L.5: Laser cutting of stuck north end of S-7 coolant channel of KAPS-2 reactor

KAPS-2 is the first Indian pressurized heavy water reactor to use improved pressure tubes made of Zr-Nb2.5% material and started its commercial operation in 1995. After a period of 10 years, it was decided to remove pressure tube of S-7 coolant channel in year 2005 for post irradiation examination studies. For its removal, laser cutting of liner tube and end fitting was performed from south end only, however, bellow lip cutting was carried out by mechanical method as laser cutting technology for bellow lip was not developed at that time. After bellow lip cutting, in-board end fitting and pressure tube was removed from south end. This coolant channel was thus quarantined. Recently, in 2017 *en-masse* coolant channel replacement (EMCCR) of KAPS-2 was carried out by laser cutting of bellow lip weld joints (612 Nos.) of all the 306 coolant channels and separation of all the bellow ring was ensured. Although all the coolant channels could be removed after laser cutting of bellow lips during EMCCR, but, north end of coolant channel S-07 was stuck in the calendria and could not be removed or rotated by any of the mechanical methods despite of all efforts. It was suspected that due to huge rusting at split sleeve location and/or opening of split sleeve in two parts and also rusting at the two journal rings might have jammed the coolant channel. The channel was not getting pulled out or getting rotated even with huge mechanical loads in tons.

Later on, it was decided that if liner tube and end fitting can be cut near the farther end of split sleeve from E-face, pulling force of one journal ring and split sleeve will be reduced and it may become possible to remove end fitting in two parts. In view of this, a remotely operable laser based cutting tool for cutting of liner tube and end fitting at the end of split sleeve location was developed and controlled depth grooving method for cutting of end fitting was deployed for in-situ cutting in reactor. As split sleeve is made of mild steel, it was risky to cut end fitting with oxygen as assist gas since uncontrolled blasting of mild steel may take place, which may damage the lattice tube. Thus, it was decided to deploy multi-pass laser grooving technique of 12 mm thick SS410 end fitting up to the full depth of end fitting without damaging split sleeve.

An in-house developed fiber coupled pulsed Nd:YAG laser of 250 W average power with pulse duration in the range of 2-20 ms and repetition rate in the range of 1-100 Hz was deployed for laser cutting operation. Laser beam was delivered through a flexible 150 m long 400 μm optical fiber for remote laser cutting operation. Laser cutting objective consisted of fiber gripping mechanism, collimating and focusing lenses along with 90^{o} beam bending mirror. Laser beam was focused to a diameter of 800 μm using 1:2 imaging optics and high pressure gas for removal of molten material was provided through a nozzle at the end of the focusing objective. Nozzle was made air tight to avoid damage of its optics by accumulated debris and fine oxidized SS powders ejected during laser grooving process. Initially, laser grooving process and parameter for cutting of 12 mm thick end fitting was optimized with compressed air as assist gas during mock up trials. Laser cutting tool consisted of a 2 m long arm holding laser cutting nozzle at the end and is driven by a DC micromotor for circular motion. It can be fitted and locked on E-face of the end fitting using a locking pin. In order to avoid overhanging of its arm and nozzle at cutting location, a guiding disc having diameter equal to that of liner tube was provided on its arm and can be located along the length of end fitting by using two sliding bars fitted with the disc and a handle projecting out from the locking disc of tool on E-face. A guiding roller was attached with nozzle to maintain a fixed gap of laser beam focus with liner tube and end fitting during its circumferential rotation from inside. A HEPA filter was connected through high pressure feeder coupling hub to collect debris ejected during laser cutting process to avoid any airborne activity and contamination in air. Initially, laser cutting of liner tube of 4 mm thickness was carried out at 1733 mm distance from E-face using oxygen as assist gas and was pulled by 50 mm and then end fitting was cut at 1713 mm distance from E-face with optimized controlled depth laser grooving passes without any damage to split sleeve and lattice tube. Figure L.5.1 shows in-situ laser cutting of stuck north end of S-7 coolant channel of KAPS-2 reactor. After this laser cutting operation, long portion of stuck north end of S-07 coolant channel and split sleeve was removed successfully. This was for the first time that remote laser cutting operation was successfully carried out inside the core of the reactor in close collaboration with LED, RRCAT and NPCIL with minimum radiation dose consumption.

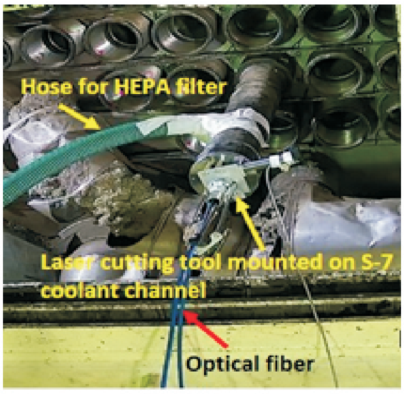

Fig. L.5.1: In-situ laser cutting of stuck north end of S-7 coolant channel of KAPS-2 reactor.

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