ISSUE NO. 283

AUGUST 2007

बीएआरसी न्यूज़लैटर

BARC NEWSLETTER

IN THIS ISSUE

ADVANCED SERVO MANIPULATOR: A MILESTONE IN REMOTE HANDLING TECHNOLOGY

EFFECTS OF CYCLIC LOADS ON LBB ASSESSMENT OF HIGH ENERGY PIPING

बीएआरसी
न्यूज़लैटर
BARC
NEWSLETTER

CONTENTS

URL:http://www.barc.gov.in

बीएआरसी न्यूज़लैटर
BARC NEWSLETTER

ADVANCED SERVO MANIPULATOR: A MILESTONE IN REMOTE HANDLING TECHNOLOGY

K. Jayarajan, D.D. Ray and Manjit Singh
Division of Remote Handling and Robotics

Introduction

Future nuclear installations would need a higher level of remotisation and automation, to improve their safety and productivity. Plants using Thorium-based fuels introduce additional problems in remote handling, due to the build-up of radioactivity in the U-232 decay chain. In such plants, operators can handle the material only behind thick shields, using reliable and advanced remote handling tools. In this context, we have recently developed an Advanced Servo Manipulator (ASM), based on in-house mechanical design and indigenous drives and controllers.

A servo manipulator consists of two arms: the slave arm and the master arm. There is no direct mechanical links connecting the master arm and the slave arm. The slave arm is usually kept in the remote hotcell and the master arm in the control room. During operation, as the operator holds and moves the handgrip of the master arm, the slave arm reproduces his hand movements and performs the necessary task in the remote area.

A servo manipulator can handle heavy objects with less operator effort. As mounting the slave arm on a transporter augments its operating range, a single pair of servo manipulators is sufficient to serve a large hotcell. It also offers flexibility in equipment layout, within the hotcell.

Although, there are many mechanical master-slave manipulator installations in various hotcells, only a few servo manipulator installations exist in the department.

ASM represents a new generation of servo manipulators with force reflection capabilities available to the human operator. The operator's hand in the control station acquires the proportional force acting on the slave arm in the hotcell. Force reflection makes remote operation faster, safer and more accurate. Other major enhancements of ASM over earlier designs include, reconfigurable arm structure, higher payload and digital control. In ASM, we have provided advanced features in control and user interface, using advancements in digital microelectronics. Moreover, we have made it more flexible for future requirements.

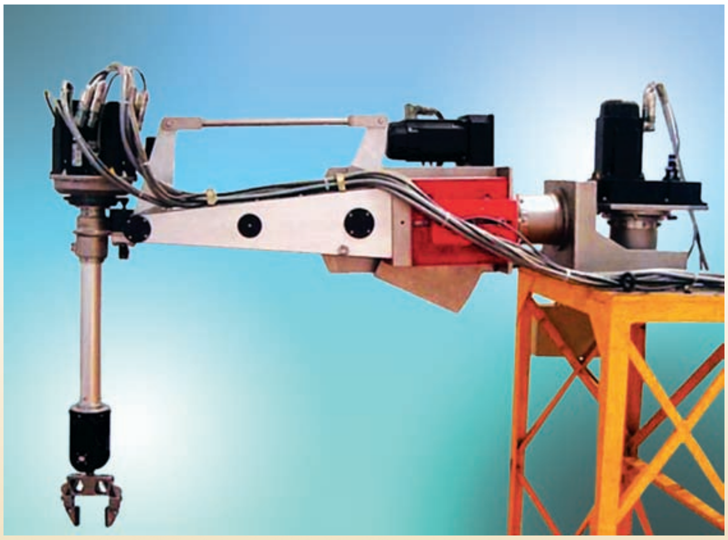


Fig. 1: Slave Arm of ASM

Development of ASM involves meeting many challenging tasks in mechanical, electrical, electronics, control, software and radiological areas. The slave arm located in the hotcell, needs to be highly reliable and made from radiation-tolerant and washable components. Placing electronic components away from the slave arm is a design challenge. ASM controls involve real-time control of a non-linear, time-varying, multi-axis and coupled system for position trajectory as well as force trajectory. This article discusses important features and major sub-systems of the ASM.

Mechanical Design

We have designed the master arm and the slave arm kinematically similar to each other. The slave arm uses only radiation resistant materials and components. Ball bearings used in the slave arm are of stainless steel material, filled with radiation-resistant grease. Electric components used in the slave arm are radiation-resistant and of IP65 class. Materials used ASM are of high strength and lightweight.

Degrees of Freedom

For the end-effector to attain arbitrary position and orientation, six independent motions are necessary for any manipulator. In addition to the necessary six Degrees Of Freedom (DOF), we have provided an additional (optional) joint in the slave arm to increase its range. The additional range may be necessary in certain hotcells, where the manipulator has to approach areas beyond cell crane hook. In addition to the six or seven joints, arms have end-effectors. Fig. 2 shows the various axes and major sub-assemblies of the manipulator.

Manipulator Structure

The manipulator has articulated structure, with all revolute joints. It can be configured as elbow-down or elbow-up type, to suit the equipment layout in the hotcell. Elbow-down configuration is similar to the human hand. Fig. 3 shows the slave arm in elbow-down configuration. It can also take a tabletop structure (like a robot), which can be mounted on a mobile platform. Mounting the slave arm on an overhead telescopic bridge crane, increases the effective range of the slave arm.

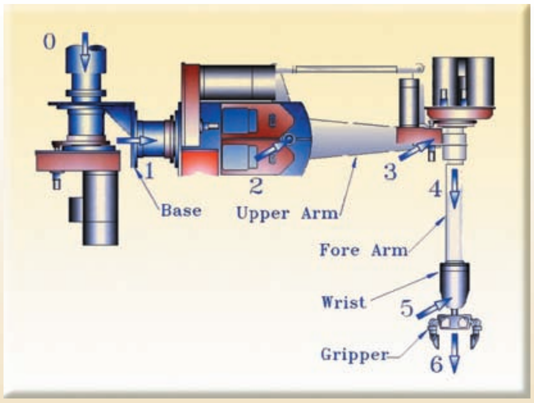


Fig. 2: Joint axes and sub-assemblies of ASM

Fig. 3: Slave Arm in "Elbow-Down" configuration

Modular Design

It is easy to assemble or disassemble the manipulator sub-assemblies for maintenance. The major modules of the manipulator are base, upper arm, forearm, wrist and gripper as shown in Fig. 2. The actuator assemblies of joints, consisting of motor, resolver, brake, gearbox and potentiometer are also replaceable. Operator in the control station can replace the slave arm fingers, which are in the hotcell.

Power Transmission

Mechanical transmission elements transmit power from motors to joints. The major consideration in deciding motor locations and type of transmission linkages are joint size, joint weight, inertia, joint angle range, friction, rigidity and position error. Mounting the motor near a joint, will increase joint size and make the approach to task area difficult for the arm. It will also increase gravity and inertia loads of preceding motors. However, mounting it away from a joint will increase flexibility, position error and friction. It will also reduce the joint range, due to the mechanical coupling among transmission elements. Therefore, we have decided actuator locations judiciously to optimize the above factors.

Flexible elements like tapes and ropes were used as mechanical manipulators and previous model of servo manipulators was used for transmitting power between motor and joint. Although, they have lower size, inertia and friction, their maintenance and replacement need considerable plant downtime. Therefore, we have designed ASM with rigid mechanical transmission elements like spur gears, bevel gears, shafts and 4-bar mechanisms. To improve force reflection characteristics, we have kept low the gear ratios in joints.

During operation, the master arm converts every movement of its handgrip into joint rotations. Moreever, it converts the torque generated by its motors into force and torque at handgrip, for providing force reflection to the operator. In the slave arm too, the conversion of force and motion between the gripper and joints are bi-directional. Therefore, we have designed all mechanical transmissions in master arm and the slave arm to be back drivable. Back-drivability also helps the slave arm to align itself to the job, in response to the constraints imposed by the task.

All major joints of the manipulator are mechanically counterbalanced. Motors mounted near the base serve as counterweights too.

Wrist

ASM has a small wrist as compared to the size and weight of the object it can handle. With a compact wrist, the manipulator can handle objects near a table, wall or other obstacles. Making a compact wrist is one of the difficult tasks in manipulator design. The wrist has spur gear pairs, bevel gear pairs and a differential mechanism, to convert rotations of two parallel shafts into roll and pitch motions of the end-effector. Wrist also transmits mechanical power to actuate the end-effector.

As we intend using the slave arm as a robot also, we designed its wrist *as spherical type*, whose orientation axes all intersect at a point. This is a deviation from all mechanical master slave manipulators and servo manipulators. Existence of a closed inverse kinematic solution is essential for robot control and a spherical wrist can meet this requirement.

End-Effectors

ASM has two types of end-effectors: slave arm gripper to hold objects in the remote area and the master arm handgrip to generate gripping command.

The major challenge in gripper design is reduction of gripper size and weight. The ability of the manipulator to orient its gripper (dexterity) increases with decrease in gripper length. Moreover, the increase in gripper length is not desirable from load carrying capacity, position error and force reflection points of view. ASM gripper, which can open upto 100 mm and handle a weight of 25 kg, has a length of only 170 mm.

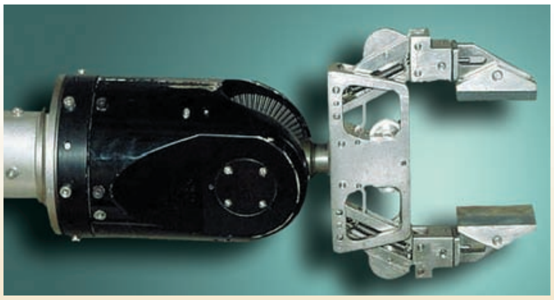


Fig. 4: Wrist and Gripper of the Slave Arm

The gripper is parallel jaw type, whose contact surfaces remain parallel, irrespective of their opening. For better gripping, the contact surfaces are made from rubber. They wear out easily by rubbing with other objects. Their frequent contact with radioactive materials contaminates them easily. As they need frequent maintenance, the jaws are made to be remotely replaceable in the hotcell. Jaw replacement also helps in handling odd shaped objects with non-planar gripping surfaces.

To ensure firm gripping, we have provided a flexible member in the transmission mechanism between the motor and the gripper. It reduces the variations in gripping force arising from factors like motor torque fluctuation.

Master Arm

Speed (task completion time), accuracy, ease of learning, operator fatigue and joint coordination are the major factors deciding the usability of an input device. Input devices of a computer, such as mouse or joystick, can control and coordinate two or three variables simultaneously. However, a typical remote handling task, needs control of six configuration variables of the end-effector. Therefore, we have designed a master arm as an input device for simultaneous control of six configuration variables. Operator can sense as well as control three components of force and three components of torque through the master arm. All these variables are controlled and sensed through the master handgrip. In addition to this, the operator can feel and control the gripping force and gripper opening of the slave arm through the master handgrip.

The master arm and the slave arm have the same structure and link lengths. The corresponding motors of the master arm and slave arm are identical. The major difference between the master and slave arms is in their end-effectors and load-carrying capacities.

Fig. 5: Wrist and Handgrip of the Master Arm

Gear ratios in the gearboxes of the master arm are so decided, that the maximum joint torque is only one-third of the corresponding slave joint torque. Reduction in friction and inertia, due to the lower gear ratios in master arm, reduce operator effort and give better force reflection. Moreover, the resulting lower torque limit protects the human operator from any controller malfunction.

Actuators and Sensors

ASM uses brushless AC servomotors as mechanical power sources. These are permanent magnet synchronous motors with wound stator and permanent magnet rotor.

The combination of an inner permanent magnet rotor and outer windings offer low rotor inertia, efficient heat dissipation and reduction of motor size. Absence of brushes reduces noise, EMI generation and eliminates the need of brush maintenance. These motors have good linear torque-current relationship, which is essential for accurate force feedback to the operator. Motor selection is standardized such that, only motors with three ratings are used in the manipulator, out of the 16 motors in the manipulator.

Between trapezoidal and sinusoidal types of motors, we have selected sinusoidal type for our application. Space-vector modulation technique creates the sinusoidal voltage waveform applied to the motors. As sinusoidal currents drive sinusoidal motors, torque ripple is eliminated. For real time control of torque and speed, Field Oriented Control algorithm is used. As this method is accurate in both steady-state and transient mode of operations, over sizing of power module was not necessary. The transient currents are continuously controlled in amplitude.

The motor has an inbuilt resolver to sense its rotor position. The drive card converts the analogue resolver signal into logic pulses. These are used for electronically switching the stator windings in proper sequence to maintain rotation of the magnet assembly. The servo control loop also uses the resolver signal for position feedback. As the resolvers take multiple turns within the joint range, they alone cannot provide absolute joint angles. Multi-turn potentiometers mounted on the joints provide absolute initial joint angle, which is used for initializing the absolute resolver output.

All motors are integrated with failsafe brakes. Operator can apply brake to all joints to hold the manipulator in position. During power failures, the brakes prevent uncontrolled joint movement and retain the held object in position. Other malfunctions also result in automated application of brakes.

We have used only radiation-tolerant motors, brakes, sensors and cables in the manipulator. These are IP65 rated, to enable decontamination of the entire slave arm by washing. We have used only shielded leads to reduce noise pickup from motor drives.

Control System

The Advanced Servo-Manipulator Controller (ASMC) is based on distributed digital control. Compared to an analogue control system, a digital system has more flexibility, long-term stability and less cable handling problems.

ASMC consists of operator interface, co-ordination computer, joint controller and servo drives. Fig. 6 shows the architecture of the control system. The coordination computer communicates with joint controllers on a shared RS485 serial communication link, while the joint controller communicates with the corresponding master and slave servo drives over dedicated RS422 links.

ASMC provides the following functionality:

1. Master slave follower
2. Force reflection to the master arm
3. Indexing of joints
4. Brake operation
5. Torque limiting
6. Artificial force reflection
7. Status reporting
8. Fault protection.

Compared to a centralized processing system, a distributed system reduces individual unit processing requirements. It also supports high update rate and large number of input-output signals required by each servo loop. In addition to this, it is less vulnerable to total system failure. It also needs less software maintenance.

All master servo drive hardware and software are identical. Likewise, all slave servo drive hardware and software are identical. DIP switch settings configure them for respective joints. Common software across drives / joint controller reduces the amount of software.

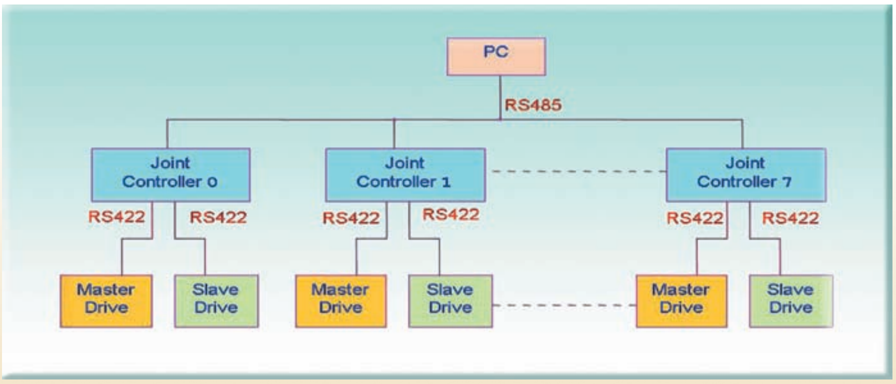


Fig. 6: Control System Architecture

The architecture allows the necessary quick data transfer between the master drive and the slave drive. Data sampling, control and information transfer are accomplished in real time.

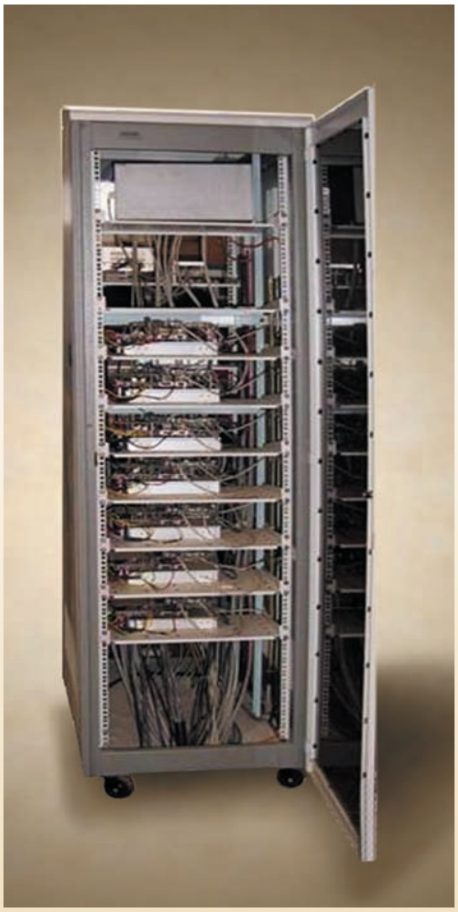


Fig. 7: Control Cabinet of ASM

A rack mounts all ASMC components. Radiation-tolerant cables connect ASMC to the motor and sensors. The length of cable connecting the control cabinet and the slave arm can be up to 100 m.

Servo Drive

Each joint of the manipulator arm is driven by a separate servomotor and drive. There are 16 drives for eight pairs of master-slave motors in the system. Each servo drive collects data and controls the corresponding joint. The power section of the drive is based on integrated power module. The current and velocity loops of the servo control are implemented using a commercially available servo control IC. The position loop and drive control software are implemented on cygnal 8051F120. The servo control IC allows the user to configure different types of motors, position feedback devices and communication protocols. The system also allows feed forward control, in addition to existing PI control. Fig. 8 shows the internal block diagram of the drive.

The manipulator joints do not have encoder, but their motors have inbuilt resolvers for position feedback. As the servo controller IC accepts only encoder input, IC AD2S80 does the necessary resolver to incremental encoder signal conversion. The incremental encoder signals update a 32-bit counter inside the servo controller IC and this count is later converted to joint angle.

AD2S80 provides only the position of the motor shaft and not the necessary joint position. To get the initial position of the joint, signals from the joint potentiometer are fed into the micro-controller. This initial position is loaded as the initial count into the 32-bit counter. Fig.9 shows the block diagram of the servo control.

The overall specification of the drive is presented below:

Position loop update rate	500 Hz
Velocity loop update rate	5/10 KHz
Current loop computation time	6 μs
PWM Carrier frequency	70 kHz
Continuous output current	5 A (750 W)
Overload output current	15 A
Max. RS232C speed	115.2 kbps

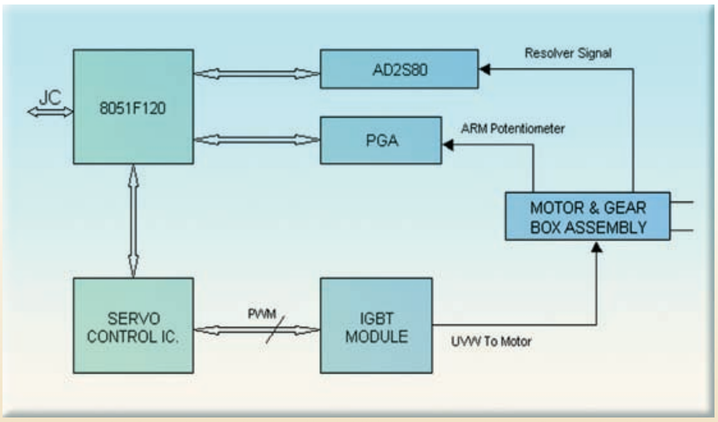


Fig. 8: Servo Drive

Joint Controller

ASMC has eight joint controllers, one for each master-slave joint pair of the manipulators. A joint controller exchanges information between the servo drives of the corresponding joints, in real time. In addition to this, it supports indexing, joint alignment, brake control and fault protection. Fig. 10 shows the hardware block diagram of the joint controller.

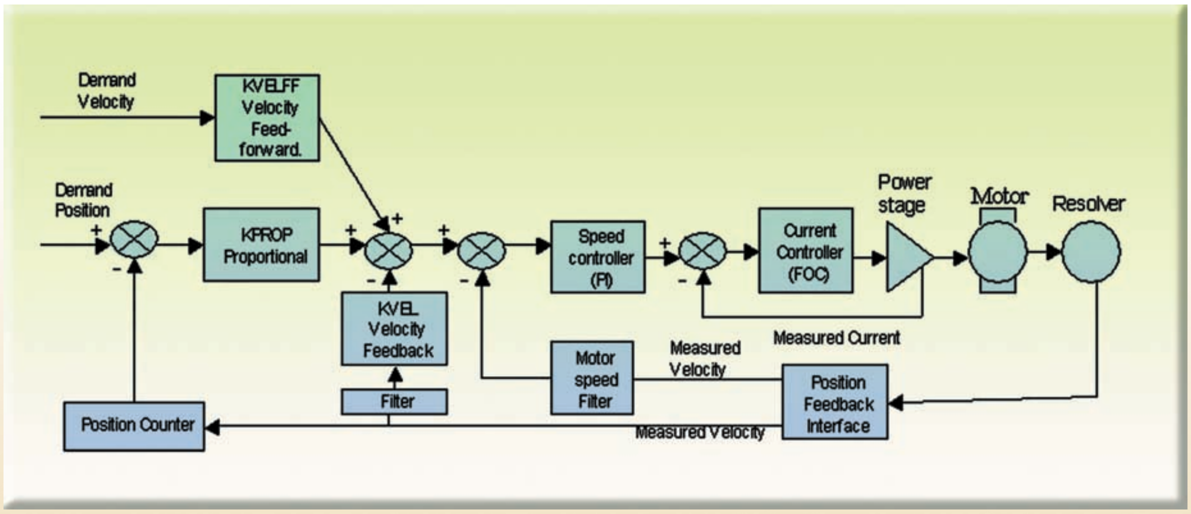


Fig. 9: Servo Control Loop

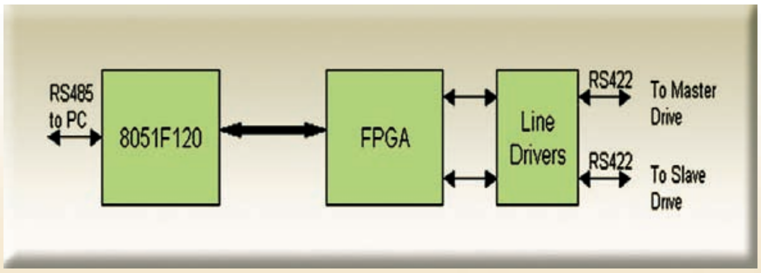


Fig. 10: Joint Controller

The processor on board is cygnal 8051F120 running at 55 MHz. This processor is different from the processor on the servo drive board. The processor was selected on the basis of the control requirements, high integration of peripheral components like timers, UART, ease of developing software using 'C' language and JTAG-based debugging capabilities. As the processor has pipelined architecture and is running at 55 MHz, i.e. 55 times faster than the regular 8051, the traditional MIPS constraint (1MIPS) could be overcome. All these MIPS are available, just for one joint controller, and we have eight joint-controllers. When we implement robot mode in ASM, the Spartan IIE FPGA on board will act as a co-processor to the 8051F120.

A joint controller communicates with the coordinating PC and corresponding master and slave drives. Parameters are updated to the drives once in every 16 mSec.

From the PC, it gets limits for position, speed and torque; gain factors for position and speed; operator applied brake status and indexing position. It provides positions, speed and torque of joints; motor brake status; motor temperature status (hot/ cold) and drive fault status to the PC for display and diagnostic purposes.

From the master drive, it gets position and speed of the joint. It updates the drive with reflecting torque and limits for position, speed and torque.

Similarly, it provides required position and velocity to the slave drive. It also updates the status and limits of position, velocity and torque of the joint from the slave drive.

Coordinating Computer

We have used an industrial PC based on Pentium processor as coordinating computer in the ASMC. The PC uses RS422 port to communicate with the operator keyboard and optic fibre cable to communicate with joint controllers. The computer controls all the master and slave joint controllers.

Operator Interface

As described earlier, the master arm is the major operator interface in ASM, which can input (position) and output (force) six variables in coordination. Operator uses its

Fig. 11: Keypad in the Master Handgrip

handgrip for control of gripper opening and closing, sensing the gripping force and applying the required force.

A keypad is mounted on the master handgrip. It has keys for selecting force reflection ratio and torque limits. Operator can select a joint for indexing and start indexing motions in forward or reverse direction. Toggle keys are provided for applying/releasing brake on all joints and locking/unlocking the slave gripper. Operator can use the keypad with his thumb, while holding the handgrip.

Operator uses the PC during the startup of the system. The PC displays the joint variables of the master and slave, status of the settings and error conditions, if any. The administrator uses it for setting the control parameters. Sound alarm also indicates the status of the system.

Like other servo manipulator systems, here also CCTV cameras will be used for visual feedback of the remote environment.

Master Slave Operation

During master slave manipulation, operator holds and moves the master handgrip. The slave gripper, which is in the remote area, follows the movement of the master handgrip doing the necessary tasks.

The mechanical design of the manipulator is such that, when all joint angles of the slave arm match with those of the corresponding master arm, their end-effectors will also match with their configurations. Therefore, the primary role of the controller is to match the angles of all the slave joints to corresponding master angles, at every instant.

As the operator moves the handgrip, position sensors (resolvers) mounted on the joints sense the master configuration. The controller computes the instantaneous errors between corresponding joint angles of the master and slave, converts them into a set of currents and applies them to the slave motors. Velocity errors are also added to the position errors to stabilize the control system. Fig. 9 shows the closed loop control for the same.

Gains of each joint controller are separately tuned, to achieve accurate and stable trajectory, following the slave joint with respect to that of the corresponding master joint. Fig. 12 shows the typical trajectory of slave motor with reference to the master input.

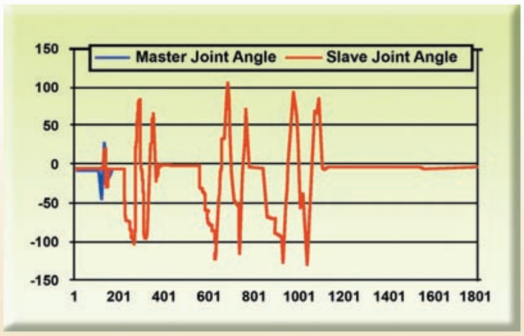


Fig. 12: Master Slave Follower

Gripper operation involves closing and opening the gripper and applying the necessary gripping force. Though it involves position control as well as force control, we use the gripper controller identical to that of other joints. During gripping, as the operator closes the handgrip, the slave fingers move and touch the object. Further closing of the handgrip will increase position error, as the object surface restricts further movement of slave fingers. As the force generated is proportional to the position error, operator can control the gripping force by controlling the handgrip opening.

Advanced Features

The total digital control system used in ASM provides flexibility in control and user interface. A description of some of the advanced features implemented in ASM follows.

Force Reflection

ASM is a bilateral manipulator, which allows the force acting on the slave gripper to be reflected on the operator's hand. Force reflection makes the operator aware of any resistance in movement, provides a feeling of the load being handled and helps him to control the applied force. It prevents the operator from unknowingly applying damaging forces to the object being handled, to the nearby objects or to the manipulator itself. Ability to feel and control the applied force helps the operator to perform the task faster and more accurately. It is an inherent property of mechanical manipulators, that no significant loss of mechanical power or motion occurs, in their transmissions between the master and slave. However, implementation of force reflection is a difficult task for servo manipulators.

In ASM, we have provided motors in the master joints also to generate force. These motors operate in the torque control mode. As it is difficult to use force sensor in radiation environment, the slave motor current (which is proportional to the slave motor torque) is taken as an indication of slave load. The slave motor current is applied on the corresponding master motor, after necessary scaling, filtering and compensation. The direction of the torque generated at the master motor is opposite to that applied on the corresponding slave motor. The Master arm converts the motor torques into force and torque of handgrip, providing force feedback to the operator, who is holding the handgrip. Operator can change the Force Reflection Ratio (FRR), which is the ratio of the force reflected on the operator's hand to that acting on the slave end effector, from zero to one. Fig. 13 shows the implementation of bilateral control in ASM.

Friction in motors, brakes, gears and mechanical transmission elements increase operator effort in handling the manipulator. We have implemented a friction compensation scheme to reduce the effects of friction. Fig. 14 shows the applied master current and measured slave current of ASM. Initially FRR is 0 and no current is applied to the master. FRR is 0.5 in the second part.

Indexing

In ASM, the range of the slave arm is more than that of the human arm. We have provided indexing motions to

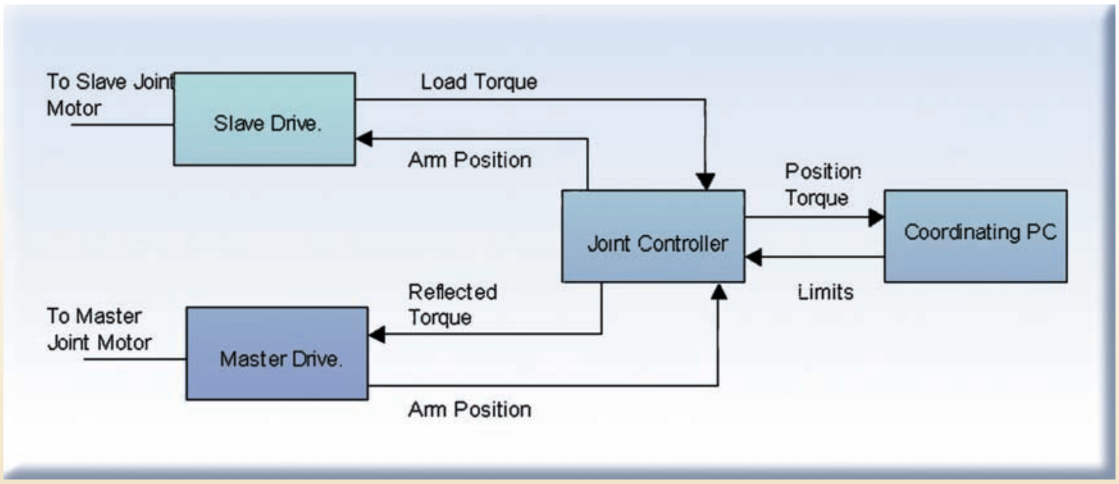


Fig. 13: Bilateral Control of Manipulator

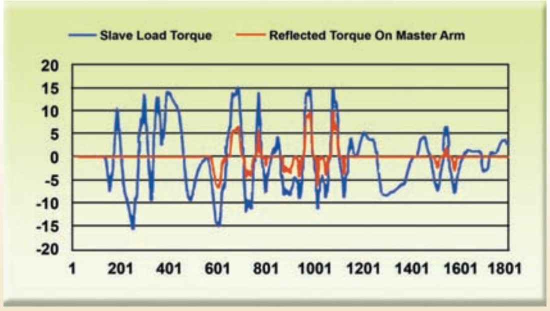


Fig. 14: Slave Joint Current and Reflected Master Current

the positioning axes, to use their entire range effectively. In indexing mode, an operator can rotate selected slave joints, without rotating their corresponding master joints. Indexing also helps the operator to control the manipulator sitting in a comfortable posture.

The Operator can select the joint for indexing and command the joint to move in the desired direction through the handgrip keypad. After indexing, though there will be a mismatch between the master and slave joint angles, operator can continue master slave operation in the mismatched positions.

Torque Limit

ASM can handle 25 kg load (Fig. 15). However, to protect the manipulator and nearby objects during accidental collisions, it is desirable to operate it at a lower capacity. The operator has an option of limiting the manipulator capacity to a specified load using the handgrip keypad. Only when the manipulator fails to handle the object that he needs to increase the torque limit. This feature is also useful in handling fragile and delicate objects.

Soft Joint Limits and Artificial Force Reflection

The master arm and the slave arm can have independent joint limits and their complex workspaces are modelled in the computer. The joint limit settings will prevent slave joint to move beyond the set limits, even if the operator tries to move the corresponding master joint. A sound alarm indicates whether any joint of the master arm or slave arm has reached its limit.

Fig. 15: ASM handling a glass flask. ASM can handle objects weighing upto 25 kg. It can also handle delicate object safely, using force control and force limit

In the force reflection mode, when a master or slave joint approaches its limit, the operator gets a repelling force on his hand, resisting him from moving closer to the limit. It helps in preventing internal collision of manipulator parts. Other undesirable conditions, like large position error, also result in a repelling force to the operator.

Conclusion

Development of the Advanced Servo Manipulator has been completed and the manipulator is available for demonstration. The digitally controlled manipulator has force reflection and other advanced capabilities. The development strategy was based on in-house mechanical design and indigenous control hardware and software.

To enhance its performance further, we will be providing features like motion scaling and compensation for manipulator dynamics to ASM. We are also planning to use ASM in telerobot mode, where the slave can perform autonomous operations without operator assistance.

We have taken up the development of Four-Piece Servo Manipulator (4PSM) from this core technology. Conventional servomanipulators need hotcells specifically designed for their installation. However, we can install 4PSM in conventional hotcells, which were designed for mechanical manipulators. It will be more operator-friendly than the conventional mechanical manipulators. We are also developing other servo manipulator systems, including a miniature servo manipulator and a surgical robot.

We have developed ASM with flexible and expandable features, for ease in enhancement and customization to meet user requirements. The indigenous technology has laid a foundation on which we can develop many advanced robotic systems in future.

General Specifications

- ❖ Degrees of freedom: 6 (+1 optional)
- ❖ Payload: 25 kg (at all positions)
- ❖ Maximum reach: 1.2 m
- ❖ Gripper opening: 100 mm
- ❖ Force reflection ratio: 0 to 1.0, subjected to a maximum force of 8 kg

Forthcoming Symposium

Trombay Symposium on Radiation & Photochemistry

TSRP-2008

The Radiation & Photochemistry Divn., BARC, will be organizing a five-day symposium, from Jan. 7-11, 2008, in collaboration with the Indian Society for Radiation & Photochemical Sciences. This biennial symposium, the ninth in the series, sponsored by DAE/BRNS, will be held at the Yashwantrao Chavan Academy of Development Admn. (YASHADA), Pune, India.

The scientific programme of the symposium will comprise invited lectures and contributory poster presentations. Invited lectures (extended abstracts of five A4 size pages) and contributory papers (extended abstracts of two A4 size pages) are to be submitted in the prescribed format to the Secretary, TSRP-2008 at tsrp2008@barc.gov.in. The broad range of topics include:

- Ultrafast spectroscopy and dynamics of photoinduced chemical processes in solutions and interfaces
- Gas phase reaction dynamics in bulk and beams
- Radiation and photochemistry in Nuclear Fuel Cycle
- Radiation and photochemistry of: Atmosphere and Environment; Nanoscale materials; Biological Compounds, antioxidants and drugs
- Industrial and Societal applications of radiation and photochemical processes.

Important Dates:

Submission of preliminary registration form	: 1st Sept. 2007
Submission of manuscripts (contributory papers)	: 1st Oct. 2007
Submission of manuscripts (invited papers)	: 15th Oct. 2007
Intimation of acceptance to authors	: 1st Nov. 2007

Final confirmation of participation (by the delegates) against payment of registration fee: 1st Dec. 2007

For accommodation and other details, either of the Conveners can be contacted at the following address.

Dr Dipak K. Palit or Dr Tusar Bandyopadhyay

Radiation & Photochemistry Division
Bhabha Atomic Research Centre
Trombay, Mumbai 400 085, India
Tel.: 91-22-2559 5091
91-22-2559 0300
Fax: 91-22-2550 5331
91-22-2550 5150 / 5151
E-mail: tsrp2008@barc.gov.in
Homepage: http://www.barc.ernet.in/symposium/tsrp2k8/home.htm

EFFECTS OF CYCLIC LOADS ON LBB ASSESSMENT OF HIGH ENERGY PIPING

Suneel K. Gupta, Vivek Bhasin, K. K. Vaze, A.K. Ghosh and H. S. Kushwaha
Reactor Safety Division
Health Safety and Environment Group

Introduction

The Leak-Before-Break (LBB) assessment of pressurized nuclear components, for example Primary Heat Transport (PHT) piping, is done for two reasons. One is to provide assurance that there would be an early warning before any major break in pressure boundary occurs. In this regard the calculations also helps in serving the design basis of leak monitoring devices, etc. The second important reason is to arrive at design simplifications in minimizing design and operational penalty. This is due to the fact that rupture of the pipe does not form the design basis of pipe supports, jet shield, pipe whip restraints etc. This in turn leads to lesser operation stress and improves the accessibility to pipes which leads to lesser radiation exposure during in service inspection.

LBB assessment involves three levels. In level 1 it is ensured that material is ductile/tough and free from objectionable flaws/cracks. This is usually achieved by adhering to standard design codes, sound design and manufacturing practices and rigorous quality assurance. In level 2 a credible sized part-through flaw is postulated, assuming it might have escaped detection during pre-service inspection. Assessments are done to ensure that under different service loads it will not grow to a size where breakage may occur before the leak.

In level 3, as a worst-case assumption, it is postulated that a through-wall crack exists with maximum credible size, such that, flow through can be detected using leakage sensors under Normal Operating Conditions (NOC) loads. Such postulated crack is called Leakage Size Crack (LSC). LSC is postulated, at all the potential locations and rigorous fracture assessment is performed, for demonstration of LBB capability and safety margin against fracture failure, under postulated design basis accident event loading; which, in several countries including India, is Safe Shutdown Earthquake (SSE) event. Here, the pipe fracture analysis considers the seismic loading as a one time applied load of magnitude equal to peak load at the postulated flaw location during the earthquake event.

There are no explicit considerations for the cyclic damage or for the number of applied load cycles during earthquake events. Some of the most referred to USNRC guides [1] and IAEA-TECDOC reports [2, 3] on LBB, are also silent on cyclic fracture aspects under earthquake conditions. However, during a typical SSE event, the nuclear power plant piping experiences around 10-20 cycles of large amplitude reversible cyclic loads. It is a well-known fact that the reversible cyclic loading significantly reduces fracture resistance (J-R curve) of the material when compared to monotonic J-R curve. A cracked component, which is safe for monotonic load, may fail in limited number of reversible cyclic loads of the same amplitude. Hence, for a realistic assessment of LBB, cyclic tearing should be considered.

Recently, the International Piping Integrity Research Group (IPIRG) [4] and the Central Research Institute of Electric Power Industry (CRIEPI) [5] have conducted tests on straight pipes and investigated the fracture behaviour of circumferentially cracked piping, subjected to loadings that are typical of seismic events. The IPIRG research focused on A106 Grade B carbon steel and TP304 austenitic stainless steel materials. CRIEPI conducted tests on pipes made of Japanese carbon steel (STS410). These investigations ascertained the significant influence of cyclic nature of loads on fracture stability assessment. However, they have not provided methods or rules to incorporate cyclic tearing into the LBB assessment procedure.

In view of the above, experimental and analytical investigations were carried out, by conducting full scale pipe tests, on the PHT piping material of the Indian Pressurized Heavy Water Reactors (PHWRs) and proposed Main Heat Transport (MHT) piping material of the Advanced Heavy Water Reactor (AHWR), under reversible cyclic loading conditions. Twenty five cyclic tearing tests were carried out on circumferentially through wall cracked straight pipes, subjected to cyclic bending/ loading. It is well known that for a piping system that seismically induced response is combination of load and displacement controlled loadings. The investigations have been carried out on simulated loadings for both the types of loadings.

The cyclic test results have been compared with the corresponding monotonic pipe fracture test results. Based on these test results and its comparison with corresponding monotonic tearing, a simplified master curve has been generated to address the cyclic tearing issue in LBB assessment. Based on these investigations, new design rules for level 3 LBB assessment that is, additional safety margins were suggested to account for the damage due to reversible cyclic loading. Analytical evaluations for crack growth were also made and compared with test results.

Test Details

Variabilities considered were: pipe sizes, crack sizes, material and test loading conditions

- Pipe Sizes: 6", 8", 12" & 16" NB
- Crack Sizes: 60°, 90°, 120° Through Wall Circumferential Crack
- Crack Location: Base Metal, Weld Metal
- Material: SA333Gr6. Carbon Steel, SS304LN Stainless Steel
- Loading Parameters: Load Ratio, Load Amplitude, Cyclic Displacement Increment
- Loading Mode: Load Controlled mode, Displacement Controlled mode

The pipes of 8", 12" & 16" NB size are made of carbon steel and are similar to the ones used in PHWR piping. The pipes of 6" NB size are made of stainless steel and are representative of proposed feeder and tail piping of AHWR. Primarily the crack sizes are chosen such that, the experiments will provide the critical load of the pipe with a postulated through wall crack of size nearly equal to twice the LSC. However some tests are performed to study the crack size effects too.

A total of 25 cyclic tearing tests have been conducted to cover the above variabilities. 15 cyclic tearing tests were conducted on SA333 Gr.6 carbon steel pipes, which are the same as those used in PHT system of Indian PHWRs and 10 other tests on SS304LN stainless steel pipes which are similar to the proposed material for MHT system of AHWR. The tests were conducted under quasi-static cyclic loading conditions. A four point bend loading setup as shown in Fig. 1a and Fig. 1b was used, for reversible loading. During the test, Load, Load Line Displacement (LLD), Crack Mouth Opening Displacement (CMOD) and Crack Growth were continuously monitored and recorded.

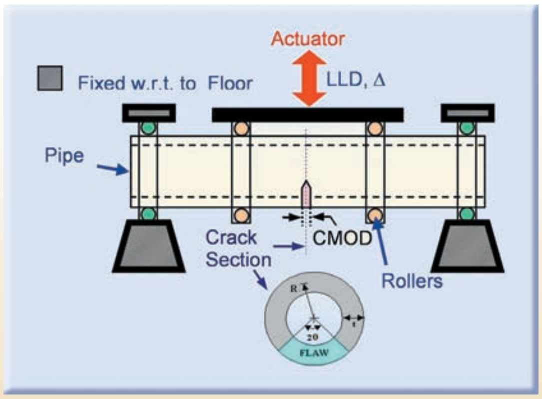


Fig. 1a: Cyclic Tearing Test Setup (Schematic)

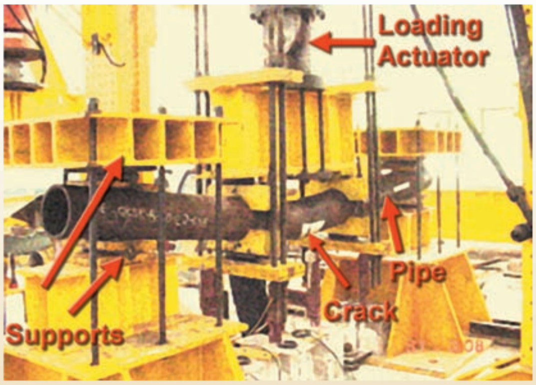


Fig. 1b: Cyclic Tearing Test Setup (Picture)

Results and Discussion

The number of cycles in load controlled tests is important in fracture assessment of piping, subjected to cyclic loading event. The cyclic fracture tests have shown that, the pipes may fail in limited number of load cycles with the load amplitude sufficiently below the monotonic fracture/collapse load as shown in Fig. 2. The comparison of the displacement controlled quasi-static cyclic test and the corresponding quasi-static monotonic test results in Fig. 3a show that the cyclic loading has less influence on the maximum load carrying capacity, but there is significant loss in the energy absorbing capability of the piping during the cyclic loading. It has been observed that there is significant reduction in fracture resistance (J-R curve) under cyclic loading conditions as shown in Fig. 3b. The J-integral is evaluated using the crack growth data and the area (energy) under the load versus load line displacement (or moment vs rotation) curve and is a measure of the resistance of material to crack extension / growth.

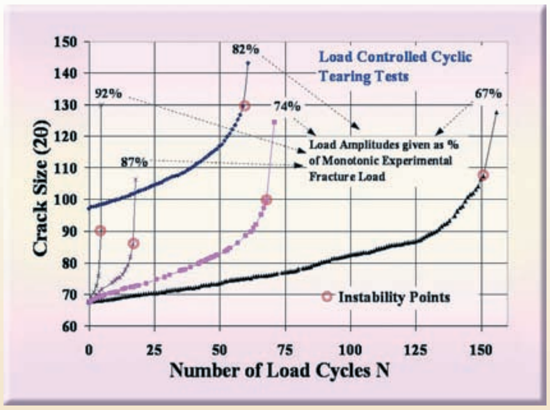


Fig. 2: Crack Growth versus number of load cycles for load controlled cyclic tests

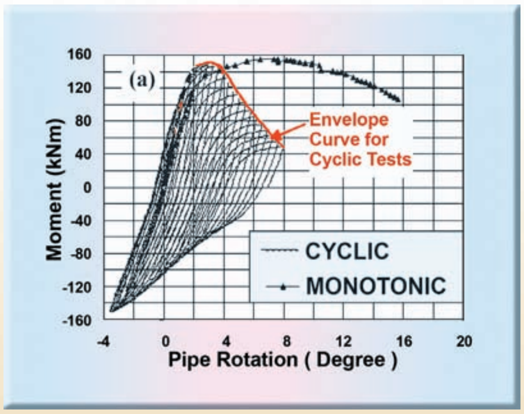


Fig. 3a: Moment versus Rotation

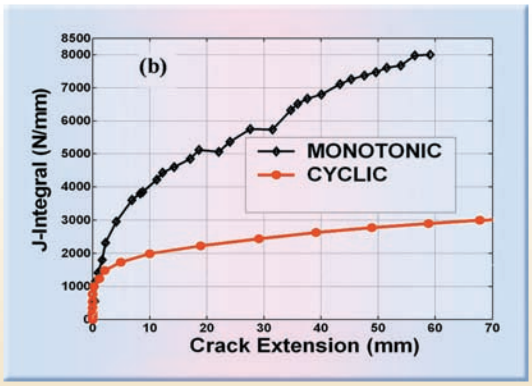


Fig. 3b: J-resistance curve, for displacement controlled cyclic tests

Cyclic Tearing and Current LBB Assessment

The current LBB design procedure and requirements are described at length in standard documents like NUREG-1061 [1] and IAEA-TECDOC-710 and 774 [2, 3]. These standard documents recommend the following safety margins to be demonstrated against the normal operating plus SSE loads.

Margin to Critical Crack Size:
$(M_{noc} + M_{sse}) < M_{crit}$ (at 2 x LSC)

Margin on Loads:
$(M_{noc} + M_{sse}) \times \sqrt{2} < M_{crit}$ (at LSC)

The above equations ensure a margin of 2 on the Leakage Size Crack (LSC) and a margin of √2 on normal operating plus safe shut down earthquake load. These safety margins intend to account for uncertainties associated with leak detection capabilities, analytical flaw evaluation procedures, material properties and specified loadings.

Although the above equations are recommended to be applied for SSE conditions, the evaluation of the critical load and the critical crack size are based on the monotonic collapse or monotonic fracture instability. Here the SSE load is considered as a one-time-applied-load of magnitude equal to peak load at the postulated flaw. The above equations do not account for cyclic tearing as a failure mode neither do they ensure the safety margins for the desired number of load cycles of SSE load. Likewise, the safety factors used in these equations, are also not intended to cover the cyclic tearing damage and the number of load cycles. However, the displacement-controlled tests have shown significant loss in fracture resistance and the load-controlled tests have highlighted the importance of the number of load cycles in the fracture assessment of piping, subjected to a cyclic loading event. Hence cyclic effects should be accounted for in the LBB qualification of the piping components.

Master Curve Development

In view of the above discussions, a simplified master curve has been generated directly from the pipe cyclic tearing tests. The master curve is the plot of the cyclic load amplitude (given as % of maximum load recorded in corresponding monotonic fracture test) versus number of load cycles to failure (N_f) and has been shown in Fig. 4. The curve plots all the load-controlled tests with load ratio equal to -1. This curve can readily be used in the current practice for LBB qualification for evaluating the critical load (which accounts for cyclic damage and number of load cycles) in terms of the percentage of monotonic critical load. The master curve is developed directly from the experimental results and covers a wide range of pipe sizes (NPS: 4", 6", 8", 12", 16") as well as crack sizes (2θ : 60°, 90°, 120°) and relevant nuclear piping material (Low Carbon manganese steel, Stainless steel). The master curves were plotted from base metal pipe as well as from welded pipe cyclic tearing tests. Few available results on similar tests from CRIEPI Japan [4,5] have also been plotted in the master curve. This figure clearly shows that the results for load controlled cyclic tearing of Japanese carbon steel are in good agreement with the results of the present tests series on SA333Gr6 carbon steel base material.

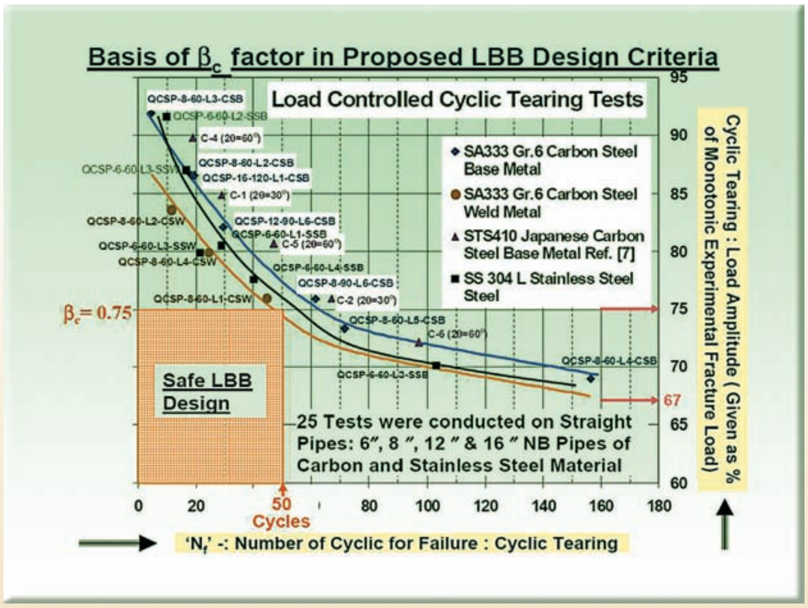


Fig.4: Master Curve for Cyclic Tearing Damage Assessment and Safe LBB Design Domain

The small difference in the results is attributed to the difference in the material chemical composition. The number of cycles to failure depends on the load amplitude and the initial crack length. Fig. 4 clearly shows that the cracked pipe can fail in a limited number of load cycles with the load amplitude sufficiently below the monotonic fracture/collapse load.

Modification in LBB Rules

Based on the master curve and the comparisons with corresponding monotonic tearing, new design rules for level 3 LBB assessment, that is, additional safety margin were suggested for accounting for the damage due to reversible cyclic loading. Since the design basis loading is of a cyclic nature, the number of load cycles must be considered in the fracture assessment of the nuclear plant piping. Usually in a typical SSE, there are around 10-20 high amplitude cycles. Considering the uncertainties associated with an earthquake i.e. its magnitude, number of seismic load cycles, after shocks etc. and uncertainties in the cyclic degradation of material, the factor of safety should be higher than revealed by these material-specific master curves. Alternatively one can fix margins on higher number of cycles. Currently it has been decided to use a load reduction factor corresponding to 50 load cycles of SSE, in LBB qualification of the pipe. However, the number of cycles to which the piping components have to be LBB qualified is a matter of safety philosophy. From the master curve (Fig. 4), the failure load for 50 cycles reduces to 78% of the monotonic failure load for the base material and to 74% of the monotonic failure load for weld material for the present series of tests. It is suggested to use the reduction factor of 3/4 (75%) over the monotonic critical load. For any other number of cycles, the master curve can be readily used for reading the reduction factor (β_c) as a function of the number of load cycles and can be applied on the monotonic critical load in LBB assessment against SSE loads, in order to account for cyclic tearing damage. Hence, with the use of β_c, the required safety factors for LBB qualification have been modified as given below

Margin to Critical Crack Size:
$(M_{noc} + M_{sse}) < \beta_c \times M_{crit}$ (at 2 x LSC)

Margin on Loads:
$(M_{noc} + M_{sse}) \times \sqrt{2} < \beta_c \times M_{crit}$ (at LSC)

Apart from single event of SSE, 5 events of OBE are also considered in the design of piping components and other structures of Indian Nuclear Power Plants (NPPs). Extending the reasoning given above for SSE loading, it was decided to use a reduction factor of 2/3 on the monotonic critical load. The factor for OBE is smaller to account, for their higher frequency of occurrence. It is apparent from the master curves (Fig. 4) that for load amplitude as 2/3 of monotonic failure load, the number of safe load cycles are more than 150. It is due to the fact that at low loads, the fatigue crack growth is predominant.

The above safety factors for OBE and SSE are directly derived from the load controlled tests and their use will guard against the instability under any seismic event. However, it is well known that the seismic event will also induce cyclic displacement-controlled loads. These loads may not lead to instability on their own but they add to the damage due to cyclic fracture resistance degradation (Fig. 3b) and can cause large crack growths (Fig. 5). Hence, a safety margin is required to guard against excessive tearing. Usages of proposed reduction factors i.e. 3/4 for SSE or 2/3 for OBE loading, reduce the critical load and the crack extension corresponding to the reduced critical load is insignificant under cyclic loading too as seen in Fig. 5. This fact shows that the proposed margin is sufficient and will guard against excessive tearing also.

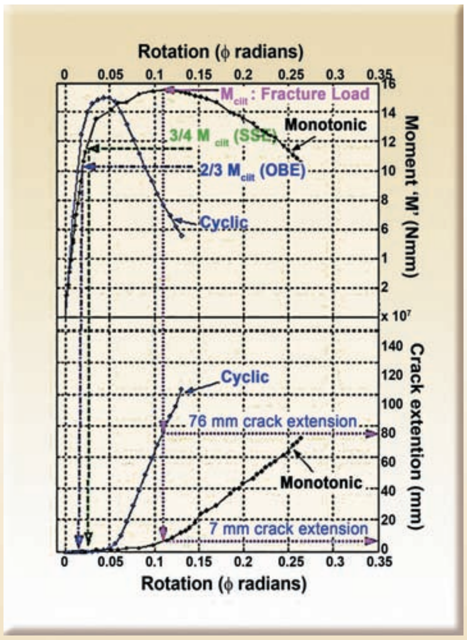


Fig. 5: Safety Factor demonstration for displacement controlled Cyclic Tearing Tests

Analytical Evaluation

The crack growth in cyclic tearing consists of two parts: one is crack growth due to low cycle fatigue and the other is due to static tearing. Few load-controlled tests have been investigated in detail with the objective to establish a methodology for prediction of instability and failure life under fully reversible cyclic loads. In the study crack growth by both, fatigue (under large scale yielding) and static fracture have been considered. The cycle-by-cycle crack growth contribution by both the modes has been calculated and then accumulated, predicted crack growth has been plotted against number of cycles as seen in Fig. 6.

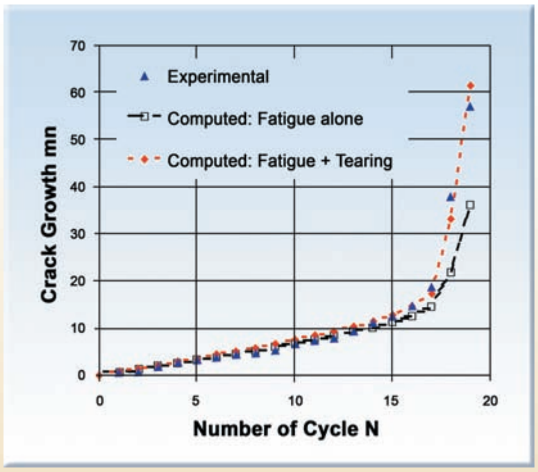


Fig. 6: Crack growth versus Number of cycles for cyclic tearing test

Conclusion

The experimental investigations reported in this paper clearly illustrate the need of addressing the cyclic fracture / tearing and number of safe load cycles in the fracture analysis of NPP piping components. Following conclusions have been drawn from the investigation:

1. The load-controlled tests have highlighted the importance of the number of load cycles in the fracture assessment of piping, subjected to a cyclic loading event. The cyclic fracture tests have shown, that the pipes will fail in limited number of load cycles with the load amplitude sufficiently below the monotonic fracture/ collapse loads. The displacement-controlled cyclic tearing tests have shown, significant reduction in the fracture resistance in comparison to corresponding monotonic. Hence cyclic effects should be accounted for in the LBB qualification of the piping components.

2. Based on experimental results, a Master Curve was developed to quantify the damage (loss in load carrying capacity and loss in fracture resistance) due to cyclic loading as a function of number of load cycles and monotonic fracture load of circumferentially through wall cracked straight pipes made of ductile material such as Low Carbon Steel or Stainless Steel. The curve is independent of crack sizes as well as pipe sizes, since all experiment data lie within a narrow scatter band. This curve gives the load reduction factor as a function of the number of load cycles and is applied on the monotonic critical load.

3. Based on Master Curve "Additional Safety Margins" were evaluated to account for the cyclic tearing damage and the same has been recommended for LBB qualification of PHT piping of NPPs. It was deciced to use a safety factor of 4/3 for SSE loading and 3/2 for OBE loading over the monotonic critical load, for LLB assessment. For an OBE, the factor is relatively higher in view of its higher frequency of occurrence than a SSE. These additional safety margins would be applied to Indian nuclear power plants, since none of the current international standards or regulatory guides account for these effects.

More details on certain aspect of the above investigations can be referred to in Gupta et al [6].

References

1. Report of the U.S. Nuclear Regulatory Commission Piping Review Committee, 1984 "Evaluation of Postulated Pipe Breaks", NUREG-1061, Vol. 3, Prepared by the Pipe Break Task Group.

2. International Atomic Energy Agency, 1993, "Applicability of the Leak Before Break Concept", IAEA-TECDOC 710, Report of IAEA extra budgetary program on the safety of WWER-440 Model-230 Nuclear Power Plants.

3. International Atomic Energy Agency, 1994, "Guidance for the Application of the Leak Before Break Concept", IAEA-TECDOC 774, Report of IAEA extra budgetary program on the safety of WWER-440 Model-230 Nuclear Power Plants.

4. Rudland, D. L., Scott, P.M. and Wilkowski, G., 1996, "The Effect of Cyclic and Dynamic Loads on Carbon Steel Pipe", NUREG/CR-6438, Report prepared for U.S. Nuclear Regulatory Commission.

5. Miura, N., Fujioka, T., Kashima, K., Kanno, S., Hayashi, M., Ishiwata, M., and Gotohm, N., 1994, "Low Cycle Fatigue and Ductile Fracture for Japanese Carbon Steel under Dynamic Loading" *Nuclear Engineering and Design*, Vol.153, pp. 57-69.

6. Suneel K. Gupta, Vivek Bhasin, K.K. Vaze, A.K. Ghosh, H.S. Kushwaha, 2007, "Experimental Investigations on Effects of Simulated Seismic Loading on LBB Assessment of High Energy Piping", *ASME-Journal of Pressure Vessel and Technology*, Vol.129,

BARC SUPPLIES "ACOUSTIC EMISSION ANALYZER" TO CROMPTON GREAVES

An Advanced Multi-channel (4-Channel) Acoustic Emission Analysis System* (AEA), developed by the Control Instrumentation Division (CnID) was supplied to M/s. Crompton Greaves Ltd., (CGL) Mumbai on the 27th of April, 2007.

Crompton Greaves Limited is one of the leading manufacturers of power transformers in India. It came to know about BARC's indigenous development of the AEA system through a National Workshop held in CPRI, Bangalore. M/s. CGL has plans for use of AE technology for the detection and location of partial discharges, which is a vital diagnostic parameter for power transformer health.

Acoustic Emission Analyzer (Fig. 1) has powerful state-of-the-art high-speed hardware and is flexible, easy to use, with 32 bit software tools and Windows 98/2000-based GUI. It is based around PCI bus for high throughput for no loss of AE data and easy expandability in terms of increasing the number of channels and performance. The Acoustic Emission Data Analysis (AEDAQ) Card (Fig. 2) acquires AE parameters and wave forms from four independent channels. It uses 32-bit Digital Signal Processor (DSP) for waveform processing and control and Field Programmable Gate Arrays (FPGAs) for real time AE parameter extraction. Input section consists of programmable gain amplifiers and band pass filters. Windows-based software has three operating modes viz. Parameter extraction mode, Waveform analysis mode and Source Location mode (Fig. 3).

M/s. CGL's Global R&D centre reported complete development of an online Power Transformer detection and Monitoring of Partial Discharge, using BARC's AEA System. The system was tested by CGL's personnel as per ASTM E-750 standard.

The Technology Transfer & Collaboration Division managed all activities related to supply of AEA to Crompton Greaves in terms of preparation of documents, quotation and co-ordination for testing and inspection.

Fig. 1: Four Channel AEA System

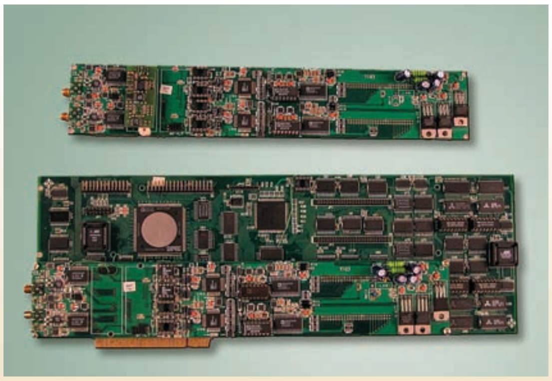


Fig. 2: Four Channel AEDAQ Card

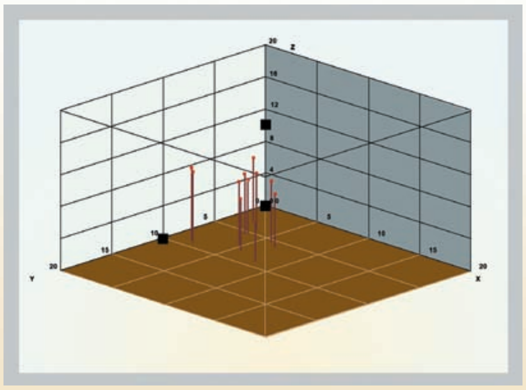


Fig. 3: Snapshot of online 3D Graph display

*BARC Newsletter No. 240, January 2004, "Development and Evaluation program on Multichannel Acoustic Emission Analyzer."

Forthcoming Symposium
DAE Solid State Physics Symposium

The DAE/BRNS has organized a five-day symposium, the 52nd in the series, at the University of Mysore, Manasagangotri, Mysore, from 27-31 Dec. 2007. As part of the symposium, two awards " Best Ph.D. Thesis Award" and "Young Achiever Award" have been instituted and nominations are invited for the same. Papers on the following topics are to be submitted by e-mail to pap_ssps@barc.gov.in

a) Phase Transitions b) Soft Condensed Matter including Biological Systems & Liquid Crystals c) Nano-materials d) Experimental Techniques & Devices e) Liquids, Glasses & Amorphous Systems f) Surfaces, Interfaces & Thin Films g) Electronic Structure & Phonons h) Superconductivity i) Transport Properties j) Semiconductor Physics k) Magnetism including Spintronics l) Novel Materials.

Important Dates:

Submission of paper	: 3rd Sept., 2007
Intimation of acceptance	: 20th Oct., 2007
Registration	: 15th Nov., 2007
Accomodation Request	: 15th Nov., 2007

Final confirmation of participation (by the delegates) against payment of registration fee: 1st Dec. 2007.

The local convener of the symposium may be contacted for accomodation and other local arrangements. For further details, one may contact

Dr. S.K. Gupta
Convener, DAE-SSPS 2007
TPPED,
BARC,Trombay
Mumbai 400 085, India
E-mail:ssps07@gmail.com
website:http://www.barc.gov.in/symposium/ssps2007

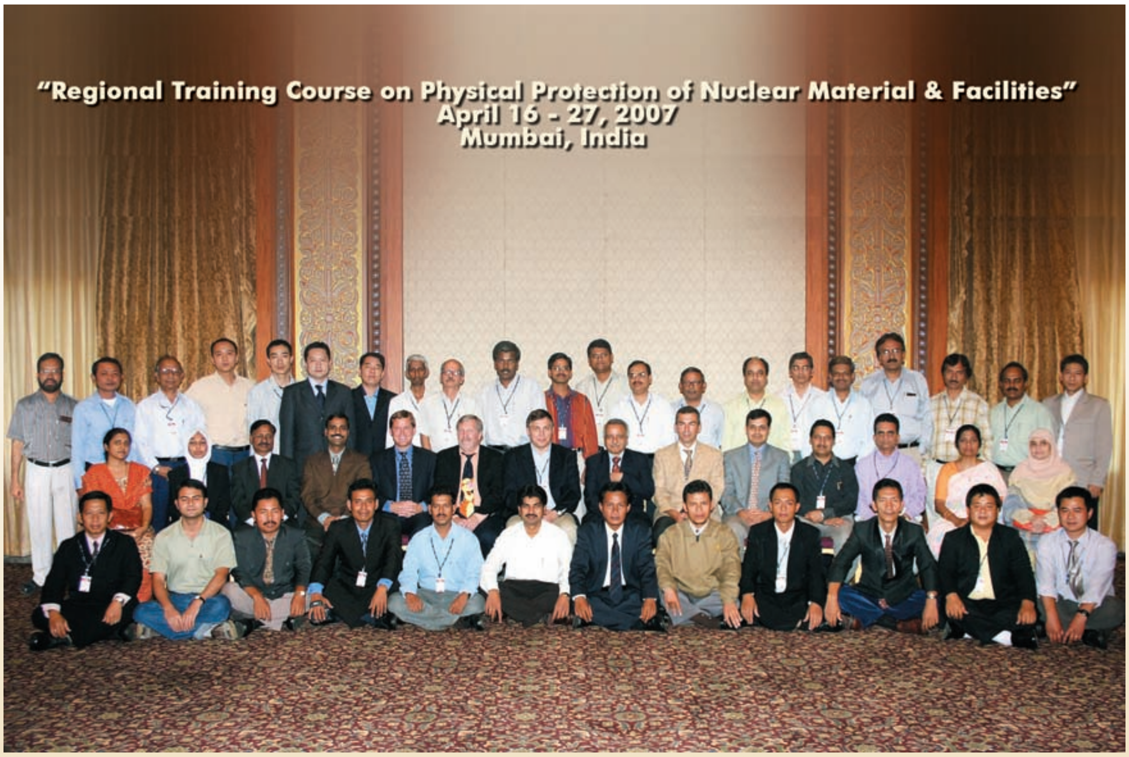
Prof. D. Revannasiddaiah
Local Convener, DAE-SSPS 2007
Dept. of Studies in Physics
University of Mysore
Manasagangotri
Mysore - 570006
E-mail: ssps@physics.uni_mysore.ac.in

REGIONAL TRAINING COURSE ON PHYSICAL PROTECTION OF NUCLEAR MATERIALS AND FACILITIES: A REPORT

The fourth Regional Training Course on Physical Protection of Nuclear Materials and Facilities was organized jointly by the Department of Atomic Energy, Government of India and the International Atomic Energy Agency (IAEA) during 16 – 27 April, 2007 at Hotel Sea Princess, Juhu, Mumbai. The course was inaugurated by Mr S.S. Bajaj, Senior Executive Director (Safety), Nuclear Power Corporation of India Limited (NPCIL) and concluding session was chaired by Mr H.S. Kushwaha, Director, HS&E Group, BARC. This two week course was organized with 37 lecture sessions and 10 workgroup sessions, a plenary session and a field visit to KAPS.

Wide ranging topics under nuclear security like nuclear fuel cycle activities and their physical protection concern, Design Basis Threat (DBT), design and evaluation of physical protection system, international physical protection regime, IAEA activities in nuclear security, security technologies, security and control of radioactive sources etc. were covered in depth during this course. It also included several emerging areas of nuclear security like safety-security interface, interface between nuclear material control, accounting and security etc. Working group exercises were carefully designed, to cover different aspects of designing of physical protection systems for

At the inauguration: left to right: Dr K. Raghuraman, Head ISD, DAE, Mr G.P. Srivastava, Director. E&IG, BARC, Mr S. Bhattacharya, Head CnID, BARC (Course Director), Mr S.S. Bajaj, Senior Executive Director (Safety) NPCIL, Mr Vladimir Kryuchenkov and Ms Cindy Coolbaugh IAEA.



Participants at the Training Course

nuclear facilities including designing of sub-systems, evaluation and upgradation of design.

There were 34 course participants, 19 foreign participants; 7 from Indonesia, 3 each from China and Bangladesh, 2 each from Thailand and Vietnam, one each from Malaysia and Korea. There were 15 participants from India. Among the Indian participants 3 were from BARC, 2 from AERB and 1 each from NPCIL Mumbai, NAPS, MAPS, TAPS, MHA Delhi, AMD Hyderabad, NFC Hyderabad, BRIT Mumbai, ECIL Hyderabad and IGCAR, Kalpakkam. A total of 17 faculty members were involved in deliberations of the 37 lecture sessions. Among these 17 faculty members, 2 were from SNL, USA, one from IAEA, one each from Russia and Spain and 12 faculty members from India were involved.

Three volumes of course material containing more than 700 pages of handouts of the presentations as well as detailed lecture notes and a CD containing all the lecture notes and other related documents provided by IAEA, was prepared for this course. The course was very well received by all participants and feedback from them was very encouraging. Agency members were extremely satisfied with the course organization, course material and the faculty.

63rd BRNS-IANCAS NATIONAL WORKSHOP ON RADIOCHEMISTRY AND APPLICATION OF RADIOISOTOPES: A REPORT

The 63rd BRNS-IANCAS National workshop on "Radiochemistry and Application of Radioisotopes" was organized at the Birla Institute of Science and Technology, Pilani, Goa Campus during January 19-28, 2007.

The workshop was inaugurated by the Vice Chancellor of BITS Pilani on 19th of January. Dr V. K. Manchanda, President, IANCAS presided over the function and delivered the inaugural address. Dr S. Kannan, coordinator of the workshop, briefed about the workshop. Dr Ray, Convener of the workshop thanked the IANCAS for organizing and conducting the workshop at BITS , Pilani, Goa campus, Goa. There were seventy participants who attended the workshop, out of which thirty were from outside Goa, twenty from the faculty of BITS, Pilani Goa and the remaining were students of BITS, Pilani and Goa. The participants were divided into six groups for the practicals. Extra time was given to some of the participants, who wanted to repeat the experiments in the evening.

Dr D'Souza, Associate Director, Biomedical group, Dr Shivaprasad, Senior General manager, BRIT, Dr Borole, Senior Scientist, NIO, Goa, Dr S.B. Manohar, Dr A. Ramasamy, Dr P.N. Pathak, Dr Vijay, Dr S. K. Sali, Dr S. Kannan, Mr M.Y. Ali and Mr. S. B. Deb delivered the invited lectures and conducted the practicals along with Mr Nilesh Tawade.

At the Inauguration: left to right: Dr Uppal Das, Dr S. Kannan, Coordinator, IANCAS, BARC, S.B. Manohar, Dr V.K. Manchanda, Prof. Maheswari, Vice-Chancellor, BITS, Dr Goyal, Director, BITS, Goa and Prof. S.K. Ray, Local convener

Dr S.K. Sali, Resource person, demonstrating the experiment

There were four school-level workshops conducted one each at VASCO, Madgaon and two at Panaji. More than 1000 students attended these workshops. On 28th of January, a special school workshop was conducted at BITS-Pilani, Goa campus for students from different parts of Goa. More that 600 students participated in this workshop and the workshop was presided by the Minister for Education, Government of Goa and Director for School Education, Government of Goa. The demonstration experiment on half-life determination being very relevant and simple for the school students, kindled enthusiasm in the children and the teachers who teach this subject. Mr. S.G. Markandeya, Head, P&CD, BARC gave a detailed account on the activities of BRNS in promoting the subject of Nuclear Science and Technology through projects. Many faculty members interacted with him during his lecture.

The Valedictory function was presided by Dr Shivaprasad from IANCAS and Dr Goel, Director, BITS-Pilani, Goa. The certificates were presented by Dr Shivaprasad. Dr Shivaprasad, donated the GM and NaI/Tl counters to Dr Goel. Dr Kannan expressed his opinion about the workshop and took feedback from the participants. Mr. S. B. Deb, Practical Coordinator, proposed the vote of thanks.

NATIONAL SAFETY DAY CELEBRATIONS AT BARC

The National Safety Day was celebrated on 5th March, 2007 at the Centre. An exhibition was arranged at the Central Complex Auditorium, BARC, Trombay. Display of safety posters on different themes and safety-related information charts, conducting safety slogan contest and safety poster competition and screening of safety films were the highlights of the programme.

Mr H.S. Kushwaha, Director, HS&E Group and Chairman, BARC Safety Council inaugurated the safety exhibition. He appreciated the efforts taken towards spreading safety awareness among the employees. Many Heads of Divisions graced the occasion. The programme was supported by the employees at all levels by way of active participation in the competitions.

As part of its efforts in promoting safety through educational and motivational activities under the Accident Prevention Programme, Industrial Hygiene and Safety Section (IHSS), Radiation Safety Systems Division, organizes this one-day common safety programme every year. The results of the Safety Poster Contest – 2007 and Safety Slogan Contests – 2005 & 2006 were displayed in the exhibition. To evaluate the entries, Dr D.N. Sharma, Head, Radiation Safety Systems Division constituted a committee comprising Dr U.V. Phadnis and Dr R.M. Bhat, RS Section, RSSD, Mr Lal Chand, Health Physics Division and Mr M.S. Kulkarni, RPIS, RSSD. Members of IHSS coordinated with the committee.

Posters displayed at the exhibition

TECHNICAL MEET OF SAFETY COORDINATORS OF BARC

The Industrial Hygiene and Safety Section of the Radiation Safety Systems Division, organized the first 'Technical Meet of Safety Coordinators of BARC' during April 18-19, 2007 at the Central Complex Auditorium, BARC. The two-day programme was inaugurated by Director, BARC and comprised a session of invited talks and six Technical Sessions. In all there were twenty technical talks, on varied health and safety related topics, delivered by eminent personalities, senior scientists and safety coordinators. The technical meet provided a bird's eye view of safety aspects that are practised in different fields of activities of BARC facilities. Also, the Meet served as a forum for the safety coordinators for sharing their views and experience.

During the welcome address Dr D.N. Sharma, Head, Radiation Safety Systems Division, recalled the background of nomination of Safety Coordinators way back in 1969. He mentioned that the safety coordinators were the key personnel, who liaise with IHS Section, in strengthening the safety programme of this centre. Mr H.S. Kushwaha, Director, Health, Safety and Environment Group and Chairman, BARC Safety Council, in his presidential address, highlighted the importance of exchange of expert opinion and knowledge, to improve our safety performance. Mr P.B.Kulkarni, Chairman, CFSRC and Chairman, Director's Safety Award Committee, briefed the process of selection of the winner of Safety Shield and announced the winner of the award for the year 2005. He wanted the Safety Coordinators to publicize this scheme for an improved participation in the competition. Dr S. Banerjee, Director, BARC inaugurated the Meet. In his inaugural address, the Director outlined a comprehensive approach to betterment of safety status. He stressed the importance of a pragmatic and conscientious method in the implementation of our safety programme, especially in the light of our assumption of self-regulatory responsibility. Mr S. Soundararajan, Head, IHS Section proposed the vote of thanks.

Mr R.V. Raje, Safety Coordinator, and Mr P. Janardhan, Plant Superintendent, PREFRE Plant receiving the Safety Award for 2005 from Dr S. Banerjee, Director, BARC

भा. प. अ. केंद्र के वैज्ञानिकों को सम्मान

BARC SCIENTISTS HONOURED

V.K. Dhar

Dr A.K.Tickoo

M.K. Koul

R. Koul

Dr B.P. Dubey

दिनांक 7-9 फरवरी 2007 के दौरान उस्मानिया विश्वविद्यालय में हुई भारतीय खगोलीय सोसाइटी की 25 वीं बैठक में "सर्वोत्कृष्ट पोस्टर" का पुरस्कार "फिजिबिलिटी ऑफ यूजिंग ए.एन.एन.-बेस्ड एल्गोरिथम्स फॉर इंप्रूविंग द सेन्सीटिविटी ऑफ टी ए सी टी आई सी इमेजिंग टेलिस्कोप " नामक शोध-पत्र को दिया गया । यह शोध-पत्र खगोलभौतिकी विज्ञान प्रभाग के श्री वी.के. धार, डॉ. ए.के. टिक्कू, श्री एम.के. कौल, श्री आर. कौल और इलेक्ट्रॉनिक्स एवं यंत्रीकरण सेवाएं प्रभाग के डॉ बी.पी.दुबे द्वारा लिखा गया था ।

The paper entitled, "Feasibility of using ANN-based algorithms for improving the sensitivity of TACTIC imaging telescope", was given the "Best Poster" award at the 25th meeting of the Astronomical Society of India, held at Osmania University during 7th – 9th February 2007. The paper was authored by Mr V.K. Dhar, Dr A.K. Tickoo, Mr M.K. Koul, Mr R. Koul of Astrophysical Sciences Division and Dr B.P. Dubey of Electronics and Instrumentation Services Division.

B.K.Shah

श्री बी.के.शाह, गुणवत्ता आश्वासन प्रभाग (Quality Assurance Division), भाभा परमाणु अनुसंधान केंद्र को इन्डियन सोसाइटी फॉर नॉन-डेस्ट्रक्टिव टेस्टिंग (ISNT), मुंबई के द्वारा संस्थापित " एजुकेशन एण्ड ट्रेनिंग एचीवमेंट अवार्ड 2006" पुरस्कार से सम्मानित किया गया। यह पुरस्कार इन्हें विभिन्न एनडीटी प्रशिक्षण कार्यक्रमों के पाठ्यक्रम अध्यक्ष एवं क्षेत्रीय नियंत्रक की हैसियत से प्रमाणक कार्यक्रमों को उपयोगी एवं प्रभावशाली बनाने में विशेष योगदान देने के लिए प्रदान किया गया। इनको "बेसिक मेटलर्जी फॉर एनडीटी एण्ड ऑरगनाइज़ेशन ऑफ दि प्रोफिशंसी टेस्टिंग प्रोग्राम इन एनडीटी फॉर दि फस्ट टाइम इन दि कंट्री " जैसे लोकप्रिय पाठ्यक्रम की पहल करने का श्रेय भी दिया गया है।

Mr B.K. Shah, Quality Assurance Division (QAD), BARC has been conferred the "Education & Training Achievement award 2006' instituted by the Indian Society for Non-Destructive Testing (ISNT), Mumbai. The award was presented to him for his significant contributions as Course Director for several NDT Training Programmes & as Regional Controller of the Certification Programme for making it more effective. He is credited with having initiated the popular course" Basic Metallurgy for NDT and organization of the proficiency testing programme in NDT" for the first time in the country.

Edited & Published by :

Dr. Vijai Kumar,

Associate Director,Knowledge Management Group &

Head, Scientific Information Resource Division,

Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India.

Editorial Management : Ms. S.C. Deokattey, Computer Graphics & Layout : N. Kanagaraj, SIRD, BARC

BARC Newsletter is also available at URL: http://www.barc.gov.in (for private circulation only)