L.1: Laser cutting of yoke assembly triangular blocks of coolant channels in pressurized heavy water reactors (PHWR)

One of the major life limiting parameters of coolant channels in Pressurized Heavy Water Reactors (PHWRs) is expansion and deformation of coolant channels due to creep and growth. The shock absorber assemblies of coolant channels have a provision for periodic adjustment of the axial creep to compensate for axial elongation of the coolant channels. This is done periodically by adjusting a nut on the yoke stud. The two halves of yoke assembly are usually tightened on the coolant channels using 18 mm thick rectangular fixing blocks of AISI SS410 stainless steel. However, in the shock absorber assemblies of RAPS-3 in several coolant channels triangular shape blocks have been used instead of rectangular fixing blocks for the yoke assemblies. The apex part of the triangular block has a hole for inserting it through the yoke stud. Due to the thick apex part of the triangular block, the creep margin of coolant channel reduces by 19 mm (18 mm thick fixing block plus 1 mm thick washer). In RAPS-3, the creep margin of some of the coolant channels with these triangular blocks has now reached the maximum value and no further margin is left for creep adjustment. This is a dangerous situation, since without the creep adjustment there will be severe axial load on the coolant channels. Hence, as per the AERB guidelines these coolant channels would have to be closed, which would have resulted in substantial loss in power generation and revenue. There were two options to create additional margin for the creep adjustment, i.e. either replacement of the triangular blocks with rectangular blocks without damaging the yoke or to cut away the apex part of the triangular fixing block. The first option was not feasible due to time factor and radiation dose. Hence second option was preferred.

Mechanical cutting of these blocks was difficult, due to radiation exposure, increased hardness of these blocks in the radiation environment Further, the cutting location is at a distance of 1.5 m and the available free gap between the two channels is at some points as small as 50mm. Alternate approach for cutting of these blocks is laser based cutting without damaging the yoke. Since triangular fixing blocks are tightened on the yokes, through and through cutting is not possible since no space is available for removal of debris from the back surface of the block. Thus, a multi-pass laser grooving method was adopted to cut the block and a laser grooving process for grooving up to a depth of 19 mm in arc shape was developed in which molten material can be removed tangentially along the cut surface.

A home-built fiber coupled pulsed Nd:YAG laser with 250 W average power has been used for laser cutting of these triangular blocks. Further, a compact laser cutting fixture has also been developed, which contains a rotary gear mechanism for movement, a locking mechanism for tool, mounting of nozzle at an angle, mounting of motor and limit switches for controlled motion of nozzle during cutting process. Fixture can be inserted easily between feeder pipes and neighboring channels with the help of semi flexible inserting rods. It can be precisely mounted on shock absorbing stud and can be locked with triangular fixing blocks. For grooving, laser cutting nozzle has been mounted at an angle with respect to normal to the surface and debris is removed by a high pressure assist gas. In laser grooving, material removal requires a particular combination of cutting speed and gas pressure along with laser power, so that a clean groove up to certain depth is achieved in each laser pass. A total of 22 laser passes were required to groove up to a controlled depth of 18 mm of fixing block without any damage to yoke assembly. Cutting radius was selected to be 50 mm, so that strength of remaining piece of triangular block has sufficient strength to hold the yoke assembly and simultaneously it can provide extra space for creep adjustment. Laser grooving parameters such as laser pulse energy, pulse duration, pulse frequency, nozzle angle for grooving, gas pressure and cutting speed were optimized for safe cutting of triangular blocks. In-situ cutting of 12 triangular blocks of six coolant channels was performed successfully in RAPS#3 reactor without any damage to yoke assembly with a total radiation dose consumption of only 3.5 Rad. With this cutting operation, creep margin in these coolant channels has been increased to 18 mm, which will increase the life of these channels by 9 more years. Thus, laser based maintenance work prevented the loss of about 15 MWe of power generation per year of reactor operation, which translates in a huge financial gain of ~ Rs. 75 Cr/yr. Fig. L.1.1 shows laser cutting trial of triangular fixing block of coolant channel and the inset shows the laser cut triangular block. The laser grooving technique has been successfully proven in the field and will be deployed in future also.

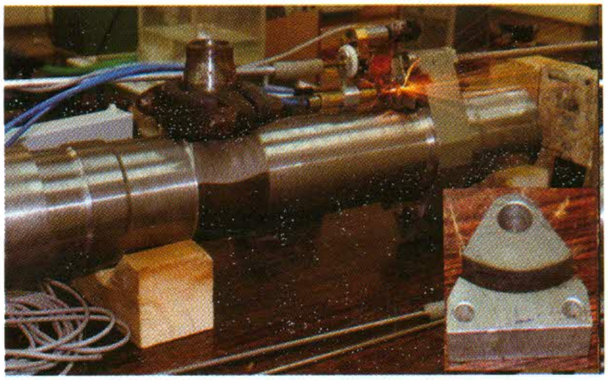

Fig. L.1.1: Laser cutting mock-up of triangular fixing block of coolant channel of pressurized heavy water reactors and the inset shows the laser cut triangular block

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