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Monitoring of Axial and Radial Creep of Coolant Channels in Operating PHWRs

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Abstract

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). The environment of high stress, temperature and neutron irradiation causes axial and radial creep in pressure tubes. Creep monitoring of coolant channels is required to be done periodically in PHWRs as part of life management program for coolant channels. Axial and Radial creep measurement techniques have been developed by Refuelling Technology Division (RTD), Bhabha Atomic Research Centre (BARC) and successfully implemented in Indian PHWRs.

Keywords: Creep monitoring; radial creep; axial creep; pressure-tube creep; Indian PHWR

1. Introduction

The operating 220MWe and 540MWe PHWRs consist of 306 and 392 number of pressure tubes respectively. Pressure Tubes (PT) are among the critical components of this type of reactor. The material of construction of PT in Indian reactors is Zr-Nb alloy. The pressure tubes are subjected to high stress due to the coolant pressure of heavy water and high temperature and neutron irradiation during operation. These factors causes both thermal and irradiation creep in the pressure tube.

The expansion of coolant channels due to creep and growth is one of the major life limiting parameters of coolant channels in PHWRs. Axial creep leads to increase in coolant channel length. This needs to be monitored to maintain the definite gap in the end fitting hardware to allow for axial creep as interference may cause pressure tube to sag. Expansion due to radial creep increases coolant channel inner and outer diameters (ID & OD) which may lead to insufficient cooling to the fuel bundles due to coolant flow bypass and also reduces the gap between pressure tube and calandria tube due to outer diameter increase of pressure tube. Hence creep monitoring of coolant channels is required to be done periodically in PHWRs as part of life management programme for coolant channels. RTD, BARC has evolved techniques to measure these

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parameters remotely. These techniques use Fuelling Machine (FM) to approach the channels and perform measurements remotely, saving time and reduces man-rem exposure.

This paper describes the principles of these techniques and the results obtained using these techniques on operating PHWRs.

2. Measurement of axial creep

The axial elongation of all the coolant channels must be periodically (every two years) measured in order to assure the following:

- The end fittings remain in the bearing sleeves in the end shield at all times during operation and reactor shutdown.
- The creep gap provided in 220MWe units must not reduce to zero during operation.
- There are no hardware interferences i.e. gap exists between feeder to feeder in the same bank and feeder to adjacent channel Grayloc clamp joint nuts.
- The fuelling machine can clamp the end fitting without interfering with adjacent channel end fitting due to higher elongation in that channel.

Axial creep of coolant channels were being initially measured using an Optical Method which was manual, and has limitations due to geometric layout in fuelling machine vaults, significant men-rem consumption and was taking about one week for measurement. This method of measurement was dependent on the skill of the operators and was error-prone and has been abandoned now.

Subsequently a PC based remote Technique for Measuring Axial Creep (TMAC) was developed which uses existing FMs on both sides of FM vault to butt on the coolant channels to take measurements. TMAC is currently in use by all operating plants for axial creep measurement and it takes about 14-18 hours for complete measurement. Recently an improvised system based on non-contact ultrasonic sensor, Ultrasonic Measurement of Axial Creep (UMAC), was developed to reduce measurement duration further and making the measurement more operator friendly. Since the fuelling machines need not to touch end fittings, UMAC is faster than TMAC and takes about 4-6 hours for the entire measurement. UMAC provides a graphical profile of all the coolant channels (Fig. 1).

2.1. TMAC technique

TMAC is a remotely operated tool developed for measuring axial elongation of coolant channels using FM. TMAC technique uses the existing linear potentiometer of the FM for the measurement by comparing the length of coolant channel with its original length. Since the length of coolant channel cannot be measured directly the expansion due to creep is measured by measuring the gap between FM and channel face. The method requires a reference plane, which remains fixed throughout the reactor life. The end fitting face (E-face) of a Rehearsal Tube Facility (RFT) channel is used as a reference plane, which remains fixed throughout the reactor life (as RFT channels do not experience high temperature and fast neutron flux, which cause the in-reactor creep). The original distance of channel E-face from FM face is measured from this reference plane at the time of commissioning of the reactor, which is known as base data. The distance of the channel E-face from the reference plane is measured on both sides of the coolant channel every two years. The difference between the measured data from base data, after normalization, gives the measurement of the channel up to the time of measurement.

2.2. UMAC technique

Development of an Ultrasonic Measurement technique for Axial Creep, UMAC is another step in advancement of the creep measurement techniques for coolant channels of Indian PHWRs. This method reduces the measurement duration further and makes the system more operator-friendly [1]. Similar to TMAC, this technique also uses FMs for creep measurement. UMAC has its own non-contact ultrasonic sensor for distance measurement which enables the FMs to scan the channels while TMAC uses linear potentiometers