L.2: Laser cutting of 603 bellow lip weld joints at KAPS-2 reactor

Leakage in one of the pressure tubes of KAPS-2 reactor was detected after a commercial operation of about 20 years. Later on post-irradiation examination (PIE) of a few pressure tubes was carried out. Based on PIE data, it was decided to go for *en-masse* coolant channel replacement (EMCCR) of KAPS-2 reactor, which requires cutting of bellow lip weld joints. Mechanical methods for cutting of bellow lip take longer time, result in large cut width, frequent failure of cutting tool and huge radiation dose exposure. In view of this, a laser based bellow lip cutting technology was developed earlier in 2006. Based on previous laser cutting experience during EMCCR campaigns, earlier developed laser cutting technology for bellow lip weld joints was modified with refined tool design and interlocks for safety of tool, motor and controller for more reliable operation during repeated operations on industrial scale. During EMCCR campaign at KAPS-2 reactor, laser cutting of 603 bellow lip weld joints (9 bellow lips already cut during single coolant channel removal operations) was carried out successfully and separation of bellow rings was also ensured in seven days of round the clock operation. Radiation dose consumption was further reduced as compared to earlier EMCCR campaigns in NAPS-1, NAPS-2 and KAPS-1 reactors by auto-control of several parameters, training of unskilled manpower and automation.

Two indigenously developed 250 W average power pulsed Nd:YAG laser systems with four port time shared fiber optic beam delivery were utilized for 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. Miniature laser cutting nozzles of 20 mm diameter and 120 mm length were used for cutting operation. Laser beam was delivered through 150 m long 600 µm core diameter optical fibers. Laser cutting nozzle has been designed in such a way that the tube containing optical fiber also carries the assist gas coaxially through the nozzle and makes it very compact for use in restricted space around the coolant channel. Focused beam diameter on the bellow lip joint was kept 900 µm using 1:1.5 imaging lenses with working distance from focusing lens of 30 mm. Gap between nozzle tip and job was kept 2 mm to avoid any obstruction of nozzle from any rough weld bead of bellow lip. Although, it is always preferred to cut steel components using oxygen as assist gas due to extra energy added by exothermic reaction. However, there is always a risk of blasting or uncontrolled material removal in case of laser cutting of mild steel/carbon steel with oxygen as assist gas. In order to avoid any risk of damage of outer bellow rings which has to be used for rewelding of fresh coolant channel, laser cutting process was optimized with compressed air at 10 bar pressure as assist gas for removal of molten material. As the bellow lip weld depth was only up to 3 mm, laser grooving process with cutting nozzle inclined at an angle of 30° with respect to weld bead was utilized, so that cutting debris is ejected out at an angle and does not get redeposited at the cut location. Laser cutting tool has also been designed in such a way that it can be fixed on end fitting E-face by just tightening of a single nut in less than one-minute time. Laser cutting nozzle held on fixture moves very precisely around the bellow lip weld joint with the help of remote controlled motor. The laser beam is always located at the middle of the weld bead while its circumferential rotation around the bellow lip by means of roller of fixed height. One end of the roller is attached to nozzle fixture tool and it rolls on coolant channel surface. Cutting time for each bellow lip weld joint was 6 minutes. One more pass of laser was provided to remove the debris and clean the cut groove, so that bellow lip gets easily separated with minimum separation load on bellow lip. There was no failure of tools or damage of any of the motors during the entire massive operation due to safety measures. Figure L.2.1 shows in-situ laser cutting of bellow lip weld joint and Fig. L.2.2 shows laser cut and separated bellow lip weld joint for removal of coolant channel. This indigenously developed laser based cutting technology for bellow lip weld joint has been successfully deployed at KAPS-2 reactor without any radiation hazard and has enormously reduced radiation dose consumption, time and cost as compared to conventional mechanical methods.

Fig. L.2.1: In-situ laser cutting of bellow lip weld joint at KAPS-2 reactor

Fig. L.2.2: Laser cut and separated bellow lip weld joint for removal of coolant channel

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