L.10: Development of underwater laser cutting technique for steel and zircaloy for nuclear applications

Recently, worldwide research in underwater laser cutting and welding has started due to its prospective applications in nuclear facilities and ships as a promising technique for maintenance/dismantling operations. In the nuclear field underwater cutting and welding technique is required for post-irradiation examination (PIE), maintenance, decommissioning and to reduce storage space of irradiated materials like used zircaloy pressure tubes etc., of nuclear power plants. For such operations, it is highly useful to delivery of the laser beam through optical fiber is very convenient as the fiber can be inserted in remote areas which are difficult to access. During dry laser cutting process, a high power laser beam is focused on the job so that material reaches its melting temperature. Simultaneously an active or inert gas is used at a high pressure to remove the molten material. During dry laser cutting process of metal, a huge amount of energy is conducted into the work piece resulting in changes in the material properties and the microstructure of the material, i.e., large heat affected zone (HAZ). In addition, debris and metal vapour from the cut kerf may spread in air and have to be sucked out. In case of cutting of irradiated material, debris and metal vapour creates airborne activity, which may be harmful for people working nearby. On the other hand, underwater cutting is advantageous in terms of a narrow HAZ adjacent to the laser cut surface providing better samples for analysis of irradiated material with minimum thermal damage and effective reduction in debris spread in air. Underwater laser cutting also results in better natural convection than that in air, which results in reduction of the temperature gradient and thermal stress in the material and thereby reduces possibility of crack formation. It also helps in removal of the debris from the surface and hence results in better cut surface. We have developed an underwater laser cutting nozzle and process for cutting of metals using in-house developed 250W average power fiber coupled pulsed industrial Nd:YAG laser. Underwater cutting of 12 mm thick SS304 and zircaloy using air and oxygen as assist gas has been performed along with analysis of HAZ and microstructure near cut surface.

In laser cutting experiments, an in-house developed fiber coupled pulsed Nd:YAG laser with 400μm fiber optic beam delivery providing an average output power of 250W with pulse duration from 2-20ms and repetition rate from 1-100Hz has been utilized. The diverging output beam from optical fiber was collimated and focused using a 1:1 imaging optics, which provided a focused beam diameter of 400μm. Two samples, one of 12 mm thick SS304 and another of zircaloy were cut in dry air and then underwater using both air and oxygen as assist gases. The gas/air pressure in both the cases was 12 kg/cm^2. The nozzle tip-to-work-piece distance was 1 mm. Fig. L.10.1 shows experimental set up for underwater cutting of metal samples. The samples were placed in water jar, which was mounted on an XY-table. The samples were kept at a depth of 100mm from water surface. Fig.L.10.2 shows a view of underwater laser cutting process in which submerged SS sample and laser cutting nozzles have been indicated. During underwater cutting process a lot of water bubbles are formed . These bubbles burst as they come out on surface. Water fumes also appear during the process due to heating of water and its vaporization. On analysis of cut samples it was found that adhesion of dross is less in case of underwater laser cutting as compared to that in dry laser cutting. The heat affected zone was also about half compared to cutting in air.

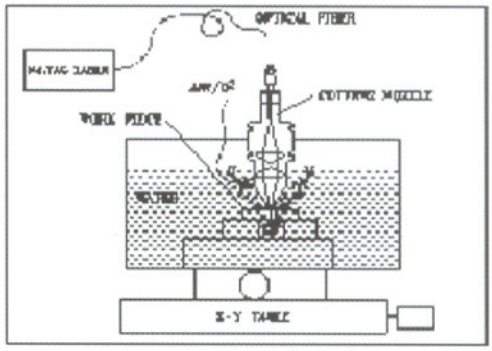

Fig. L.10.2: Experimental set up for underwater laser cutting..

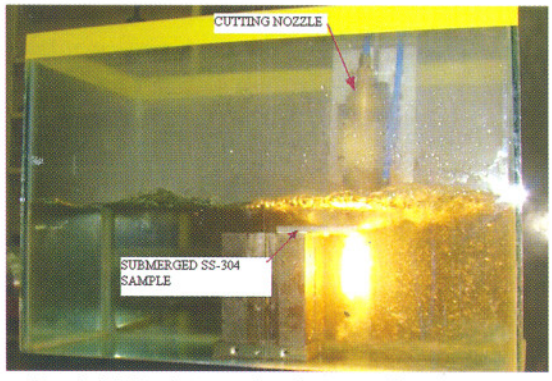

Fig. L.10.2: A view of underwater laser cutting of SS304.

The design and development of different fiber delivery manipulators are under progress at RRCAT for underwater laser cutting of zircaloy pressure tubes for NPCIL and BARC for PIE data, for aluminium fuel racks in Dhruva reactor, and for cutting of irradiated Cobalt bundles for RAPPCOF (RAPP Cobal facility).

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