DESIGN, DEVELOPMENT AND DEPLOYMENT OF INSIDE DIAMETER MEASUREMENT TOOL FOR 220 MWE PHWRS

G. Sharma, S. Bhattacharyya, V.P. Bodile and R.J. Patel
Refuelling Technology Division

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Abstract

Inside Diameter (ID) measurement of PHWR coolant channels is required to be carried out for diametral creep assessment. Inside Diameter Measurement Tool (IDMT) has been developed for mass scale ID measurement in water flooded condition using Fuelling Machines. IDMT is having a conical ball actuator which actuates three balls axially outward. The ball actuator is moved by the Ram-C of Fuelling Machine and travel of ball actuator is reflected on potentiometer of the Ram-C. The IDMT is quickly deployable and does not requires hose / cable connection to operate. IDMT was first time deployed in KAPS-2 for carrying out measurement in 26 numbers of channels. This experience enabled refinement in the technique before deploying again in KAPS-2 for measurement in 16 channels. Implementation of IDMT has given leverage to reactor operation in terms of significantly reduced man-rem consumption. IDMT is useful for faster scanning of large number of channels to identify bigger diameter channels for further scanning due to its quick deployment capability.

Introduction

Expansion of coolant channels due to creep and growth is one of the major life limiting parameters of coolant channels in Pressurized Heavy Water Reactors (PHWRs). Heavy water at high pressure and temperature flows inside the coolant channels. The radioactive environment causes axial and radial creep in pressure tubes. Expansion due to radial creep increases pressure tube diameter which may lead to coolant bypass resulting in insufficient cooling to the fuel bundles and is a safety concern. It also results in reduction in gap between pressure tube and calandria tube. Hence periodic radial creep monitoring of pressure tubes of PHWRs under life management program is necessary.

BARC has developed few tools for measuring ID of coolant channels in past viz. 3-point micrometer,
HYdraulic Remote Inside diameter Measurement system (HYRIM) and recently UT based measurement technique incorporated in the BARCIS. Elaborate preparation, more reactor shut-down time and human presence in the vault make these tools less attractive in terms of man-rem consumption and ease of operation.

An innovative IDMT has been evolved for mass scale wet-condition measurements of coolant channel ID remotely using Fuelling Machines (FMs). The tool is having three numbers of balls located equispaced and can be moved radially outward by axial movement of ball actuator. The tool can reach up to centre of channel using extensions. The tool remain sandwiched between fuel column and Ram-B of FM. IDMT is positioned at desired location by moving fuel column and Ram-B. Fig. 1, shows the scheme.

**Working Principle**

IDMT is assembled with three balls supported on a ball actuator and retained in the radial holes in the body. The balls move radially outward due to axial motion of a taper ball actuator. Fig. 2 depicts cross section of the tool. In normal condition, ball actuator is held backwards by spring force and balls remain in collapsed condition. In this condition, tool is positioned at desired location using fuelling machine. For measurement of ID, Ball actuator is pushed by Ram-C of FM causing balls to move radially outward to touch ID of Pressure Tube. The radial movement of balls is a linear function of ball actuator travel. Ram-C travel is calibrated in terms of inside diameter.

<table>
<thead>
<tr>
<th>Major Dimensions of IDMT</th>
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<tr>
<td>Length</td>
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<tr>
<td>Diameter</td>
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<tr>
<td>Stroke</td>
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<td>Cone Angle</td>
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<td>Measurement range</td>
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**Overall Scheme**

IDMT is positioned by Ram-B at desired location. During measurement tool front face gets supported against the fuel column. Fuel column at other end is supported by Ram-C of other FM. Extensions are used to position tool inside the channel since reach of Ram-B is limited. Space available in the FM magazine allows maximum four number of extensions to be stored, which can facilitate measurement up to middle of the channel. Other half of channel can be measured by deploying IDMT from other side (refer fig. 3).

Fig. 2: ID Measurement tool –sectional view and photograph of IDMT
FM Ram-C (measurement side FM) is advanced to move balls radially outward. As soon as the balls come in contact with Pressure Tube, ball actuator stalls causing Ram-C to stop. The travel of Ram-C is recorded to calculate inside diameter of Pressure Tube.

**Design Calculations and Qualification**

IDMT has challenges for design and deployment in terms of ensuring safety of Pressure Tube and getting satisfactory accuracy. These concerns were addressed by analysis, calculations and performing elaborate experiments.

![Fig. 3: IDMT with one extension](image)

Insertion of tool and extension in channel restricts the flow through channel and bundle cooling may be affected. A flow analysis was performed to ascertain bundle safety. Current geometry of the tool and extensions allows sufficient flow for bundle cooling after 3 days of shutdown.

Full-fledged mock-up trials were conducted at Rehearsal Facility Tube using FM to validate the operating procedure. Theoretical uncertainty in the measurements was estimated using NIST guidelines. IDMT measurement accuracy is within 0.2 mm.

**Deployment in the reactor**

IDMT was first time deployed in KAPS-2 for carrying out ID Measurement of 26 numbers of channels. Based on this campaign, procedures were further improved to get enhanced accuracy.

IDMT was again deployed in August 2012 for ID measurement in 16 channels. The IDMT measurements were compared with BARCIS. The agreement between both techniques was within 0.24 mm and this variation is within uncertainty margin. The IDMT took about 2 hours to complete half channel scanning.
Conclusions

Inside Diameter Measurement Tool (IDMT) has been developed for measurements of coolant channel ID in water flooded condition using Fuelling Machines. The IDMT is a remotely operable tool which can be quickly deployable and do not requires hose/cable connection to operate. The IDMT was used for ID measurement in half the channel from hot end side. The performance of the IDMT is found to be satisfactory and measurement of a channel can be completed in 2 hours. The IDMT is found to be convenient to use and due to remote operation the consumption of man-rem was negligible. IDMT performed as intended and the ID data generated found useful for safety assessment. IDMT is useful for faster scanning of large number of channels to identify bigger diameter channels for further scanning due to its quick deployment capability.

![Fig. 6: Bar plot representing radial creep in KAPS-2 as on September 2010](image)