L.1: Removal of Q-16 coolant channel of KAPS-2 reactor by laser cutting

Kakrapar Atomic Power Station Unit-2 (220 MWe) started commercial operation in 1995 and it is the first Indian pressurized heavy water reactor which has all the pressure tubes made of Zr-Nb2.5% for longer life as compared to earlier reactors with pressure tubes of zircaloy without Nb. In a reactor, pressure tubes are exposed to high radiation, temperature and pressures. Thus, after a few years of operation, periodically, a pressure tube is removed from reactor for post irradiation examination. During January 2005, i.e. after a commercial operation of 10 years, a pressure tube of S-7 coolant channel was removed by laser cutting of liner tube and end fitting for post irradiation examination (PIE). Later in October 2012, another coolant channel Q-10 was removed using laser cutting of bellow lip. Recently, the reactor was shut down on 1st July 2015 due to observation of heavy-water traces in annular gas monitoring system. This was due to leakage of heavy-water from one of the 306 pressure tubes. Detailed inspection of pressure tubes by BARC Inspection System revealed a very fine crack at ~ 11 O'clock position near the rolled joint portion of pressure tube (PT) with end fitting in the Q-16 coolant channel. For PIE data and for further decision on power generation from this reactor it was necessary to remove this coolant channel to retrieve the portion of PT near the roll joint. This was a very complicated operation and was almost impossible by mechanical devices. RRCAT team visited the site in August 2015 and found that the more standard method of removal of pressure tube by cutting of bellow lip was not possible in Q-16 channel due to obstruction from all sides by five feeder pipes of nearby coolant channels as well as its own feeder pipe. In view of this, it was decided to carry out cutting operation in several steps in the following sequence: a) cutting of PT using mechanical chip-less cutter by NPCIL at a distance of 2250 mm from E-face, both at north and south side, b) laser cutting of 4 mm thick liner tube at a distance of 926 mm from E-face and from inside of the tube, then pulling it by 20 mm to create space for inserting laser cutting nozzle for cutting of end fitting from north and south vaults, c) laser cutting of 11 mm thick end fitting at a distance of 905 mm from E-face and from inside of the tube. Removal of outboard end fitting to create a space for laser cutting of bellow lip d) laser cutting of bellow lip weld joint using a new tool with miniature nozzle of 60 mm length, e) After cutting of bellow lip weld joint from both the sides, it can be separated mechanically and feeder pipes can be slightly jacked to remove inboard end fittings from both the sides. f) After removal of outboard and inboard end fittings, these were welded again to axially cut PT stubs at rolled joint in underwater condition for post irradiation examination. Fig. L.1.1 shows the mock trial cutting of bellow lip after cutting of outboard end fitting.

A home-built 250 W average power pulsed Nd:YAG laser with four time shared fiber ports for beam delivery was deployed for laser cutting operation. This laser provides a maximum pulse energy of 100 J with variation in pulse duration in the range of 2-20 ms and repetition rate in the range of 1-100 Hz. For all the above mentioned operations, three different types of laser cutting fixtures and nozzles were developed: one for cutting of liner tube and end fitting, another for cutting of bellow lip and third one for underwater laser cutting of PT stubs. All the fixtures were motor driven and were operated remotely. Time for cutting of liner tubes, end fittings, and bellow lips were 4, 11, and 12 minutes, respectively. For cutting of bellow lip, a miniature nozzle of only 60 mm length and 20 mm diameter was used as there was an axial gap of only 75 mm for nozzle rotation.

After removal of inboard and outboard end fittings, these were brought to active workshop for underwater retrieval of PT stubs. Radiation field at end fittings with rolled joint portion of PT was ~ 500 Rad/hr. A dual chamber water column of ~1 m height was made and the hot end having rolled joint portion of PT was inserted in water column. Underwater gas-jet assisted laser cutting technique using a fixture of length 2250 mm with optical fiber and laser cutting nozzle was used to cut PT stubs of 210 mm length and 3.6 mm thickness. Rolled joint portion of PT was cut axially at six locations from both of the end fittings to retrieve PT stubs without destroying the crack location. Time for each linear cut was 36 minutes and a total of 12 cuts were made. The water vapour generated during cutting process was passed through a HEPA filter to avoid any airborne activity. Entire laser based cutting process for coolant channel removal was successfully completed in September 2015 in about one week with a very low radiation dose consumption of only ~2.5 Rad for the entire team.

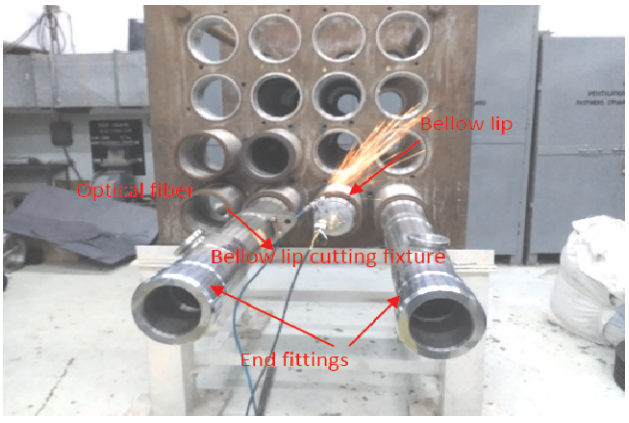

Fig. L.1.1: Laser cutting tool mounted for cutting of bellow lip after laser cutting of outboard end fitting.

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