L.7: Laser cutting for repair/replacement of injection valves of emergency core cooling system in KKNPS-2 reactor

Kudankulam Nuclear Power Station Unit-2 (KKNPS-2) is a water-cooled, water-moderated 1000 MWe reactor which was commissioned in Kudankulam with Russian collaboration and the reactor started commercial operation in 2017. During recent shutdown, laser cutting of pipelines of emergency core cooling system was urgently required for replacement or repair of some of injection valves of the system. The cutting of pipes at some locations was required in presence of coolant in reactor since pressure vessel is at higher elevation with respect to injection valves. A section of pipeline at the required location was therefore ice plugged by flowing liquid nitrogen using ice plugging freeze box. Due to ice plugging, a cutting technique with lower heat generation was desired, thus cutting by laser was preferred as compared to manual grinding to cut and chamfer the pipelines. The pipeline is made of Russian SS321 material with 159 mm outer diameter and 17 mm thickness. Total of eight cuts in horizontal and vertical pipeline positions at different elevations of reactor building along with chamfering/beveling of pipes for re-welding was required while holding the reactor coolant by ice plugging. For this laser cutting requirement, a motorized orbital laser cutting tool was designed and fabricated in short time. Laser cutting tool is able to grip on the pipe to be cut and rotates along the tube circumference with the help of rollers using a DC motor. The tool also holds the laser cutting nozzle and is remotely operable using flexible fiber optic beam delivery and motion controller from a distance of ~150 m. When the tool rotates on the tube, it has a tendency to slip down, which is prevented by using another ring below the tool, which is engaged with the upper part of the tool and keeps the tool at its location using a roller guide. Figure L.7.1 shows laser cutting tool and nozzle mounted on pipeline in reactor for cutting operation.

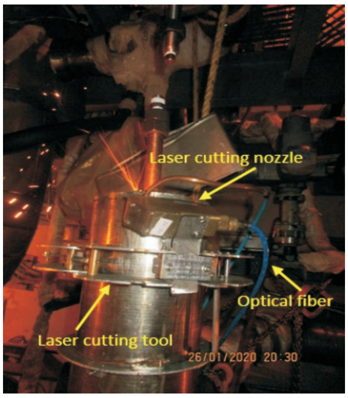

Fig. L.7.1: Laser cutting tool and nozzle mounted on pipeline in reactor for cutting operation.

An indigenously developed 500 W average power and 10 kW peak power fiber coupled pulsed Nd:YAG laser system having three time shared fiber ports of 400 μm core diameter and 150 m long length was deployed for cutting operation. Laser pulse duration can be varied in the range of 2-20 ms and pulse frequency in the range of 1-100 Hz. A compact 90º bending nozzle was utilized at the fiber end for laser cutting at required locations. Laser beam was focused to a spot diameter of 1 mm using a 1:2.5 imaging ratio ½" diameter optics. Laser cutting parameters such as pulse energy, pulse duration, cutting speed were optimized using oxygen as assist gas. Initially, mock up trials were carried out outside the reactor building to qualify laser cutting tool and cutting process. After qualification, laser system was shifted in reactor building at required height for in-situ cutting. For cutting of pipeline, nozzle was kept at right angle with pipe surface, whereas for beveling nozzle was mounted at an angle with the pipe surface. A CCD camera and monitor was used to monitor laser cutting process. Total cutting time for each location was ~50 minutes. Figure L.7.2 shows laser cut ring removed from pipeline end face after beveling and Figure L.7.3 shows surface of beveled pipe end for re-welding. Laser cutting and chamfering/beveling were performed successfully for replacement or repair of four injection valves in KKNPS-2 reactor with minimum ice plug holding time and radiation dose consumption. This laser cutting technology can be deployed in future requirements as and when required.

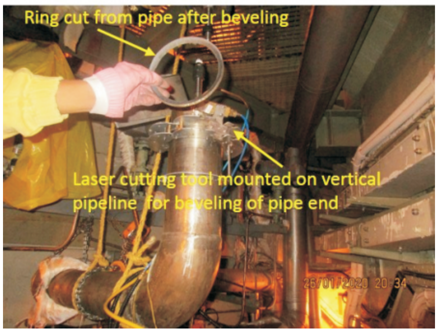

Fig. L.7.2: Laser cut ring removed from pipeline end face after beveling.

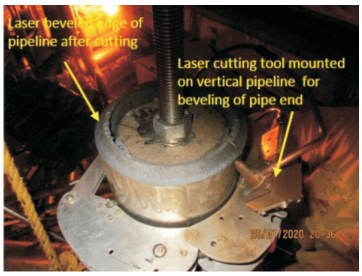

Fig. L.7.3: Surface of beveled pipe end for re-welding.

Reported by:
B. N. Upadhyaya (bnand@rrcat. gov.in)