L.3: Development of Laser Cutting and welding Technique for Secondary Shutdown System Standpipe Bellow Repair of Pressurized Heavy Water Reactors

A few leaks were detected in the bellow to ring weld joints of secondary shutdown system (SSS) standpipe assembly of Kaiga Atomic Power Station-3&4 (KGS-3&4) and the reactor was shut down temporarily in 2010. This bellow is made up of SS 304, which is double walled with a thickness of each wall of only 200 μm and access to the weld leak position is restricted due to the presence of a long tube running through the middle of the bellow and its joint with another outer concentric tubes. As the whole assembly is very long, the replacement with a new bellow, by conventional mechanical methods is difficult, costly and time consuming and also involves high dose rate. Repair of weld leak by TIG welding method was not possible due to space restriction and low wall thickness of bellow, which may get damaged due to large heat input. This issue was temporally solved by KGS site engineers using a stop gap arrangement. However, a permanent solution for leak repair is essential. Hence Nuclear Corporation of India Limited (NPCIL) decided to explore laser cutting and welding for repairing the defective bellows with the help of expertise at SSLD, RRCAT. For in-situ repair of SS standpipe bellow by laser techniques at KGS site, we designed a special manipulator, as shown in Fig. L.3.1, for mock up trials and qualification using four different methods, namely: (a) Repair by fusing weld bead all around the end ring for bellows having convolutions at inner diameter (ID); (b) For bellows having convolutions at outer diameter (OD), repairing of punctured bellow by filler & patch welding; (c) Replacement of bellow assembly by laser cutting all around the weld lip joint; and (d) Replacement of bellow assembly by laser cutting all around the weld at bottom end ring.

Laser manipulator consists of three concentric tubes with an overall length of ~ 50 cm and overall diameter ~ 160 mm. It can be fitted precisely at any location on the tube passing through middle of the bellow for repair by tightening of a single bolt. Both linear as well as 45 bending laser focusing nozzles can be mounted on this manipulator. Circular movement of nozzle at desired speed is done by means of a DC motor and gear mechanism. Mock-ups trials were carried out at R&D NPCIL, Tarapur, using the laser system supplied by SSLD, namely the fiber coupled pulsed industrial Nd:YAG lasers with 600 μm diameter and 400 m long fiber optic beam delivery providing an average output power of 250W with pulse duration from 2-20ms and repetition rate from 1-100Hz were utilized. Laser manipulator was used during mock-up trials and qualified for the following: (a) For bellows having convolutions at ID, repair by fusing weld bead all around the end ring as well as for small segment was tried & successfully carried out (Figs. L.3.2, L.3.3 & L.3.4); (b) Patch welding repair of bellows plies with patch as filler was successfully demonstrated by manual movement of laser beam (Fig. L.3.5); (c) Laser cutting of all around weld at lip joint was tried for separating the retainer nut sleeve from upper stand pipe. Both portions were successfully separated and retainer nut sleeve could be removed from stand pipe (Fig. L.3.6); (d)Trial of laser cutting all around the weld joint at bottom end ring was not tried since fusing weld bead all around the bottom end ring was successfully carried out and cutting will be rather easy than welding to separate the bottom end ring by changing the nozzle.

After successful mock-up trials of evolved schemes in close co-operation with NPCIL team, it is planned to deploy the developed laser cutting and welding technique for leak repair of SSS standpipe bellow during shutdown of KGS-3&4 reactors or any other pressurized heavy water reactor as and when required.

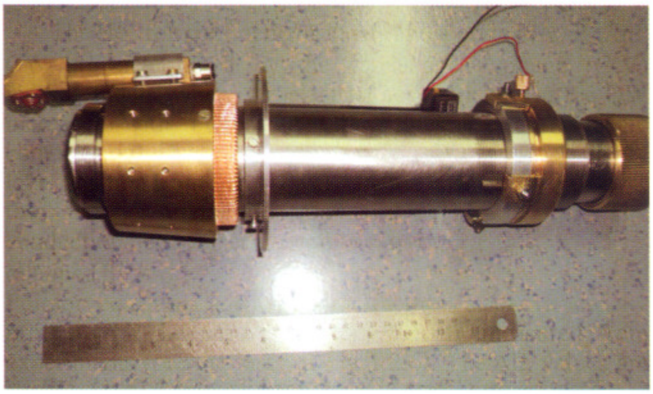
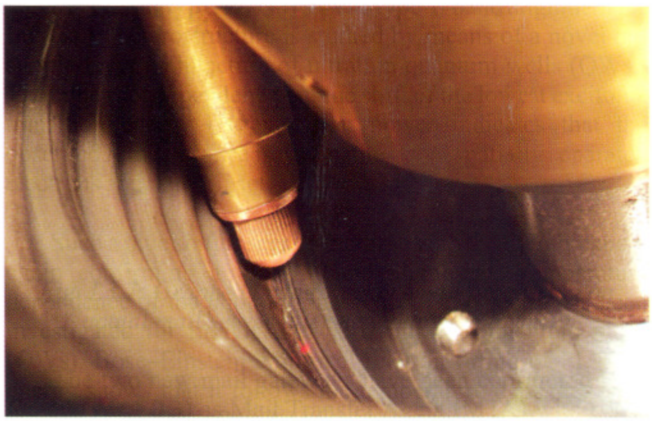


Fig. L.3.1: Manipulator developed for laser cutting and welding and it can be mounted on secondary shutdown system shut off tube.

Fig. L.3.2: View showing laser based repair of inter-junction



of inner bellow ply & insert ring by adding extra insert ring & carrying two full round welds.

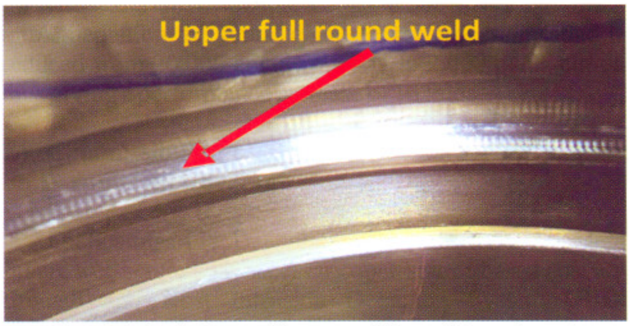


Fig. L.3.3: A View of laser welding of inter-junction of inner bellow ply & insert ring.

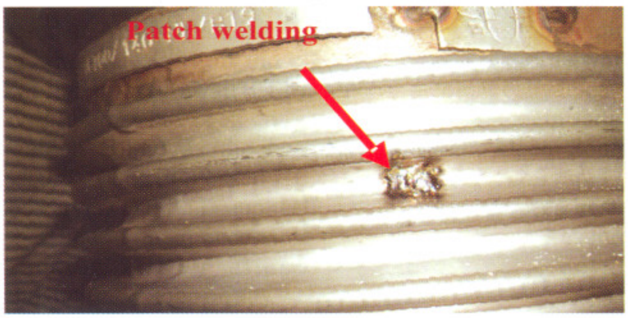


Fig. L.3.4: A view of punctured bellow ply at inner convolution after repair by patch welding.

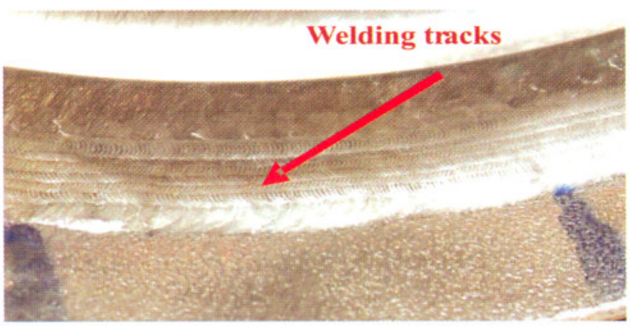


Fig. L.3.5: View of the end ring from inside after repair by fusing weld bead for small segment around.

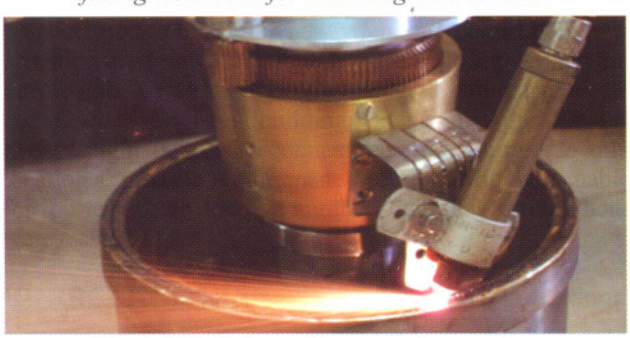


Fig. L.3.6: A view of laser cutting mock up of bellow ring joint with outer tube.

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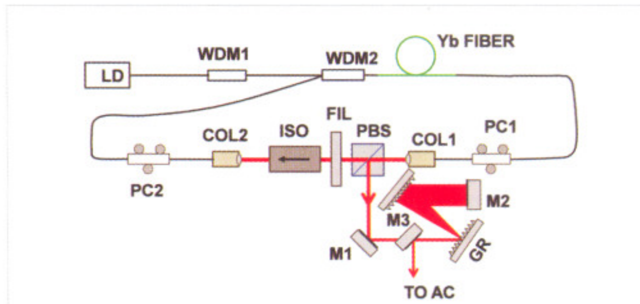
L.4: Femtosecond pulse generation from mode-locked Ytterbium doped fiber laser

There is a strong interest in the development of ultrafast fiber laser systems providing femto-second pulses as fiber based system can offer many advantages compared to the solid-state counterparts like flexibility, reduced thermal effects, diffraction limited beam quality, compactness and reliable maintenance free turn key operation. A Ytterbium (Yb) doped mode-locked fiber laser in all normal dispersion (ANDisp) configuration has been developed in the Solid State Laser Divison of RRCAT producing a train of stable pulses in the femtosecond regime.



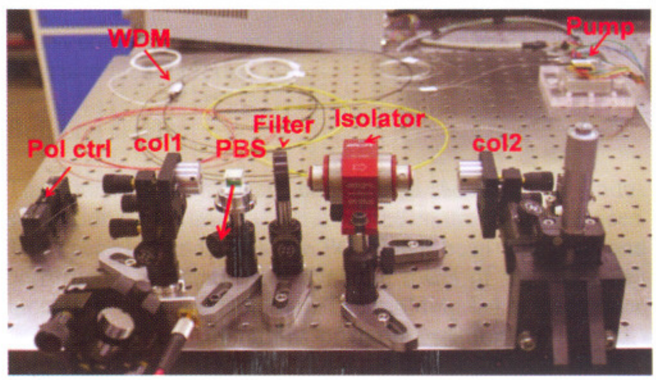


Fig.L.4.1 Schematic and photograph of the laser setup

The schematic of the mode-locked Yb-doped fiber laser setup under all-normal dispersion configuration is shown in Fig.L.4.1. The laser comprised of 150 cm long single clad single mode Yb-doped fiber and was pumped in-core by a FBG stabilized single mode fiber coupled laser diode at 976 nm. One end of the Yb-fiber was spliced to the output port of a WDM and at the other end, a standard single mode fiber (SMF) was connected. At the signal port of WDM2 a long (300cm) SMF was spliced. The free ends of the two SMFs are connected to in-fiber collimators (COL1 and COL2). The total cavity length including the free space between the collimators was measured to be 570 cm. In the free space between the two collimators a polarizing beam splitter (PBS) is placed. The PBS in combination with the two in-fiber polarization