IGC Newsletter
ISSN 0972-5741
Volume 77 July 2008

Inside

From the Director's Desk

I wish to share three significant events that happened in the last three months, from April to June 2008. The first one is the visit of Honorable Dr. A.P.J. Abdul Kalam, Former President of India and a doyen of Science and Technology to our Centre on 24 April, 2008 and his inspirational advice to the student community of IGCAR, the second one is his address on the event of "National Technology Day Celebrations-2008" at BARC, Mumbai and the last one is on the erection of the Safety Vessel in the reactor vault of Prototype Fast Breeder Reactor (PFBR) on 24 June, 2008 which marks an important milestone in the commissioning of PFBR at Kalpakkam.

Dr. A.P.J. Abdul Kalam visits the Centre

We are greatly honored by the visit of Dr. A.P.J. Abdul Kalam, Former President of India, to the Centre. Dr. Anil Kakodkar, Chairman, AEC and Dr. S. Banerjee, Director, BARC accompanied him during the visit. Dr. A.P.J. Abdul Kalam showed keen interest during the visit to various facilities at IGCAR. We briefed him on the status of operations at FBTR, fuelled with the unique high plutonium content mixed carbide, which has been performing without any breach well beyond 155 GWd/t burn-up. At the hot cells in the Post-Irradiation Examination Division, he was explained about some of the experimental programmes on irradiated fuel bundle and about new robotic instruments developed in-house. We described unconventional and innovative Non Destructive Evaluation Techniques being pursued at the Centre and the sensors and instrumentation developed in-house. At the pilot plant for compact reprocessing of advanced fuels in lead cells, we explained the progress in R&D relating to dissolution of high burn-up high plutonium content mixed carbide fuel and reprocessing of

Dr. Baldev Raj, Director, IGCAR, explaining the status of Fast Breeder Test Reactor to Dr. A.P.J. Abdul Kalam. Dr. Anil Kakodkar, Chairman, AEC and Dr. S. Banerjee, Director, BARC join the discussion

advanced carbide fuel. He was impressed with our efforts which prompted him to make a special mention about the same in his address on the occasion of "National Technology Day Celebrations - 2008". During his visit to BHAVINI, he was briefed on the construction and commissioning activities of PFBR. He visited the Assembly shop, Nuclear Island etc. He admired the magnificence of indigenous technology which was at the forefront in all these activities.

Interaction with Young Officers and Research Scholars

Dr. A.P.J. Abdul Kalam's passion towards youngsters especially students is well known and it was reflected in the interaction session with the student community of IGCAR comprising the Trainee Scientific Officers and Research Scholars. In his address to the students he said:

"Everyone especially the students should do a SWOT analysis in life. The four main points which one should ponder towards achieving success in any endeavor are: aim, acquiring knowledge, hard work and perseverance. To be successful, one has to become a captain and defeat the problem"

While touching upon the great strides our country is taking towards economic growth, he stressed upon the necessity to be self-reliant and to push the GDP from the present level of 8% to 10%. He envisaged the following areas (1) Education and Health Care (2) Agriculture and Agro products (3) Nuclear Technology and (4) Information Technology to be the key players in leading India to the forefront in the international arena.

With his exceptional experience in scientific research and technology management, he gave several tips to the students to tackle scientific problems and achieve outstanding results. I reproduce below the highlights of his address.

I quote:

- *Wherever I am, a thought will always come to my mind as to what I give*
- *Whatever the minimum I do, my motto will be to work with integrity and succeed with integrity*
- *I will always remember that let not my winged days be spent in vain*
- *I realize that I have to set a great goal that will lead me to think high and realize the goal*
- *My greatest friends will be great human beings, great teachers and greatest books*
- *I firmly believe that no problems can defeat me and I will be the captain of my problems and defeat the problem and succeed*

Dr. A.P.J. Abdul Kalam addressing the students

Dr. A.P.J. Abdul Kalam answering a query from an enthusiastic student

Dr. A.P.J. Abdul Kalam interacting with Training School Officers and Research Scholars

- *I believe that dreams are transformed to thoughts and thoughts lead to success*

Dr. A.P.J. Abdul Kalam, enthusiastically answered the volley of the questions put forth by the intriguing students. I am sure that the young minds will be pondering on the advice given by this great mentor. I feel these tips are nevertheless applicable to all of us in different contexts. If we are inclined to adopt even a few of his suggestions, we would be making a great impact towards accomplishing the task that has been set before us, towards attaining global leadership in Fast Reactor and associated closed fuel cycle technologies.

"The learned teacher makes you enjoy learning; On leaving, makes you to keep thinking of his teaching"- ***Thirukkural 394***

Dr. A.P.J. Abdul Kalam's Address at the "National Technology Day Celebrations-2008"

On 11 May, 2008, Dr.A.P.J. Abdul Kalam was the Chief Guest at the "National Technology Day Celebrations-2008" at BARC, Mumbai where he also gave away the prestigious DAE merit awards for excellence in Science and Technology for the year 2006. I take this opportunity to congratulate the numerous colleagues from IGCAR who are the recipients of the awards. I am sure our colleagues would be receiving several more awards in the coming years.

In his address to the gathering, Dr. A.P.J. Abdul Kalam touched upon the topic ***"Evolution of Leadership for Extraordinary Mission"***. In his talk he envisioned the distinctive profile of India in 2020, and highlighted the three most important innovative achievements that have inspired the people of India, namely the progress made in Space Technology, Indigenous technology in the development of AGNI and LCA at DRDO and Carbide fuel reprocessing at IGCAR. I am proud to reproduce his account on the R&D activities that are being pursued at IGCAR in the following paragraphs. I quote him:

"Fast breeder reactors with closed fuel cycle are a sustainable resource of nuclear energy. They permit effective and almost complete utilization of the uranium resources and are thus vital for India. They produce much less quantities (per unit energy produced) of the high level nuclear waste and with the aid of specialized separation processes, can reduce the time period for which the waste has to be stored in order that the radioactivity levels reach that of natural uranium. Fast breeder reactors are best suited for the conversion of thorium to produce large quantities of U^{233}, which would be a fuel for the future reactors. They also enable burning of the long lived actinide isotopes which are produced in nuclear reactors. Thus, fast reactors are an essential ingredient of a large nuclear power programme for our country. Based on my visit to Kalpakkam, I can see the following innovative actions by our nuclear scientists and technologists for developing unique fuel, fuel processing and fuel recovery system.

(a) The Fast Breeder Test Reactor (FBTR) at Kalpakkam uses a unique plutonium rich mixed carbide as the driver fuel containing 70% plutonium and 30% uranium. The specification of the unique fuel has been designed after carrying out series of experiments on the properties of the fuel, out of pile studies on its thermal behaviour and modeling the performance.

(b) Increasing the burn-up capability progressively from 50,000 MW day per tonne to 1,55,000 MW day per tonne without any integrity breach of the pins.

(c) Development of special equipment and technology for dismantling of sub-assemblies containing the fuel pins and the chopping of the fuel pins in an inert atmosphere.

(d) Establishing the reprocessing technology of dissolving the fuel in nitric acid and separating the uranium and plutonium from the highly radioactive fission products.

(e) Development of special centrifugal extractors for separation of fuel for avoiding third phase formation due to high plutonium concentration fuel and mitigating the problem of high radioactivity due to high burn-up of fuel.

The high burn-up reached and the reprocessing of the high burn-up carbide fuel after short cooling constitute important landmarks achieved by Indian scientists and technologists for the first time in the world. ***I congratulate our nuclear scientists and technologists for building this unique capacity for launching the large fast reactor programme with closed fuel cycle.***

Nuclear science has total technology solution. Nuclear science can give clean energy and clean environment, nuclear science can provide irradiated seeds to enhance food production of certain crops and nuclear science can give solution to healthcare problems such as treatment of cancer using radio isotopes. Dear friends, ultimately all of us have to work for achieving clean green earth. Certainly DAE has the core competence in research and development."

"Listen to the learned and acquire the balance of mind and wisdom. That alone can help you in your bloom and gloom" - ***Thirukkural 425***

Erection of Safety Vessel – A Milestone in PFBR Project

I would like to share my happiness and pride on the occasion of the successful erection of safety vessel into the reactor vault on 24 June, 2008. This is arguably the third largest size thin vessel for FBR erected successfully in the world, after French Reactor SPX-1 and Russian Reactor BN-600. This event is a milestone in the history of India's pursuit of FBR technology and underlines the country's capability in design, manufacture and erection of challenging FBR Components.

FBR is most potent and ready to be exploited sustainable energy option for India and the world, for producing mega energy to meet large industrial demand. On the occasion of safety vessel erection, I would like to highlight a few unique characteristics of FBR namely: (1) Effective

utilization of natural uranium (nearly 80%) (2) Consumption of the depleted fuel discharged from thermal reactors (3) Breeding more fissile material (plutonium) than consumed (4) Burning of long lived radioactive fission products and (5) Generation of precious metals such as cesium, palladium etc., which have many important societal applications and can be extracted from its waste (wealth from waste). Owing to these characteristics, the ultimate nuclear waste from FBR is truly insignificant, hence its importance from the waste management and environmental considerations. With a large number of thermal reactors operating worldwide and being constructed and planned in the near future, the limited available natural uranium would be consumed very fast. On the other hand, with FBRs, energy supply can be ensured over a few centuries, which has renewed the interest in FBR internationally. FBRs have already accumulated more than 380 reactor years of operating experiences worldwide, since 1960's. It is worth mentioning here that the technology FBRs is considered to be complex. Therefore a few countries only have been pursuing the programme. In this context, PFBR is receiving greater attention from the international community to meet their own aspirations on FBR programme. The success of PFBR is an important mission for the country. In order to achieve this, IGCAR and BHAVINI along with the Indian Industries are working in a well coordinated manner with excellent synergism. The PFBR project is progressing well. Civil construction of the project is nearing completion. The manufacture of major components is also nearing completion.

To avoid loss of coolant in case of an unlikely event of a leak from the main vessel, a safety vessel is incorporated with an annular gap of about 300mm around the main vessel. The safety vessel supports thermal insulation panels which are provided for minimising the heat loss from the reactor to vault. The safety vessel also provides support for the in-service inspection equipment for the inspection of main vessel. The safety vessel is a thin slender shell with diameter of 13.5m, 15mm thickness and 13m height. The material of construction is stainless steel grade 304LN. Hence, manufacturing of the vessel is a very challenging activity and it has been completed by M/s Larsen & Toubro. The stringent profile tolerance of ±12mm has been achieved. Achieving such tight tolerances, manufacture of thermal insulation panels, minimum repair welds during fabrication and handling of components in an innovative way are of truly international quality. These are achieved by adopting stringent dimensional control at the petal level, robust weld fit up and weld sequence methodologies, state-of-the-art techniques for inspection & quality control, numerical simulations of forming and welding procedures, innovative mockup trials, incorporating the lessons learnt from feedback experiences of various industries and elaborate technology development exercises.

Thermal insulation panels are delicate parts in the vessel. As these type of insulations are not commercially available, the same has been designed and fabricated indigenously using 0.1mm thick sheets stacked to form panels. Dimples are provided to ensure spacing between the sheets. The manufacture and assembly of the panels were completed overcoming several challenges in view of thin sheets forming, requirement of uniform emissivity, uniform spacing, formation of dimples without cracks, complicated assembly sequences over the safety vessel etc. Innovative experiments were carried out to confirm compliance of thermal and seismic design requirements.

The safety vessel erection methodology was verified systematically through the use of state-of-the-art computer simulation techniques followed by elaborate mockup trials. A new heavy duty crane (the largest in the country) was acquired from M/s. Liebherr Germany. The actual erection was preceded by mockup tests that simulate possible wind load conditions and as-built dimensions of safety vessel, to ensure that the vessel would be inserted accurately maintaining the verticality, horizontality and co-axiality, without damaging the insulation panels.

The mockup exercises were also carried out to establish the precision of movements of the crane operations. Further, the close co-ordination required between several individuals/agencies with regard to movement of such large size heavy component was firmed up during the mockup trials. With the accumulated experience gained

Seismic qualification test on typical panel

Combined wind and dead load testing

Testing for vessel insertability into vault

Lifting from base frame and erection of safety vessel into reactor vault

from mockups, the safety vessel has been erected successfully. The vessel has been welded to the embedment in the reactor vault and the specified erection tolerances on the verticality and horizontality have been ensured. All the above activities have been carried out within a challenging time schedule.

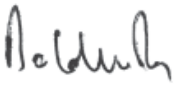
The in-situ protection of austenitic stainless steel component, in sensitive environment, has been carefully planned with adherence to strict preservation techniques.

Several agencies were involved in the design and successful erection of safety vessel. The design, technology development and testing has been done by IGCAR and in-depth safety review has been performed by safety committees of Atomic Energy Regulatory Board (AERB). The construction and commissioning responsibility was entrusted to BHAVINI. The civil construction of vault was completed by M/s Gammon India Ltd and vessel & insulation panels were manufactured by M/s Larsen & Toubro. The quality assurance of civil and mechanical structures has been ensured by experts from BHAVINI and NPCIL. The overall co-ordination of manufacture and erection activities was carried out by a dedicated task force, steered by Dr.P.Chellapandi, Associate Director, Nuclear Engineering Group, and Director, Safety Group, IGCAR which performed its task in a systematic and scientific manner by way of timely resolution of all the technical issues.

The entire gamut of activities has been possible through excellent co-ordination between IGCAR, BHAVINI, other DAE & NPCIL Units, AERB, Academic & R&D institutions. This event has raised the confidence towards accomplishing the future missions of the department.

We are marching towards realizing the vision of attaining the global leadership in fast reactor and associated closed fuel cycle technologies and towards ascertaining the confidence that our peers and our nation have reposed on us. We have reaffirmed our faith in the words of Thiruvalluvar in that, I quote,

"There is nothing too difficult to be accomplished when done carefully with unflinching endeavour"
- ***Thirukkural 537***



(Baldev Raj)
Director, IGCAR

Seismic Analysis of Primary Sodium System Components for the Seismic Re-evaluation of Fast Breeder Test Reactor

FBTR is a 40 MWt (13.5 MWe) loop type reactor operating with a unique plutonium rich carbide fuel. The first criticality was achieved in October 1985 with a small core of twenty two fuel subassemblies (SA) of MARK-I composition (70% PuC - 30% UC), with a design power of 10.6 MWt and peak linear heat rating (LHR) of 250 W/cm. Progressively the core was expanded by adding SA at peripheral locations. Towards increasing the core size and hence the reactor power, carbide fuel of MARK-II composition (55% PuC - 45% UC) was inducted in the peripheral locations in 1996. Turbine Generator was synchronized to the grid for the first time in July 1997. After twenty years of successful operation, it is planned to extend the life of FBTR. Towards this, seismic reevaluation of structures, systems and components has been undertaken. This article deals with the seismic analysis for the primary sodium system components.

Geometrical Details

The main components of the primary sodium system are the reactor vessel, two Intermediate Heat Exchangers (IHX) and two sodium pumps. Their isometric layout is shown in Figure 1. Two primary sodium pumps deliver sodium into the reactor. The outlet sodium from reactor flows by gravity to the intermediate heat exchangers and then back to the pump suction. The entire primary sodium system is

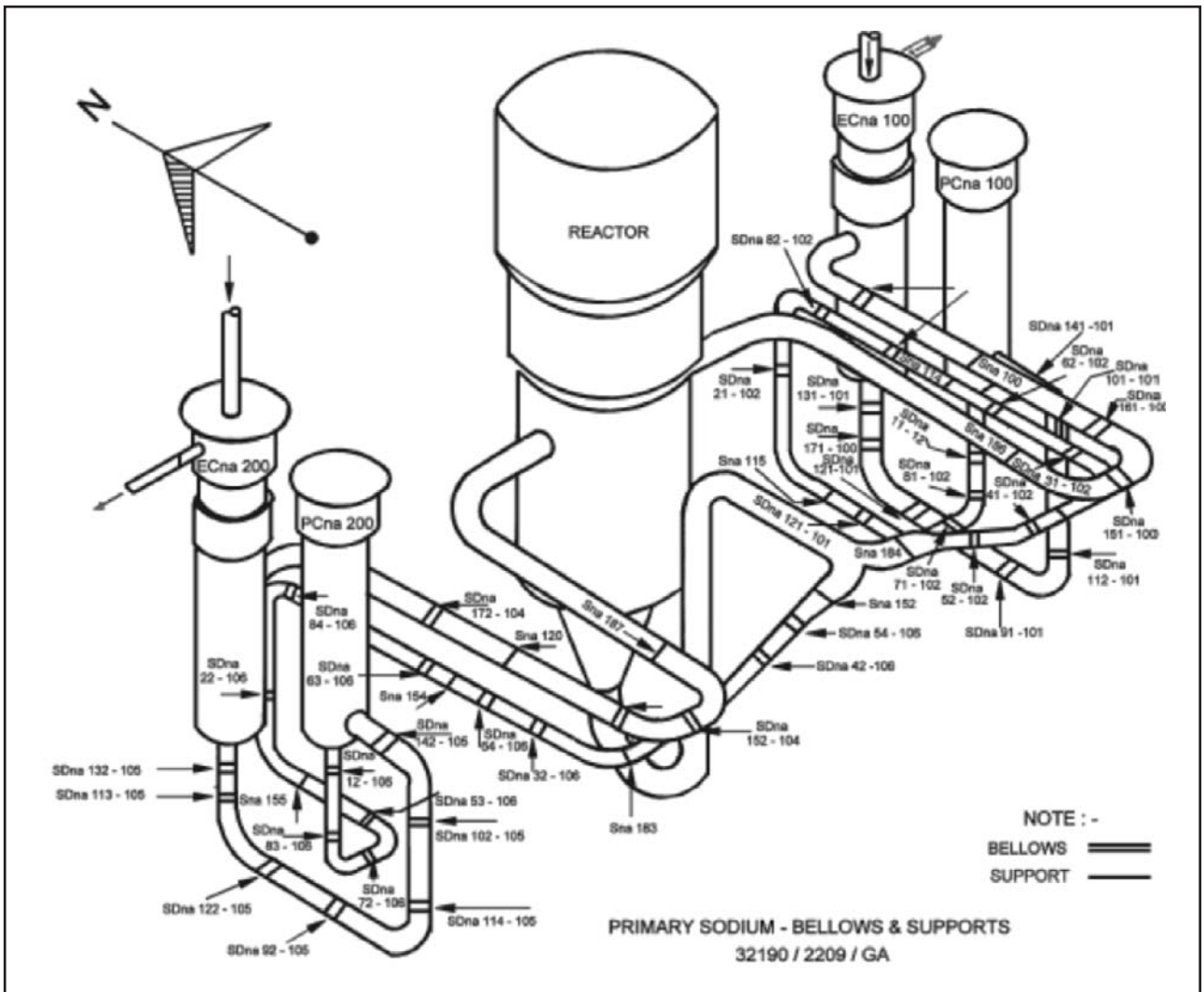


Figure 1 : Isometric layout of primary system

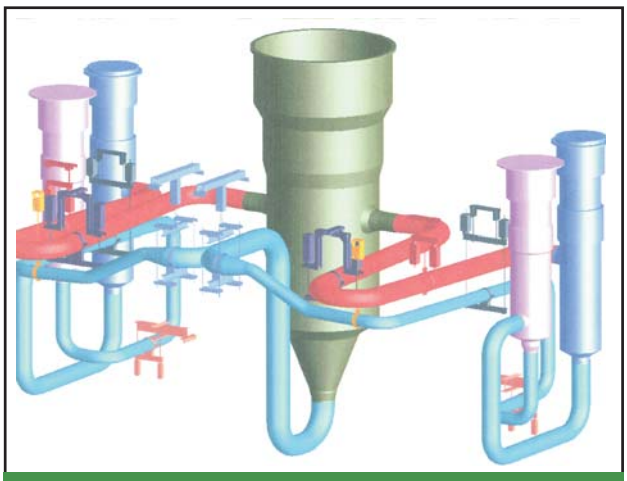


Figure 2 : PDMS output of primary system

housed in concrete cells below zero level in the Reactor Containment Building (RCB). The system is provided with a nitrogen-filled envelope called double envelope, to avoid sodium fire in case of main pipe leak. As far as sodium pipings are concerned, the hot pipe lines coming from the reactor joining to intermediate pipe line between IHX & pump, cold line running from pump to 'Y' junction, called 'cullotte' and finally reactor inlet pipe are the main sodium pipings. The main pipe is provided with double envelope, throughout its length. There are four hangers (two for east loop and two for the west loop), attached in the double envelope of the hot pipings and eight hangers (four per loop) in the cold line. There are six bellows in the double envelopes of hot line (three per loop), twelve bellows in the intermediate line (six per loop) and twenty two bellows in the cold loop (eleven per loop). At a few locations the double envelopes are welded to the main pipes. At few more selected locations, there are only guides which allow the axial sliding while constraining all the radial directions, between them. Thus, the system is complex because of strong coupling of components, pipelines and double envelopes. Hence, there is a need to analyse them together with appropriate boundary conditions, which need special kinematic relations to be implemented in the computer code. Figure 2 depicts 3D graphical display of geometry developed by Plant Design Management System (PDMS), which helps to confirm the accuracy of the geometrical data translated.

Loadings

To comply with the design code requirements, the analysis is carried out for the dead load, internal pressure and seismic excitations. Total self weight of main components including east and west loops and sodium is about eighty four tonnes. The total weight of double envelopes including east and west loops is about ten tonnes. Average temperatures vary from 380 to 525° C for the main components and pipings. The temperatures of double envelopes are less by a maximum 50°C than the temperatures of the respective components at steady state condition. The pressure for reactor vessel and main pipings is taken as 0.5 MPa under normal operating conditions, adding some margin on the design pressure for pump

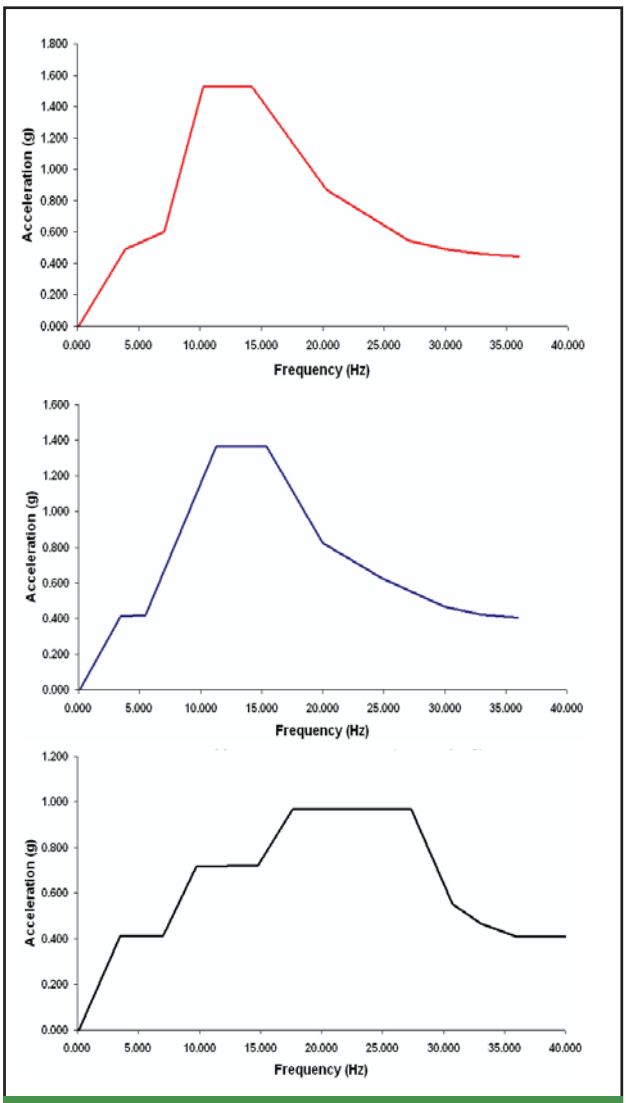


Figure 3 : Floor response spectra
(System support elevation 5% damping)

(57 meters of liquid column). For the purpose of seismic reevaluation, Review Base Ground Motion (RBGM) spectra were generated at the ground level. Subsequently, floor response spectra at the primary system support elevations are generated from the seismic analysis of civil structures. Floor Response Spectra generated at the elevation of reactor supporting elevation in two horizontal and one vertical directions corresponding to 5% damping are applied in such a manner to yield conservative results. Figure 3 shows the floor response spectra used for the analysis.

Overall Analysis Approach

The analysis is aimed to determine displacements and stresses to check the functional and design code limits. For preventing mechanical interactions between main component / piping and their respective double envelopes, the relative radial displacements are limited to gap between main and double envelopes at respective locations. For ensuring the structural integrity of bellows, the effective axial deflections of bellows are limited to the respective limits prescribed by the bellow manufacturer.

Stresses are limited by the primary stress limits recommended by RCC-MR (2002 edition).

While pipelines have 1D feature, components especially at the junctions and branch pipes call for 3D treatment. Addressing these issues, seismic analysis is carried out by following an integrated approach. Finite element method is used for the entire analysis, with the computer code called 'CAST3M' issued by CEA France. The analysis is completed in three steps. In step-1, global analysis is carried out to determine the deflections, forces and moments due to dead load and seismic loadings using straight pipe elements and bends. The deflections are used for verifying the deflection limits. The forces and moments are used for the computation of P_m(Primary membrane stress intensity) & (P_m+P_b)(Primary membrane bending stress intensity), following either step-2 or step-3. In step-2, P_m & (P_m+P_b) are computed by using the correlations recommended in RCC-MR for the pipes, bends and branch pipes. The correlations for the "tees" recommended in RCC-MR are used for the branch pipes by assuming that the dimensional restrictions for the fillet radius, etc., based on which critical branch pipes are identified for the detailed Finite Element Method(FEM) analysis in step-3.

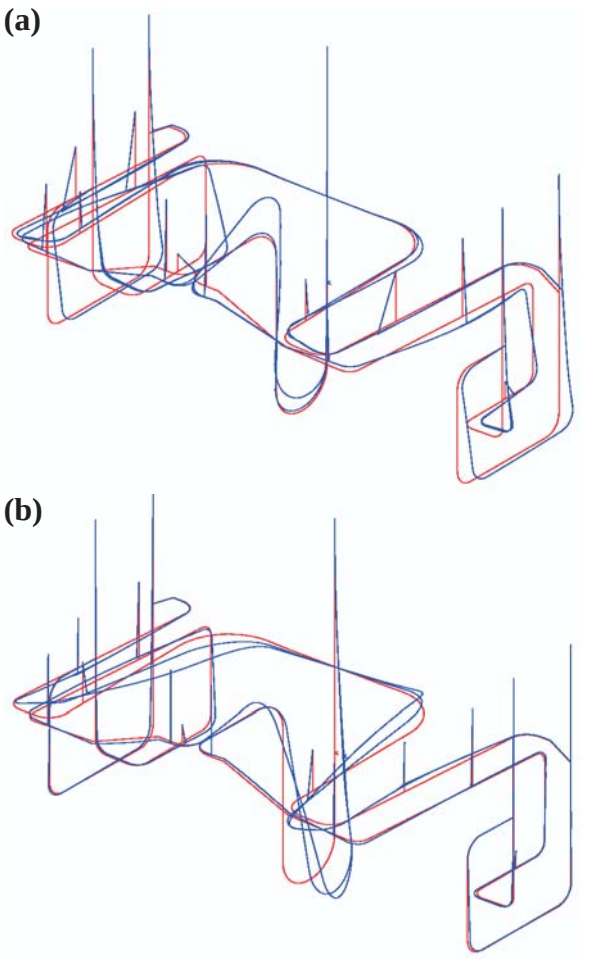


Figure 4 : (a) Mode shapes depicting IHX and pump vibrations at 9 Hz, (b) Mode shapes depicting reactor vessel vibration at 11 Hz

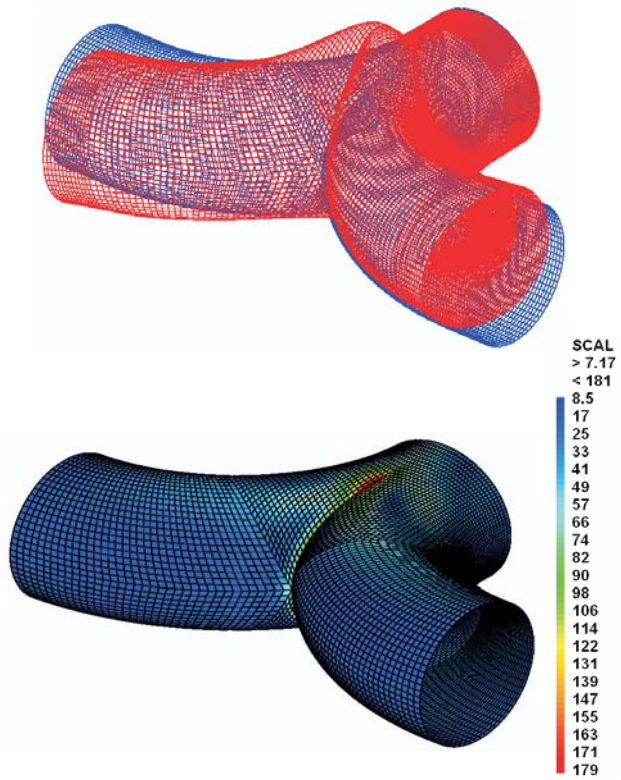


Figure 5 : Deformation and von Mises stresses in cullotte under combined loadings

Summary of Results

As the first phase, natural vibration analysis is carried out to determine natural mode shapes and associated frequencies, which have been extracted up to 50 Hz. Figure 4(a) & Figure 4(b) show the critical mode shapes that are associated with the pumps, IHXs and reactor vessel contributions are predominant. Figure 5 shows the 3D local deformations and von Mises stress distributions under combined pressure and seismic induced forces and moments in the Y-junction at reactor inlet called 'Cullotte', the critical location in the reactor.

Based on the analysis, it is concluded that the seismic behaviour of components in east and west loops including double envelope are similar. The deflection limits to prevent the mechanical interaction between the main and respective double envelopes are met with comfortable margin. The maximum net axial deflections are found to be less than minimum acceptable values. The stresses induced in components namely, reactor vessel, IHX and pumps including their double envelopes are small. As far as pipings are concerned, the hot lines are critical, particularly the shell nozzle junctions. However, stress limits are met with detailed Finite Element Method analysis. The pipe bends including cullotte are meeting the design code limits.

In summary, all the main components in the primary sodium systems of FBTR in the as-built conditions meet the seismic design requirements.

(Reported by P. Chellapandi, REG)

Experiences during Replacement of Rupture Disc Assemblies for FBTR Secondary Sodium System

Rupture Disc Assemblies are provided in the sodium inlet/outlet headers of steam generators and in expansion tank cover gas space in the secondary sodium system of FBTR. These safety devices protect the system and components from over pressurization resulting from any sodium-water reaction in the Steam Generator. The existing rupture disc assemblies were of knife edge type developed in-house through an elaborate fabrication and testing programme, in view of nonavailability of an indigenous supplier. Thanks to good fabrication standards, no water leaks happened and rupture discs were not called to play their role. However, as a good operation practice, it was required by safety bodies to take out one set of assemblies and test them for any degradation. As no spare assemblies were available and indigenous capability to manufacture state of the art scored rupture discs existed with M/s. BS&B Safety Systems, Chennai, a development order was placed on them.

As per specification, the rupture discs (Figure 1) are to be seal welded to the mating flange. This requirement has come from the usage of liquid sodium as the process fluid

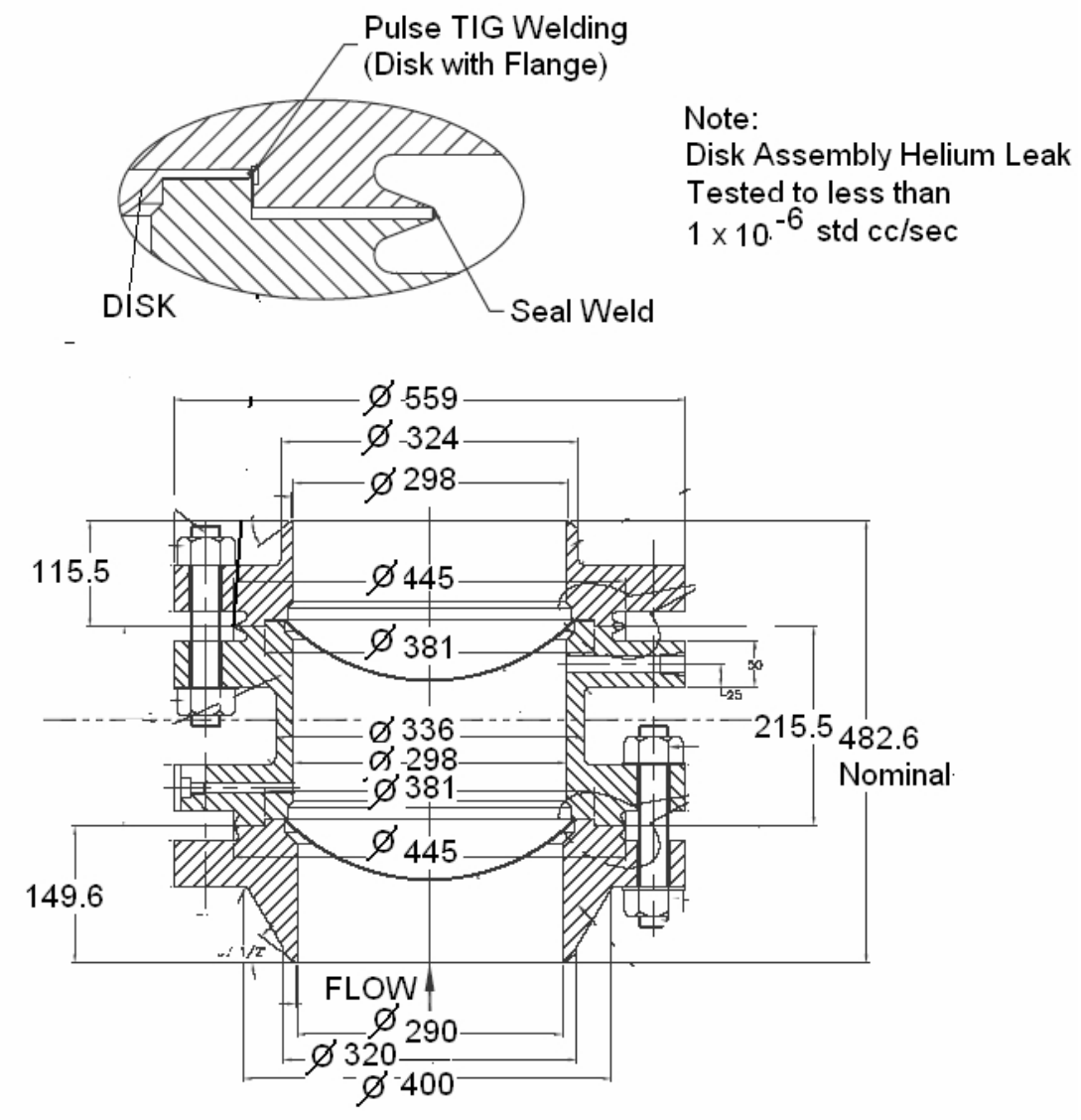


Figure 1 : Steam generator rupture disc

Figure 2 : Removed steam generator rupture disc assembly

Figure 3 : Frozen sodium after removing the SG rupture disc

used in FBTR which is highly reactive with moisture and air. Normally no welding will be done on rupture discs after its manufacture as welding will alter the rupture setting of the discs. Sufficient care was taken in minimizing the weld heat transferring to the disc. This assembly was burst tested in an oven at the operating temperature (515°C). The rupture disc which was designed for 8.2 kg/cm^2 setting has ruptured within the acceptable tolerance, justifying the procedure followed for seal welding.

Replacement of expansion tank rupture disc assembly was taken up first. The existing rupture disc assembly was cut by grinding. A large amount of sodium was found accumulated in the upstream of the rupture disc assembly. The sodium was cleaned from the pipe line. Seal plugs were installed in the upstream side and downstream side to prevent ingress of air and to conserve argon during edge preparation, edge dye penetration test and trial fit up. After removing the sealing plugs, fit up was done and the new rupture disc assembly was welded by the Gas Tungsten Arc Welding (GTAW) process. Purging requirement for the welding of upstream side joint was met from the system side and downstream side from external supply.

Replacement of steam generator inlet header rupture disc assembly was taken up next. For this, the expansion joint in the cyclone separator side of the rupture disc was dismantled. Special handling fixture was made for handling the rupture disc assembly. The existing rupture disc assembly (Figure 2) was cut and removed from its position. The sodium inlet header was found partially filled with sodium (Figure 3) as there is no provision for draining the sodium fully from the header. The cutting, sodium cleaning and welding works were to be carried out in an area with limited access from outside. Special tools were made for frozen sodium removal and cleaning. The header was completely cleaned off sodium (~ 30 kg). Special seal plugs were used for sealing the opening to prevent air ingress during the various operations. Welding the new assembly was carried out by following the same procedure.

Finally, replacement of steam generator outlet rupture disc assembly was done. The location of this assembly was found to be more congested than the inlet. The sodium outlet header was also found partially filled with sodium as observed in the inlet header. The existing assembly removal, sodium cleaning and welding were done safely without any fire incident. The weld joints of all the rupture disc assemblies were qualified by Gamma radiography and argon sniffing. After replacing the rupture discs the system was filled with sodium. The plugging temperature was increased to 120°C and this gave the testimony of the extent of sodium cleaning and non-entry of air & moisture into the system during the work.

The removed rupture discs were then cleaned to remove sodium deposits, by immersing them in hot thermo-fluid oil. Both the assemblies were then tested at room temperature to find out its rupturing pressure using a separate setup. The rupturing pressure was found to be within the design bursting pressure range, indicating no degradation over the years.

The complete execution of the replacement work was planned meticulously and with utmost care. The various activities planned required special care due to the presence of large quantity of sodium and congested locations and presence of inert gas argon in the vicinity of the work. The personnel involved have carried out the task in a safe and commendable manner. The experience gained during this work has instilled tremendous confidence in the working group to take up similar challenging jobs in the future.

(Reported by S.Varadarajan and A.Babu, ROMG)

Young Officer's FORUM

Aspects of Evolution and Characterization of Microstructural Topology during Industrial Scale Thermo-mechanical processing of Alloy D9

Shri Sumantra Mandal obtained his B.E. degree in Metallurgical Engineering from B.E. College, Shibpur in 2002 and M.Tech degree in Materials and Metallurgical Engineering from IIT, Kanpur in 2004 under DAE Graduate Fellowship Scheme (DGFS). He is from DGFS-2002 batch and joined IGCAR as Scientific Officer (SO/C) in September 2004.

Understanding the kinetics and mechanism of microstructural evolution during thermo-mechanical processing of materials is required in order to optimize the microstructure and properties in the formed product. Towards this, kinetics and micro-mechanism of the dynamic processes of alloy D9 has been investigated by performing various industrial scale metal forming processes such as hammer forging, hydraulic press forging and rolling. These hot forming operations have been carried out in a wide range of temperatures (1223 – 1423K) and strains (0.1 – 0.5) in order to understand the complete dynamic recrystallization behaviour of alloy D9.

A modified JMAK (Johnson-Mehl-Avrami-Kolmogorov) model has been employed to investigate the kinetics of dynamic recrystallization in alloy D9. The modified JMAK model is expressed as, $X_v = 1\text{-}exp(\text{-}k\varepsilon^n)$, here, '$X_v$' is the fraction of dynamic recrystallization, 'ε' is true strain, 'k' is constant and 'n' is Avrami exponent or JMAK exponent. According to this modified model, if X_v vs. ε is plotted, it should yield a sigmoidal curve. In Figure 1(a), the plot of X_v vs. ε for forge hammer operation has been drawn. From this Figure one can see that the curves are sigmoidal in nature. According to the modified JMAK model, if $ln(-ln(1-X_v))$ is plotted vs. $ln(\varepsilon)$, it should yield parallel straight lines whose slope would be equal to Avrami exponent, n. Such relationship is plotted and is shown in Figure 1(b). From this figure, one can see that the plots are straight line in nature. The straight lines are almost parallel. Therefore, it can be corroborated that modification carried out in JMAK model is well supported by the experimental results.

The values of Avrami exponent n at different hot-working operations have been found to vary in the close range 1.17-1.34. The variation of the Avrami exponent is associated with the transition from cyclic to single peak dynamic recrystallization. A large value of n (~2) is an indication of cyclic dynamic recrystallization where as a low value of n(~1) conforms to single peak dynamic recrystallization. Therefore, based on the value of n, it could be suggested that alloy D9 exhibits single peak dynamic recrystallization. The single peak dynamic recrystallization is also termed as growth controlled dynamic recrystallization where a large number of growing nuclei are formed and these growing nuclei mutually inhibit grain boundary. As a result grain growth is restricted that eventually leads to grain refinement.

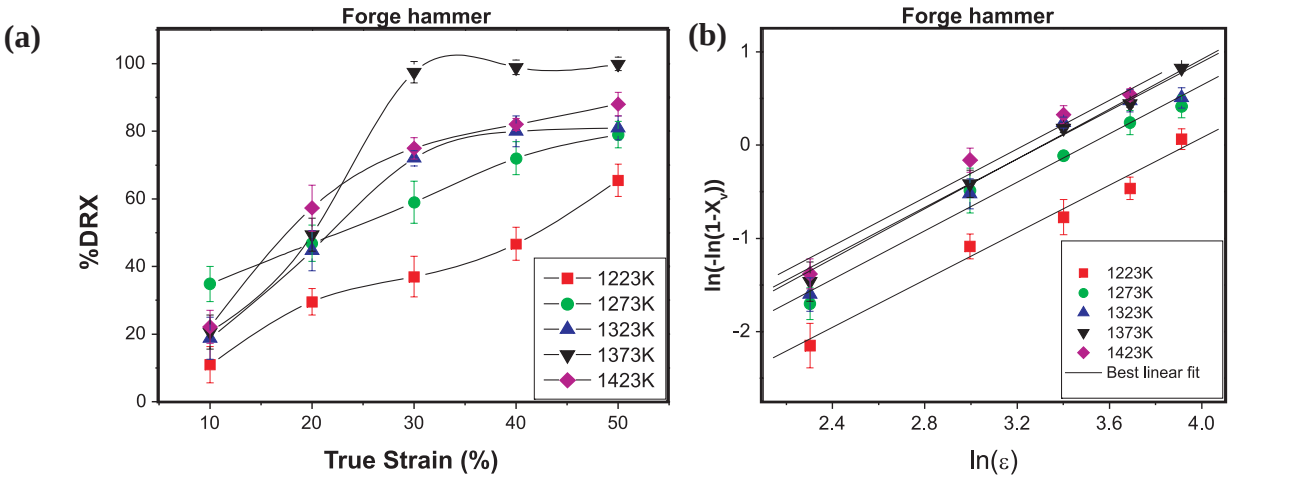


Figure 1 : (a) Effect of strain on recrystallization kinetics (b) modified JMAK plot of dynamic recrystallization kinetics

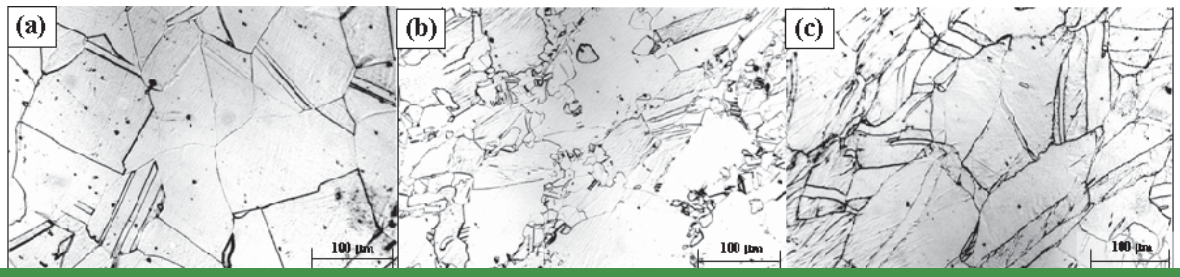


Figure 2 : Microstructural evolution during thermo-mechanical processing of alloy D9 (a) forge hammer: T = 1223 K, ε = 0.1 (b) hydraulic press: T = 1223 K, ε = 0.21 (c) forge hammer: T = 1273 K, ε = 0.28

Some typical microstructural evolution of alloy D9 during industrial scale thermo-mechanical processing is shown in Figure 2. The bulging of parent grain boundary and subsequent evolution of new dynamic recrystallization grain is clearly manifested in Figure 2(b). This signifies that nucleation of dynamic recrystallization takes place in the parent grain boundary by bulging mechanism. The bulging mechanism is able to describe how the first recrystallized grains and, correspondingly, the first layer of new recrystallized grains around the prior grains form. However, this mechanism could not be accounted for the expansion of the necklace structure throughout the deformed matrix. This is because, in course of dynamic recrystallization when pre-existing grain boundaries are entirely covered by new grains (site saturation), bulging would have to proceed from the small recrystallized grains that requires a very high boundary curvature. This makes further nucleation by bulging unlikely, because the very high driving force necessary to offset the high surface tension of the bulge is not available in hot deformed microstructure.

The most crucial step for nucleation of dynamic recrystallization in the deformed matrix is generation of mobile grain boundary. The mobility increases with increasing misorientations, but a 10-15 degree mis-orientation is commonly assumed to be necessary. From the Orientation Image Microscopy (OIM) map [Figure 3(a)] and corresponding misorientation distribution plot [Figure 3(b)], it has been seen that relative frequency of misorientations in excess of 10 degrees was significantly low. On the other hand an appreciable amount of large misorientations (>55 degrees) are observed in the matrix which could be accounted for twin boundaries. The substantial amounts of twins are also observed in optical micrograph. From the Electron Back Scattered Diffraction studies (EBSD), it has been observed that no significant texture component has been developed in the recrystallized volume. It has been reported that multiple twining results in moderation of texture in the matrix. So, from the present observations, it seems twin may play an important role during the nucleation and subsequent expansion of dynamic recrystallization in alloy D9, which in turn moderate the texture in the recrystallized matrix.

Imaging of microstructural features through non-destructive ultrasonic measurements is advantageous as the average of the microstructural features in the thickness direction is revealed by ultrasonic measurements as compared to only surface information through metallographic techniques. A new methodology based on ultrasonic C-scan presentation has been identified to image the microstuctural evolution of alloy D9 during dynamic recrystallization, establishing the viability of non-destructive assessment of recrystallization in the entire volume of the product to ensure its high quality and reliability. Even though the C-scan imaging has been extensively used for defect detection applications, a conventional C-scan imaging system has been used in this study for imaging the microstructural variations in the specimen by selecting the amplitude of first backwall echo. Further, to corroborate the C-scan results, detailed EBSD studies have been carried out.

The C-scan images generated based on the amplitude of the first backwall echoes from the specimen with true strain values of 0.2 and 0.5 are shows in Figure 4(a) and 4(b) respectively. It could be observed that the specimen

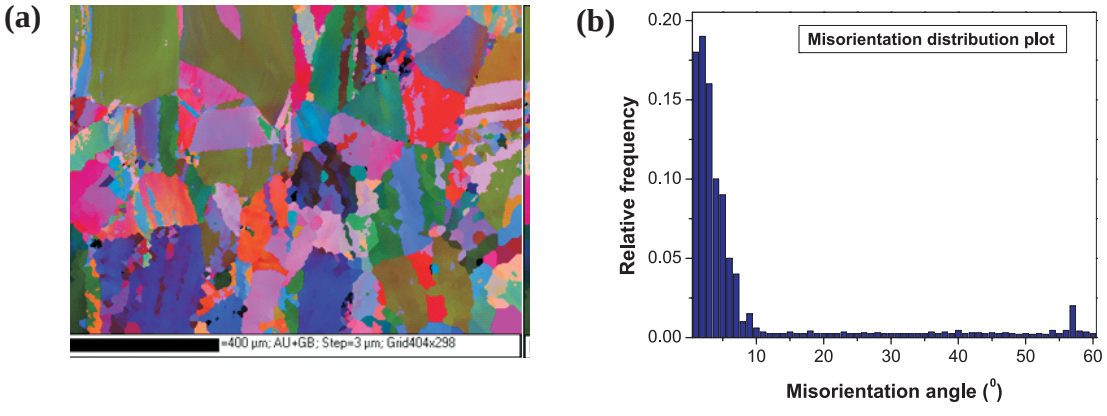


Figure 3: (a) Orientation Image Microscopy map and (b) corresponding misorientation distribution plot of the forge hammered sample hot worked at 1273 K temperature with 0.2 strain

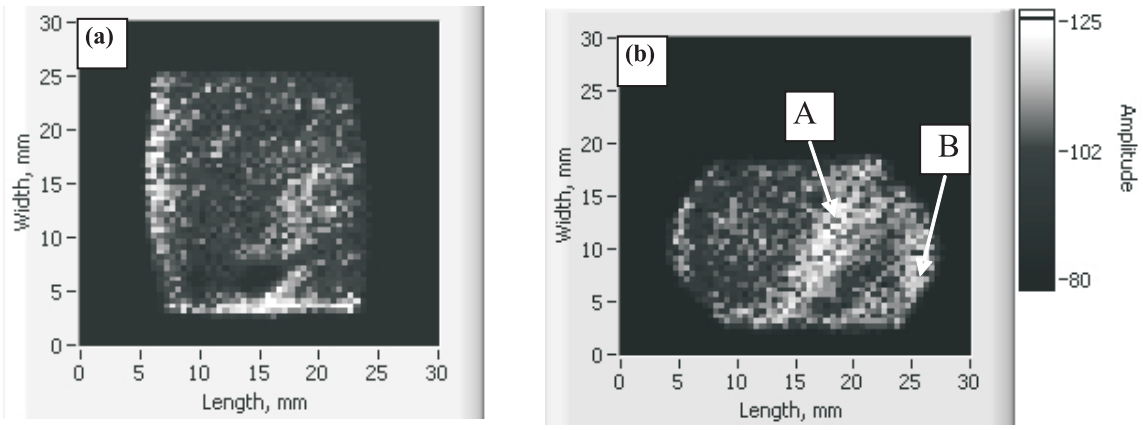


Figure 4 : C-scan image of samples forged in hydraulic press at 1273 K to a strain of (a) 0.2 and (b) 0.5

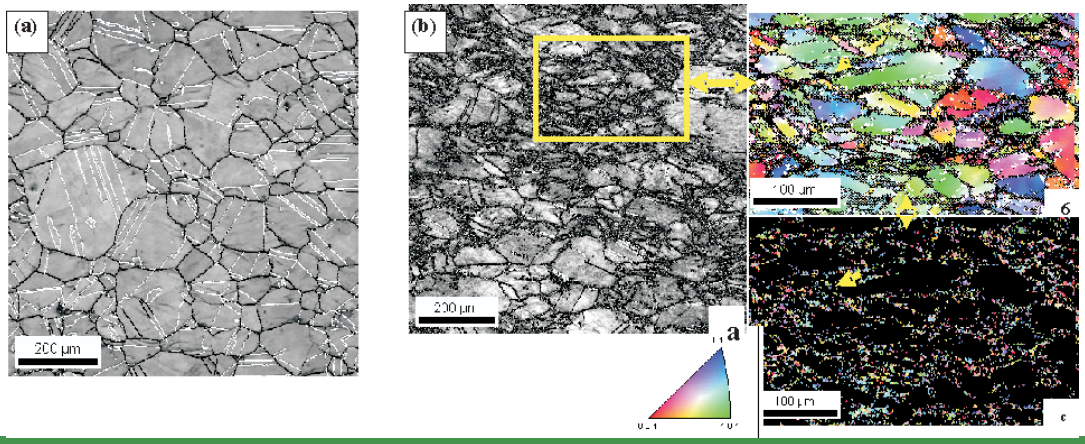


Figure 5: EBSD map of the specimens forged at 1273 K to a strain of (a) 0.2 and (b) 0.5

with 0.2 strain does not show any variation in the amplitude of the first backwall echo. The specimen forged to 0.5 strain could clearly bring out systematic variation in the amplitude of the first back wall echo. It exhibits higher amplitude of the first backwall echoes along one of the diagonals and one of the curved sides [marked as A and B in Figure 4(b)]. It has been shown in our recent study that attenuation of ultrasonic wave of a particular frequency in alloy D9 is mainly governed by grain size. The specimen with larger grain size has been found to scatter more as compared to the finer one. Accordingly, larger grain size leads to lower amplitude of first backwall echoes and vice versa. This observation could be employed to analyze the findings of C-scan images as shown in Figure 4(a) and 4(b). Since specimen with 0.2 strain does not show any perceptible variation in the amplitude of the first back wall echo, it is likely that this specimen contains almost uniform grain size distribution. This could be corroborated from the image quality (IQ) map of this specimen as shown in Figure 5(a). It could be observed that the microstructure consisted of big parent grains along with continuous twin boundary. The dynamic recrystallization, which could provide non-uniformity in grain size distribution, is yet to set in these deformation conditions.

As shown in Figure 4(b), the specimen with 0.5 strain exhibits higher amplitude of the first backwall echoes along one of the diagonal and one of the curved sides. The higher amplitudes in these areas undoubtedly indicate presence of finer grains, which could only arise due to higher deformations and subsequent dynamic recrystallization in these zones. In order to elucidate the variations in C-scan image, a detailed EBSD studies has been carried out on this specimen. The IQ map of this specimen is shown in Figure 5(b). It could be observed that the hot deformed microstructure at this strain level has two distinct features – large deformed grains and nearly equiaxed grains forming on the grain boundaries. The marked rectangular section of Figure 5(b) has been brought out as inverse pole figure map, with more than five degree boundaries and twin boundaries marked respectively as dark and white lines. The presence of the nearly equiaxed grains signifies the initiation of 'necklace grains' dynamic recrystallization [shown by arrow]. So, it is quite evident that the non-uniform distribution of grain size due to initiation of dynamic recrystallization in this specimen has actually provided the variation in C-scan. The EBSD studies, therefore, substantiate that the ultrasonic C-scan system can be used for imaging the variations in microstructure, in particular grain size, in the specimens. As a logical extension, a systematic study has been initiated to combine on-line process parameters and ultrasonic signal to predict the grain size and the percentage recrystallization and thus the mechanical properties to use as a feed back that aids intelligent processing of materials.

(Sumantra Mandal and colleagues in Materials Technology Division, MMG)*

He is the recipient of 'INAE Young Engineer Award 2007' for this work

Young Researcher's FORUM

Microbiology in Metallurgy: Microbiologist in Metallurgy

Ms.Judy Gopal has obtained an interdisciplinary Ph.D. in Microbiology-Metallurgy in the year 2007. During her research work at IGCAR, she also worked on a three year collaborative project with the IISc. Bangalore. She has published 15 papers in national and international journals and has 9 best paper awards to her credit. She is presently working on materials characterization using AFM in CSTD-RPM, MMG and designated as Visiting Scientist.

Background

The official reason why a microbiologist like me had something to do in the metallurgy division of IGCAR for a good long period of five years was only because microbes had something to do with metallurgy. Besides, my interaction with IGCAR as research scholar was made possible because of the metal-microbes interactions, so a big thank you to them. To name a few of the metal-microbe interactions

- Biofouling
- Biocorrosion
- Biomineralisation
- Biodegradation
- Bioaccumulation
- Bioremediation

Of these, my work focused much on Biofouling, Biocorrosion and Biomineralisation. All these areas fall within the mandate of IGCAR's research and development interest because of the materials used as condenser tubes in the cooling water system. The seawater flowing within these condenser tubes, due to the presence of natural micro and macroorganisms result in biofouling, biocorrosion and biomineralisation of material surface in contact with them. So, this called for special attention and hence a collaboration project between the Indian Institute of Science and IGCAR was initialized to look into biomineralisation and biofouling of titanium.

Since titanium is proposed as the condenser material for the Prototype Fast Breeder Reactor (PFBR), my research work focused on studying the probability of biofouling of titanium in the coastal waters of Kalpakkam, possibility of biomineralisation of manganese on titanium surfaces and finally control of biofouling on titanium surfaces by surface modification.

Biofouling of titanium in the coastal waters of Kalpakkam

Titanium is being used as heat exchange material in sea water cooled power plant all over the world and also is to be used in the PFBR because of its excellent corrosion resistance and total immunity to Microbially Influenced Corrosion (MIC). But titanium is reported to be highly susceptible to biofouling because of its inert nature and biocompatibility. Biofouling in condenser tubes leads to reduction in the heat transfer efficiency of the material as well poses a physical obstruction to the flow of water. Biofouling is not a standard phenomenon and depends on the type of material, environment, seasonal variation

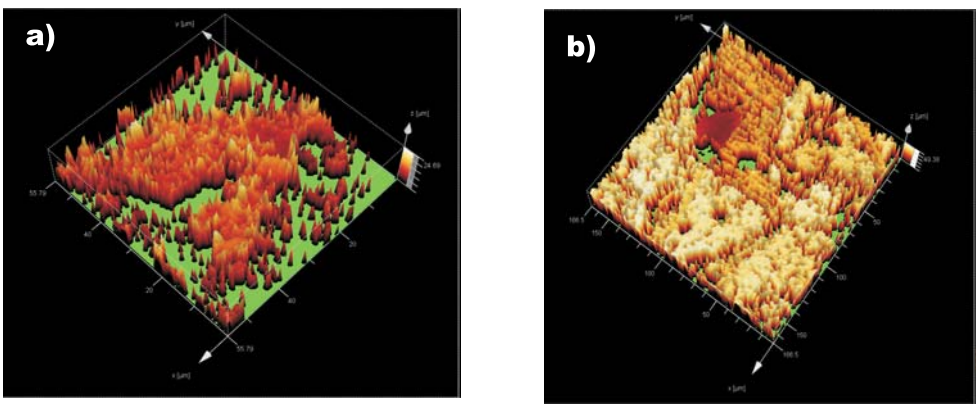


Figure 1 : Confocal Laser Scanning (CLS) micrographs showing (a) one week and (b) one year old biofilm formed on titanium surfaces exposed to seawater

etc. Therefore, although it was established by studies conducted elsewhere that titanium is susceptible to biofouling, efforts were made to study the extent of biofouling on titanium surfaces in the coastal environment of Kalpakkam. These studies were conducted for a period of two years as a part of the IISc-IGCAR collaborative project. The results of these studies showed that the titanium surface was prone to biofouling and was a home to a large number of microorganisms. The biofouling reported occurred in spite of the fact that the seawater used for exposing the coupons was treated (containing 0.1-0.3 ppm residual chlorine). Figure 1 shows the increase in biofouling on titanium surfaces as a function of exposure time. These studies showed that chlorination was successful in controlling the fouling of macrofoulants (only exception was a serpulid worm which occurred in large numbers, reported to be resistant to chlorination) while majority of the marine bacteria and marine microalgae were resistant to the above mentioned levels of chlorination. Therefore the problem of fouling in titanium surfaces exposed to chlorinated seawater was identified to be more of microfouling rather than macrofouling.

Biomineralisation of titanium in the coastal waters of Kalpakkam

Formation of biogenic manganese oxide on the condenser tube surfaces and resulting decrease in heat transfer have been reported from a US power plant that changed over from 90/10 Cu-Ni alloy tubes to Type 304 stainless steel tubes for its condenser. Biomineralisation on titanium surface has been reported to further reduce the heat transfer properties as well as make the biofilm refractory to treatment regimes. In order to understand the manganese oxidizing potential of various bacterial species (since microbial fouling was the major problem in spite of chlorination) present in the coastal waters of Kalpakkam, a study has been carried out to isolate and characterize various bacterial species present in the biofilm formed on titanium surfaces exposed to the seawater. The results showed that a large number of manganese oxidizing bacteria were able to survive low residual chlorine levels and produce an enrichment of manganese on the titanium surface (Figure 2). Also, 60-80% of the bacteria in titanium biofilm were capable of oxidizing manganese(II), and so the possibility of biomineralisation of manganese dioxide cannot be ruled out. Finally, periodic atomic absorption spectroscopic analysis showed that there was an accumulation of manganese in the seawater biofilm formed on titanium, indicating signs of initiation of biomineralisation by the bacteria present in biofilm formed on titanium surfaces exposed to the coastal waters of Kalpakkam.

Surface modification of titanium to control microbial fouling

From the condenser point of view, chlorination and mechanical sponge ball cleaning do play a significant role in condenser tube clean up and maintenance. However if the fouling rates are high clean up operations become more difficult. Increasing the chlorination dosage may seem a catchy option but the final outcome involves environmental risks such as danger to aquatic flora and fauna. Increasing mechanical sponge ball cleaning

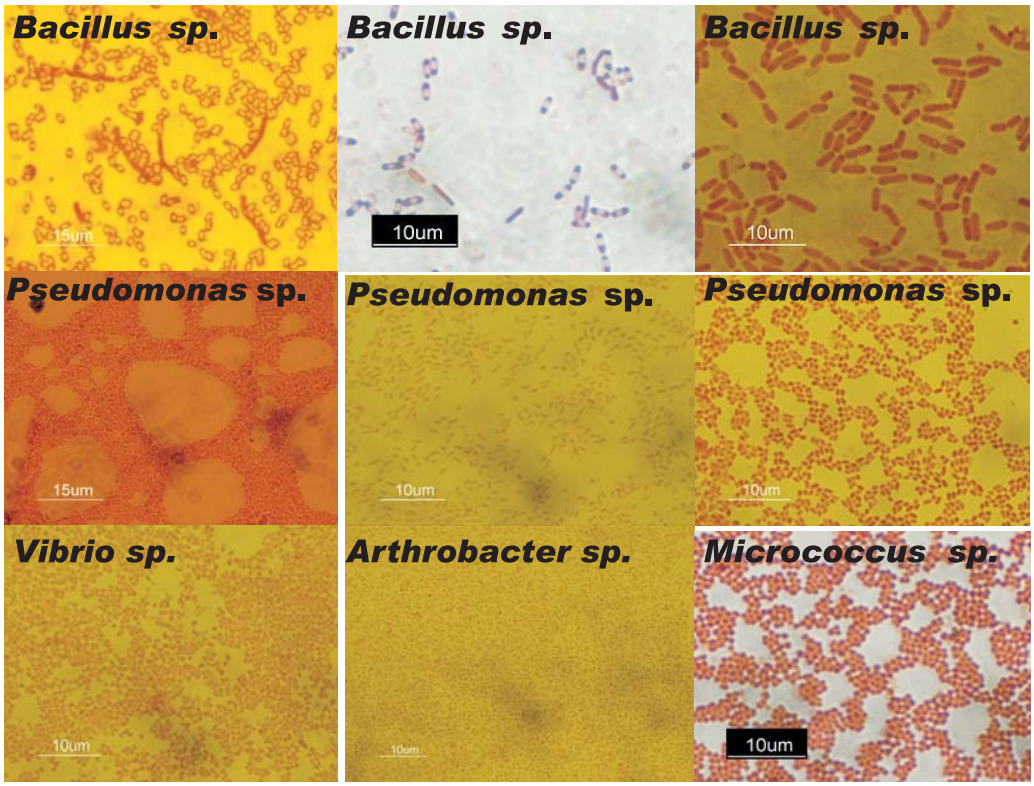


Figure 2 : Predominant manganese oxidizing bacteria isolated from the marine biofilm formed on titanium surface exposed to seawater

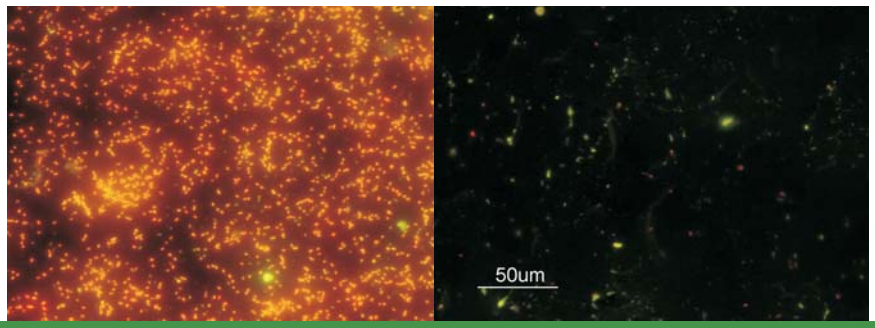


Figure 3 : Epifluorescence micrographs showing significant reduction in attachment of bacterial cells on acid pickled titanium surfaces and surfaces modified by anodizing (anodized and heat treated- 30V/48 hours)

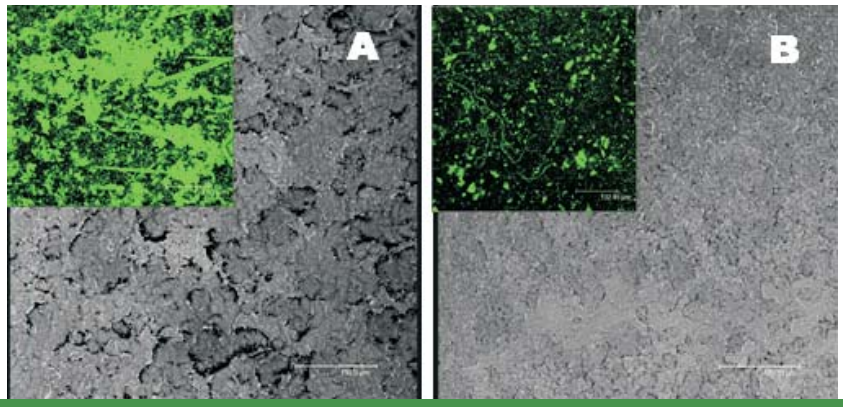


Figure 4 : CLSM images of the (A) Control, (B) Repeatedly pickled surfaces acquired in reflection mode, Inset represents biofouling on these surfaces, imaged in fluorescence mode

increases risk of abrasion of the material surface especially in case of titanium, which is a light metal. Innumerable studies have shown that no single treatment program can inhibit fouling, so we need to probe for other methods which can be used in addition to the existing ones to combat the problem of biofouling. Therefore, it is necessary to look for methods of modifying the titanium surface so as to reduce the density of foulants settling on the surface.

Taking cue from the vast literature on the photocatalytic activity of semi conducting oxides especially the anatase form of titanium oxide, studies were carried out to see whether microbial attachment on Ti and Ti_6Al_4V alloy surfaces can be reduced by photocatalytic killing of the cells. The anodizing parameters were optimized to produce the best anatase film as confirmed by Glancing Incidence X-ray diffraction (GIXRD), Atomic Force Microscopy (AFM) and photocatalytic degradation of methylene blue dye. From Figure 3 it can be seen that significant reduction in microbial fouling was observed on the anodized surface under near-UV illumination (350-380nm) using black light blue (BLB) fluorescent lamps. It was also found that anodized Ti_6Al_4V alloy shows better photocatalytic cell killing than anodized Ti. The GIXRD and AFM results showed that the oxide formed on anodized alloy has higher crystallinity and is composed of particles, which are smaller in size; both these attributes are reported to enhance photocatalytic activity. It was also observed that anodized Ti_6Al_4V surface showed bactericidal effect even in visible light, probably due to the presence of vanadium in the titanium oxide lattice that is reported to shift the photo response of the anatase to visible range. Heat treatment of the anodized Ti surfaces at 500°C for three hours was found to improve the bactericidal property of the surface by an order of magnitude. Structural characterization of the oxide by GIXRD showed that there was partial conversion of anatase to rutile on heat treatment and it has been demonstrated by earlier workers that a mixture of anatase and rutile is a better photocatalyst than anatase alone. Thus, our extensive studies on Ti and Ti_6Al_4V alloy has shown that anodization is an effective surface modification method to reduce bacterial attachment on these surfaces.

Repeated pickling (five cycles of five minutes each) in an HNO_3: HF bath was also observed to bring about an order of magnitude reduction in microbial fouling on titanium surfaces. The CLSM based surface analysis showed that the microroughness decreased with increasing pickling cycles, up to an optimum number of five pickling cycles. Figure 4 depicts the effect of microroughness reduction on the reduction in biofouling.

Thus, all these studies indicate that biofouling should not be overlooked and techniques like surface modification of titanium are effective in controlling fouling of titanium surfaces and need to be used in conjugation with the existing treatment programs to achieve fouling free condenser operation.

(Judy Gopal,
Corrosion Science and Technology Division,
MMG)

NEWS AND EVENTS

Conference / Meeting Highlights

Sixteenth DAE-BRNS "National Symposium and Workshop on Thermal Analysis" (THERMANS-2008)

February 4-8, 2008

Delegates of THERMANS-2008 from various academic and research institutes

The sixteenth DAE-BRNS "National Symposium and Workshop on Thermal Analysis" (THERMANS-2008) was organized by Indian Thermal Analysis Society (ITAS) and IGCAR during February, 4-8, 2008. The symposium was held in the Sarabhai Auditorium at IGCAR during February 4-6, 2008 followed by a two-day workshop at the Seminar Hall of the Safety Research Institute Guest House during February 7 and 8, 2008. In all, there were 220 registered participants. Nearly half of them were from the academic and research institutions with a significant percentage of student and research scholar participants.

The symposium was inaugurated by Dr. Baldev Raj, Director, IGCAR. In his thought provoking inaugural address, Dr. Baldev Raj emphasized the need for bringing out good quality text books in Thermal Analysis for improving the standard of teaching of the subject in academic institutions. He also pointed out that the best way to enthuse the young researchers is to give challenging assignments to them. There were twelve invited talks covering the various facets of thermo analytical techniques. Five of them were delivered by scientists from abroad. The symposium and workshop had emphasis on the enthusing young researchers for active participation. All the twenty oral presentations of the one hundred and twenty contributed papers were by young researchers. The rest of the papers were presented as posters in two sessions. An introduction to the posters was given before each of the poster session. There were four lectures from the equipment manufacturers on the latest developments in the field. It included a lecture on the thermochemical computational software, THERMOCALC. The valedictory function was chaired by Dr. P.V. Ravindran, Anaytical Chemistry Division, BARC.

The THERMANS workshop was inaugurated by Dr. S.R. Dharwadkar, Institute of Science, Mumbai who is a doyen of thermodynamics. In the workshop, there were totally forty five participants comprising of research scholars and students. There were eleven invited lectures by eminent scientists on the various aspects of thermal analysis. The workshop had discussions on various experimental techniques like transpiration method, galvanic cell methods, calorimetry etc. Prof. A.D. Pelton, one of the developers of the FACTSAGE software conducted a two day, hands-on workshop on the software. Thirty eight participants from DAE and other academic and research institutes attended the workshop and learnt how to use the software for various applications including phase diagram computations.

(Reported by K. Nagarajan, Co-Chairman, THERMANS-2008)

"International Conference on Advances in Manufacturing Technology" (ICAMT 2008) for Young Engineers

February 6-8, 2008

Dr. P.S. Goel, President, INAE releasing the CD proceedings of ICAMT 2008 and giving the first copy to Dr. Baldev Raj, Chairman, ICAMT 2008 and Director, IGCAR

International Conference on Advances in Manufacturing Technology (ICAMT 2008) for Young Engineers was conducted jointly by DAE and Indian National Academy of Engineering (INAE) in Chennai during February 6-8, 2008. IGCAR took the lead role and organised the conference. The main objective of ICAMT 2008 was to bring together young engineers, scientists, academicians and technocrats and to provide a comprehensive forum for discussing the recent advances and futuristic trends in manufacturing technology including rapid prototyping, materials modelling, micro-machining, TQM, CAD/CAM, CIM, plant layout, automation, robotics, sensors, artificial intelligence and human resource development. During the inaugural function held on 6th February 2008, Dr. Baldev Raj, Chairman, ICAMT 2008 and Director, IGCAR welcomed the invited speakers and delegates from India and abroad and elucidated the origin of this conference theme based on the suggestion and encouragement of mentors like Dr. R. Chidambaram, Dr. Anil Kakodkar and Dr. K. Kasturirangan. Dr. P.S. Goel, President, INAE inaugurated the conference and released the Souvenir and CD proceedings. As part of the inaugural function, Dr. Baldev Raj gave a plenary lecture on 'A Perspective on Engineering Manufacturing'.

ICAMT 2008 received nearly equal participation from academics, research and industry. Forty five international experts delivered motivating invited talks and two hundred and fifty delegates including seventy young engineers participated. There were twenty international delegates from Australia, Brazil, Germany, Japan, Malaysia, Singapore, South Korea, UK and USA. During the conference, one hundred and seventy five papers were presented in three parallel sessions. Each parallel session started with invited talks by eminent speakers on specific topics followed by contributory papers. Wide range of topics covered include advances in micro and nano machining, emerging trends in material modeling and product development, designers perspective on manufacturing technology, rapid prototyping and role of design in cost reduction during manufacture. There were four invited talks and twenty one contributed talks from IGCAR. Quiz and essay writing competition were conducted for the young engineers. The trainee engineers of IGCAR training school also took part in the conference and the competitions. A unique panel discussion on 'Advances in manufacturing processes and product development' was conducted on February 8, 2008 and this was followed by the valedictory function in which Prof. M.S. Ananth, Director, IIT Madras delivered the valedictory address. Speaking during the function, Dr. Baldev Raj advised the young engineers to strengthen the research networks they established during this conference with mentors and aim big towards developing innovative products for making India a developed nation. He stressed the need to scale up this conference to 'Olympics of Manufacturing' to be conducted every four years and to honour the best manufacturing ideas in chosen key areas of manufacturing science and technology. He gave away prizes and merit certificates to the winners of quiz and essays competitions and also presented the best presentation awards.

(Reported by B.P.C. Rao, Convener, ICAMT 2008)

Theme meeting on "Structure and Thermodynamics of Emerging Materials" (STEM-2008)

April 17-18, 2008

Dr. S. Banerjee, Director, BARC and President, IIM , Dr. Baldev Raj, Director, IGCAR, Prof. S.Ranganathan and other senior colleagues of the Centre during the inaugural session

STEM-2008 was organized during April 17 & 18, 2008 at Convention Centre, Anupuram, to review the recent advances in the "Structure and Thermodynamics of Emerging Materials" and identify emerging directions. Dr.P.R.Vasudeva Rao, Director, MMG welcomed the gathering and the meeting was inaugurated by Dr. S. Banerjee, Director, BARC and President, IIM. He gave an in-depth analysis of the pioneering work on zirconium alloys and provided an insight into the understanding wide spectrum of apparently different transformations, in terms of a single mechanism: namely the instability of the *bcc* lattice to different types of external stimuli. Dr. S. Banerjee also discussed how a unified understanding would enable prediction of behaviour of emerging thorium based systems, which exhibit similar tendencies. Dr. Baldev Raj, Director, IGCAR delivered the theme address highlighting the role of "Structure and thermodynamics in the design of newer materials for the nuclear industry". He explained the evolving trends in materials development and the need of the present century to shorten the span of time for development through interdisciplinary activities and reliable predictive abilities. The plenary lecture "New geometries for new materials" by Prof. S. Ranganathan, INAE Distinguished Professor, IISc, Bangaluru was an excellent review of the physical metallurgical principles behind the geometrical shapes that different systems assume. Dr. K. Bhanu Sankara Rao, Associate Director, Materials Development and Characterisation Group, discussed the genesis of STEM-2008 and Dr. M. Vijayalakshmi, Head, Physical Metallurgy Division and Convener, STEM-2008 delivered the vote of thanks.

There were lectures by eminent scientists from all over the country and stimulating discussions on various focused themes like materials characterization at atomic level, Diffusion and Phase Transformations, Functional Nanomaterials, Emerging trends on texture studies, Thermodynamics and Kinetics, Computational methods in Physical Metallurgy, Emerging Materials and Microstructure & Microtexture. Specialists from various academic and R&D institutions like Indian Institute of Science, IITs, DMRL, R&D, Tata Steel, NIST-Thiruvananthapuram, PSG College-Coimbatore and many others, delivered twenty seven presentations on various themes related to structure and thermodynamics of emerging materials. About 150 delegates from academic and R&D institutes have participated in the two-day deliberations.

(Reported by M. Vijayalakshmi, Convener, STEM-2008)

Theme Meeting on "Recent Advances in Post Irradiation Examination (PIE)" (RAP-2008)

May 22-24, 2008

Dr. Baldev Raj, Director, IGCAR and senior colleagues of the Centre and BARC during panel discussion

A theme meeting on "Recent Advances in Post Irradiation Examination (PIE)" (RAP-2008) was organized by IGCAR and sponsored by Board of Research in Nuclear Sciences, Mumbai during May 22-24, 2008 at Convention Centre, Anupuram. The theme meeting was intended to bring together experts and researchers working in the area of PIE and related fields such as fuel fabrication, irradiation experiments and fuel design and to identify the challenges ahead and draw a road map for the future work. Shri K.V.Kasiviswanathan, Chairman, RAP-2008, welcomed the delegates and distinguished invitees and gave a brief genesis of the theme meeting. Shri S.Ananatharaman, Co-Chairman, RAP-2008 presented the details of the technical programme and the organization of the various technical sessions. Shri P.V. Ramalingam, Director ROMG, IGCAR presided over the inaugural function. The theme meeting was inaugurated by Shri H.S. Kamath, Director, Nuclear Fuels Group, BARC who also delivered the plenary lecture on "Fuel performance issues in thermal reactors". Shri H.S. Kamath released the CD containing the proceedings of the theme meeting. The three day theme meeting was organized in ten technical sessions covering a broad spectrum of topics under various themes. A total of hundred and forty delegates from IGCAR, BARC, NPCIL, NFC and academic institutions participated in the theme meeting. One plenary talk and seventeen invited talks were delivered by experts in the field and more than sixty contributed papers were presented in the form of oral and poster presentations which included many young scientists and engineers. On the concluding day of the theme meeting, the panel discussion was chaired by Dr. Baldev Raj, Director, IGCAR. The following points were highlighted during the panel discussion.

- Facilities and advanced analytical equipments for in-depth studies
- Data generation, documentation and modeling
- Standardisation, benchmarking, traceability and computerization
- Planning of irradiation experiments
- Human resources for PIE

Director IGCAR concluded the panel discussion stressing on the need for integrating PIE with the academia and industry for realizing the end goals. He also urged the PIE community to reach out to the industry and nurture them for more role in designing equipments for PIE.

(Reported by N.G. Muralidharan, Convener, RAP-2008)

Visit of Dignitaries to IGCAR

During his visit to Kalpakkam, **Dr. Anil Kakodkar**, Chairman, AEC met the Trainee Scientific Officers and Research Scholars of the Centre on **April 5, 2008** at the Research Scholars Enclave. Dr. Baldev Raj, Director, IGCAR was present during the lively interactive session. Chairman enlightened the students on the prospects of pursuing R&D at a mission based Centre like IGCAR and advised them on taking great strides. He patiently answered to several of their queries.

Dr. Anil Kakodkar, Chairman, AEC and Dr. Baldev Raj, Director, IGCAR during interaction session

Dr. Bernard Bigot, Dr. Claude Guet & Dr. Hugues De Longevialle from CEA, France visited the Centre during **April 13-14, 2008**. The team held discussions with the Director, IGCAR and senior colleagues of the Centre on the status of R&D related to FBR in India and France. Dr. Bigot also put forward the strategies adopted to attract young talent towards Nuclear programmes in his country. They visited the Fast Breeder Test Reactor, Hot cells and Non destructive evaluation laboratory, Sensor laboratory and Construction site of Prototype Fast Breeder Reactor. Dr. Bigot addressed the student community of IGCAR comprising of Trainee Scientific Officers and Research Scholars.

Dr. Bernard Bigot, Dr. Claude Guet & Dr. Hugues De Longevialle from CEA, France during discussions with Dr.Baldev Raj, Director, IGCAR

Visit of Dignitaries

The **Members of Atomic Energy Regulatory Board** headed by Shri S.K.Sharma, Chairman, AERB, visited the Centre on **May 2, 2008**. Dr. Baldev Raj, Director, IGCAR made a presentation on the "*Perspective on Fast Breeder Reactors and Associated Fuel Cycle Research and Facilities at IGCAR and Kalpakkam*". A discussion with the senior colleagues of the Centre on issues related to the Fast Breeder Reactor Technology, Operation Cycle of PFBR, next generation FBRs including metal fuelled and Hydrogen based fusion reactors followed the presentation. After the discussions they visited sodium facilities of Fast Reactor Technology Group, Structural Mechanics Laboratory and facilities in Safety Group.

Shri S.K.Sharma, Chairman, AERB and other board members of AERB during discussion with Dr. Baldev Raj, Director, IGCAR and senior colleagues

Forthcoming Meetings / Conferences

Conference on "Role of IT-Enabled Knowledge Management in Growth of India" (SANGOSHTHI 2008)

July 24-26, 2008

The conference aims to discuss the implementation / acceptance of Knowledge Management in the various interrelated areas like libraries, industries, higher education system and societal development. The organisers also aim to explore the areas of commonality, where sharing of resources and knowledge is possible among these different areas.

Theme: Role of IT-Enabled Knowledge Management in Growth of India

Sub-Topics:

- Knowledge Management and Digital Libraries
- Knowledge Management for overall growth of India Industry
- Knowledge Management in Higher Education System
- Knowledge Management in Health Care
- Knowledge Management in Financial Sector
- Knowledge Management for Rural and Societal Development

Organised by: Library & Information Science Promotion Society (LISPS), Kalpakkam

In association with: IGCAR, BARC(F), BHAVINI and NPCIL, Kalpakkam

For more information , Please contact:

Dr. T.S. Rao
Secretary, Sangoshthi:2008
WSCD, BARC(F), Kalpakkam – 603 102,
Tamil Nadu , India
Phone : +91 44 27480203
Fax : +91 44 27480097
Mobile : 094451 69589
Email : subbarao@igcar.gov.in
Website : http://www.lisps-india.org/sangoshthi/

- **Dr. Baldev Raj,** *Director, IGCAR* has been nominated as a Member of the Governing Body, Sree Chithra Tirunal Institute of Medical Sciences & Technology, Thiruvananthapuram.
- **Shri S.C.Chetal,** *Director, Reactor Engineering Group* has been awarded Vividhlaxi Audyogik Samshodhan Vikas Kendra (VASVIK) award for the year 2003 for his contribution towards research in Mechanical & Structural Sciences and Technology.
- **Dr. A.K. Bhaduri,** *Head, Materials Technology Division, Metallurgy and Materials Group* has been awarded the VASVIK award for the year 2005 jointly with **Dr.Gautam Kumar Dey** *of BARC* for their contribution towards research in Material & Metallurgical Sciences and Technology.
- **Dr.Shaju K. Albert,** *Materials Technology Division*, **Shri R. Sritharan**, *Reactor Component Division, Reactor Engineering Group* and **Shri C. Balasubramanian,** *M/s Omplas Systems, Chennai* have been awarded the ISAMPE Outstanding Design and/or Process Development Award-2008 by the Indian Society for Advancement of Materials and Process Engineering (ISAMPE), Bangaluru.

Department of Atomic Energy has instituted annual awards for excellence in Science, Engineering and Technology in order to identify best performers in the area of Research, Technology Development and Engineering in the constituent units (other than Public Sector Undertakings and Aided Institutions). The Young Scientist, Young Engineer, Young Technologist, Homi Bhabha Science and Technology Award and Scientific and Technical Excellence Award fall under this category. Group Achievement awards for recognition of major achievements by groups have also been instituted. Life time Achievement Award is awarded to one who has made significant impact on the DAE's programme. They are the icons for young scientists and engineers to emulate. The awards consist of a memento, citation and cash prize.

The recipients from IGCAR for the year 2006 are:

Homi Bhabha Science and Technology Award

Dr.G.Amarendra, Materials Science Division, Metallurgy and Materials Group

Scientific and Technical Excellence Awards

1. Shri V. Balasubramaniyan, Reactor Components Division, Reactor Engineering Group
2. Dr. M.Joseph, Fuel Chemistry Division, Chemistry Group
3. Shri Shekar Kumar, Reprocessing Research and Development Division, Reprocessing Group
4. Dr. Kinkar Laha, Mechanical Metallurgy Division, Metallurgy and Materials Group
5. Dr. John Philip, Non Destructive Evaluation Division, Metallurgy and Materials Group
6. Dr.K.Velusamy, Mechanics and Hydraulics Division, Reactor Engineering Group

Awards & Honours - contd.

Young Engineer Awards

1. Shri V. Karthik, Post Irradiation Examination Division, Metallurgy and Materials Group
2. Shri T. Karthikeyan, Physical Metallurgy Division, Metallurgy and Materials Group

Young Scientist Award

Dr. Anish Kumar, Non Destructive Evaluation Division, Metallurgy and Materials Group

Meritorius Services Awards

1. Shri N. Chinnasamy, Materials Science Division, Metallurgy and Materials Group
2. Shri A.Elumalai, Reactor Maintenance Division, Reactor Operation and Maintenance Group
3. Shri S.Ganesan, Central Workshop Division, Engineering Services Group
4. Shri B.Ramachandran, Central Workshop Division, Engineering Services Group
5. Shri S.Sundaramurthy, Reprocessing Research and Development Division, Reprocessing Group

Group Achievement Awards

1. **Penetration Enhancing Activating Flux Tungsten Inert Gas (PEAF-TIG) Welding of Dummy Fuel Sub-Assemblies (DFSA) of PFBR**

   Dr. A.K. Bhaduri, Dr. M. Vasudevan, Shri M. Arul and Shri M. Munivel of Materials Technology Division, Metallurgy and Materials Group and Shri A.S.L.K.Rao, Shri R.Veluswamy, Shri P.Sivaraman, Shri G.Kempulraj, Shri M.Krishnamoorthy, Shri T.M. Chandra sekaran, Shri M.Damodaran, Shri M.Kuppan, Shri V.Kodiarasan, Shri A.Padmanabhan and Shri N.Dhanasekaran of Central Workshop Division and Shri K.Loganathan of Quality Assurance Division, Engineering Services Group

2. **Design of PFBR Main Vessel and Safety Vessel**

   Dr. P.Chellapandi, Shri V.Balasubramaniyan, Shri P.Selvaraj, Shri P.Puthiyavinayagam, Shri R.Srinivasan, Dr. K.Velusamy, Shri S.Jalaldeen, Shri T.Selvaraj, Shri A.Biswas, Shri R.Ravi Prasan, Shri U.Parthasarathy, Shri K.Natesan, Shri C.Raghavendran, Shri R. Sritharan, Shri R.Suresh Kumar, Shri Sriramachandra Aithal, Shri S.D.Sajish, Shri Bhuwan Chandra Sati, Shri Abhishek Mitra, Shri S.K.Pandey, Shri P.Ravi, Shri Gyanendra Prasad, Shri P.V.Sellaperumal, Shri Sebasti John, Shri G.Venkataiah, Shri D.Ajay Kumar, Shri A.Sivakumar and Shri S.Saravanan of Nuclear Engineering Group, Reactor Engineering Group

3. **Development of Compact Facility for Reprocessing Advanced Fuels in Lead Cells (CORAL)**

   Shri M.Venkataraman, Dr. S.B.Koganti, Shri P.Ramkumar, Shri V.Sundararaman, Shri A.Ravisankar, Shri N.Ramnath, Shri V.Vijayakumar, Shri B.M.Ananda Rao, Dr. R.V.Subba Rao, Shri Geo Mathews of Reprocessing Group and (former employees) Shri G.R.Balasubramanian, Shri M.S.Ilangovan, Shri R.Sudharsanam, Shri P.K.Verghese, Dr. A.Palamalai, Shri R.G.Diraviyam, Shri Joseph Benjamin, Shri E.Doss, Shri C.A.Dixit, (Late) Shri S.Dhanapal, Shri S.Shanmugam and Shri S.Arunachalam

Published by Scientific Information Resources Division, IGCAR, Kalpakkam - 603 102