smoothly on small ups and downs. Light weight components (main body and seating) decrease the overall weight without compromising on safety. A lead acid battery bank (24 V, 25 AH) with built-in chargers is provided on board. Electronic soft touch control using joystick based commands, voice command and auto navigation facility is provided. Additional features include collapsible foot rest and interchangeable seating.

Fig. 1.76 Working Model of Autonomous Intelligent Robotic Wheel Chair

Micro-EDM Prototype Machine

CSIR-CMERI has developed prototype of micro-EDM machine. This test bed consists of three micro positioning stages with travel resolution of 0.1µm and travel length of 150mm, which are used for precision travel in X, Y and Z axis. The RC circuit based pulse generator has been integrated for EDM power supply. The discharge voltages and currents have been measured using digital oscilloscope. The hardware systems were interfaced as a complete system, controlled through LabView. The approach and retraction movement of an electrode

with respect to the work piece were programmed. The discharge voltage has been 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 prototype and the craters of 300µm diameter machined on laser sintered Cu-Ni alloy. This first generation prototype is being modified to incorporate micro milling features and also integrated dynamically controlled electrode erosion compensation system, so that prototype can be used for micro milling and EDM operations.

Fig.1.77 Prototype of Micro EDM and the craters of 300µm diameter machined Cu-Ni alloy

Mobile Bridge Inspection Unit

CSIR-CMERI jointly with CSIR-CRRI has developed the first indigenously Mobile Bridge Inspection Unit (MBIU) for conducting bridge inspection systematically, scientifically and quickly. The machine is designed as per the international safety standard. The unit is simple to operate and comprises six mechanical joints, which are controlled through an automated PLC Control System by the operator.
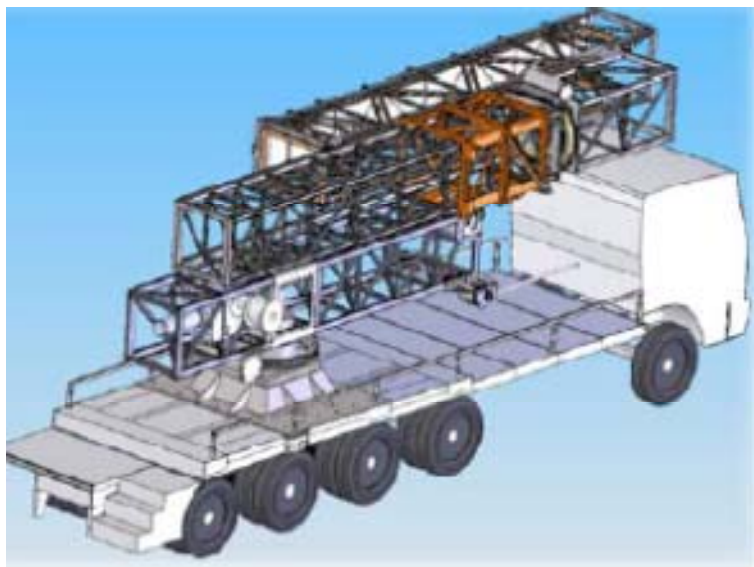

Fig. 1.78 3D CAD of the model

The design of MBIU had conflicting requirements such as the truck must act as a rigid platform during inspection and it should be flexible during moving on the road. This conflict was resolved by installation of pneumatic suspension units in place of mechanical springs. When the air is exhausted in the pneumatic units, there would be metal to metal contact and thereby rigidity was assured. With this motion of 4", the two axles with wheels can be lowered on ground. Therefore during inspection 4 axles would support the off-centered load.

Fig. 1.79 Machines in actual operation

Demonstration of an Advanced Eco-friendly Energy Efficient Process for Utilization of Iron Ore Resources of India

Suitable process flowsheets have been developed by CSIR-IMMT to beneficiate low grade iron ore fines containing 55-58% Fe from Odisha-Jharkhand region to produce a concentrate having 63-65% Fe that is suitable for sintering and pelletisation at an yield of 65-70%. A common flowsheet has been developed to beneficiate different low-grade ore fines. Laboratory scale results have been demonstrated at plant site by installing a 0.5 meter diameter column flotation unit at M/s Jindal Steel Power Limited Barbil. It has been shown that a product with 64-65% Fe can be produced from a feed with 48 -52 % Fe at 32-40% yield.

Flow Sheets of beneficiation of low-grade iron ores

CSIR-IMMT has developed flow sheets for beneficiation of low-grade irons to many industries. Some of them are: M/s Rawmet Commodities Pvt. Ltd., Bhubaneswar; M/s Jayaswal Neco Industries Ltd., Raipur; M/s Sandur Manganese and Iron Ores Limited, Bengaluru; M/s Shri Bajrang Power and Ispat Ltd., Raipur; M/s Kalawati Ispat & Power Pvt. Ltd., Vandana Group, Raipur; M/s Earthstone Group, Jakarta, Selatan; M/s Pacific Iron Ore Manufacturing Ltd., Mumbai; and M/s V.M. Salgaocar & Bro. Pvt. Limited, Goa.

Land treatment and disposal of effluent from Mahindra Vehicle Manufacturers Ltd. using High Rate Transpiration System (HRTS)

CSIR-NEERI provided a technological solution to M/s Mahindra Vehicle Manufactures Limited (MVML), Pune for treatment and safe disposal of its effluents using high rate transpiration system. The design of HRTS has been prepared and submitted to M/s MVML, Pune for implementation at field level. The detailed composition of filter media which provides more surface area for interaction of pollutants and also removes the suspended solids present in the wastewater was also prepared.

Fig.1.80 Implementation of HRTS at M/s Mahindra Vehicle Manufacturers Ltd. site, Pune

Improving the Life Cycles of Expensive Crucibles

CSIR-NAL has developed technology for carbon and pyrolytic carbon coating (PyC) on graphite crucibles being used by Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam through Chemical Vapour Infiltration (CVI) process. The process gives dense coating which sealed the surface pores. It not only increased the life cycle but also provided corrosion resistance, helping in reusability. Further, Institute has also developed and stabilized BN/SiC interface technique using CVI

Fig. 1.81 IGCAR's graphite crucibles coated with PyC

process resulting in improved mechanical and oxidation resistance properties of panels of Vikaram Sarabhai Space Centre (VSSC), Thiruvanthapuram and helped in meeting the requirements of flexural strength and fracture toughness.

Pilot scale smelting and pre-feasibility studies on nickel–chromium–cobalt bearing magnetite ores from Nagaland

The nickel – chromium – cobalt bearing magnetite deposits of the Nagaland is a rare type of occurrence associated with ophiolite. The largest deposit occurs in the North – Eastern most part of Nagaland – Manipur ophiolite belt, a part of the Indo-Burma ranges comprising the Arakan Yoma, Chin and Naga hills. The probable reserve in the North Block is 1.83 million tonnes while that in the South Block 2.966 million tonnes. The discovery of nickel - chromium – cobalt bearing magnetite in the Tuensang district of Nagaland assumes particular significance since India is totally dependent on imports with reference to strategic metals like nickel and cobalt. The technology has been developed by CSIR-NML in three stages (i) Laboratory scale (ii) Bench scale and (iii) Pilot scale making use of limestone as flux and petroleum coke as reductant.

The hardness of the product (Special Iron Alloy) is high (570 – 600 BHN). This iron alloy can be used for producing several value added products such as grinding media and automobile steels of EN-24 grade. A number of foundries in and around Nagaland in North East region can make use of this iron alloy. The process is ready for commercialization in small/medium scale (7.5 MVA/ 10 MVA) commercial Submerged Arc Furnace.

Fig. 1.82(a) Pilot Scale submerged arc furnace operation

Fig. 1.82(b) Metal tapping from submerged arc furnace

Closed Cell for Production of Sodium Metal by Fused Salt Electrolysis of Sodium Chloride

As a part of the indigenous efforts towards the development of sodium extraction technology for the Fast Breeder Reactor program of India, CSIR-NML has designed and developed a 500A closed cell. The cell was operated continuously for three days and about 1 Kg of sodium metal was collected through withdrawal system in the collection chamber. The collected Na metal was analyzed and it was about 90% pure. Efforts are on to modify the design of the 500 A cell and run it for a sustained period of 20-30 days to enable generation of design data for larger capacity commercial cells.

Fig: 1.83a Sodium extraction by 500A closed cell

Fig:1.83b In-house system for chlorine handling during sodium extraction

Commissioning of the Bio-fuel Pilot Plant

A bioethanol pilot plant of 80 kg biomass per batch capacity has been designed by CSIR-NIIST. The plant is based on the data obtained for the process for conversion of different selected biomass types to bioethanol. The design of the pilot plant was fine tuned by an Engineering Consultant, M/s Hitech Biosciences Pvt. Ltd., Pune and erection and commissioning was done by M/s Scigenics India Pvt. Ltd., Chennai.

Fig. 1.84a Pretreatment Reactor

Fig. 1.84b 200 L Fermenter for bioethanol production

Photoactive nano titanium oxide Coatings on Solar Panels

CSIR-NIIST could demonstrate low temperature titanium oxide coatings on large area solar cell glass covers. The dip coating process developed in laboratory level was switched over to spray coating for large area panels. Near transparent coatings having excellent photo

activity and hydrophobicity were achieved. First layer consists of a UV curable monomer over which a functionally modified titania layer is deposited and then the glass is subjected to curing under UV radiation for a period of 5 minutes.

The adherent coating is transparent (transmittance - 94%), hydrophobic (water contact angle - 96°) and self cleaning (dye degradation efficiency -94%). Specific nano titania doped composition has also been developed for coating on front glass of the visibility measuring system "Dristi" developed by CSIR-NAL which is installed in the airports of New Delhi and Lucknow. Field studies showed that even under severe fog conditions, the visibility was excellent due to the self cleaning titania coatings provided on the front glass of the equipment, so that the sensors could perform well.
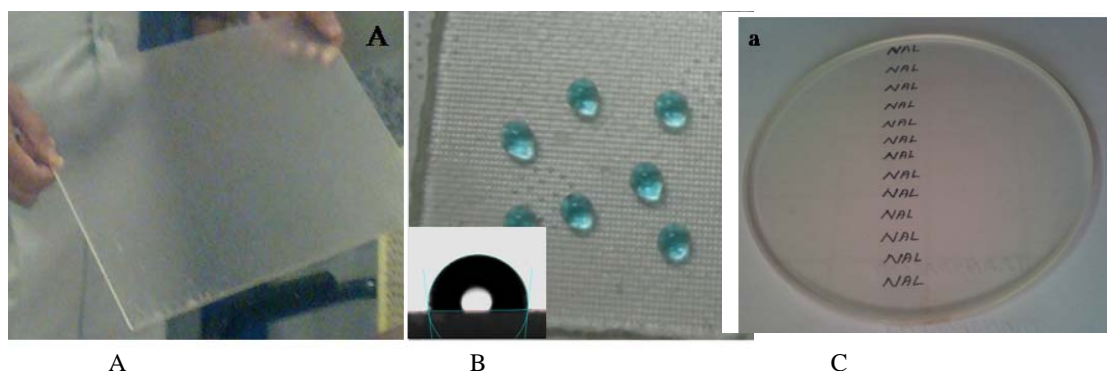

| A | B | C |

Fig. 1.85 Solar cell cover with (A) Inorganic-organic hybrid coating (B) Hydrophobic nature of hybrid coating and (C) Photograph of CSIR-NAL glass substrate coated with doped titania composition

Virtual Casting Solver transfered to M/s 3DFoundry Tech Pvt. Ltd

Virtual Casting is a software developed by CSIR-NIIST for design of the casting process by simulation of mold-filling and solidification in a casting. The Virtual Casting Solver code was transferred to M/s 3D Foundry Tech Pvt. Ltd., (3DFT) a company incubated in the IIT, Bombay as a better marketing strategy.   3DFT is an IIT-B start up company that maintains and markets AutoCAST-X which is based on a geometric reasoning engine developed at IIT Bombay, allowing semi-automatic design, 3D modelling and analysis of casting elements like cores, feeders, and gating channels. 3DFT has acquired the solver code of the CSIR-NIIST software, Virtual Casting with the aim of enhancing the power and marketability of Autocast-X. Integration of the Virtual Casting solver into Autocast-X would add important features like coupled simulation of metal flow and solidification, enabling visualization of mold filling sequence, changes in casting temperature and solidification rate. This helps in prediction of casting defects such as cold shut and shrinkage porosity without shop-floor trials, saving valuable time, energy and other costs. The new module is named FLOW+.
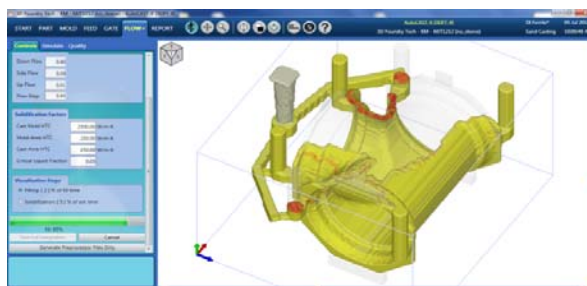

Fig. 1.86 3D model of virtual casting

Assessment of Microstructural Degradation in 2.25Cr-1Mo Steel using Miniature Specimen Technique

CSIR-IMMT has used Miniature specimen technique viz. small punch test (SPT) at room temperature in order to identify the parameters of SPT representing the microstructural degradation in 2.25Cr-1Mo steel. Microstructural degradation in this steel has been introduced as a result of thermal ageing corresponding to LMP values of 33,012, 35,402, 37,846 and 38,374. Optical and transmission electron microscopy were used to identify the carbide precipitates and examine their coarsening behaviour. Shape, size and distribution of precipitates have also been studied using TEM. Two of the SPT parameters viz. total area and area under the region of plastic instability of load-displacement

Fig. 1.87 Samples of 2.25Cr-1Mo Steel

curve have been found to decrease with increase in L-M parameters. Coarsening of carbide particles along with change of shape of iron carbides from platelets to spheres could be the possible reason for decrease in these SPT parameters with increase LMP values. The result indicated that small punch test could be successfully used to assess the degradation of microstructure in 2.25Cr-1Mo steel generated due to their exposure at high temperature service environment. This is a step forward towards the application of this technique for failure analysis and life extension studies.

Moisture meters for detection of moisture in transformer oil

Transformer oil deteriorates gradually day by day and absorbs moisture from transformer winding and by adsorbtion from atmosphere which lead to gradual fall in dielectric strength and causes sparks. CSIR-CGCRI developed nanoporous thin film γ-alumina based capacitive sensors with adequate sensitivity over the moisture range from 5 to 20 ppm for detection of trace moisture in transformer oil. The oxide γ-alumina with its pore structure is the active material. When the water molecule enters the pores it changes state from moisture vapor to liquid increasing the overall dielectric constant and capacitance of the material.

The developed sensors were calibrated by an electronic device for low range moisture measurement in hand held devices in connection with environmental and meteorological monitoring. A few moisture meters were transferred to M/s Nisha Engineering Corporation, Kolkata for field trials.

Improvement in MgO-C refractories to enhance the steel making convertor life

MgO-C refractory is used in the lining of primary steel making converters. Rashtriya Ispat Nigam Ltd. (Vizag Steel) produces this refractory at their captive plant. However, variations take place over time in the lining life of the converter from 4000 to 7000 heats. CSIR-CGCRI has

Fig. 1.88 Upscaling of MgO-C Brick at Vizag Steel with modified technology of CSIR-CGCRI

made an attempt to increase the converter life by improving brick quality through a techno-economically viable process.

Institute could improve the brick quality through changing the granulometry of MgO, combining fused and sintered MgO in optimum ratio and optimizing antioxidants like Al, Si, B_4C and their combination. The antioxidants inhibited carbon oxidation and subsequently developed high melting phases within MgO to improve Hot MOR (71 kg/cm^2 to 93 kg/cm^2) and corrosion resistance (wear index reduced from 79 % to 47%) of the brick.

Green Technology for producing iron using hydrogen plasma

CSIR-IMMT has developed a technology for reduction of hematite in the presence of pure hydrogen plasma. The involvement of highly energetic atomic and ionic states of hydrogen provides a very high driving force for reduction of ore into metal. The process is completely carbon free and hydrogen plasma alone acts as a reducing as well as heating source.
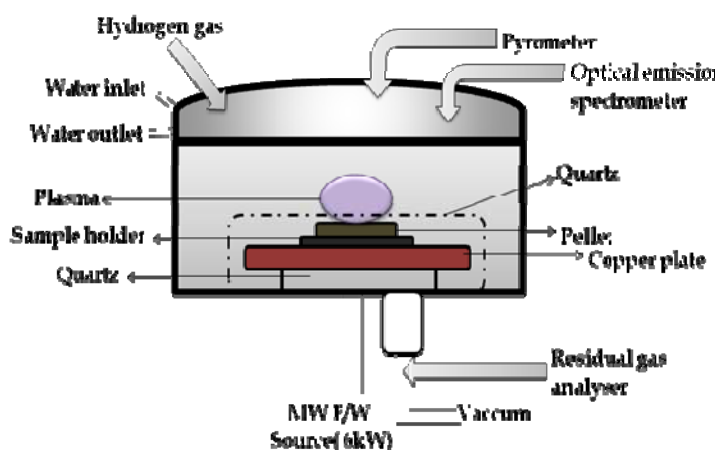

Fig: 1.89 Scheme of the 6 kW Microwave plasma areactor

A 6kW microwave plasma reactor is employed for carrying out the reduction experiments. It is coupled with a pyrometer, optical emission spectrometer and residual gas analyser for in situ measurement of temperature, plasma diagnosis and exhaust gas analysis respectively.

The chemical analysis of the product indicated around 90% reduction of the ore, the chemical analysis results are found to be complimentary to the XRD indicating the removal of oxygen in hydrogen atmosphere and thus the formation of metallic iron.

Studies on SiAlON-metal interaction

SiAlON ceramice are a special class of high temperature refractory materials with high strength, good thermal shock resistance. It can withstand harsh environments and support temperatures beyond which metals and polymer fail. The cutting ability of SiAlON tools are in the range of ~3000 m/min in comparison to the conventional carbide tools (~150-300 m/min) for application in metals. The cutting ability is governed by the wear process at the tool-work piece interface. Hence the knowledge of the metal-ceramic interaction is important. CSIR-CGCRI has carried out studies to understand the effect of compositional varieties of α-SiAlON, a yttrium stabilized solid solution of α-Si3N4, against 304L stainless steel through interacting couples prepared under hot pressing (1100–1300°C, 1.8 MPa, 5 h) with respect to their chemical interactions and interface bonding. Behaviour of α-phase against steel was observed to be similar to that of β-Si$_3$N$_4$/ β-SiAlON phases but to a lesser extent.
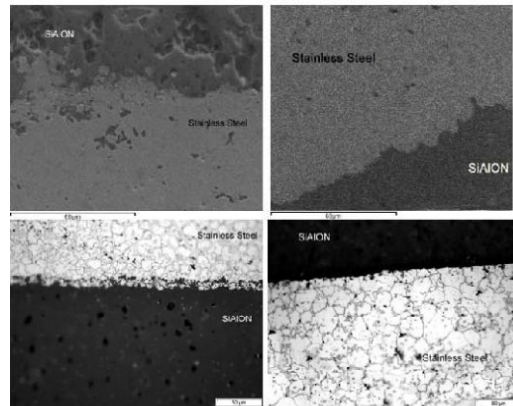
Fig. 1.90 Static interaction couple of α-SiAlON-304L stainless steel showing the interface, elemental distribution across the interface and the hardness profile

Interaction has been found to be guided by the anion ratio of the α-phase. Interdiffusion of elements takes place at both the ceramic and the metal sides. Interphase contains silicides and nitrides of Fe, Cr and Mo. Conditions of diffusion bonding were found to be much hostile than what appeared at insert tip during cutting operations.

Rare Earth Doped Optical Fibers for High Power Fiber Laser Application

In order to build up complete fiber laser systems for industrial, medical and strategic applications, CSIR–CGCRI is developing Rare Earth (RE) doped preforms/fibers suitable for high power laser applications through Vapor Phase Doping Technique. A state of the art facility has been established at CSIR-CGCRI and process technology successfully demonstrated for fabricating large core preforms/fibers doped with Yb- and Al- oxides with superior longitudinal and radial uniformity.

A large core Yb-doped optical fiber has been developed with core diameter up to 40 µm with respect to an overall diameter of 125 µm, numerical aperture in the range of 0.08-0.11 and maximum Y_b^{3+} concentration as high as 1.3 mol% through optimization of process parameters. The optical properties and lasing performance of the fibers are at par with those available commercially. The salient features of the vapour phase doping technique developed at CSIR–CGCRI include multiple RE–doped layer deposition for achieving large core area, high dopant incorporation ability, uniform distribution of dopant materials in the preform and flexibility of doping different RE elements. The technique provides independent, well controlled precursor vapor generation for stable, reproducible *in-situ* core layer deposition which leads to better ability of fabricating large mode area (LMA) fibers for high power laser applications.
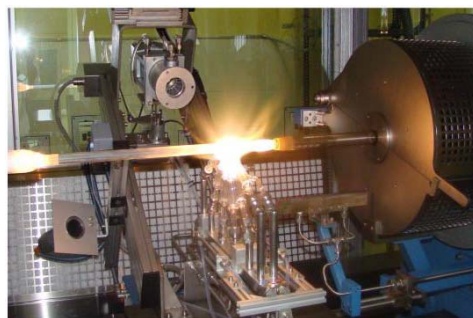

Fig. 1.91 Rare earth doped preform fabrication

Electronic nose for monitoring of obnoxious odorous constituents generated from pulp and paper industries

The odorous emissions generated from pulp and paper industry have been the cause of nuisance since the inception of the industry. Reduced sulphur compounds generated from these mills have several health implications and the ever increasing population accompanied by other socio-economic factors leading to the development of habitant in the proximity of these
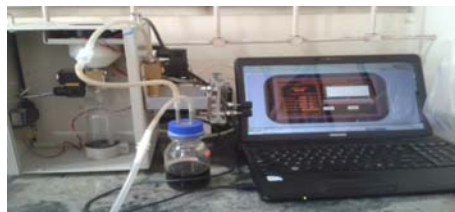

Fig. 1.92 Prototype of e-nose

mills is making it mandatory to monitor the emissions generated. Present available analytical techniques do not depict clear picture of odour perceived, time consuming and expensive. CSIR-NEERI has developed prototype of an electronic nose (e-nose) for monitoring sulphurous compounds emitted during pulping process from paper mills. The gas samples collected from industry were tested with the e-nose and an oduor index was generated corresponding to varying concentration of compounds. The prototype e-nose has been calibrated using various odorous compounds such as DMS, H_2S, DMDS individually and in combination also.

Performance Evaluation of Fibre Reinforced Plastic (FRP) Strengthened Structural Elements

CSIR-SERC has carried out the Performance Evaluation of retrofitted reinforced concrete beam-column joint under reverse cyclic loading. The investigation mainly focused on the performance of the beam-column joints designed for gravity loading and strengthened using two different methods for seismic loading. The methods adopted were; (i) Providing CFRP laminates in the compression face of the beam and CFRP wrap and (ii) Providing additional reinforcement in the compression zone by cutting a groove and the same filled with non-shrink cementitious material and CFRP wraps in junction. The cyclic deformation behaviour predicted from the model using hysteretic energy and incremental damage compares well with experimental results. It is also seen that the damage parameter varies uniquely with non-dimensional parameter for both the repaired specimens. Hence, cyclic load testing under reversed cyclic loading is a good candidate for performance evaluation of various repair methods.

A compendium on repair methodologies has thus been brought out which covers various types of deterioration that can take place in a concrete structure, Non Destructive Evaluation (NDE) techniques, repair materials, tests on repair materials, besides guidelines to be followed during the strengthening process and various repair methods which can be adopted in field.

Fig. 1.93 Test set for cyclic test on beam-column joint

Smart Energy Harvesters from Ambient Sructural Vibration for Seismic Mitigation and Health Monitoring of Civil Infrastructure

Energy harvester applications of the smart materials which can be incorporated into structural infrastructures has been established by CSIR-SERC. A suitable smart material which is flexible enough to integrate with the structure was identified and experiments were continued to explore its application domains. The experimental programme could realize some of the additional capabilities of the smart materials which were unknown earlier. It has been observed that the material holds excellent sensing capabilities almost equivalent with that of traditionally available materials. The smart material was integrated with concrete and tests were conducted using concrete cylinder specimens.
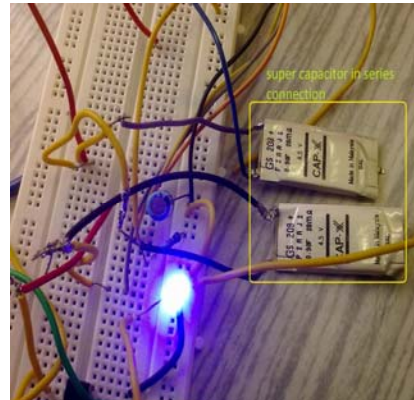

Fig. 1.94 View of the energy storing experiment

Book based on the report of CSIR-SERC-NDMA Project 'Development of Seismic Hazard Map of India'

CSIR-SERC in association with National Disaster Management Authority (NDMA) has been developing and refining the basic scientific and technological tools to assist the administration at the national and other levels to manage disasters, aided by appropriate technology. One of the important activities identified as an urgent need in the National Disaster Management Guidelines: Management of Earthquakes, brought out by NDMA is the development of a more realistic and scientific seismic zonation map of India.
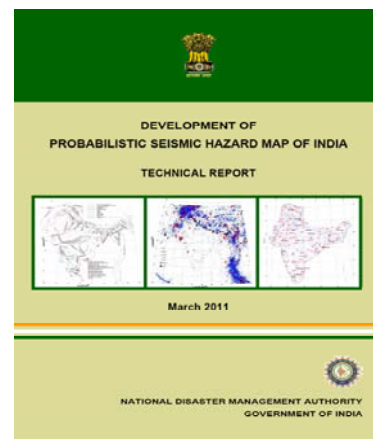

Fig. 1.95 Cover page of the technical report on development of probabilistic seismic hazard map of India

Stress Analysis of 24 inch Diameter Gas Pipeline at proposed Coastal Road crossing at Dronagiri, Navi Mumbai

The City and Industrial Development Corporation of Maharashtra Limited (CIDCO) is constructing a 2x3 lane road of 39m wide in 60m wide acquired width of land. This road alignment is crossing the GAIL's MSEB – Uran GAIL 24" gas pipeline near Navnagar to Sector 63 at Dronagiri. CSIR-SERC has assessed the condition of the pipeline by carrying out detailed stress analysis to evaluate the exact stress developed in the pipeline due to the ground improvement work. Detailed analysis was carried out to evaluate the stresses developed due to the expected settlement of 1.5m during ground improvement work. Also the stress developed due to the formation of road embankment was determined. Based on the analysis, remedial measures to protect the pipeline were designed. A detailed report has been prepared.

Retrofitting of off-shore tanker terminal of Vishakapatnam Port Trust

Offshore-Tanker Terminal of Vishakapatnam Port Trust is nearly 30 years old structure, consisting of seven spans.   The deck carrying the oil pipeline has a width of 3.0m for spans 5, 6 and 7 and a width of 5m for spans 1, 2, 3 and 4, and is supported over 2 numbers of prestressed concrete girders kept side by side.

CSIR-SERC has carried out experimental investigation to assess the residual prestressing force of the two PSC girders in span 3. In each girder, ten locations were instrumented at the inner/outer side of the girder. Linear type electrical resistance strain gage of 30mm size were fixed at the selected locations using suitable adhesive and the gages were oriented along the longitudinal axis of the girder. Trepanning technique was applied and the strain release during the testing was recorded. From the strain release the existing prestress has been evaluated. From the measurements it is observed that the loss of prestress is around 40

Fig. 1.96 Investigated distressed PSC girder of span 3 of off-shore tanker terminal of VPT

to 50%. In order to make the structure to carry the design load, external strengthening measures have to be carried out in the distressed girder. In practice several strengthening measures are available out of which external prestressing was found to be suitable for strengthening the distressed girder.

Fig. 1.97 Assessment of residual prestressing force using Trepanning technique

Scientific Excellence

Glass-free LTCC tapes for microwave substrate applications

CSIR-NIIST has developed glass free Low Temperature Co-fired Ceramic (LTCC) tape of $LiMgPO_4$. The tape casting slurry was prepared by dispersing $LiMgPO_4$ powder in ethanol/xylene mixture followed by addition of organic additives such as binder, plasticizer and homogenizer. $LiMgPO_4$ ceramic powder of average particle size 1.1 µm and BET surface area of 2.7 m^2g^{-1} was
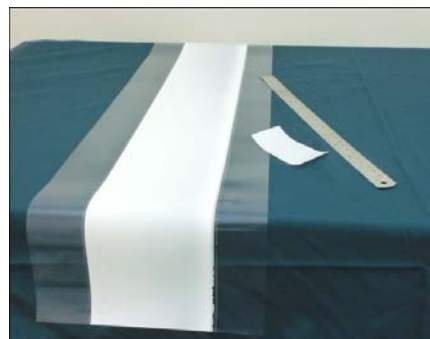

Fig. 1.98 Cast $LiMgPO_4$ ceramics Green tape

used for the slurry preparation. Tape casting slurry of LiM_9PO_4 with typical pseudo-plastic behavior was cast into thin tapes of thickness 70 μm using the doctor blade technique. The green tape of $LiMgPO_4$ has a ϵ_r of 3.2 and tan δ of 0.0688 at 5 GHz. The thermo-laminated tape (4 layers) sintered at 950°C for 2 hours showed good microwave dielectric properties: ϵ_r = 6.4 and tan δ= 0.0002. $LiMgPO_4$ ceramic showed a coefficient of thermal expansion of 10.5 ppm/°C and thermal conductivity of 7.1 $Wm^{-1}K^{-1}$. The glass-free nature and the good microwave dielectric properties obtained for the final tape makes the newly developed tape casting formulation attractive for LTCC applications.

Mesoporous alumina thin films with hexagonal and cubic symmetries as catalyst support

Thermally stable ordered (2D or 3D) mesoporous alumina is of immense importance as adsorbent material, catalyst and catalyst support owing to its high surface area, narrow pore-size distribution and uniform pore structures. The development of this kind of materials with different symmetries in thin film forms on ordinary glass substrates is important because of easy maneuverability with reusability in catalysis. CSIR-CGCRI has synthesized 2D hexagonal (p6mm symmetry) and 3D cubic mesoporous alumina films with high thermal stability with the aid of triblock non-ionic surfactants, P123 and F127 respectively. The 2-D film acts as an efficient catalyst in the decomposition of aqueous $KMnO_4$ to MnO_2 nanoparticles. It showed ~17 times enhanced catalytic activity than that of the ill-organised disordered mesoporous alumina film of comparable thickness and porosity.

Further cubic mesoporous alumina films (3-D) incorporated with Au nanoparticles (CMAF-Au NPs) were found to be potentially very active as a reusable catalyst in the reduction of 4-nitrophenol to 4-aminophenol using aqueous $NaBH_4$ at 25°C. The reaction does not proceed in absence of catalyst.
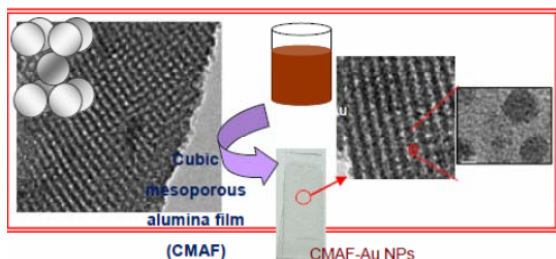

Fig. 1.99a Highly ordered cubic mesoporous alumina film containing Au nanoparticles used as catalyst for reduction of 4-nitrophenol
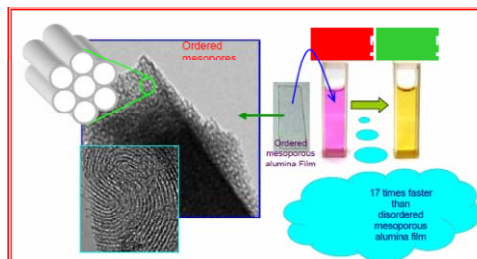

Fig. 1.99b Schematic representation of the ordered mesoporous alumina film used as a catalyst for conversion of $KMnO_4$ to MnO_2 nanoparticles

Fabrication technology of advanced glasses: an important step forward

Advanced glasses are being used increasingly in a host of applications such as touch screen mobiles, tablet computers, i-pads, ultra slick cameras, remote sensing, healthcare, green energy, space, and strategic sector technologies. Being a brittle solid, glass is prone to suffer from contact damage-induced brittle fracture. While the advanced applications of glass require very accurate grinding and
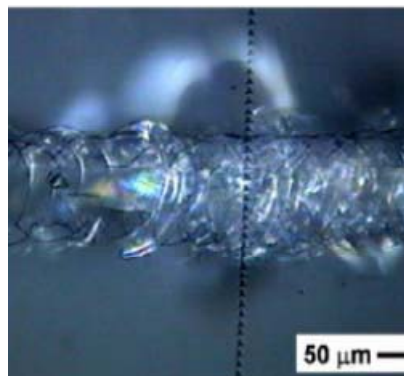

Fig. 1.100 Nanoindentation across scratch groove of SLS glass

polishing that involves controlled removal of glass, the material removal mechanisms are not well understood which impairs further technological advancement. CSIR-CGCRI has conducted unique combination of nanoindentation and microscratching experiments. The results show, for the very first time globally, that local degradation in nanohardness (H) and Young's modulus (E) in the scratch damaged regions could be as high as ~ 30-60% in soda lime silica (SLS) glass that is of significant technological importance. It was shown further that such a phenomenon could be explained in terms of the model of a micro-cracked brittle solid. Localized shear induced sub-surface deformations and microfractures were shown to have major roles in the material removal mechanisms.

Host mediated synthesis of cobalt aluminate/γ-alumina nanoflakes

CSIR-CGCRI developed a simple, facile, and scalable synthetic procedure for the preparation of high surface area $CoAl_2O_4/\gamma-Al_2O_3$ composite nanopowder which can be used as self cleaning blue pigments. A stable cobalt aluminate has been synthesized at low temperature (500°C) compared to the conventional high temperature methods. It has been established that when boehmite powders impregnated with Co salt was heated at 500°C, the conversion of boehmite to $\gamma-Al_2O_3$ facilitated the formation of isostructural (spinel) $CoAl_2O_4$. For the first time it could be shown that the $CoAl_2O_4$ spinel composite could act as an efficient reusable catalyst for the decomposition of H_2O_2 for releasing oxygen that may oxidize a wide range of organic and inorganic pollutants.
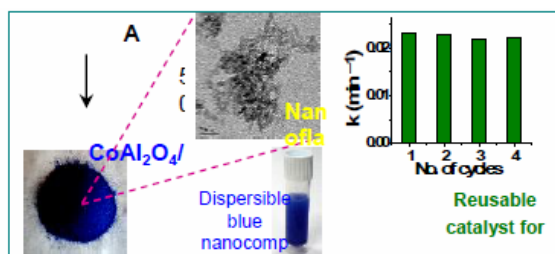

Fig. 1.101 $CoAl_2O_4/Al_2O_3$ composite: an efficient catalyst for the decomposition of H_2O_2.

TiB-TiN composite coatings for implant applications

Titanium and its alloys are widely used in aeronautical, chemical, defense and biomedical applications due to their high specific strength, excellent corrosion resistance and biocompatibility. The presence of TiN in combination with TiB in Ti_6Al_4V alloy matrix is important as it is expected to enhance the toughness and biological properties of these composites. However, no attempts have been made on laser processing of simultaneous in situ synthesized TiB + TiN reinforced composite coatings on Ti alloys.

Using Laser Engineered Net Shaping (LENS), a laser-based additive manufacturing technology, CSIR-CGCRI has made a novel attempt to create in situ formed TiB– TiN-reinforced Ti_6Al_4V alloy matrix composite coatings on commercially pure (Cp) Ti. These hard composite coatings showed lowest *in vitro* wear rate of 1.90×10^{-6} mm^3/Nm in 15BN coating, which is an order of magnitude lower than 5BN coating and 2-3 orders lower than Ti substrate.

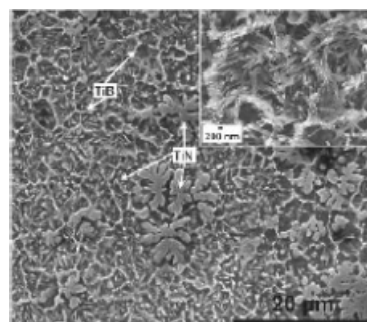Fig. 1.102 Laser processed Ti_6Al_4V-5BN composite coating showing TiB and TiN phases; Magnified view (inset)

Large Scale Milling Process for Production of ODS Steel Powder

CSIR-IMMT, through a mechanical alloying process of ovide dispersion strengthened (ODS) steel powder carried out in an indigenously developed dual drive planetary ball mill for the first time. The dual drive planetary ball mill consists of a gyratory shaft and four cylindrical steel jars, all are rotated simultaneously and separately at high speed. Such high-speed rotation of all jars and the shaft makes the balls to move rapidly, leading to large impact energy of balls that improves the alloying performance. This could result in reducing the milling time and production of larger batch of powder, which in turn result in better impurity control, more homogeneity and powders with close size range in addition to cost and energy saving. It was found that 5 hours milling time, was sufficient to reduce the particle size and convoluted structure of particle which is suitable for ODS steel powder preparation. TEM results revealed homogeneous distribution of nano Y_2O_3 in ferritic steel matrix at optimum milling time of 5 hours. The process of mechanical alloying using dual drive planetary ball mill was found to be very effective in reducing the milling time as compared to other high energy ball mills. The powders will be used for qualification testing for process optimization of ODS steel tube nulear power plant.
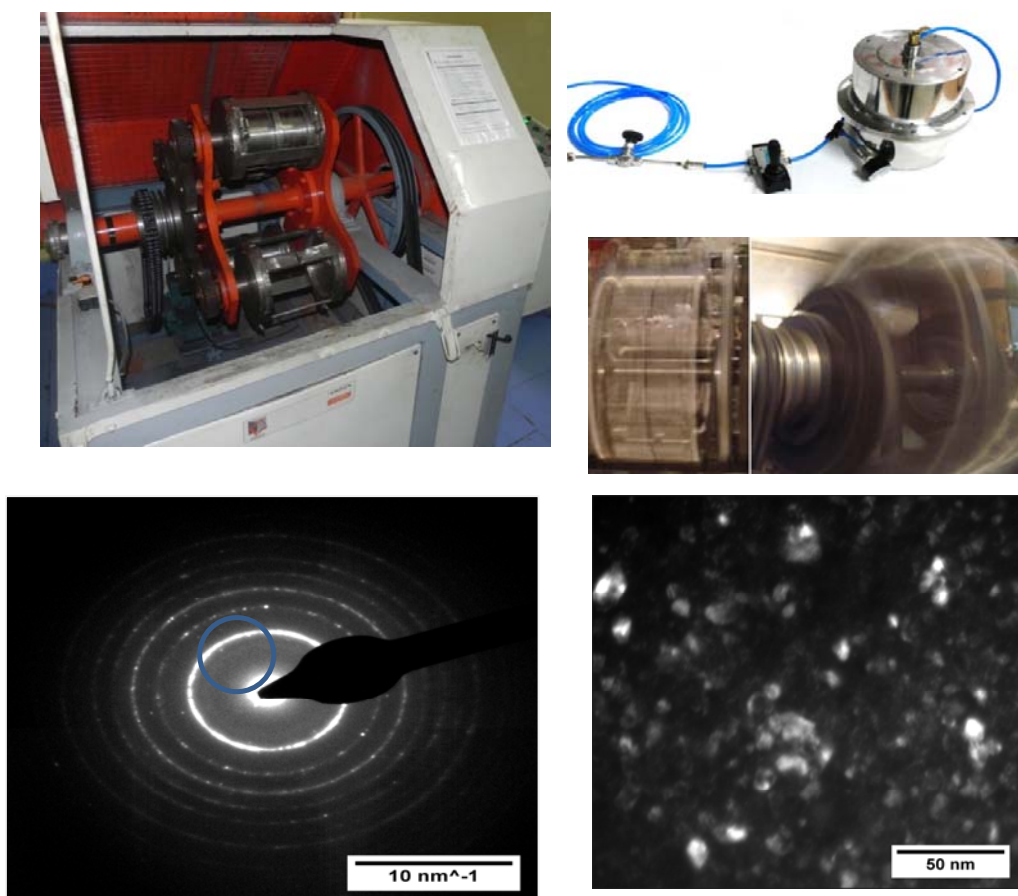
Fig. 1.103 Dual Drive Planetary Ball Mill Unit with Gas Purging Jar Assembly*(Capacity:1.5kg)*

Novel $Sm_2Ti_2O_7$/$SmCrO_3$ composite for degradation of Rhodamine R6G dye

CSIR-IMMT has studied the removal of R6G dye under its natural pH using $Sm_2Ti_2O_7$/$SmCrO_3$ composites prepared by solid state combustion method taking urea as a fuel. $Sm_2Ti_2O_7$/$SmCrO_3$ composites were synthesised by taking $Sm(NO_3)_3.6H_2O$, TiO_2, Cr_2O_3

and urea together by mechanical grinding in the presence of ethanol followed by calcination at 800°C for 4 hours. In these syntheses only Cr_2O_3 ratio was varied keeping the other three ratios constant (Cr:Sm:Ti:urea = X:1:1:4). As prepared composites were abbreviated as 0.2STC (0.2:1:1:4), 0.5STC (0.5:1:1:4), STC (1:1:1:4), 2STC (2:1:1:4). Pure $Sm_2Ti_2O_7$ (STO) and $SmCrO_3$ (SCO) were prepared by keeping metal to urea ratio 1:2 under the same reaction conditions. The prepared catalysts were characterized by X-ray diffraction (XRD), UV-vis diffuse reflectance spectroscopy (DRS), Photoluminescence spectra (PL) and X-ray photoelectron spectroscopy (XPS).

Fig. 1.104 Illustratation of enhanced mechanism for the R6G degradation

XRD patterns showed the presence of both of $Sm_2Ti_2O_7$ and $SmCrO_3$ peaks thereby confirming the existence of both $Sm_2Ti_2O_7$ and $SmCrO_3$ phases. The rate of degradation of R6G dye by composites is higher than that obtained by single phase i.e. pure $Sm_2Ti_2O_7$ or $SmCrO_3$. The composite prepared at (Cr:Sm:Ti=1:1:1) ratio degrades the dye faster among all the prepared catalysts. The photocatalytic degradation of R6G over STO and SCO is only 25 and 30 % respectively as compared to composites such as STC, 0.5STC, 2STC, 0.2STC which shows 70%, 59%, 50% and 44% degradation respectively.
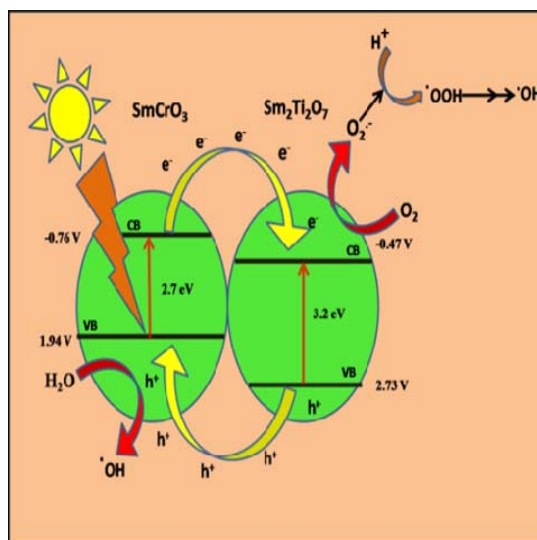
High-strength Nano-Crystalline Mg-Al Powder Synthesized by Mechanical Alloying

CSIR-IMMT has developed nanostructured Mg93.3 Al6.7 powder with crystallite size of 30mm through mechanoalloying route. These material posses high specific properties, improved wear resistance and lower coefficients of thermal expansion. The nanostructured powder was then consolidated into highly-dense bulk samples through hot pressing followed by hot extrusion to give nanocrystalline specimens with crystallite size of about 80 nm. Phase analysis and microstructure investigations revealed that the microstructure of the consolidated material consists of gamma-$Al_{12}Mg_{17}$ particles with size below one micro meter homogeneously dispersed in a continuous Mg(Al) matrix. This microstructure leads to a remarkable mechanical behavior of the bulk specimens. Room temperature compression tests of the consolidated material reveal high compressive strength of about 690 MPa combined with plastic strain exceeding 9%. These findings demonstrate that powder metallurgy is a suitable method for the production of nanostructured Mg-based materials characterized by high strength and considerable plastic deformation.

Nickel recovery from refinery electrolyte

The bleed solution of 150 m^3/day from electrolytic cells contains nickel which amounts to 300 tpa is being processed as waste effluent. As India is not having any nickel plant with primary raw materials, it is essential to utilize the secondaries and wastes as a source of nickel. During refining of copper, the bleed solution obtained from liberated cells contains significant amount of nickel, arsenic and copper along with other minor impurities.

CSIR-IMMT has developed a process to recover nickel values. The unit operations comprises of neutralization, bulk hydroxide precipitation, dissolution of hydroxide cake, purification, cementation of Cu, solvent extraction of Ni and electrowinning of Ni. In order to reduce the volumes in the downstream unit operations such as purification and solvent extraction, bulk hydroxide precipitation with subsequent dissolution is suggested. Ferric arsenate precipitation is suggested for removal of arsenic using ferric sulphate. Ni was recovered as Ni cathodes of 99.9% purity after cementation of Cu and solvent extraction of Ni. The overall recovery of Ni was 85%.

Ferromagnetic Shape Memory Alloys by Rapid Solidification Route using Melt Spinning Technique

CSIR-NML has developed ferromagnetic shape memory alloys (FSMAs) in the form of ribbons by rapid solidification route and optimised heat treatment schedules to modify magnetic and structural properties. A series of $Ni_{55}Mn_{22}Ga_{23-x}Al_x$ (x=0, 0.5, 1, 2, 3, 5) alloys have been prepared in the form of ribbons by melt spinning. The ribbons were found to be in martensitic state at room temperature. Transmission electron micrograph of a typical $Ni_{55}Mn_{22}Ga_{22}Al_x$ alloy ribbon annealed at 1073K for 30 hours shows equally spaced martensitic lath. Magnetic field induced strain was measured for the

Fig. 1.105 TEM of ferro-magnetic shape memory alloy showing equally spaced martensitic laths

melt spun ribbons using a system developed in the laboratory. The alloy with x=1 showed high magneto-strain of 482ppm.

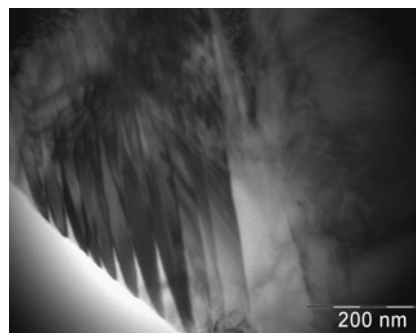## Ultrasonic Technique for Surface Crack Detection of Semi HSS and HSS Rolls

Over the last few years, the use of work rolls for hot rolling of flat steel has changed. In the roughing stands, conventional high chrome steel (70 – 75 ShC) has been gradually replaced by new grades like carbide enhanced high chrome steel (75 – 80 ShC), ultra low carbon grades like Semi – HSS, matrix type HSS (80 – 90 ShC), Konkordia (Cr-based HSS) and a variety of other HSS grades (HSS 75 – 85 ShC). As the hardness of HSS reaches 80/85 ShC, it becomes crack-sensitive and the developed crack is usually oriented parallel to the roll axis but propagates in a non-radial direction. Usually after each grinding, non-destructive eddy current and Dye-penetrant techniques are used for checking of surface cracks. Eddy current technique is not successful in predicting fine surface cracks on HSS rolls. CSIR-NML has developed a surface wave based ultrasonic technique to detect fine cracks on the barrel surface of HSS rolls as well as to find the optimal grinding condition for a complete crack free roll surface. A joint patent has been filed and the implementation of the technique at the Hot Strip Mill of the Steel plant has reduced significantly the spall rate of the HSS rolls.

Failure Analysis of Metal Components

CSIR-NML, over the years, has developed expertise in failure analysis of aircraft wings, turbine blades rotor blades etc. During the year, the laboratory has provided its technical services to many areas, some significant ones are as below:

Low Pressure Turbine: Metallurgical investigation was carried out on failed aeroengine components to establish the cause of failure. The fractographic examination of the failed low

pressure turbine (LPTR) blades showed generally intergranular fracture with secondary cracking. One of the LPTR blades that failed near the root showed clear signatures of fatigue related damage at the leading edge. This could be the primary cause of the failure of the particular LPTR Blade which failed first causing subsequent secondary damages to other aeroengine components. The fractured LPTR blade rubbed on the nozzle guide vane casing, severely damaging the honey comb structure and puncturing the outer casing as well as damaging the trailing edges close to the root of the nozzle guide vane.

Compressor Blade: The stage-I compressor blade of an aeroengine got damaged at the leading edge. The metallurgical investigation involved microstructural analysis, material composition by EDS and fractographic studies. It was found by EPMA analysis that the blade was damaged due to impact of non-metallic foreign objects consisting of C,O, Mg, Al, Si, P.
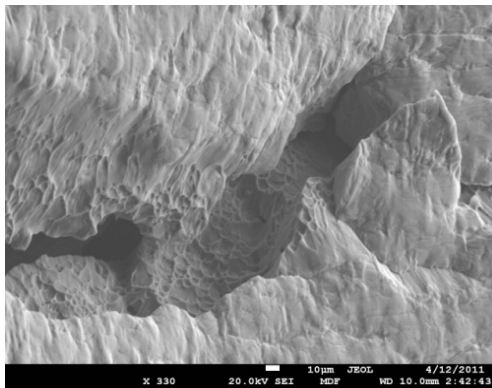

| Fig. 1.106a Dimples as well as shear type failure on the damaged surfaces | Fig. 106b SEM fractography showing tearing on the damaged blade |
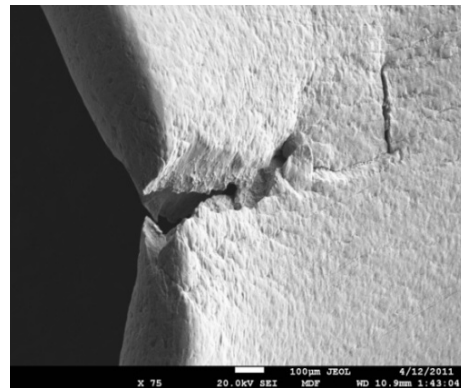
Diamond thick film for RF transparent window

CSIR-CGCRI has achieved a notable breakthrough by developing large area, uniform and high quality polycrystalline diamond thick films for Radio Frequency (RF) window component using microwave plasma enhanced chemical vapor Fired tiles coming out of roller hearth during manufacturing deposition (MPCVD) process in a 915 MHz, 15 kW microwave cavity reactor. By suitable manipulation of the reactor parameters, it was possible to deposit whitish translucent quality freestanding diamond coating as well as to grow black color opaque quality thick circular plates of dimension 60 mm diameter/0.6 mm thick for thermal management and other high end applications.

| Fig. 1.107a Few Coated components | Fig. 1.107b (L) Translucent and (R) Opaque quality, large area sub-mm thick diamond plates |

Sputter Deposited Nano-structured Coatings for Tribological Applications

CSIR-NAL has made extensive efforts to develop superhard nano-structured coatings on small engineering components, including cutting tools for the machining of difficult-to-machine aerospace and other engineering materials. Performance evaluation tests of the coated tools on various engineering materials have shown considerable improvement in the tool life. The coating technologies developed by CSIR-NAL are at par

Fig. 1.108 Nanostructured coatings for industrial drill bits

with the technologies available elsewhere in the world. Other concepts such as plasma nitriding of tools, super-tough coatings and nano-structured solid lubricant coatings have also been developed to improve mechanical and tribological properties of various engineering components. These nano-structured coatings can be used in cutting tools, automobile, aerospace, biomedical, and other industrial sectors. In particular, the solid lubricant coatings based on metal-dichalcogenide nano-composites hold great promise for aerospace applications.

Mg Alloys

CSIR-AMPRI has synthezised Mg alloys using liquid metallurgy route. A specially designed electrical resistance melting furnace with a facility for the inflow and outflow of the protective atmosphere during melting has been employed for the purpose. The furnace can handle 30 kg of Mg at a time. Attempts have been made to produce different Mg-alloys like AZ91, AZ31 etc. and subject them to rolling and extrusion using optimised process parameters. The alloys have been analysed for their microstructural features and mechanical properties. The effects of rolling variables such as bite angle, temperature, strain and strain rate have been investigated. Another aspect of the studies is modelling the process of material deformation for a few Mg alloys with the help of processing and microstructure maps. Optimization of extrusion die profile and processing parameters like strain rate and temperature with the help of laboratory scale experimentation and FE simulation studies are envisaged to the development of a (process) model enabling safe deformation of the Mg alloys to fabricate good quality and defect free materials/components in actual practice.

Evaluation of Operational Efficiency of Highway Network Using Travel Time Reliability Measures

CSIR-CRRI has made an attempt for selection of appropriate traveltime reliability indices for Indian Highway and evaluation of operation efficiency of roadway system by considering traveling time reliability measures. Reliable transportation system provides safe and accessibility and efficient movement of people and goods. Travel time variation on each road network occurs due to variation in traffic flow and therefore the travel time reliability on road link changes as the link flows changes. A stable condition is reached only when no traveller can improve his travel time reliability by unilaterally changes routes. This is the characterization of the reliability user equilibrium. This Rut characteristic have been studied by considering Rut base traffic assign algorithm for any transportation network.

Microscopic Traffic Simulation Model for Speed-Flow Equations and Roadway Capacity for High Speed Corridors

CSIR-CRRI has attempted for the first time in the country to explicitly study the free speed profiles and speed-flow characteristics on various types of multi-lane highways covering four-lane, six-lane and eight-lane divided carriageways in plain terrain. Extensive data on Time Mean Speed (TMS) and Space Mean Speed (SMS) under free flow conditions coupled with traffic flow data was collected on sites spread over different regions of India. Microscopic traffic simulation softwares namely VISSIM and PARAMICS have been utilized. The simulation model is able to reduce the error (from 3 ~ 34% to 0.1 ~ 18%) as compared to traditional method. Further, capacity norms developed for these high speed corridors were also evolved from the speed-flow equations. The estimated roadway capacity is 5574, 7733 and 9796 PCU/hr/Direction for four, six and eight-lanes divided carriageways respectively.

The lane change behaviour affects roadway capacity on multi-lane highways has been assessed through microscopic simulation approach resulting areduction of 3 to 9% in the estimated capacity. On a eight-lane divided urban expressway, PARAMICS software has been used to model vehicular behavior such as virtual lanes etc. The speed-flow equations developed and the estimated roadway capacity of eight-lane divided urban expressway, the impact of virtual lanes and lane change on capacity is assessed using developed simulation model resulting 15% and 9% reduction in capacity due to the restriction of virtual lane and restriction of lane respectively. It can also be seen that free speeds are increasing only marginally. Finally, the Design Service Volume (DSV) for various multi-lane highways under the prevailing heterogeneous traffic conditions has been evolved with reasonable degree of confidence. The outcome from this study is expected to form an important input for developing Road User Cost (RUC) models, exclusively for multi-lane highways.

Assessment of Methodologies for Seismic Performance Evaluation of Structures

CSIR-SERC has studied an ensemble of near fault earthquakes and the significant parameters like energy content, significant duration, etc. Various ground motions which give rise to critical response of structures were characterized. The experimental investigations on rectangular water tanks were continued for different types of earthquake time histories, namely near fault and far distance earthquakes on the 3D Shaking table. Experiments were carrried out for single direction and three direction earthquake loadings for varying water heights. Two sets of ground motion records were selected for a range of acceleration levels and duration. It included artificially generated narrow band time history as well as ground motion record which involves near source effects. Out of the various parameters studied like accelerations on the tank walls and sloshing wave height, the hydro dynamic pressure on tank walls is found to assume importance as it is a major parameter in the design of liquid tanks. It is found that a near field earthquake with three directional earthquakes loading produces the maximum hydro dynamic pressure on the tank walls.

Performance of Concrete Foundation for Turbo Generator in Power Plants

The concrete foundation supporting turbo generator (TG) is a critical structure in a power plant. In addition to the static behaviour, dynamic behaviour of the foundation plays an important role in ensuring normal operating conditions of the turbo-machine. Turbo generator foundation supports heavy equipment at a large height and hence seismic forces are significant for a proper and safe design of the TG foundation. The present design practice of

performing the seismic design of machine foundations using response spectrum analysis, gives estimation of internal forces and displacements due to seismic excitation, but does not consider the non-linear behaviour of the system. In order to consider the non-linear effects, CSIR-SERC has attempted to perform the pushover analysis of the machine foundation. A 250MW TG foundation was modeled in SAP software. The TG consists of 14 columns connecting the sole plate to top deck, which is made of heavy beams. The overall geometry of the TG foundation was 30 m X 12 m X 15 m. The machine weight is around 1104 tons. The mass of the concrete structures is 1962 tons. Eigen value analysis was also carried out to obtain the natural frequencies and mode shape. The default M3 hinges are assigned to both beam and columns. The lateral load capacity in ADRS format is computed as 1.1g and the displacements are 0.5 mm and 4 mm at yield and ultimate stages respectively. It was found is that the lateral force capacity of TG foundation is large and the structure is not critical under seismic conditions.

Traffic Studies for Junction Improvement on Major Road Corridors in Ahmedabad

CSIR-CRRI has prepared a Junctions Improvement Plan for selected junctions on road network for Ahmedabad Municipal Corporation. Traffic surveys and preparation of junction improvement plans for 23 identified intersections based on traffic projections were conducted for the next 10 years, as per IRC guidelines. Various field studies undertaken include road inventory and traffic studies which were carried out to collect primary data to understand the existing problems and to analyze traffic demand. In addition, secondary data information such as vehicle population, land-use data, ongoing and future envisaged developments in the surrounding areas were also collected. The projected peak hour traffic volume at the five intersections has been estimated for the horizon year 2017 and 2022.

Evaluation and Monitoring of Rohari Steel Bridge in Katni-Manikpur Section of Jabalpur Division for Increased Axle Load of Freight Wagons

CSIR-CRRI has evaluated Rohari bridge, Katni-Manikpur section of Jabalpur division, West Central Railway (WCR) for possible increase in axle load of freight wagons. This bridge has one 33.45m long span of steel through truss type. Strain, deflections, temperature, accelerations etc. were monitored at critical locations by fixing several sensors in rails, couplers, superstructure, bearings and abutments of the bridge. After the installation of sensors, continuous monitoring was done by extending the cables of the various sensors up to the data acquisition systems. The bridge was tested under various loadings cases of Test train as well as regular trains. Theoretical analysis of the steel truss bridge superstructure was carried out using FEM based software. Dimensions and sectional details of the various members of the truss were taken from the drawings/details supplied by WCR officials. The 3-D model of the superstructure was carried out for the vertical as well as longitudinal loads due to the various loadings viz. HML, MBG, BGML, CC+8+2, and actual test train used for testing as specified by the Railways.

Preparation of Guidelines for Construction of Roads, Culverts and Bridges in Cyclone prone Areas

CSIR-CRRI has prepared 'Guidelines for Construction of Roads, Culverts and Bridges in Cyclone prone Areas' for National Disaster Management Authority (NDMA). Two interactive workshops were organized at Bhubaneswar and Visakhapatnam to discuss various aspects of the Guidelines and fine tuning the recommendations. Engineers from state Public Works

Department (PWD) and Rural Works Department entrusted with the task of road works in cyclone prone areas participated in the workshops. Salient features of the Guidelines were presented in the workshop and CSIR-CRRI faculty interacted with engineers to get firsthand knowledge about problems associated with road works in cyclone prone areas. Field visits for the road works constructed in these areas was also undertaken. Based on the recommendations of the workshop, Guidelines have been finalized and would be published by NDMA.

Disaster Mitigation: Post-Earthquake Reconnaissance Survey – Sikkim Earthquake

An earthquake occurred in eastern Nepal near the Nepal-Sikkim border on 18 September 2011 at 18:11 IST, causing significant damage of the built environment in Sikkim alone, especially roads and buildings. At the outset of National Disaster Management Authority (NDMA), CSIR-CBRI scientists participated in Reconnaissance Team (PERT) to study (i) Structures damaged by the Earthquake (ii) Collect perishable data related to the built environment in the affected area; (iii) Identify vulnerable construction typologies and their performance; (iv) Identify main reasons for damage to masonry, RC frame, traditional construction and other construction; and (v) Evaluate the performance of structural, non-structural and functional elements in major critical and lifeline buildings and facilities, such as hospitals.

The built environment in hill areas affected by the earthquake includes mainly four type of building construction in the region, namely RC frame type with infill walls, R/R masonry with stone or wooden post and beam, RC buildings. Traditional houses (Ekra houses) built with a wood frame from sloping ground to roof level, light corrugated galvanised iron (CGI) sheet roofing supported on the wood frame, mud walls from plinth to sill level, and cross-woven Ekra or bamboo spilt matting plastered with mud or fine sand with lime as rest of the walling.

The traditional houses like Ekra and Shing-Khim performed significantly better compared to RC-frame / masonry buildings and suffered only minor damages at ground story level. Various monasteries all over Sikkim suffered extensive damages, wherein mainly random rubble (R/R) masonry laid in mud/lime mortar was used as construction material. Major civil-engineering projects in the area includes hydel power plants, steel and RC bridges, wherein no significant damage was observed.

The event prominently highlights the presence of vulnerable building stock in Sikkim and adjoining states. The lessons learnt from the event, aiming to proactive role in reduction of seismic damage are briefly bulleted herein:

- Use of good construction practice and quality of material;
- Development of typified designs keeping local architecture and use of locally available material reinstated and integrated with modern construction practices. Proven technology, which satisfy all the fronts like confined masonry shall be promoted;
- Compliance for seismic codes in design;
- Retrofitting strategies should be outlined specially for lifeline and heritage structures;
- Need to strengthen the activities of State Disaster Management Authority (SDMA) with a strong group guiding activities on development of technical and administrative personnel;
- Lack of earthquake engineering education of stakeholders; and

- Capacity building for Masons, carpenters and bar benders need to be trained to undertake earthquake-resistant construction in high seismic regions; certified artisans should be given preference over their untrained counterparts to promote quality construction.

Fig. 1.109a Typical urban landscape along hill slopes of towns, Gangtok, Darjeeling, Kalimpong and Kurseong


Fig. 1.109b Damage due to Mudslide at Lachung

Coastal Ocean Monitoring and Prediction System

CSIR-IMMT has made an attempt to elucidate the trends of pollutants in the sea and also processes associated with land and sea interface. Sustainable management of coastal and marine resources is essential for long term economic growth and to ensure the equilibrium between economic development and the protection of the environment.

Higher bacterial load in water and sediment was observed in the shore stations which are probably due to anthropogenic activities. More abundance of bacterial population in low tide than high tide may be due to dilution of contaminated water during high tidal condition. Normally during monsoon high tide resuspension of bacteria from sediments by strong current movements gives higher bacterial counts. However, there appeared to be no significant diel or time variation in bacterial abundance.
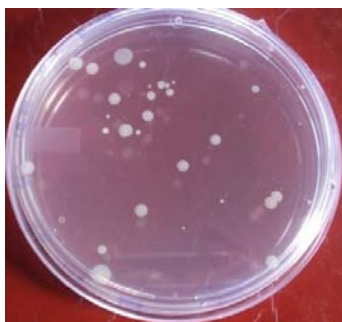
Total Viable Count (TVC)
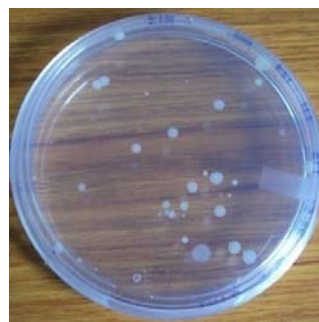
Streptococcus Faecalis
Fig. 1.110
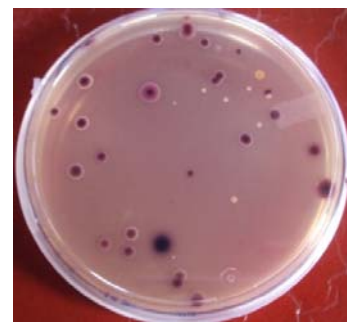
E.coli like organism

During the year, total 117 species of phytoplankton from Odisha coast and 85 species from West Bengal coast were recorded. Compared to West Bengal coast Odisha coast registered higher phytoplankton population and chlorophyll-a concentration. Blooms of *Asterionella japonica* were found along Paradip shore during the month of July 2011. Pollution indicating species like *Pseduonitzchia, Oscillatoria* sp., *Prorocentrum micans, Noctiluca scintilans* were identified from Paradip, Sandheads and Hoogly estuary. The winter diatom blooms and

summer–early monsoon blooms were apparently driven by changes in nutrients, water temperature and turbulence, clearly demonstrating the role of river flow and climate variability.

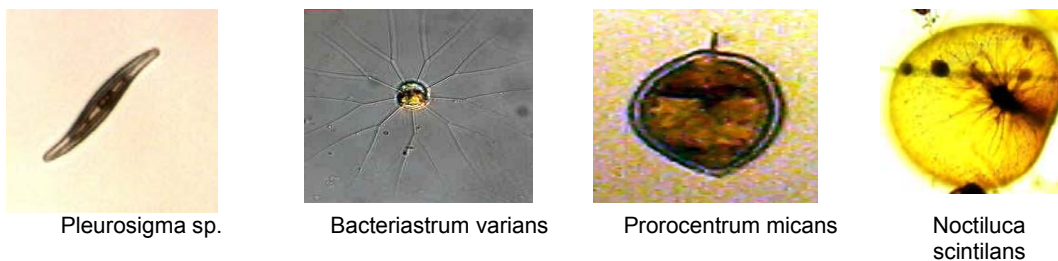|			
Pleurosigma sp.	Bacteriastrum varians	Prorocentrum micans	Noctiluca scintilans

Fig.1.111

Seasonal and diurnal Variability of Zooplankton population were also studied. Higher population was observed in premonsoon season than monsoon and postmonsoon. In off-shore regions higher zooplankton population and low biomass were observed during high tide than low tide. Copepoda is the dominant group both in Odisha and West Bengal coasts. Polychaetae larvae as pollution indicating species were identified from Paradip, Sandheads and Hoogly estuary.

Fig. Polychaetae larvap.   Hydrpzpa   Copepoda
Fig. 1.112

Similarly, Benthic population was also studied in the eastern coast of Bay of Bengal. Irrespective of seasonal variation Paradip coast always registered higher macro faunal abundance compared to West Bengal coast. Although the Donax species dominated over all other groups in every tidal sampling the highest population (87775 nos/ m^2) of this particular Bivalve species occurred during early monsoon season of Paradip coast. This has occurred first time in Odisha coast.

Fig. Donax   Turritellidae   Turbinellidae
Fig.1.113

Integrated Process for Mitigation of Oxides of Nitrogen – a Potential Global Warming gas

Nitrogen oxides (NOx) are formed by burning forming fuels, which have a negative impact on the environment. According to various international protocols, the NOx emissions in India need to be reduced. Commercial technologies for NOx emission reduction for stationary sources range from combustion modifications to flue gas treatments. The most widely used

technology is Selective Catalytic Reduction (SCR), able to achieve NO removal efficiencies up to 90%. But drawbacks of this technology are the relatively high costs involved and environmental concerns about the use of ammonia. CSIR-NEERI has explored the possibility of using an alternate technology for nitrogen oxides removal. In a novel approach, a mixed denitrifying culture was isolated from an inoculum of municipal sewage sludge consisting of three dominant organisms, including representatives of the genera *Citrobacter, Enterobacter* and *Streptomyces.* The enriched mixed culture was used in a series of batch experiments in order to determine kinetic constants associated with biomass growth and nitrite denitrification in aqueous Ferrous EDTA/NTA solutions and Ferric EDTA/NTA solutions using ethanol as the organic electron donor. The maximum specific reduction rates of nitrite (present as nitrosyl adduct) in Ferrous EDTA and Ferrous NTA solutions were 0.041 and 0.043 mMoles $L^1d^{-1}mg^{-1}$ biomass respectively while those in Ferric EDTA and Ferric NTA solutions were 0.022 and 0.024 mMoles $L^{-1}d^{-1}mg^{-1}$ biomass respectively. In case of Ferric EDTA/NTA solution, the kinetic constants associated with reduction of Ferric EDTA/NTA to Ferrous EDTA/NTA were also evaluated simultaneously. The maximum specific reduction rates of FeIIIEDTA and FeIIINTA were 0.0021 and 0.0026 mMoles $L^1d^{-1}mg^{-1}$ biomass.

Fig. 1.114 Bench Scale reactor system for chemo-biochemical deNOxiing

Hybrid Chemo-Biochemical Process for Biogas Generation from Complex Industrial Effluent

The existing biological processes for the treatment of distillery/tannery/pharmaceutical wastewater generate treated effluents with a residual COD of 30-40 % of the initial which requires appropriate value addition for economical and ecological gains. CSIR-NEERI has explored the possibility of wet air oxidation (WAO) based pretreatment of complex effluent to selectively enhance the biodegradability (without substantial COD destruction) and facilitate biogas generation potential. A lab-scale wet air oxidation reactor with biomethanated distillery wastewater (B-DWW) as a model complex effluent was used to demonstrate the proof-of-concept. WAO pretreatment of B-DWW enhanced the biodegradability of the complex wastewater by the virtue of enhancing its biodegradability index (BI) from 0.2 to 0.88, which indicate favorable Biochemical Methane Potential (BMP) for biogas generation. The kinetics of COD destruction and BI enhancement have been evaluated along with activation energy estimation. Biogas experiments using pretreated wastewater indicated favourable potential for substantial biogas generation. A genetic expression based

programming model has been developed and is able to capture the non-linearity of the pretreatment process.

HYDROPLUME – High Rate Circular Secondary Clarifier for Wastewater Treatment

In wastewater treatment, the conventional secondary clarifiers do not take hydraulic energy dissipation into account. They are either too large or often fail in giving the efficient solids-liquid separation. CSIR-NEERI has developed a clarifier named HYDROPLUME, which ensures minimum suspended solids (SS) concentration in the treated effluent. It requires minimum hydraulic retention time (1 – 1.5 hours) and saves 25 – 30% foot print area resulting 40% savings in capital and recurring costs. It produces excellent effluent quality (98 – 99% SS removal) and helps in attaining the treated effluent quality according to the prescribed discharge standards. High underflow solids concentration minimizes pumping rate, and maintains desired active biomass concentration in aeration tank. HYDROPLUME does not require a separate sump cum pump house for sludge recycling/removal, and also provides natural flocculation thereby saves capital and recurring costs.
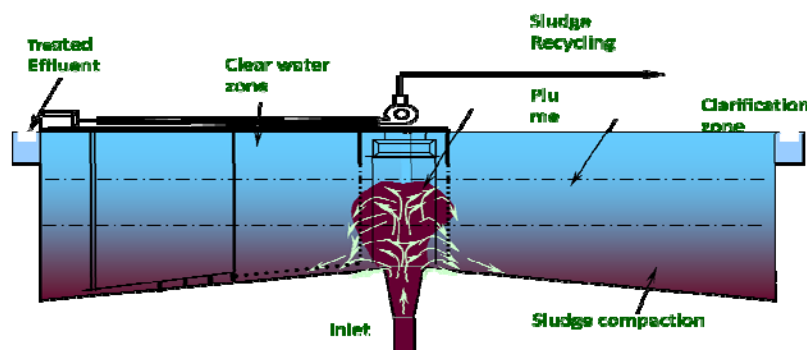

Fig. 1.115 Functioning of HYDROPLUME® showing plume formation solids-liquid separation

Inter linkages of air quality, climate change and health with recourse to molecular modeling and tracking analysis of regional transport of air pollution

The air pollution and respiratory health investigation study has been carried out jointly by CSIR-NEERI and CSIR-IGIB on the children of various schools in Delhi. A questionnaire was designed based on the international parameters for respiratory illness. The respiratory health survey was approved by the Directorate of Education, Delhi. Schools were selected based on land usage pattern i.e. commercial (Chandni Chowk), industrial (Mayapuri) and residential (Sarojini Nagar) areas. Approximately 1800 students (600 / zone) of age 10 – 14 years participated in the survey which included spirometry tests also. Indoor and outdoor levels of SO_2, NO_2 and PM were also measured within the school premises as well as at outdoor locations. The questionnaire data showed that the students having respiratory disorder symptoms were maximum in Chandni Chowk (66%) followed by Mayapuri (59%) and Sarojini Nagar (46%). Spirometry test results demonstrated that a significant population of subjects in Chandni Chowk (19%) had mild to severe pulmonary obstruction. However, the percentage of subjects with such conditions was comparatively less in Mayapuri (17%) and Sarojini Nagar (14%) area. Outdoor and indoor PM_{10} concentrations at schools located in Chandni Chowk, were observed 815±354.45 µg/m^3 and 337±85 µg/m^3 respectively. In this commercial zone, the concentrations were found ten times above the permissible limits. The PM10 concentration was lower in the industrial zone - Mayapuri (694.6±322.9 µg/m^3 and 274±78 µg/m^3) and least in Sarojini Nagar (534.3±94.22µg/m^3 and 197±48 µg/m^3) which is a

residential zone. However, levels of SO_2 and NO_2 were observed below the permissible limits in all three areas.

Unique Major Facilities

Semi- Free Jet Test Facility

A semi free-jet test facility has been established and commissioned at CSIR-NAL for high Mach number applications. The test rig was designed for Mach number of 3.5, total pressure of 20 bar, total temperature of 1700 K and mass flow rate of 20 kg/s. In the connected mode the test rig can be utilized up to Mach number of 3.5, but in semi free-jet mode with Mach number of 3.5 at entry to

Fig.1.116 Semi- Free Jet Test Facility

the test section. The facility consists of 200 bar air compressor and storage vessels of 30 m^3 capacity. The rig has two-step kerosene combustion heaters to heat the air up to 1700 K. The water-cooled nozzle accelerates the flow to a Mach number of 3.5 at entry to the test section. The scaled models can be mounted in the test section. The diffuser system was provided for diffusing the high supersonic flow to low subsonic flow. A state-of-the-art data acquisition system has been installed in conjunction with the in-house developed control software.

This is India's first state-of-the-art scramjet facility with safety clearance from ISRO and other statutory bodies of Govt. of India.

Augmented Engineering Environment

The Aircraft Integrated Development Environment or Augmented Engineering Environment (AEE), is an outcome of the collaboration with CAE Inc., Canada. Augmented Engineering Environment (AEE) simulator has been made operational at CSIR-NAL after integration of the hardware and software. The main focus is to study the technologies which have high human interaction content, including Integrated Enhanced and Synthetic Vision Flight Control System, integrated Modular Avionics and Cockpit Ergonomics.

This facility is one of its kind in the country to address the Design and Development of Flight control systems for both the manned and unmanned airframes for civilian and military applications

Adaptive Antenna Facility for Simulation

The dedicated test bed for adaptive arrays which enables both indoor/outdoor Hardware developments has been established at CSIR-NAL. The facility can be used for strategic applications in X-band and active RCS reduction techniques, for stealth and low-observables. The facility can also used for study of active cancellation in phased arrays, conformal and meta-material antennas. It is one of its kind facility in India.

Fig. 1.117 Adaptive antenna facility for simulation

FSS-based Design and Development Facility for Aerospace Applications

This is an exclusive dedicated FSS Facility (2-40 GHz) in the country. The facility was extensively used for CSIR-NAL-Boeing collaborative project related to EM material characterization of panels for Boeing 787-9 Dreamliner aircraft. This facility is essential for FSS design of Aerospace Structures. This is the only known dedicated FSS Facility (worldwide) 2-40 GHz.

Fig. 1.118 FSS based design and development facility

LENS™ (Laser Engineered Net Shaping) (Model MR-7) from Optomec, USA

LENS™ process is a laser assisted direct metal manufacturing process, a kind of rapid prototyping technique specifically used for medical implants fabrication has been commissioned at CSIR-CMERI. LENS™ technique offers: Customized complex shaped functional implants with functionally graded porosity, composition and properties; Demand based manufacturing that hugely cuts cost and inventory and enable superior properties compared to traditionally manufactured counter parts.