L.1: Gas-assisted underwater laser cutting of pressure tube stubs of pressurized heavy water reactor (PHWR)

Underwater laser cutting has potential application in nuclear facilities as a promising technique for maintenance/ dismantling operations. In nuclear field, underwater cutting technique is required for post-irradiation examination (PIE), maintenance, decommissioning and to reduce storage space of irradiated materials of nuclear power plants. For such operations, it is highly useful to deliver the laser beam through optical fibers as it can be inserted in remote areas which are normally difficult to access. During well-known dry laser cutting process, a high power laser beam is focused on the job so that material reaches its melting temperature and simultaneously an active or inert gas is used at a high pressure to remove the molten material. However, in case of cutting of irradiated materials with this process, ejected debris and metal vapour may create airborne activity, which is of major concern for people working nearby. Thus, in cutting of such irradiated materials, underwater cutting process is advantageous as debris will be ejected in water and metal vapour will also get dissolved in water with effective reduction in spread of debris in air. In addition, it will also result in narrow heat affected zone (HAZ) adjacent to the laser cut surface due to water cooling effects and hence provides better samples for analysis of irradiated material with minimum thermal damage. It also results in better natural convection than that in air, resulting in reduction of the temperature gradient and thermal stress in the material and thereby reduces possibility of crack formation. In view of the advantages of underwater cutting, a water sealed laser cutting nozzle and process for underwater cutting of metals using in-house developed 250W average power fiber coupled pulsed industrial Nd:YAG laser has been developed. However, during gas-assisted underwater laser cutting process, a lot of water bubbles are formed. These bubbles burst as they come out on the surface and an undesirable stream of water vapour appears during the process due to heating of water and its vapourization, which needs to be collected and filtered out.

Recently, this underwater laser cutting process has been deployed successfully for cutting of pressure tube (PT) stubs from the rolled joint portion of pressure tube with end fitting at KAPS-2, Kakrapar in a very high radiation field of 700 Rad/hr. KAPS-2 is the first reactor to use Zr-2.5%Nb PTs. Thus, post-irradiation examination (PIE) data of PT of this reactor after a certain operating life is extremely important for future strategy about Indian PHWRs. Hence, it was required to remove one of coolant channels and retrieve full length of PT and PT stubs from the rolled joint portion of one of the coolant channels. It was decided to remove Q-10 coolant channel from KAPS-2 reactor for PIE data of Zr-2.5%Nb PTs after a life of 17 years. Initially, Q-10 coolant channel was removed by laser cutting process of bellow lips from both the sides in presence of obstructions of feeder pipes and yoke assembly in Oct. 2013 using an specially designed tool having two laser cutting nozzles placed diametrically opposite on the arm of laser cutting tool. Although, after this cutting process, 5 m long Zr-2.5%Nb PT became available for PIE data, however, a portion of PT (~118 mm long) rolled joint with end fitting of coolant channel was left with end fitting. As it was also desired to have PIE data of rolled joint portion, a 2.2 m long fixture having facility to be mounted from end-face of coolant channel was developed in close co-operation with KAPS site and NPCIL for cutting of PT stubs from the hot end of end fitting. Fig. L.1.1 shows a view of remotely operable motorized fixture developed for linear cutting of 3.6 mm thick zircaloy pressure tube from ID of end fitting and Fig. L.1.2 shows set-up for underwater cutting at KAPS-2 site. A total of six cuts of 118 mm length were performed by laser grooving method and total time for cutting operation of PT stubs from one end fitting was ~3 hours. Two such cutting operations were performed out for both the end fittings. The water vapour generated during cutting process was passed through a HEPA filter to avoid any airborne activity. This technique was successfully deployed and job was carried out with minimum radiation dose and without any radiation hazard in Feb. 2014. This technique has now been proven for cutting in nuclear field and can be deployed in for such operations in future also as and when required.

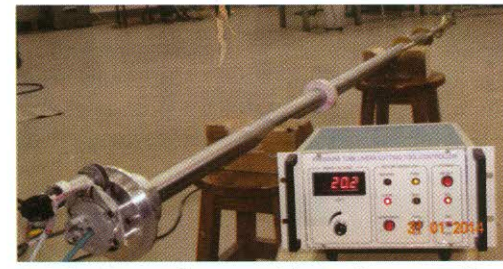

Fig. L.1.1: Remotely operable underwater laser cutting fixture with optical fiber.

Fig. L.1.2: Underwater laser cutting set up of PT stubs at KAPS-2 site (Inset: laser cut PT stubs).

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