L.2: Laser cutting of pipeline for replacement of DCV at KKNPP-1 reactor

Kudankulam Nuclear Power Plants (KKNPP-1 & 2) contain four numbers of second stage hydro-accumulators at the top of the reactor pressure vessel (RPV), which ensures long term flooding of reactor core with borated water at lower pressures. The borated water in the tank is normally filled at the atmospheric pressure. Under loss-of-coolant accidents (LOCA), when the pressure in the RPV is low, the double check valve (DCVs) which are connected to the upper portion of the hydro-accumulators get open and the pressure of the hydro-accumulators gets equal to that in RPV. At this pressure the non-return valve connected between the outlet of the hydro-accumulators and RPVs open and the borated water injects into the reactor core to remove the heat and to preserve core integrity for a long time. Certain deficiencies were observed in the DCVs of the second stage emergency core coolant system (ECCS) during operation of reactor, so it was decided to replace these valves. It is very difficult to replace DCV by conventional mechanical methods due to space constraint and complexity of location, high radiation dose, requirement of cutting ~16 mm thick pipe, longer process time, and secondary waste generation. Thus, it was decided to cut these pipe joints using laser cutting technology.

In view of this, an in-situ laser cutting process was developed. For deployment of laser cutting technology, a compact orbital laser cutting tool and nozzle (Figure L.2.1) capable of revolving in a total circumferential diameter of 200 mm around the pipe of 133 mm diameter was developed in a very short time on war footing basis. The orbital laser cutting tool is worm gear driven, which is driven by miniature low speed DC planetary geared motor. Since the pipe to be cut was in the closed loop, so the tool was designed in such a way that it can be opened and mounted on the pipe. Dove-tail groove on the worm wheel was also made, so that the nozzle mounted slide can move around the pipe smoothly during laser cutting operation.

Our indigenously developed 250 W average and 5 kW peak power pulsed Nd:YAG laser system along with controller was made available at the site for remote cutting operation. Laser beam was delivered using a flexible optical fiber of 400 µm core diameter, 0.22 numerical aperture (NA) and 150 m long length. At the end of the fiber, a 90^0 bending nozzle developed for this purpose was used to focus the laser beam on the job. Nozzle contains 1:3 imaging optics to focus the beam on the job with a focused spot diameter of 1.2 mm. Laser cutting is basically a thermal process in which laser power density on the job is increased to a level of $\sim 10^6$ W/cm^2 which melts the material, and the molten material is blown away using a high pressure gas. When oxygen is used as high pressure assist gas, exothermic reaction takes place and extra energy is released, which helps in cutting process. Laser cutting depth depends on pulse energy, pulse duration, and assist gas pressure. Laser parameters were optimized to cut 14 mm thick SS321 pipe joint having outer diameter of 133 mm. Thickness at cutting location was 16 mm due to presence of weld bead at pipe joint. The optimized pulse energy was 68 J in pulse of duration 12 ms at 2 Hz repetition rate. Oxygen at 12 bar pressure was used as assist gas for successful cutting trials of 16 mm thick pipe joint. After optimization of cutting trials on full scale mock-up, laser system was installed in the reactor building at 31 meter elevation. The optical fiber and assist gas tube were routed through the man hole to the cut location at 10 meter elevation. Cut location of the pipe joint was marked and a dedicated wireless communication between the laser system operator and the nozzle head operator was established. Detailed procedure was qualified during the mock-up trials to cut both ends of the tube segments and its removal from the tube assembly.

In view of remote cutting operation, an online CCD camera based viewing system was also implemented at actual location to monitor laser cutting process. Laser cutting of the tube was carried out successfully at four locations at a cutting speed of ~14 mm/min. and time for cutting at each location of the pipe was ~30 minutes. Figure L.2.1 shows a view of laser cut pipe in KKNPP-1 reactor for replacement of DCV. Radiation dose consumption was minimum due to remote operation. Total time for cutting operation and secondary waste generation was also less due to deployment of remote operation by means of laser cutting technology as compared to conventional mechanical methods. This technology can be deployed in future also as and when required.

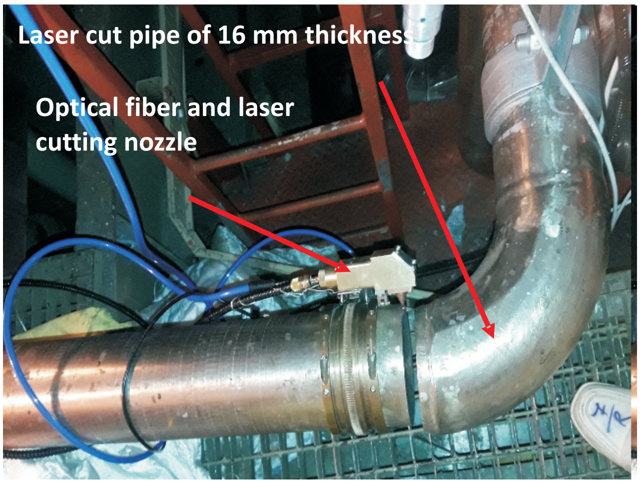

Fig. L.2.1: Laser cut 16 mm thick pipe joint for replacement of DCV in KKNPP-1 reactor.

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