ISSN 0972-5741 Volume 90 October 2011

IGC Newsletter

IN THIS ISSUE

Technical Articles
- Successful Localization of the Failed Fuel Pin of Fast Breeder Test Reactor
- Standardization of Technique for Characterization of Sodium Aerosol (metal vapor) from Cover Gas region of Sodium Cooled Fast Reactor

Young Officer's Forum
- Microcantilever based Mass Sensors

Young Researcher's Forum
- Thermal Conductivity and Rheology Studies in Magnetic Nanofluids under an External Stimulus

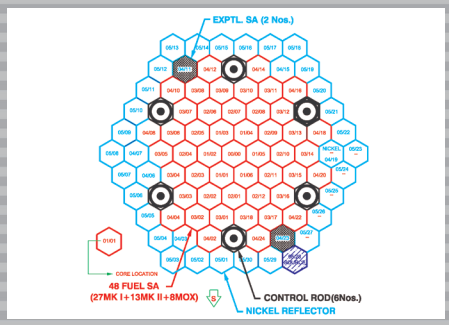
Conference/Meeting Highlights
- Theme Meeting on Manufacturing Simplifications for CFBR Core Sub-assemblies

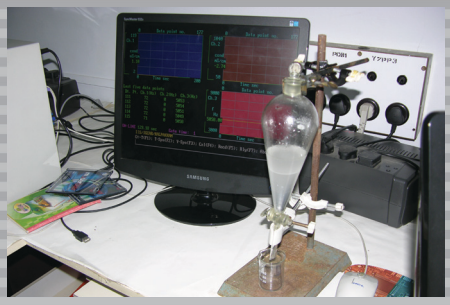
News & Events
- Annual Meet of Quality Circles – 2011
- Graduation Function of the fifth batch of Trainee Scientific Officers of Training School at IGCAR

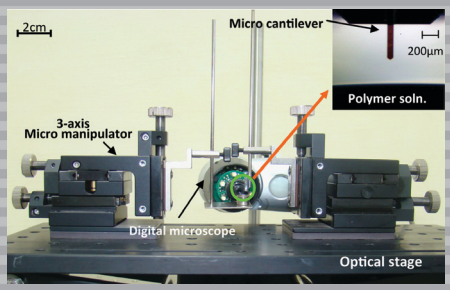
Visit of Dignitaries

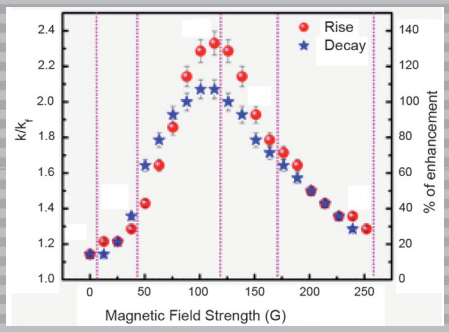
Forthcoming Meeting / Conference
- Structure and Thermodynamics of Emerging Materials (STEM-2011)
- 8th National Conference on Recent Advances in Information Technology (READIT)
- 19th National Symposium on Radiation Protection (NSRP-19)

Awards & Honours









INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH
http://www.igcar.gov.in/lis/nl90/igc90.pdf

From the Editor

Dear Reader

It is my privilege to present the latest IGC Newsletter (Volume 90, October 2011) for your kind perusal.

In the Director's Desk, Shri S. C. Chetal, Director, IGCAR has highlighted the complexities and challenges of Fast Reactor Fuel Reprocessing. Shri Chetal indicated the challenges ahead in this programme to be, commissioning of the Demonstration Fuel Reprocessing Plant and development of a road map for augmenting the pyrochemical reprocessing technology for metal alloy fuels.

Shri Suresh Kumar and his colleagues, share their excitement on locating a first ever failed fuel pin in Fast Breeder Test Reactor. They have estimated the activity ratio between krypton isotopes using failed pin localization system, contrast ratios from east and west delayed neutron detectors in addition to constant monitoring of signals from delayed neutron detection system and activity in cover gas to successfully identify the failed pin.

Dr. Baskaran and his colleagues have developed a standardization technique for the characterization of sodium aerosol from cover gas region of sodium cooled fast reactor. The sodium aerosols interfere with the heat and mass transfer mechanisms in the cover gas. The standardization technique involves a special procedure for the collection of sodium aerosol samples and its analysis subsequently. The team has been successful in accomplishing a suitable technique within 2% error limits.

In the young officer's forum, Dr. Prabakar has given an account of his contributions towards the development of microcantilever based mass sensors which can be operated in static and dynamic modes. These sensors can be tailored by working at higher modes to enhance their mass sensitivity to unprecedented dimensions.

Ms. Shima has described her studies on thermal conductivity and rheology changes in magnetic nanofluids under an external stimulus in the young researcher's forum. The wide application of these nanofluids is due to their properties being amenable easily by an external magnetic field. Also, the thermal and rheological properties of these fluids are perfectly reversible rendering them ideal candidates for application in miniature and smart devices.

This newsletter carries reports on the theme meeting on, "Manufacturing simplifications for commercial fast breeder reactor core sub-assemblies" and the Graduation function of the 5th batch of Trainee Scientific Officers from the Training School at IGCAR.

Shri T. K. A. Nair, Principal Secretary to the Prime Minister, Dr. R. Chidambaram, Principal Scientific Advisor to Government of India and a delegation from American Nuclear Society led by Dr. Eric Paul Loewen visited the Centre during the last quarter. A brief report of these visits are covered in this issue.

We are happy to share with you the awards, honors and distinctions earned by our colleagues.

This is the first issue of the IGC Newsletter after the new editorial committee has taken over and presented in a new format.
We look forward to your comments, continued guidance and support.

With my best wishes and personal regards

M. Saibaba

(M. Sai Baba)
Chairman, Editorial Committee, IGC Newsletter
&
Associate Director, Resources Management Group

From the Director's Desk

Fast Reactor Fuel Reprocessing at Indira Gandhi Centre for Atomic Research

Fast reactor fuel reprocessing is considered more complex than the thermal reactor spent fuel reprocessing, as plutonium rich materials have to be handled with high levels of radioactivity, even though both employ the same PUREX process. Thus the fast reactor fuel reprocessing programme has been identified as a vital area for development while formulating the various facets of R&D on fast reactor technology at Kalpakkam. When mixed carbide fuel of high plutonium concentration (70 mol %), was chosen as fuel for Fast Breeder Test Reactor, the complexity increased further. Criticality, problems of third phase formation and plutonium contamination during maintenance, were identified as main issues while planning the R&D programme.

Reprocessing Development Laboratory was designed in early seventies and the commissioning of inactive facilities was carried out in 1976. The plutonium handling facilities were cleared for operation in 1980. The reprocessing of irradiated thorium rods which was carried out during the period 1989 to 1992 in the concrete shielded cells, was the first major radioactive operation. The U^{233} recovered during the operation was used in fabricating the fuel for the KAlpakkam MINI reactor (KAMINI). U^{233} was also useful for the fuel development programme for carrying out the Prototype Fast Breeder Reactor test fuel irradiation experiments in Fast Breeder Test Reactor. Apart from this, the operation aided in validating the equipment and design of system as well as the manpower training.

Later a hot cell facility for reprocessing of Fast Breeder Test Reactor fuel was conceived which had the necessary features for delivering the product with all the uncertainties in the dissolution of irradiated fuel and process flowsheet. Added to this was the need for the deployment of the yet to be proven designs of centrifuge and centrifugal extractors without which the success of the PUREX process for fast reactor fuel reprocessing would be doubtful. With these minimal inputs, the hot cell facility, Lead Mini Cell (LMC) was created, which was later rechristened as CORAL (COmpact Reprocessing facility for Advanced fuels in Lead cells). Based on the dissolution experiments carried out on unirradiated single

pellets and systematic studies related to the third phase formation, the flow sheet, prepared earlier for the oxide fuel was modified.

It was decided to test all the process equipment developed for the fast reactor fuel reprocessing in this facility. Also, the cell design, which was conceptualized for future fast breeder reactor fuel reprocessing plants, was validated in CORAL facility. Thus, some of the key equipment such as single pin chopper, dissolver, centrifugal extractors, the process flowsheet and the design of the hot cell with the objective of remote operation and maintenance to avoid plutonium contamination, were evaluated.

Inactive commissioning trials with acid runs in CORAL were started in 2002. The regulatory clearances for handling plutonium with low burn-up fuel was obtained and the plant was hot commissioned in May 2003. The first batch of irradiated fuel pins with 25 GWd/t burn-up was taken for reprocessing in CORAL in December 2003.

With the successful reprocessing of mixed carbide fuel with burn-ups of 25, 50, 100 and 155 GWd/t in CORAL, the fast reactor fuel reprocessing technology has reached a satisfactory level of maturity. The fact that the recovered product has been refabricated into fuel and put in Fast Breeder Test Reactor, thereby closing the fast reactor fuel cycle, is a testimony to the dedication of the design, operation and maintenance teams of CORAL. The designer team continues to be involved in the review of CORAL operations ensuring and accumulating safe and successful experiences.

It is to be noted that the reprocessing of spent mixed oxide fuel from power producing large fast reactors, would pose relatively less challenges as compared to the reprocessing of plutonium rich mixed carbide fuel of Fast Breeder Test Reactor irradiated to a high burn-up of over 150 GWd/t. Thus, it can be said that, facing difficult challenging assignments has helped the Reprocessing Group to develop credence and confidence to take up larger challenges and responsibilities in the coming years.

The development activities on process, equipment and systems are being continued with objectives of obtaining the recovered product with better purity and reduction in contamination. As the success of deployment of PUREX process for fast reactor fuel reprocessing lies in minimizing the damage to the solvent, the thrust was on the development of short residence time contactors, such as centrifugal extractors and also in reducing the solvent loss by suitable treatment process. For example, a hydrazine carbonate based solvent wash process for treating the lean organic has been developed which has resulted in the reduction of the solvent waste volume from CORAL operations. Developing processes and equipment for the removal of secondary diluent degradation is being pursued for further reduction of waste volumes. The development and deployment of centrifugal extractors in CORAL, and the improvement in the design of motors for hot cell application in nitric acid environment for increased life, is a satisfying experience.

With the experience of design of centrifugal extractors for hot cells, the reprocessing group is internationally recognized as a leading group for the design of centrifugal extractors of different capacities. For example, a high throughput (25 m^3/hr) centrifugal extractor for uranium recovery from phosphoric acid has been designed for Heavy Water Board. The centrifugal extractor has been fabricated and ready for deployment in plant.

It is not sufficient to develop process and equipment for recovering the valuable materials from the spent fuels, but also necessary to monitor the plutonium content in the wastes. All these measures track the fissile material for taking appropriate mitigating actions. A spectrophotometry based analytical method for direct estimation of various plutonium species in highly radioactive solutions has been developed and deployed in CORAL successfully. This method, apart from being adaptable for online applications, has the advantage of not producing any secondary wastes. A neutron flux based waste drum monitor development in collaboration with ECIL, which could detect plutonium content in solid wastes to a level as low as 50 milligram per drum, in a radiation field upto even 10 mSv/hr is a unique system for solid wastes generated in the plant. A neutron interrogation system using linear accelerator is under development at our Centre for high gamma bearing wastes.

The next challenge is the commissioning of Demonstration Fuel Reprocessing Plant (DFRP), which would reprocess the fuel of Fast Breeder Test Reactor on a regular basis and that of Prototype Fast Breeder Reactor on an experimental basis. The process flowsheet for the plant is based on the operating experience of CORAL. In the Demonstration Fuel Reprocessing Plant, there is a head-end facility and process cell facility. The head-end facility is being constructed in which, irradiated fuel sub-assemblies of both the Fast Breeder Test Reactor and Prototype Fast Breeder Reactor will be dismantled and the pins will be transferred to process cell facility. In the process plant, they will be chopped and dissolved and subjected to product recovery by solvent extraction. While there are separate

equipment for head-end steps before solvent extraction for Fast Breeder Test Reactor and Prototype Fast Breeder Reactor spent fuel sub-assemblies, the solvent extraction, reconversion and waste evaporation process are the same. Erection of equipment and systems for the process cell facility for Fast Breeder Test Reactor fuel reprocessing is scheduled for completion in September 2012. In the initial phase, the Fast Breeder Test Reactor sub-assembly dismantling will be carried out in post-irradiation examination hot cells and the pins will be taken for the reprocessing. Subsequently the head-end facility which is presently under construction will receive the sub-assemblies.

The regular reprocessing of Prototype Fast Breeder Reactor fuel and blanket sub-assemblies will be carried out in the reprocessing plant of the integrated fast reactor fuel cycle facility. The design of this plant has already commenced. The operational experience of CORAL forms the basis for the design of process and equipment for the Prototype Fast Breeder Reactor reprocessing plant. Many improvements in the process flowsheet have been incorporated in this plant to reduce the waste volumes and radiation exposures. With the understanding of the operation of the key process equipment such as chopper, dissolver and centrifugal extractors, scaling up of these equipment has been successfully completed. The plant design is conceived with adequate redundancy and capacity factors for assured plant availability and throughput to ensure the success of closed fuel cycle operation of Prototype Fast Breeder Reactor. The closing of Prototype Fast Breeder Reactor fuel cycle will be an important milestone in the history of Indian commercial fast reactor fuel technology.

The fast reactors to be constructed in the country beyond 2020 will have metallic alloys as the fuel to exploit the higher breeding ratio that they offer. In contrast to the oxide fuels, which will be reprocessed by the aqueous route, metallic fuels are reprocessed by the pyrochemical route which reduces the number of process steps. In fact, the availability of robust pyrochemical reprocessing technology will be a crucial requirement for the introduction of metal fuelled reactors. The pyrochemical reprocessing route offers several advantages, particularly with respect to reprocessing of metallic fuels. The fuel produced through this route will be highly radioactive because the decontamination factors that can be achieved by this route are significantly less than those obtained by the aqueous processing route. It must be noted that the international experience on reprocessing of metallic fuels for fast reactors is rather limited. Thus the development of pyrochemical reprocessing route demands R&D on a variety of areas and in particular on materials and remote handling. R&D activities have been initiated at IGCAR in several groups to address various facets of the pyrochemical reprocessing technology. A combination of laboratory scale studies for understanding the chemistry of the reprocessing scheme and engineering scale studies for the development of equipment and handling techniques has been adopted. During the last year, the processing of uranium by the molten salt electrorefining route on one kilogram scale has been demonstrated. Presently, efforts are on to set up facilities for developing and demonstrating the process on ten kilogram scale. The irradiation of U-Zr alloy in Fast Breeder Test Reactor will provide us the irradiated metal alloy that would be used in studying the decontamination factors for various fission products. Further development of the process will be taken up with U-Pu-Zr fuel that will be irradiated in Fast Breeder Test Reactor in the coming year. These developmental efforts are expected to provide all the necessary inputs for the planning of a hot cell demonstration facility on an engineering scale during the XIII plan. A road map for R&D for pyrochemical reprocessing has been arrived at, taking into consideration the need for readiness of this technology by around 2020 to enable introduction of commercial fast reactors based on metallic fuels.

It is clear that fuel reprocessing is the most complex domain of fast reactor technology and success is possible only through the synergistic efforts of experts in diverse disciplines at IGCAR, aided by large collaborations with other units of DAE as well as academic and research institutes and industries. Across the globe, very few countries are engaged today in the reprocessing of fast reactor fuels. However, for our country, it is an important requirement for enabling a sustained growth of nuclear energy, and a great opportunity for emerging as a global leader in this area. I am confident that with the experience gained so far on the Fast Breeder Test Reactor fuel and the mission oriented approach that we have taken, we will be able to meet the challenge and emerge successful in this area.

S. C. Chetal
Director, IGCAR

Successful Localization of the Failed Fuel Pin of FBTR

Fast Breeder Test Reactor is a 40 MWt/13.6 MWe sodium cooled, loop type, mixed carbide-fuelled reactor. The reactor has been operating successfully for more than 25 years. The fissile zone of the current core in 17th irradiation campaign has 48 fuel sub-assemblies consisting of 27 MK-I (70% PuC+30% UC composition), 13 MK-II (55% PuC +45% UC) and 8 high plutonium containing mixed oxide (44% PuO_2) sub-assemblies. Each fuel sub-assembly has 61 fuel pins of diameter 5.1 mm. Around 1000 pins of MK-I composition were irradiated to 155 GWd/t burn-up and 61 pins to 165 GWd/t burn-up so far. The fuel clad which is made of stainless steel is the primary barrier and the reactor vessel acts as the secondary barrier in case of any clad breach. The reactor containment building acts as the final barrier against release of radioactivity to the atmosphere. There were no incidents of clad failure so far in the history of Fast Breeder Test Reactor. Clad failure is an anticipated occurrence in all nuclear reactors and many such occurrences were reported from all fast reactors in the world.

Recently, when the Fast Breeder Test Reactor was operating at 18 MWt, it underwent Scram on delayed neutron detector west signals. The counts in all three channels crossed the Scram threshold of double the background value. There was also increase in signals of delayed neutron detector in the east up to alarm threshold. The clad rupture detection circuit monitors in the cover gas (Rgz 371&372) also showed large increase in activity confirming clad breach.

An increase in the activity was also observed in the exhaust of reactor containment building and stack monitors. Air activity of the reactor containment building had gone up to 16,460 Bq/m^3 (background 268 Bq/m^3) by a factor ~61 due to increase of fission products. Increase in ^{88}Rb and traces of ^{138}Cs were also found. Reactor containment building did not get isolated on high activity (threshold of 50 mR/h) as the general background in reactor containment building increased to only about 0.5 mR/h. The activity release through stack was well within the limits. Core temperature data before and after the Scram was reviewed and there was no increase in the outlet temperatures of any fuel sub-assembly.

Mechanisms to detect failure of clad: In order to detect failure of clad, six delayed neutron detectors are provided in primary sodium circuit, three in the east loop and other three in the west loop. Sodium is sampled before inlet of intermediate heat exchangers and presence of delayed neutrons are detected by boron counters of 8 cps/nv sensitivity. Reactor is tripped by Scram on two out of three voting logic in case of increase in delayed neutron signal to the Scram threshold. In addition, there are two gas activity monitors provided; one in the clad rupture detection circuit of the cover gas and the other in the combined discharge of clad rupture detection and primary cover gas reject circuit. The sampled gas is also sent to an experimental failed fuel localization circuit where the age of failed sub-assembly is estimated from activity ratios of the fission gases, e.g. ^{85}Kr/^{87}Kr, ^{85}Kr/^{88}Kr.

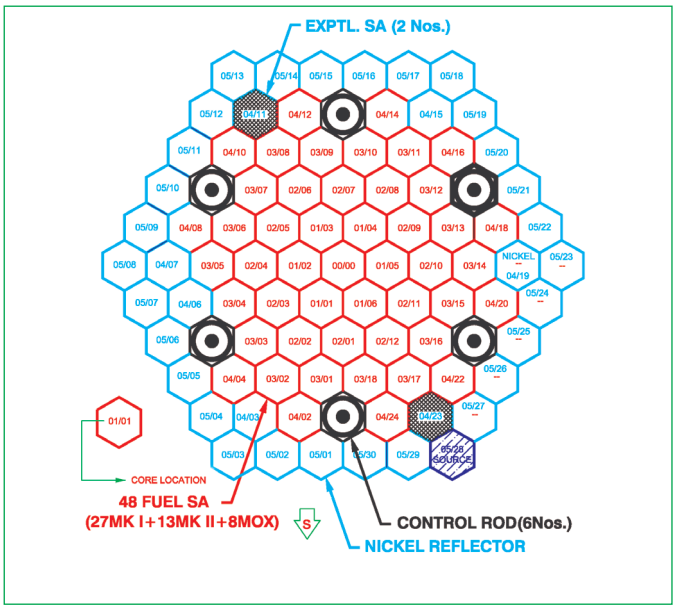


Figure 1: Schematic view of fuel sub-assemblies in FBTR

Contrast Ratio and ^{85}Kr/^{87}Kr Activity Ratio after the Scram and Assessment of the Failed Fuel Sub-assembly

The contrast ratio (West delayed neutron detector signal / East delayed neutron detector signal) during the reactor scram was observed to be more than 4.5 and the probable position of failed fuel sub-assembly was inferred to be in the west side in the third or second ring. After counting the xenon and krypton content in the cover gas sample taken from the failed fuel localization system, ^{85}Kr/^{87}Kr activity ratio was calculated. The predicted burn-up/age of the failed fuel based on this activity ratio was more than 100 GWd/t. The age of the failed fuel element was also computed from the activity ratio of the caesium isotopes present in the primary sodium sample. The activity ratio, ^{137}Cs/^{136}Cs indicated a burn-up of about 120 GWd/t.

Hence, from the observed contrast ratio of signals from delayed neutron detectors and activity ratio of ^{85}Kr/^{87}Kr at the time of reactor scram it was inferred that any one of the highly burnt sub-assemblies located in the west side of third ring could have failed. Fuel sub-assemblies in third ring locations (03/01) (03/03) (03/06) (03/08) (Figure 1) are highly burnt. Sub-assembly in 03/01 is located in north – south axis of third ring for which the expected contrast ratio is similar to the central sub-assembly (around one) and hence it is less suspicious than the remaining high burnt sub-assemblies. So it was inferred that one of the sub-assemblies in position 03/03, 03/06 or 03/08 was suspected to be failed one.

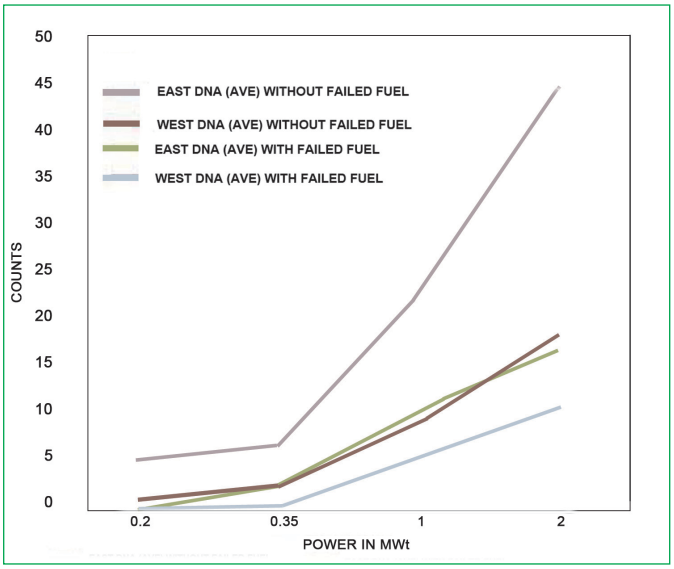


Figure 2: DND - With and Without failed fuel

Locating the Failed Fuel Sub-Assembly

As a first step, in order to check the evolution of delayed neutron detector's counts and to exactly estimate the contrast ratio, the reactor was restarted in the existing core configuration at a sodium temperature of 523 K after confirming that the iodine activity in sodium is less than 0.2 μCi/gm. The reactor power was raised in steps by closely monitoring the count rates in delayed neutron detectors and clad rupture detection in argon monitor signals. The maximum power was limited to 2.25 MWt which is 10% of target power. Scram on delayed neutron detector counts was inhibited during the experiment.

During the reactor operation with failed fuel sub-assembly in the core, the counts in east delayed neutron detectors and west delayed neutron detectors per MWt had gone up to 8.4 and 20.5 cycles per second, respectively (Figure 2). The background counts per MWt reactor power prior to fuel failure, in the east delayed neutron detector and west delayed neutron detectors was 5.8 and 9.5 cycles per second, respectively. After measuring the counts in delayed neutron detector count accurately, the contrast ratio was calculated exactly and was observed to be 4.3. This value pointed suspicion more on pin at 03/06 location as the earlier experiments with delayed neutron detector at locations along east-west central line had shown high contrast ratios. The location 03/06, though not on the east-west line, is next to the locations 03/05 and 02/04 locations on the central east-west line. No increase in fission product activity in cover gas was observed during the reactor operation at 2 MWt. This could be due to the fact that all the fission gases accumulated in the fuel pin would have got released after the clad rupture incident and the duration of the reactor operation at 2 MWt for the experiment was very low.

In order to cross check the region of failed fuel sub-assembly, neutron flux tilting experiment was carried out with reactor operating at 2 MWt. For this, control rods B and C (near to the suspected sub-assemblies) were operated between 25 and 405 mm from the bank critical height maintaining the reactor power constant by adjusting the other control rods. The increased total counts observed with control rod C at the top indicated the failed fuel sub-assembly as the one in core position 03/06. There was no change in the counts when control rod B or D was at the top position which ruled out the possibility of sub-assemblies in positions 03/03 and 03/08 as the failed ones.

Fuel handling operations were carried out to change the core configuration and to confirm the failed fuel sub-assembly as indicated below:

- MK I sub-assembly from 03/06 was transferred to storage location as this was the main suspect
- Fuel sub-assemblies between core positions 03/03 and 03/16 were swapped
- The location 03/06 was filled by shifting a fuel sub-assembly from fourth ring which in turn was filled by a reflector sub-assembly

With suspected sub-assembly in the storage location reactor was started and opertated at 2 MWt. No increase in delayed neutron detector signal was noticed. For further confirmation, reactor power was raised up to 10 MWt and operated for two hours. Before raising the reactor power, the thresholds for delayed neutron detectors scram was set corresponding to 10 MWt and inhibition on delayed neutron detectors scram was lifted. There was no increase in counts in delayed neutron detector and fission product activity in cover gas above the normal background values. With a single fuel handling operation the failed fuel sub-assembly in core location 03/06 has been successfully indentified. Two reactor start ups and one fuel handling operation in between the two start ups were only required to identify the failed sub-assembly.

The failed sub-assembly in the core was identified to be a highly burnt sub-assembly having 148 GWd/t burn-up. The techniques, estimation of contrast ratio between west and east delayed neutron detectors signals, estimation of $^{85}Kr/^{87}Kr$ ratio using the failed fuel localization system and reactor neutron flux tilting experiment were used in addition to constant monitoring of delayed neutron detector's signals and cover gas activity to identify the failed fuel.

The first fuel clad failure incident in Fast Breeder Test Reactor was handled very well. The total stack activity release was much less than the permitted value (13 Ci as against the permitted daily dischage limit of 250 Ci for noble gases during normal operation) and there was only a marginal increase in general background in reactor containment building (0.15 mR/h to 0.5 mR/h) during the incident. The failed sub-assembly was identified and reactor operation could be resumed in very short time. Later on the sub-assembly was discharged and stored in a sealed container in the storage location ouside the reactor.

Reported by K.V. Suresh Kumar and colleagues
Reactor Operations & Maintenance Group

Standardization of Technique for Characterization of Sodium Aerosol (Metal Vapor) from Cover Gas region of Sodium Cooled Fast Reactor

The sodium vapor in the cover gas space condense to form aerosols and the concentrated aerosols will participate in the radiative exchange within the cover gas space and modify the total heat transfer to the cooled roof structure by radiation absorption and scattering mechanisms. Further, the mass transfer occurs due to condensation of sodium vapor on the cooler surface like roof plug, side wall and gets deposited in the annular gaps of the roof plug. Thus, in order to predict the interaction of thermal radiation with aerosols and mass transfer due to condensation of aerosols, it is necessary to know the aerosol concentration and droplet size distribution. It is also to be considered that sodium aerosol properties would get modified due to (i) temperature difference between the sodium pool surface and the bottom of the roof top plug and (ii) possible enhanced coagulation of sodium aerosols upon interaction with gamma radiation, resulting in increase in sizes. Hence, it is proposed to carry out the experiments to characterize the size distribution of sodium aerosols in the cover gas region by adopting suitable procedures. The initial experiments are planned to be conducted in SILVERINA sodium loop facility in Fast Reactor Technology Group and followed by Fast Breeder Test Reactor under two conditions i.e. (i) when reactor is shut down and (ii) when reactor is operating. Before getting into the design of sampling system, a suitable technique for the characterization of sodium vapour aerosols has been adopted and qualified in aerosol test facility. The challenge that lies here is to aspire the sodium vapour aerosol into the collector (without exposing them to the environment) and analyze them using off-line technique. The details of the experiments conducted in aerosol test facility is described in this article.

The experimental procedure consists of two parts viz. (i) sodium aerosol sampling and (ii) sodium aerosol analysis.

Sodium Aerosol Sampling

Sodium aerosols are generated in sodium combustion cell of aerosol test facility. About five gram of sodium is heated in the cell under argon atmosphere upto 823 K. As the sodium becomes molten, the sodium vapour and the argon gas are drawn through a heated line (383 K) into two gas washing bottles each filled with 200 ml of liquid paraffin kept at room temperature. As the argon gas is made to bubble through the paraffin, the condensation of sodium vapor and solidification of aerosol particle would occur. The cover gas/argon coming out of the first bottle is made to pass through second bottle so as to remove aerosols escaped, if any, from the first bottle. A schematic diagram of the sampling system and the photograph of the gas washing bottles trapped with sodium aerosols are shown in Figure 1.

In order to achieve the complete collection of sodium aerosols, a special bottle arrangement was designed for the experiment carried out at SILVERINA loop and Fast Breeder Test Reactor. The bottle consists of a series of baffles to increase the residence time of the cover gas coming out of the bottle by forming bubbles. The baffle plates are made of stainless steel drilled with holes on one half and are fitted inside the bottle such that the holes are off-center to one another. Figure 2 shows the bottle arrangement used for sampling in SILVERINA loop and Fast Breeder Test Reactor.

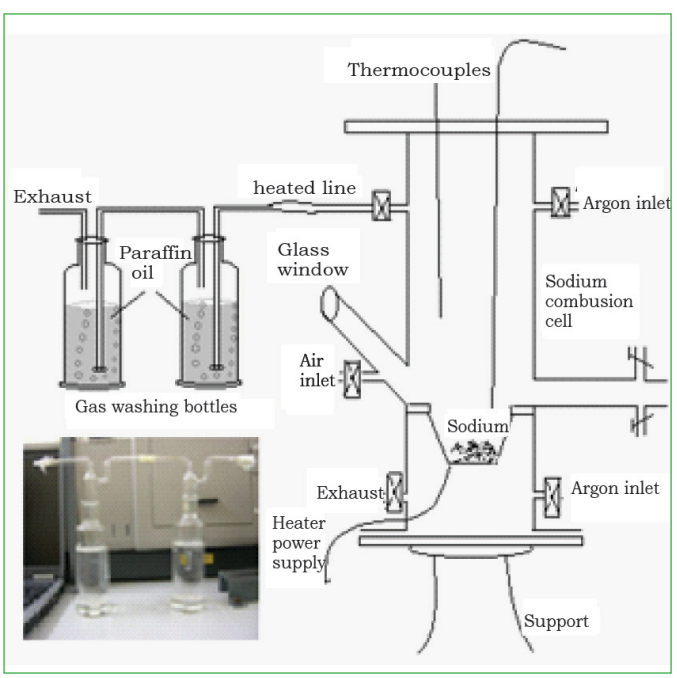


Figure 1: Sodium vapor aerosol sampling in aerosol test facility

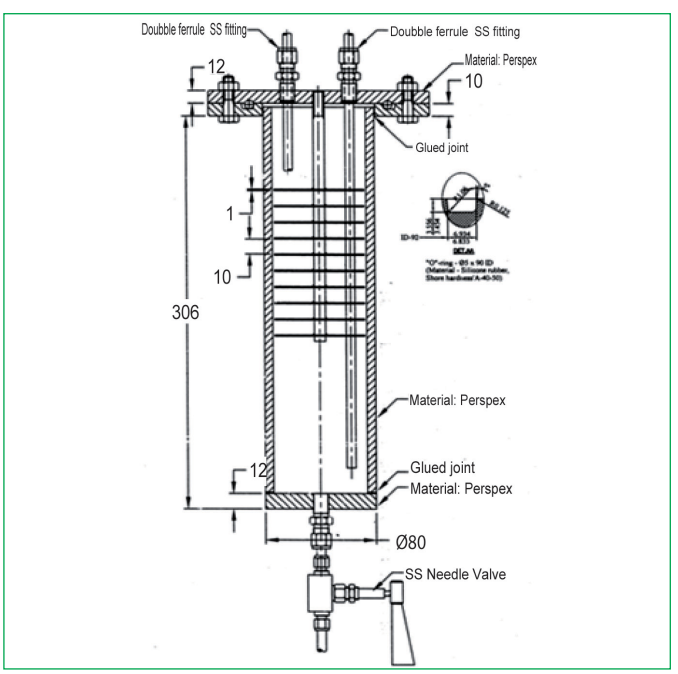


Figure 2: Sodium vapor collection bottle

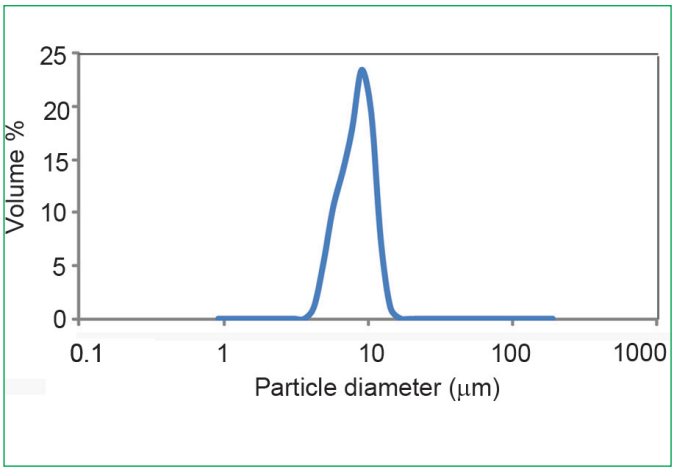


Figure 3: Volume-size distribution of sodium aerosol, Density = 0.970 g/cm^3, D (v. 0.5) =7.80 μm

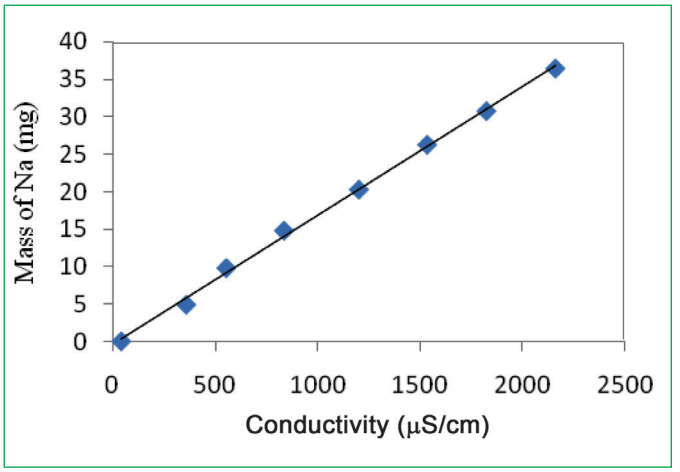


Figure 5: Calibration graph of Sodium mass vs Specific conductivity, y = 0.0173 x -0.4328, R^2 = 0.9981

Sodium Aerosol Analysis

Aerosol size distribution is measured by using the Mastersizer instrument which uses the principle of ensemble diffraction technique. The instrument is provided with a liquid flow cell and a powder spray unit and these units are useful for the measurement of particle size distribution in liquid and air medium respectively. The sampling liquid (dispersant) with suspended aerosols is made to circulate across the laser beam by using a liquid flow cell. The Mastersizer measures the volume-size distribution of particles in the volume of laden liquid medium from 0.05 – 900 μm. Sodium aerosol trapped in the liquid paraffin is made to circulate in the liquid flow cell, the volume-size distribution and mass median diameter of the sodium aerosols are determined. Figure 3 shows the volume-size distribution of trapped sodium aerosols and its mass median diameter. The sodium aerosols are distributed within the range of 5-15 μm with mass median diameter at 7.8 μm.

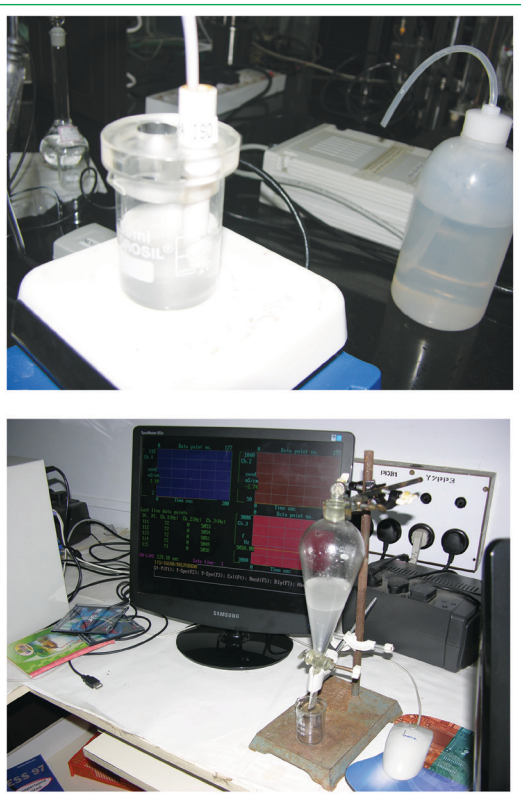


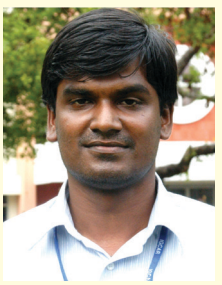
Figure 4: Photograph of the conductometric titration measurement

The mass concentration of sodium aerosol in the sample of liquid paraffin oil is determined by using conductrometric titration method. About 100 ml of paraffin from bottle is mixed with water in 1:1 ratio in a separating funnel and the sample is vigorously mixed for several hours on an orbital shaker to separate the sodium into aqueous phase. Figure 4 shows the photograph of the conductometric titration measurement used in this study. The mass concentration of sodium vapour aerosol is estimated by determining (i) the quantity of sodium trapped in the liquid medium by measuring NaOH concentration, (ii) taking the quantity of total paraffin oil used and (iii) volume of the sample drawn through the sampling system. The method of estimating sodium concentration is simplified by using an alternate procedure and drawing a calibration graph between sodium mass versus conductivity. For this, a known quantity of sodium in steps of 5 mg is added into 100 ml of water. The change in conductivity is measured using Metrohm conductometer. Variation of conductivity as a function of sodium mass is shown in Figure 5. Using this calibration graph and measuring the conductivity of the actual sample after mixing with water medium, the quantity of sodium was estimated. By adopting suitable corrections for the quantity of liquid and volume of the sample, actual mass concentration of sodium vapour aerosol was estimated. The measured value is cross-checked with conductometric titration method. Typical experimental value is determined as 2.0 mg/m^3, which is within 2% error with respect to conductometric titration value.

Reported by R. Baskaran and colleagues,
Radiological Safety Division,
Reactor Engineering Group

Young Officer's FORUM

Microcantilever based Mass Sensors



Dr. K. Prabakar did his Ph.D. in Physics from Osmania University, Hyderabad in 2007 and joined IGCAR as K S Krishnan Research Associate in the same year. He is currently Scientific Officer (D) at Surface and Nanoscience Division, Materials Science Group and working in the field of Micro Electro Mechanical Systems and microcantilever based sensors.

Microcantilever sensors are the simplest micromechanical systems and can be visualized as miniature diving boards anchored at one end with a typical dimension of 100 μm length, 20 μm width and 1 μm thick. In recent years, these sensors have attracted much attention due to their potential as a platform for the development of numerous physical, chemical, and biological sensors. The greatest advantage of these sensors is that they can be mass-produced using conventional micromachining techniques and offer improved dynamic response, high precision and increased reliability compared to conventional sensors. These sensors can be operated either in static mode (surface stress change resulting in bending) or in dynamic mode (mass change resulting in shift in resonace frequency) as indicated in Figure 1.

In dynamic mode, these sensors can be used as extremely sensitive mass sensors. The resonant frequency (f) of a cantilever is given by $f = (1/2\pi)\sqrt{k/m*}$, where k is spring constant and $m*$ is effective mass of the cantilever. When absorbents are uniformly deposited on the cantilever surface, the resultant shift in mass Δm can be calculated using shift in resonance frequency (Δf), $\Delta m = -(2m^*/f)\Delta f$. For example, when we use a cantilever with an added mass of 45 ng and a resonant frequency of 280 kHz, we obtain a mass sensitivity of 3 Hz/pg. This value is 100 times greater than the sensitivity obtained with the quartz

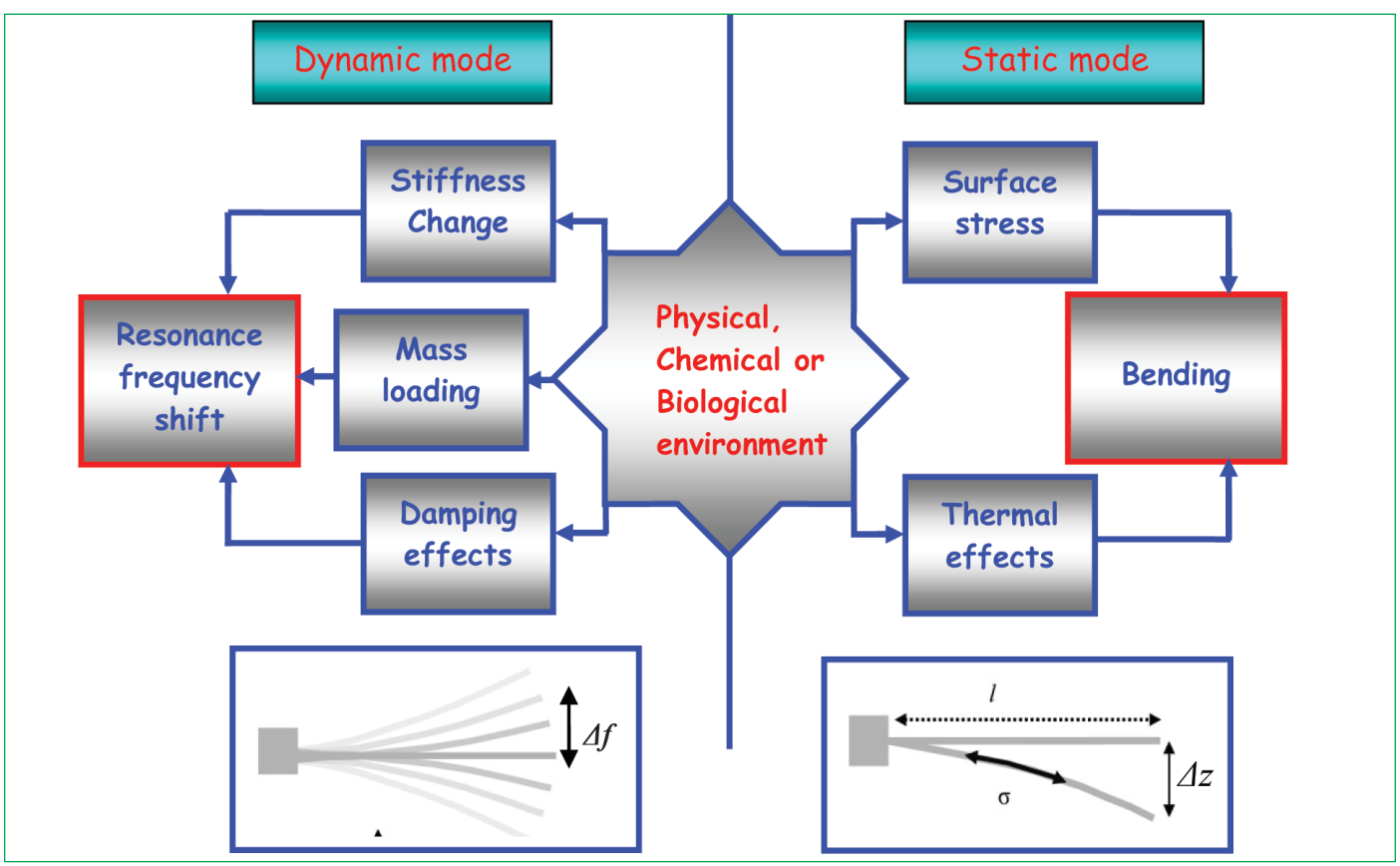


Figure 1: Modes of operation of microcantilever based sensors. In the dynamic mode resonance frequency shift (Δf) due to the addition of mass or environmental damping is measured. In static mode, cantilever bending (Δz) due to differential surface stress is measured. Optical, piezoresistive, capacitance, or electron tunneling methods, are some of the known methods for detecting the cantilever vibrations or bending

crystal microbalance method. To achieve high sensitivity in mass detection, it is necessary to use a cantilever with a small mass and a high resonant frequency. Recently systems capable of detecting masses in the zeptogram value ranges have been reported and the ultimate goal of single molecule detection seems to be within reach with nano cantilever based sensors.

At Materials Science Group, these sensors are studied for enhancing the sensitivity. Natural frequency and mass sensitivity of three different cantilevers with dimensions 125x35x4.5 μm^3 (MC1), 225x30x3 μm^3 (MC2) and 450x40x2.5 μm^3 (MC3) are studied. Natural frequency of microcantilever is detected using optical readout method using an atomic force microscopy head. The microcantilever is mounted on the piezo actuator which excites the cantilever into vibration. A laser beam of wavelength 659 nm is focused on the free end of the microcantilever. The reflected beam is received on a four quadrant photodiode which is lock-in detected using controller electronics and is calibrated to the cantilever vibration. The four quadrant photo diode can detect both vertical deflection and lateral deflection of microcantilever.

Polymer mass was added on microcantilever using indigenously rigged up dip coating setup (see Figure 2). It was performed under a probe station using micro-manipulators and by carefully observing with a digital microscope. Both microcantilever and polymer solution (polyacrylamide) in a container were mounted on two different manipulators to allow the precise movement of the both. Cantilever was slowly dipped inside the polymer solution, kept for few minutes, removed slowly and was allowed to dry over night in a desiccator. The frequency measurements were repeated after dip coating. The mass added on microcantilever was determined by the shift in the fundamental mode resonance frequency. Figure 3 shows such a shift in natural frequency (388 Hz) due to added mass of 230 pg on MC1 in fundamental vertical bending mode. This figure also shows the shift in corresponding phase angle.

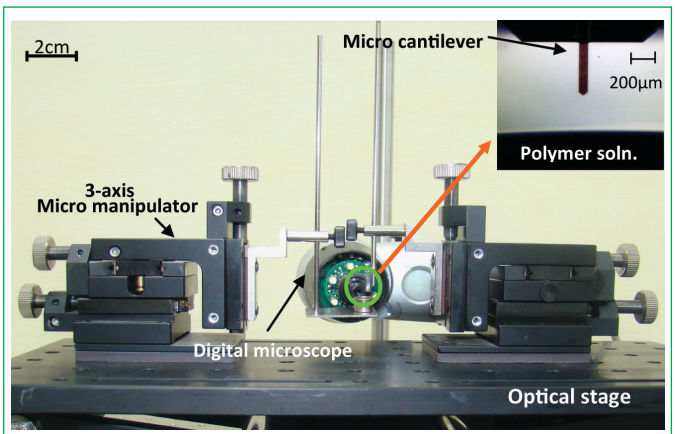


Figure 2: Indigenously rigged up dipcoating set up for microcantilevers. Microcantilever and polymer solution are mounted on two micro manipulators, and by carefully observing through the digital microscope, cantilever was dipped into the solution (see inset), kept for few seconds and removed

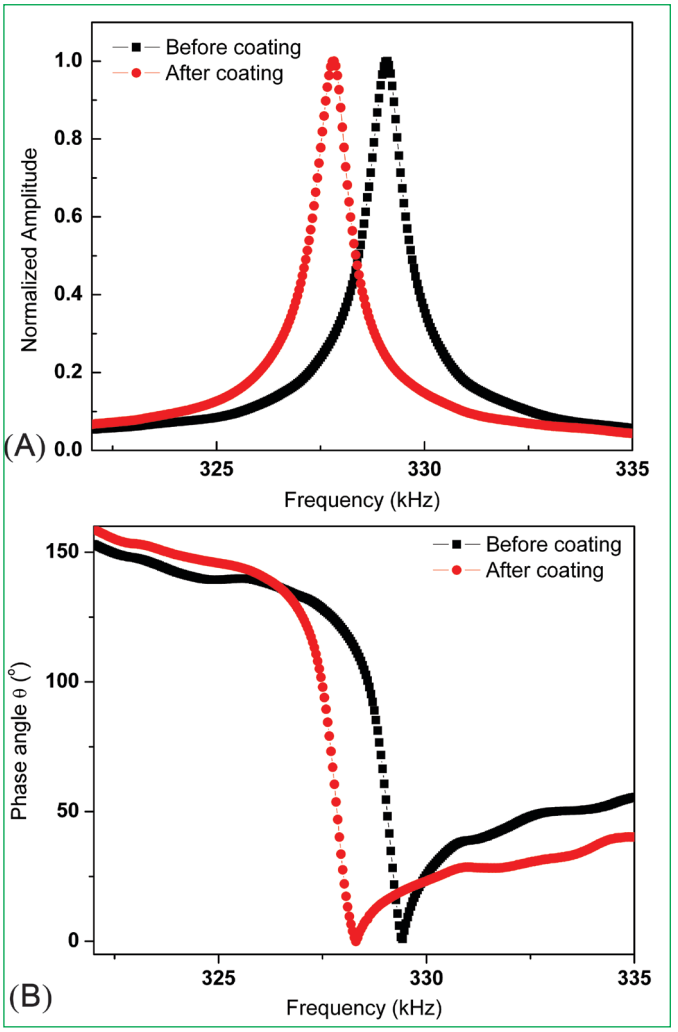


Figure 3: (A) Shift in natural frequency and (B) phase angle of the microcantilever due to an added mass (polymer coating) of 230 pg. Coating was done using the setup shown in Figure 2. The estimated mass sensitivity in this case is 5.4 Hz /pg which is not possible with conventional mass sensors

From this shift the mass sensitivity of the cantilever sensor is estimated as 5.4 Hz/pg. Similarly mass sensitivities were estimated for MC2 and MC3 and are found to be 0.84 and 0.06 Hz/pg, respectively. It is clear that mass sensitivity can be enhanced by reducing the dimensions of the microcantilever. Besides reducing the dimensions of the microcantilever, higher resonant modes of the cantilever can also be used to increase the mass sensitivity. It was found that instead of working at fundamental mode, if we work at higher modes, mass sensitivity can be enhanced several orders.

In conclusion, it is pointed out that cantilever based mass sensors show unprecedented mass sensitivity and by tailoring these cantilevers or by working at higher modes, one can enhance the sensitivity.

Reported by K. Prabakar,
Surface and Nanoscience Division,
Materials Science Group

Young Researcher's FORUM

Ms. Shima did her Masters in Applied Chemistry from Calicut University, Kerala. She is the second rank holder for B.Sc. and M.Sc. in the University. She joined as a research fellow in March 2007 under the guidance of Dr. John Philip, Head, SMARTS, NDED, MMG and has submitted her thesis in August 2011 at HBNI. The title of her thesis is "Synthesis, Characterization, Thermal and Rheological Studies in Nanofluid". She has published nine papers in reputed international journals and her work is highlighted in Nature Nanotechnology, Nanotechweb, Nature India etc. She has attended five international conferences and won the best oral presentation award at international conference on Nanomaterials. She is proceeding to the prestigious ESPCI, Paris for post doctoral research.

Thermal Conductivity and Rheology Studies in Magnetic Nanofluids under an External Stimulus

With depleting hydrocarbon reserves, the demand for reducing power consumption and development of superior coolants with improved performance is increasing. In this context, nanofluids have been considered as a potential candidate for cooling applications. Realizing the modest thermal conductivity enhancement in conventional nanofluids, there is a demand to develop nanofluids with significantly large thermal conductivity, especially for miniature devices such as micro and nano electro mechanical systems (MEMS and NEMS). Magnetic nanofluid is a unique material that exhibits both the liquid and magnetic properties. Since the properties and the location of these fluids are easily influenced by an external magnetic field, they have been employed in many scientific, industrial, and commercial applications. In an effort to develop magnetic nanofluid as a multifunctional smart material, we study both the thermal and rheological properties of magnetic nanofluids under different magnetic field strength and orientation with respect to the direction of heat flow. We have demonstrated a thermal conductivity enhancement up to 300% in magnetic fluids under external field. We have synthesized oleic acid capped magnetite (Fe_3O_4) nanoparticles of size < 10 nm and carried out systematic measurements of thermal conductivity in two different hydrocarbon based Fe_3O_4 nanofluids under varying magnetic field strengths and orientations. In addition, we also follow the microstructure of the nanofluids and the switching behavior under a magnetic field.

The magnetite nanoparticles with size < 10 nm were synthesized by chemical co-precipitation technique. The X-ray diffraction pattern confirms that the samples are magnetite with inverse spinel structure and the average particle size calculated using the Debye–Scherrer formula is found to be 9.5 nm. The particle size obtained from dynamic light scattering fairly matches with X-ray diffraction size indicating the absence of aggregation in the dispersed system. The thermo gravimetric studies confirm the presence of a monolayer of surfactant on nanoparticles. This surfactant layer ensures steric stabilization and thus prevents the nanoparticles from aggregation. The Fourier Transform Infra Red Spectroscopy studies reveal that oleic acid is chemisorbed as a carboxylate group onto the Fe_3O_4 nanoparticles and the two oxygen atoms in the carboxylate are coordinated symmetrically to the Fe_3O_4 atoms. Stable magnetic nanofluids are prepared by dispersing the oleic acid coated Fe_3O_4 nanoparticles in kerosene and hexadecane. The dispersions showed excellent long term stability, as nanoparticles are not influenced by the gravitational force owing to their small size. Further, the steric stabilization prevents aggregation of the particles. The magnetization studies show that the particles are superparamagnetic in nature with zero remanence and coercivity with a saturation magnetization of 56 emu/g after correcting the surfactant contribution.

Figure 1(A) shows the percentage of enhancement in thermal conductivity as a function of volume fraction (f) at different magnetic field strengths for kerosene based Fe_3O_4 nanofluids together with Maxwell upper, lower, series and parallel bound fits. In the absence of magnetic field, the nanofluids exhibit moderate thermal conductivity enhancements within the predictions of Maxwell's effective medium theory. The large enhancement in thermal conductivity in presence of magnetic field parallel to temperature gradient is explained as follows: Ferrofluids consist of a colloidal suspension of single domain superparamagnetic nanoparticles with a magnetic moment 'm'. Without any external magnetic field, the magnetic moments of the scatterers orient in random direction. In the presence of an appropriate magnetic field H, the nanoparticles align in the direction of magnetic field when the magnetic dipolar interaction energy $U_d(ij)$ dominates over the thermal energy k_BT, where, k_B is the Boltzmann constant and T is the temperature. The effective attraction between two ferromagnetic particles is described by a coupling constant $L=U_d(ij)/k_BT$,which involves two competing factors: magnetic dipolar interaction $U_d(ij)$ energy and thermal energy k_BT. Dipolar structure formation is

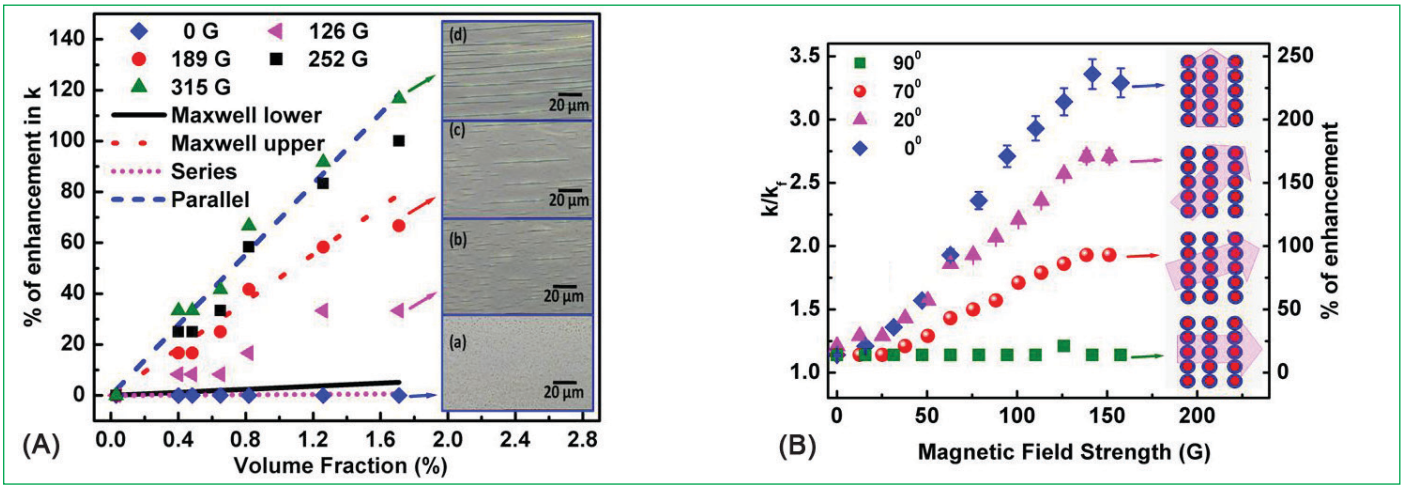


Figure 1: (A) The variation of k/k_f with volume fraction at different magnetic field strengths for kerosene based Fe_3O_4 nanofluids together with Maxwell and Hashin & Shtrikman upper and lower bounds. Inset shows phase contrast optical microscopic images for (a) Zero external magnetic field, (b)-(d) with increasing magnetic field strengths. (B): the thermal conductivity ratio (k/k_f) and the percentage of enhancement of k as a function of external magnetic field strength for hexadecane based Fe_3O_4 nanofluids. Inset shows the schematics of the direction of heat and the possible nanoparticle structures under different field directions

expected when the dipolar potential exceeds thermal fluctuations; that is, for a dipolar coupling constant $L > 1$. The extent of chain formation in presence of an external magnetic field increases with increase in f since the number of particles per unit volume increases with increase in f. Thus for a given magnetic field strength, the enhancement in k will be higher for the nanofluid with maximum particle loading. Further, the saturation magnetization of Fe_3O_4 nanoparticle dispersions also increases with increase in nanoparticle concentration.

Mean field models predict series and parallel modes of thermal conduction through nanofluids. In the lower Hashin and Shtrikman bounds limit, nanoparticles are well suspended and conduction is essentially through series modes whereas in the upper Hashin and Shtrikman bounds limit, the conduction path is through dispersed particles. In the absence of magnetic field, the particles are well dispersed, the nanofluids exhibit series mode conduction and the observed variation of k/k_f with f is well within the lower Maxwell limit. The parallel mode has the geometric configuration that allows the most efficient means of heat propagation. Therefore, extremely large thermal conductivity enhancement is possible with parallel modes. In the limit $(fk_p/k_f) >> 1$, the predicted values of k/k_f for the upper Hashin and Shtrikman bounds and parallel modes are $(2f/3)k_p/k_f$ and fk_p/k_f respectively. Here k_f and k_p are the thermal conductivity of base fluid and particles respectively. It can be seen that the experimental data points, at the highest magnetic field, falls within the parallel mode of conduction, which is striking manifestation of Hashin and Shtrikman bounds model prediction. As the magnetic field strength is increased progressively, continuous conduction paths emerge along the nanoparticle chains that result from series to parallel mode of conduction. At a magnetic field strength of 315 G, the k/k_f data fits fairly well with the parallel mode conduction. The phase contrast optical microscopy image (Figure 1(A) inset)of kerosene based ferrofluid in the absence of external magnetic field reveals no nanoparticle chains. The progressive increase in the aspect ratio of the chains with increase in field strength is evident in the images.

To obtain better insight into the effect of magnetic field orientation (i.e. the orientation of nanochains with respect to the heat flow direction) on thermal conductivity enhancement, we carried out thermal conductivity measurements under different magnetic field orientations with respect to the thermal gradient. Figure 1(B) shows the variation of k/k_f with magnetic field strength for hexadecane based Fe_3O_4 nanofluids with $\phi=0.0608$ under different field orientations of 0, 20, 70 and 90°. The maximum enhancement in thermal conductivity is observed when the field direction was exactly parallel to the thermal gradient whereas practically no enhancement is observed when field was perpendicular to thermal gradient. A gradual reduction in the thermal conductivity enhancement is observed as the field direction is shifted from parallel to perpendicular direction with respect to thermal gradient.

Figure 2 (A) shows the variation of k/k_f as a function of applied magnetic field strengths (during rise and decay) for kerosene based Fe_3O_4 nanofluids with $\phi=0.05$ The highest value of k/k_f is 2.3 for a magnetic field strength of 113 G, above which the k/k_f decreases. After the formation of linear chains, they come together to form denser chains due to interaction between fluctuations in the adjacent columns. The decrease in thermal conductivity observed above a critical magnetic field strength is expected to be due to 'zippering' (lateral coalescence) of chains. While lowering the magnetic field, the thermal conductivity value shows a small hysteresis but comes back to the original value when the magnetic field is turned off. To confirm the lateral overlap (zippering) of chains, phase contrast microscopic studies under external

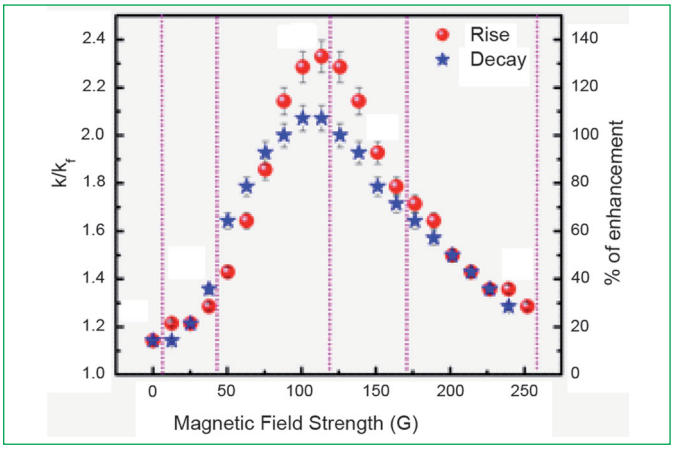


Figure 2: (A) The variation of k/k_f as a function of applied magnetic field strengths (during rise and decay) for kerosene based Fe_3O_4 nanofluids with ϕ=0.05

magnetic field is carried out at sufficiently high magnetic field strengths. The micrograph of kerosene based magnetite nanofluids with ϕ=0.05; (i) in the absence of external magnetic field, reveals no visible aggregates [(Figure 2(B,a)]; (ii) at low magnetic field strength there is a formation of small dipolar chains [Figure 2(B,b)]; (iii) with increasing magnetic field strength, the chain length increases [Figure 2 (B,c)], resulting in an evenly spaced single nanoparticle chains throughout the nanofluid volume; (iv) at very high magnetic field strength zippering of the dipolar chains is observed [Figure 2(B) (d-e)] and (v) after switching off the magnetic field no permanent aggregates are visible [Figure 2 (B,f)]. This confirms the perfect reversibility of the dipolar chains formed in the fluid.

To obtain insight into the rheology of these nanofluids under magnetic field, magneto-rheological studies are carried out. The variation of viscosity (η) as a function of magnetic field strength for kerosene based Fe_3O_4 nanofluid with ϕ=0.026 during the rise and decay of field at a constant shear rate of 50 s^{-1} is shown in Figure 3(A). According to the chain formation model, the magnetoviscous effect is described as a result of the formation of chain-like structures due to strong interparticle interaction under the influence of a magnetic field. As the magnetic field intensity increases, the interaction among nanoparticles and the flow resistance increases leading to an increase in the viscosity. The lower viscosity values observed during the decay of magnetic field strength compared to the rise is attributed to the fact that the structures formed during the rise of magnetic field takes longer time than the measurement time for the relaxation. The typical measurement time between each data point is ten seconds. However, after removal of the magnetic field, viscosity values restore its original value, indicating the absence of any permanent aggregation under external magnetic field.

Application of magnetic field not only enhances the thermal conductivity of the fluid but also the rheological properties of the fluid. Such field induced enhancements in thermal conductivity and viscosity of ferrofluids can be exploited for a number of technological applications such as damping cum cooling. Figure 3(B) (a) and (b) shows the viscous and thermal conductivity change of hexadecane based Fe_3O_4 nanofluid with ϕ=0.067, where magnetic field strength is varied in steps. Both the k/k_f and η/η_0 measurements are carried out under on–off conditions at a magnetic field strength of 120 G (ON) and zero (OFF) respectively. The shear rate for viscosity measurement is 50 s^{-1}. The steady viscosity with time for a given magnetic field indicates that the magnetic structures are not broken by shear under flow. This offers interesting possibilities of

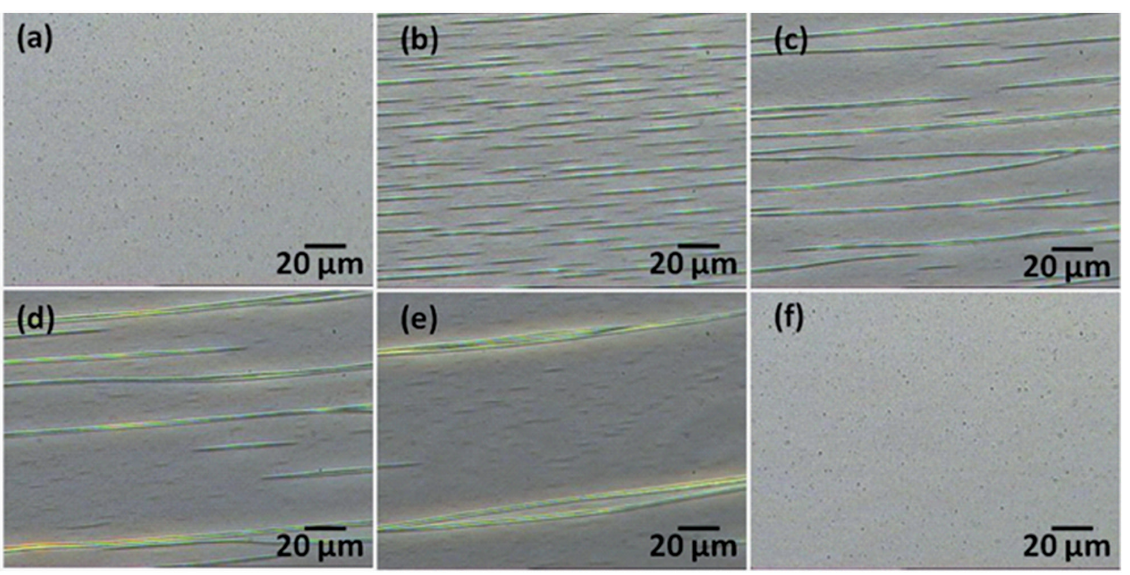


Figure 2: (B) The phase contrast microscopy images of kerosene based Fe_3O_4 nanofluids with ϕ=0.05: (a) In the absence of external magnetic field, (b)-(e) in presence of increasing magnetic field and (f) after removal of magnetic field

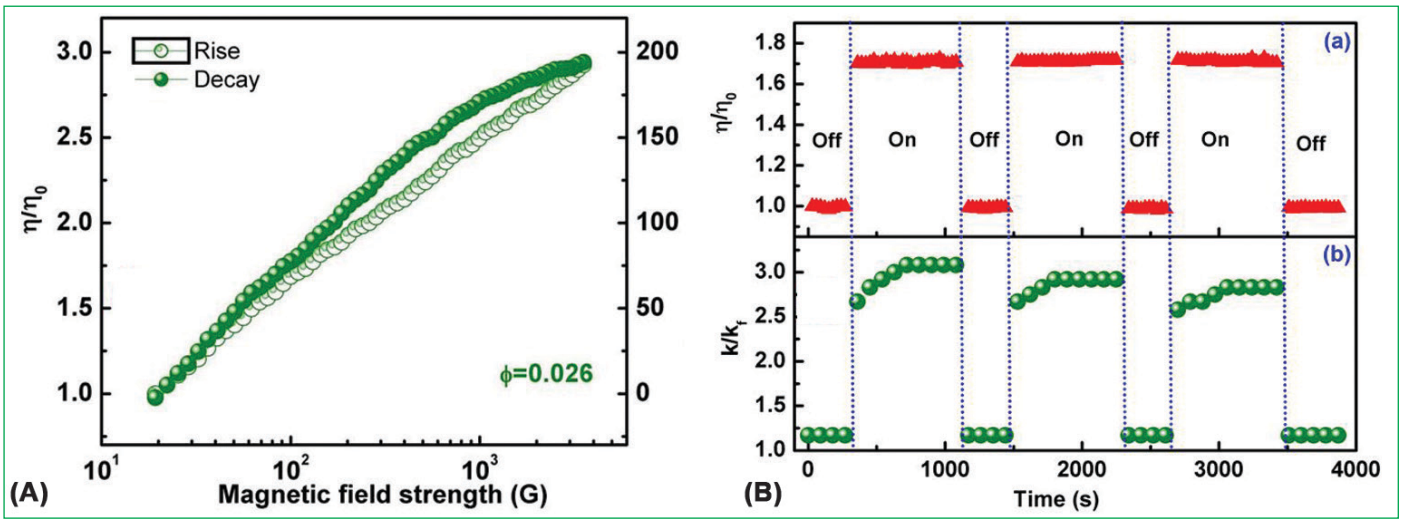


Figure 3: (A) The h/h_0 as a function of applied magnetic field strengths (during rise and decay) for kerosene based Fe_3O_4 nanofluids with f=0.026 at a shear rate of 50 s^{-1} (B): The variation of (a): k/k_f and (b) h/h_0 with time during field ON and field OFF conditions for hexadecane based Fe_3O_4 nanofluid

using these fluids in microfluidic devices. Under the influence of an external magnetic field, the magnetic moment of the particle aligns in the field direction and the particle will rotate around the field direction. When the field is perpendicular to vorticity, the viscous friction tilts the magnetic moment against the field direction. The resulting finite angle between the magnetic moment and the field direction will give rise to a magnetic torque counteracting the viscous torque that tries to realign the moment along the field direction. Hindrances of the free rotation of the particles in the flow occur due to the counteraction of the torques. Further, it also increases the viscosity of the fluid. Though the equilibrium value of viscosity is achieved instantaneously, it is realized after ~ 400 seconds in the case of thermal conductivity. However, with increase in number of switching cycles, an equilibrium value is achieved faster. Upon turning off the magnetic field, both the k/k_f and η/η_0values drops to zero immediately, which shows the perfect reversibility of the observed phenomena, which may have several interesting practical applications in smart devices.

The effect of magnetic field strength and its orientation on thermal and rheological properties of magnetic nanofluids is investigated. The thermal and rheology of the fluid is precisely tuned from low to very high values by varying the magnetic field strength and its orientation, where the mode of conduction of heat changes from a series to parallel mode. As the parallel mode has a geometric configuration that allows the most efficient means of heat propagation through nanoparticle paths, large thermal conductivity enhancement is achieved with parallel fields. The k/k_f saturate at the saturation magnetization of the nanofluid that depends on the volume fraction of the particles. The thermal conductivity decrease at high magnetic field, above saturation magnetization, due to lateral coalescence of chains, where the aspect ratio of the chains are reduced. As the thermal and rheological properties of these fluids are perfectly reversible, these magnetic fluids are ideal for applications in smart devices. As conventional nanofluids exhibit modest thermal conductivity enhancement, significantly large thermal conductivity enhancement observed in this response stimulus material makes them ideal candidate for applications in miniature devices.

Reported by P. D Shima,
Non-Destructive Evaluation Division,
Metallurgy & Materials Group

Conference/Meeting Highlights

Theme Meeting on Manufacturing Simplifications for Commercial Fast Breeder Reactor Core Sub-Assemblies

September 10, 2011

The design of future FBRs envisages manufacturing cost reduction as one of the measures towards economy. For reactor assembly components, 25% material savings has already been achieved based on which an elaborate technology development exercise has been undertaken. Similarly cost reduction is essential with respect to core components, which form recurring requirements.

In this respect, it is important to look into the rich experience obtained from the design and manufacture of PFBR core sub-assembly. Many ideas are being debated with respect to the sub-assembly design which will bring down the cost by way of simple manufacturing, reduced throughput of nuclear materials, reduced steel wastage from waste management point of view etc. Hence, an one day theme meeting was organised to deliberate on the experience and to identify from the feedback towards simple and improved design facilitating cost effective manufacture. The meeting was attended by designers, material specialists, fuel chemistry experts, PIE experts from IGCAR, fabricators from NFC, Hyderabad, AFFF, Tarapur and Quality inspection agencies particularly in Non-destructive evaluation. Concerned Unit Heads, senior officials along with young engineers participated in the meeting. The topics covered were international perspectives, design improvements, advanced quality analysis techniques and manufacturing aspects. The major highlights of the presentations, deliberations, summary of observations and road map for implementation are discussed in this report.

INTERNATIONAL PERSPECTIVES

The approach adopted and the current evolution of core design in Russia, Japan, China and France were focussed since these countries are embarking with design of future fast reactors.

In Russia, BOR-60 and BN-600 are under operation. BN-800 is planned to be commissioned by 2014 and BN-1200 is scheduled by 2020. For BN-1200, the pin diameter is chosen as 9.3 mm with the high target of average burn-up of 138 GWd/t, cycle length 1980 effective full power days and neutron dose 200 dpa.

In Japan, for the JSFR (1500 MWe), innovative technologies are under development for economic competitiveness, enhanced reliability, enhanced safety meeting the requirements of fuel design. A novel concept of rhomboid internal duct is being considered in the sub-assembly design to avoid re-criticality leading to core disruptive accident. The molten fuel will burst through the internal duct wall and will be discharged upward. The fuel pin with a large diameter is selected to enhance the internal conversion rate by a high fuel volume fraction and to control burn-up reactivity loss for a long operation period.

In China, CEFR (20 MWe) is commissioned in June 2010 which will be followed by CDFR (600 MWe) & CCFR (1000 MWe) design and construction. In France, Phenix achieved successfully 720 effective full power days irradiation period and end of life tests were completed. The ASTRID reactor will be constructed with the objective to demonstrate the industrial scale progress in the identified domains of the SFR where further improvements are planned (safety, operability & economy) and to perform transmutation demonstrations. In one of the innovative core designs, it is proposed to increase the fuel volume fraction, to reduce the sodium volume fraction and also to reduce the pressure drop across the core.

DESIGN

The approach adopted in IGCAR for improving the fuel performance

Shri S. C. Chetal, Director, IGCAR and senior colleagues of the Centre and the Department during the theme meeting

were presented and the results of the important studies carried out such as acceptable defects, influence of fabrication parameters on linear power from the point of view of higher production recovery were impressed upon.

Fuel cycle cost has to be minimum for economy of fast reactors. Economics indicate that a minimum of 4x500 MWe are to be constructed at the same site so that the gain in fuel cycle cost is high, reasonable and the levelised fuel cycle cost reduces to 40%. The throughput of blanket in the reprocessing plant needs to be reduced to bring down the cost as the average blanket burn-up does not commensurate with the inventory. However, it has conflicting requirements regarding breeding, for the reactor to be self sufficient. Hence, blanket pin design needs to be optimized, either in terms of small pin diameter or retaining the same diameter with a central hole, for future FBRs as well as for the future cores of PFBR taking into account both reactor and reprocessing aspects.

The wrapper material for future reactors is 9Cr-1Mo ferritic steels. With respect to clad, there is a necessity to develop high Cr ODS since the dissolution of iron in nitric acid during reprocessing is very high in the case of 9Cr ODS steels. This is all the more important since closed fuel cycle programme is followed by India.

The design features which are retained for future FBRs are reactor power, pin diameter and sub-assembly size. Several design features were identified for optimization, simplification, standardization, relaxation of inspection requirements and performance improvement. Ferro-boron is envisaged to be an alternative bulk shielding material which would reduce the thickness by one row. Optimization of sub-assembly height, simple end plug weld, shifting the auto orientation feature to fuel handling machine and removal of bottom labyrinth are some of the features identified for further work. Hard facing of sleeves in the grid plate is a potential area for research which has to be re-looked since it is a costlier and lengthier process. Development of alternative hard materials is an option.

QUALITY ASSURANCE

With the advent of several Non-destructive evaluation techniques, there is a strong possibility to improve on manufacturing time and recovery, some of them are:

(i) Ultrasonic or Eddy current examination of clad and hexcan tubes internal surfaces as against the fluorescent penetrant tests
(ii) phased array inspection technique for Non-destructive evaluation of hexcan welds
(iii) ultrasonic surface wave based technique for end plug welds of clad tubes
(iv) 3D Computed Tomography for fuel pin assembly to catalog the internals and also quantitatively estimate stack length, spring details etc.
(v) scanning of entire fuel pin and possibly sub-assembly also by Computed tomography giving complete 3D profile of the pellet, its density distribution, stack length etc in a much shorter time
(vi) Adoption of flat panel detectors and computed radiography techniques for reduction of overall time required for radiography
(vii) Rationalisation of sampling plan for mass and bulk production items based on the manufacturing experience obtained so far.

COMPONENT MANUFACTURE

Major observations with respect to component and fuel pin manufacture are :

(i) Hex to hex pilger route is established successfully at NFC for the production of wrapper tubes meeting all the specifications such as cold work, mechanical strength and dimensional aspects
(ii) Use of short length tubes for qualification of crimping and end plug welding in the clad
(iii) Reduction in the frequency of checking bond gas pressure and purity
(iv) Redoption of double length drawing of the clad tube which would give high recovery due to reduction in loss of the material
(v) Use of argon + cracked ammonia instead of argon + hydrogen for intermediate annealing process of clad tubes
(vi) Consideration of class A&B pellets for the blanket
(vii) Automated pin assembly operation by robotic system and
(viii) The quality of MOX fuel pin end plug weld by the LASER welding technique is superior to conventional TIG weld with a higher acceptance rate of end plug weld at 95% and hence same would continue to be adopted

ROAD MAP

Based on the detailed discussions, the following points have been identified for further consolidation and implementation

- Need to review the specification and tolerances of the different core sub-assemblies as they belong to different safety classes
- Identification and incorporation of design changes to facilitate automation in machining and assembly
- Rationale document for chemical specification giving the effect of variation of each element on the performance and manufacturing aspects
- Implementation of advanced NDE techniques with focus on reduced time and reliable detection leading to faster manufacture
- Optimization of blanket pin design taking into account breading, reactor engineering and reprocessing aspects
- Weldability studies with D9I, 9Cr-1Mo ferritic steels
- Road map and a detailed report with identification of design features for standardization and rationalization based on the rich experience from PFBR core sub-assembly manufacture would be jointly prepared by IGCAR, NFC, AFFF and BHAVINI comprising experts from different fields by March 2012.

  It was decided to continue the consultations and discussions among the concerned units on a regular basis paving the way for cost effective manufacture of core sub-assemblies for future cores of PFBR and CFBR

Reported by P. Chellapandi, NSEG

News & Events

Annual Meet of Quality Circles– 2011

August 25, 2011

MOON QC receiving Dr. Placid Rodriguez Trophy (Mechanical and Manufacturing Category) from Shri S.A. V. Satya Murty, Director, EIG

EXCEL QC receiving Shri M.K. Ramamurthy Trophy (Plant Operation & Services Category) from Shri S.A.V.Satya Murty, Director, EIG

Quality circle is a volunteer group of workers (or even students), usually under the leadership of their supervisor (but they can elect a team leader), who are trained to identify, analyze and solve work-related problems and present their solutions to management in order to improve the performance of the organization and motivate and enrich the work of employees. When matured, true quality circles become self-managing having gained the confidence of management.

In IGCAR, Quality Circles Annual Meet (QCAM) is conducted to provide a common platform to all the employees to present the QC case studies. This year, QCAM was conducted on August 25, 2011. Welcome address was given by Dr. C.Anand Babu, Associate Director, Component Development Group. The presidentia address was delivered by Shri G. Srinivasan, Director, Reactor Operations & Maintenance Group. Dr. R. Srinivasan, Director, Chennai Manufacturing Services & Chairman, NIQR, Chennai Branch delivered the key note address. Vote of thanks was proposed by Shri. V. Praveenkumar, Member, Organising committee.

Totally, eighteen Quality Circles (about two hundred members) from IGCAR presented their QC case-studies in a wide Spectrum of topics covering Technical, Research & Development and Services. Three Quality Circles of GSO QCAM-2011 with top scores were invited as guest presenters to present their QC case studies. Professional judges from Quality Circle Forum of India, Chennai chapter had assessed the QC case-study presentations held at Sarabhai Auditorium MOON QC and EXCEL QC bagged Dr. Placid Rodriguez Trophy and Shri M. K. Ramamurthy Trophy in 'Mechanical and Manufacturing' and 'Plant Operation and Services' respectively.

During valedictory function, the events were summed up by Shri. G. Kempulraj, Superintendent, Central Work Shop. The programme was concluded with the valedictory address and Prize distribution by Shri S. A. V. Satya Murty, Director, Electronic & Instrumentation Group. Vote of thanks was proposed by Shri. S. Suresh, Member, Organising committee.

Reported by C. Anand Babu
Convener, QCAM-2011 &
Secretary, Apex Steering Committee on Quality Circles, IGCAR& GSO

News & Events

Graduation Function of the fifth batch of Trainee Scientific Officers of Training School at IGCAR

August 26, 2011

Dr. S. Banerjee, Chairman, AEC and Secretary, DAE, addressing the gathering during the graduation function. Prof. G.D. Yadav, Director (Vice-Chancellor), Institute of Chemical Technology, Mumbai, Shri S.C.Chetal, Director, IGCAR, Dr. M. Sai Baba, Associate Director, RMG and Shri R. V. Subba Rao, Head, OCES –TS, RMG are seated on the dais

The fifth batch of thirty six TSOs from the BARC Training School at IGCAR have successfully completed their training and the graduation function was held on August 26, 2011 at the Sarabhai Auditorium, Homi Bhabha Building, IGCAR. Prof. G. D. Yadav, Director (Vice-Chancellor), Institute of Chemical Technology, Mumbai graced the occasion as the Chief Guest. Dr. S. Banerjee, Chairman, AEC and Secretary, DAE, presided over the function. Dr. M. Sai Baba, Associate Director, Resources Management Group welcomed the gathering. Shri S. C. Chetal, Director, IGCAR, gave an enlightening address enumerating some recipes for success. Dr. S. Banerjee released the souvenir featuring the training school programme of the academic year that passed by and Prof. G. D. Yadav received the first copy. In his presidential address Dr. S. Banerjee gave a very motivational and thought provoking lecture to the graduates passing out. Prof. G. D. Yadav gave away the prestigious 'Homi Bhabha Prize' comprising of a medallion and books worth Rs.5000 to the meritorious toppers of all the disciplines. He also gave away the course completion certificates to all the graduates passing out. A few of the Trainee Scientific Officers passing out shared their experiences and gave a feedback on the academic programme and their stay at hostel. Prof. G.D. Yadav gave a very inspiring lecture to the students. Shri R. V. Subba Rao, Head, OCES–TS, RMG proposed the vote of thanks.

Fifth Batch of Graduates of BARC Training School at IGCAR with Prof. G. D. Yadav, Director (Vice-Chancellor), Institute of Chemical Technology, Mumbai, Dr. S. Banerjee, Chairman, AEC & Secretary, DAE, Shri S. C. Chetal, Director, IGCAR and senior colleagues of the Department

(Reported by M.Sai Baba, RMG)

Visit of Dignitaries

Shri T. K. A. Nair, Principal Secretary to the Prime Minister with Shri S. C. Chetal, Director, IGCAR and senior colleagues of the Department

Shri T. K. A. Nair, Principal Secretary to the Prime Minister visited the Centre on July 9, 2011. During the meeting he was briefed about the Research and Development activities at Indira Gandhi Centre for Atomic Research by Shri S. C. Chetal, Director, IGCAR and on the status of Prototype Fast Breeder Reactor by Dr. Prabhat Kumar, Project Director, BHAVINI. Shri T. K. A. Nair visited the Fast Breeder Test Reactor, Magnetoencephalography facility and construction site of PFBR.

Dr. R. Chidambaram, Principal Scientific Advisor to Government of India, Dr. Baldev Raj, President, PSG Institutions, Coimbatore and Shri Neeraj Sinha, Senior Director, Office of Principal Scientific Advisor to Government of India with Shri S.C. Chetal, Director, IGCAR and senior colleagues of the Centre during their visit to Chemistry Group

Dr. R. Chidambaram, Principal Scientific Advisor to Government of India, Dr. Baldev Raj, President, PSG Institutions, Coimbatore and Shri Neeraj Sinha, Senior Director, Office of Principal Scientific Advisor to Government of India, visited the Centre on August 10, 2011. The team visited the Chemistry Group, Materials Science Group, UGC-DAE-CSR complex and construction site of PFBR.

A delegation from the American Nuclear Society, USA, led by Dr. Eric Paul Loewen, visited the Centre on September 27, 2011. After a meeting with senior colleagues, the delegation visited the Fast Breeder Test Reactor and facilities in Nuclear and Safety Engineering, Reactor Engineering and Materials Science Groups.

Delegation from American Nuclear Society, USA with senior colleagues of the Centre

Forthcoming Meeting / Conference

Structure and Thermodynamics of Emerging Materials (STEM-2011)

Theme meeting on Diffusion, Mass Transfer and its Consequences in Materials

November 24-26, 2011

Theme meeting on Structure and Thermodynamics of Emerging Materials (STEM-2011) focusing on the specific topic of "Diffusion, Mass Transfer and its Consequences in Materials" will be organized at IGCAR during November 24-26, 2011. STEM 2011 is being organized jointly with the Kalpakkam Chapter of the Indian Institute of Metals. The theme meeting is sponsored by Board of Research in Nuclear Sciences, India. During STEM 2011, through a series of invited lectures on the first day, the participants will be given an opportunity to interact with renowned national experts and learn about the current developments in the field of diffusion. On the second day of the theme meeting there will be tutorial type lectures on the application of Monte Carlo and Molecular Dynamic techniques for simulating diffusion processes. During the tutorials the participants can get hands-on experience using the simulation softwares. Efforts are also being made to arrange for visits to the reactor facilities housed at Kalpakkam and to Physical Metallurgy Group laboratories on the final day of the theme meeting.

Address for Correspondence

Dr. Saroja Saibaba
Convener, STEM - 2011
Head, Nuclear Materials Microscopy Section , Physical Metallurgy Group
Metallurgy and Materials Group, IGCAR, Kalpakkam–603102
Tel: +91-44-27480500 Extn-22634; Fax: +91-44-27480202; E-mail: stem2011@igcar.gov.in

8th National Conference on Recent Advances in Information Technology (READIT)

December 28-29, 2011

Scientific Information Resource Division and Madras Library Association (MALA-KC) have been conducting a series of conferences on Recent Advances in Information Technology (READIT). The earlier conferences were conducted during 1995, 1997, 1999, 2001, 2005, 2007 and 2009 which were well received by professionals engaged in IT and Library Science from R&D and Academic Institutions. Eighth national seminar on "Recent Advances in Information Technology (READIT)", with a theme of "Knowledge Sharing with Semantic Grids" is being conducted during December 28-29, 2011 at IGCAR. The conference will have invited talks by experts in the field and selected contributed paper presentation from research scholars. A Pre-Conference Tutorial on "Preservation techniques for archives" is also being arranged for the benefit of Information Scientists and Working Librarians on December 27, 2011.

Objective:

READIT targets professionals in the field of Information Technology and Library Knowledge Management to provide a forum for discussion and knowledge transfer in the field of semantic web, grid computing technologies and application of the same in sharing the organizational knowledge. Representation of knowledge in grids through semantic web and how knowledge representation would change the definition of library services. The issues in the knowledge sharing and semantic grid technologies, the standards, language and methods for knowledge representation are some areas that would be discussed in detail.

Student / Young Research Scholar Presentation

A separate technical session consisting of oral presentation will be provided for Students & Research Scholars in the field of Library & Information Science.

Address for correspondence

Dr. M. Sai Baba
Convener, Organising Committee, READIT
Head, Scientific Information Resource Division, Associate Director, RMG
Indira Gandhi Centre for Atomic Research Kalpakkam – 603 102, Tamil Nadu
Phone: +91 44 2748028, Fax: +91 44 27480096, E-mail: readit@igcar.gov.in; msb@igcar.gov.in

Forthcoming Meeting / Conference

19th National Symposium on Radiation Protection (NSRP-19)

February 20-22, 2012

Indian Society for Radiation Physics (ISRP) is organizing the 19th National Symposium on Radiation Protection (NSRP-19) during February 20–22, 2012 at Chennai Trade Centre, Chennai, India. The conference provides a unique meeting ground for the researchers, regulators, academicians and users to present their work, share their experience, discuss the current trends, dwell on future plans and interact with peers. Eminent scientists from National and International institutions, delegates working in the areas spanning across the spectrum of applications on ionizing radiation will be participating in this meeting. The symposium is supported by Indira Gandhi Centre for Atomic Research.

Topics

- Basic Radiation Processes
- Radiation Transport
- Reactor Physics and Shielding
- Radiation related problems at Accelerators
- Radiological issues in reactor operations
- Accelerated Driven Systems and Fusion Reactors
- Research reactors, AHWRs and fusion reactors
- Reactors as test bed and radiation damage studies
- Reactors for Hydrogen production
- Reactors Decay Heat removal
- Criticality safety in fuel cycle facilities
- Radiation Physics activities in Advanced Technologies
- Radiation detection and measurements
- Radioactivity transport in natural environment and radiation in space
- Radiation applications in Industry
- Agriculture, food processing, medicine and research
- Radiation protection in nuclear medicine
- Regulatory aspects in advanced Technologies
- Corrosion and degradation of materials in high radiation fields
- Radiation Dosimetry techniques – Luminescence and development of nano-phosphors
- Nuclear emergency preparedness
- Solid state nuclear track detectors
- Radwaste assay characterization
- Nuclear data
- Interdisciplinary research

Dates to Remember

- Last date for submission of full manuscripts : November 07, 2011
- Intimation of reviewers comments : December 19, 2011
- Submission of paper after incorporating reviewer's comments : January 16, 2012

Exhibition

A technical exhibition with participation from the manufacturers of radiation monitoring instruments will be organized during the conference. This will enable the participants to get to know the latest and state-of-art equipment available in the market paving way for a fruitful interface between the manufacturers/suppliers and the users. A well-furnished exhibition facility will be erected at the venue of the symposium.

Address for Correspondence

Dr. C. P. Reddy
Reactor Operations and Maintenance Group
Tel: +91 -44-27480110, Extn-26366,
Email: cpreddy@igcar.gov.in

Shri S. Bala Sundar
Reactor Engineering Group
Tel: +91 -44-27480352, Extn-23436/23438,
Email: sbs@igcar.gov.in

Awards & Honours

Dr. C. Anand Babu and the team woring on Boron Enrichment, FRTG has been granted a patent titled "Innovative Cut and Feed Operation for Enhancing the Performance using Ion Chromatography Exchange Separation" by US Patent office, Patent No - 07976708 on July 12, 2011.

PLUTONIUM Quality Circle of Chemistry Group, IGCAR with members Shri E. Mohanraj, Shri B. Vijayavelu, Shri N. Ravi, Shri N. Radhakrishnan, Shri R. Padmanabhan, Shri K. Satya Govinda Raju and Shri V. Suresh Kumar has won GOLD AWARD in the Chennai Chapter Quality Circle Convention(CCQCC-2011) held at Puducherry during September 3-4, 2011.

STAR Quality Circle of Central work Shop Division, ESG, IGCAR with members Shri R. Tamilamuthan, Shri K. M. Natarajan, Shri G. Narendar Reddy, Shri V. Kodiarasan, Shri A. Padmanaban,Shri B. Thiruvengadam, Shri R. Murugupandian, Shri J. Abilash, Shri E. Venkatesh, Shri S. Satheesh Kumar has won SILVER AWARD in the Chennai Chapter Quality Circle Convention(CCQCC-2011) held at Puducherry during September 3-4, 2011.

RAHFA Quality Circle of Hospital, GSO with members Ms M. Suganthi Robert, Ms. V. Vanasundari, Shri S Rajagopal and Shri P. Selvamani, Ms P. Jansileema, Ms P. Sumathi, Shri G.Mahalingam, Shri M.K. Mohammed Razeek has won GOLD AWARD in the Chennai Chapter Quality Circle Convention(CCQCC-2011) held at Puducherry during September 3-4, 2011.

Shri Alok Rout, Senior Research Fellow, Chemistry Group participated in the International conference on Ionic liquids (ILSEPT 2011) at Sitges, Spain and gave a keynote presentation. He was chosen to chair a session in the conference.

Shri M. Kasinathan, Ms S. Sosamma, Dr. C. Babu Rao, Shri N. Murali and Dr.T. Jayakumar received the Best Poster Award for paper titled "Liquid level measurement using Raman Distributed Temperature Sensor" at International conference on Specialty Glass & Optical Fiber: Materials, Technology & Devices (ICGF-2011), Kolkata, August 2011.

Baobab tree

Published by Scientific Information Resource Division, IGCAR, Kalpakkam-603102