Remote Visual Inspection of a Dissolver Vessel in Fast Reactor Fuel Reprocessing Plant

**EXECUTIVE SUMMARY**

Reprocessing of spent fuel is a crucial stage in Indian Nuclear Energy Programme since it facilitates recovery of fissile fuel. Reprocessing of spent fuel involves operations in highly disordered and radioactive environment. Reliable performance and safe operation of fuel reprocessing plants is essential for sustained throughputs. Consequent to successful commissioning of a reprocessing plant, periodic in-service inspection (ISI) and monitoring of critical plant components is necessary in order to ensure that service-induced defects & abnormalities are detected and remedied beforehand. During ISI and in many instances, limited access, radiation and acidic environment prevailing in a reprocessing plant obviate direct human intervention necessitating remote tools and gadgets. Remote visual inspection was carried out successfully in a COmpact facility for Reprocessing of Advanced fuels in Lead cells (CORAL) at Kalpakkam.

**OUTLINE**

Visual examination is one of the ISI techniques for the inspection of the internal surface of the dissolver vessel in the reprocessing plants. As part of ISI of dissolver vessel in CORAL, a remote inspection device using a camera was developed and successfully demonstrated in CORAL. The dissolver vessel is located inside a lead-cell containment box and the device has to be deployed inside the dissolver vessel through a double door port, of size ø 273 mm x 250 (L) mm. The device including the camera had to be light weight and compact in view of the limitation of the in-cell handling equipment.

The device has two degrees-of-freedom namely, a vertical telescopic movement and an azimuth motion facilitating visual scan of the entire inner surface. The position of the camera with respect to the vessel during viewing can be identified by physical marking laid out externally on the vessel. Collapsible feature is incorporated in the device to facilitate its posting into the containment box through the double door port. The device has modular construction to facilitate easy assembly and maintenance. The telescopic stage consists of 5 stages having a total travel range of 430 mm and the azimuth motion has 360° travel. Overall size of the device in the collapsed state is ø 195 X 305 mm. A ¼”CCD-based camera with a resolution of 320 TV lines with ring lighting using LEDs was used for the visual inspection. Fig.1(a) & (b) shows the photographs of the inspection device in collapsed and extended condition. Fig.1(c) shows the camera with ring lighting. Since the observations have to be recorded for future reference as baseline data, a VHS recorder was used for storing the video images while a video monitor was used for on-line viewing.

The scanner had to be posted into the containment box in two sub-assemblies through the double door port and then through the blister box behind the cell. The device can be made to cover the full depth of the vessel by lowering it along guideposts in 5 stages and there is provision for locking at any of these predefined locations along the guide post. Both the vertical and azimuth motions are manually controlled. The telescopic members are constructed using different diameter pipes sliding into each other causing linear motion. A steel wire rope attached to the bottom-most pipe is carried through the telescopic pipes to a capstan located at the top of the azimuth stage. The telescopic motion is achieved by rotating the capstan via a knob that releases or takes up the wire rope. Azimuth motion is achieved by rotating the azimuth stage using three equi-spaced protruding pins. Both telescopic and azimuth stages have markings by which the position and orientation of the camera inside the vessel can be determined with an accuracy of 1mm for telescopic and 10 degrees for azimuth motions.

Visual inspection of the dissolver vessel limb in CORAL was successfully carried out. Since the observations have to be recorded for future reference as baseline data, a VHS recorder was used for storing the video images while a video monitor was used for on-line viewing. It was seen that the vessel remains free of remnants after dissolution of the fuel and there is no clogging of chute. All accessible welds and surface of the vessel limb were examined closely. All ports especially the one leading to the chopper was seen clearly. In general, no degradation or corrosion has been observed. The significance and consequences of the visual inspection data obtained in this campaign can be analysed during the subsequent inspection campaigns.

![Photographs of the remote inspection device with camera and LED lighting used for the visual inspection](image1)

![Images of critical areas of dissolver vessel obtained during the inspection campaign](image2)
ISI OF DISSOLVER VESSEL

In addition to visual examination of the inner surface of the dissolver vessel, it is planned to examine the wall thinning of the dissolver vessel due to corrosion by Ultrasonic testing and surface pitting by Laser-based inspection technique. A 2-axis telescopic scanner has been developed for this purpose. The scanner has a telescopic axial motion and an azimuth motion facilitating cylindrical surface scan. The scanner with UT probe has been tested and validated in a mock-up dissolver vessel. A laser triangulation system with mechanical scanner has been developed and tested in collaboration with RRCAT, Indore.

GENERAL EXPLANATION RELATED TO THE DESCRIPTION

Dissolver is the important equipment in a nuclear fuel reprocessing plant. After chopping of the irradiated / spent fuel pins in a chopper, the bulk material will be fed to the dissolver vessel where electrolytic dissolution is carried out in boiling concentrated nitric acid by passage of current through the electrodes. The final dissolver solution contains several fission products and ions. Failure of the dissolver will cause leakage of radioactive material-contained liquid to the operating area, which is not acceptable. Hence, periodic inspection of the dissolver vessel is essential to assess the effects of corrosion-induced damage. Fig.3 shows the sectional elevation of the dissolver vessel. The inner diameter of the vessel is 100 mm and depth is 560 mm upto sparger level located inside the vessel. The vessel has number of ports which require to be inspected for clogging to the extent possible.

Fig. 3 : View of the dissolver vessel

BRIEF DESCRIPTION OF THEORETICAL BACKGROUND

As part of the program for comprehensive in-service inspection of critical components of the reprocessing plants, the dissolver vessel of the CORAL is required to be inspected periodically using NDE techniques to assess its healthiness and integrity. One of the NDE techniques envisaged is visual examination using a camera and remote device.

ACHIEVEMENT

A challenging task of remote visual inspection of a dissolver vessel as part of ISI has been successfully completed. Such comprehensive ISI campaigns in reprocessing plants especially for dissolver are not reported worldwide and it is a significant step forward in our ISI programme. The development of various gadgets for the ISI and its validation using a mock-up facility and successful implementation in the field has given immense confidence for undertaking such tasks in other areas of reprocessing plant. The ISI is also being extended using NDE techniques such as UT and Laser triangulation for fine detection of corrosion damages like wall thinning and surface pitting. The feedback gained from the experience of this campaign will be put to use while designing such systems for the demonstration as well as plant-level reprocessing facilities. Such feedbacks are also useful in providing various plant features and equipment layouts at the design stage itself for future reprocessing plants.

PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK

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