L.9: Development of mesh type spacers using laser additive manufacturing

Mesh type spacers for fuel cluster simulator of 540 MWe PHWR fuel bundle is successfully developed using laser additive manufacturing. These spacers are used to maintain the spacing among the fuel rods in Fuel Rod Cluster Simulator (FRCS) - a test facility at BARC for experimental investigation of thermal hydraulic behaviour of reactor fuel elements. For ongoing works, 25 numbers of mesh type spacers were required for the assembly of new cluster at Reactor Engineering Division (RED), BARC. Figure L.9.1 presents a typical photograph of mesh type spacer having 101.57 mm outer diameter and 10 mm depth with 37 holes of 14 mm diameter. The wall thickness of spacer is critical and is of 400 ± 50 µm. Fabrication of these spacers is challenging due to complex shape, intra-circular space, thin wall feature and critical dimensional tolerance. Conventionally, these spacers are fabricated using EDM wire cut and it takes typically 3-4 working days for the fabrication of one spacer. This makes the spacer manufacturing not only slow and cumbersome, but also very costly. Considering these facts, RED, BARC requested RRCAT to take up the development of mesh type spacers using Laser Additive Manufacturing (LAM).

Fig. L.9.1: Mesh type spacers for fuel cluster simulator of 540 MWe PHWR fuel bundle.

LAM is one of the advanced laser based manufacturing methods capable of fabricating parts directly from 3D CAD model using material build-up approach. RRCAT has indigenously developed LAM system based on both technologies, i.e., Directed Energy Deposition (DED) and Powder Bed Fusion (PBF). In PBF system, the laser along with galvano-scanner and control system is deployed to selectively melt the powder spread on a bed and shape the engineering components in layer-by-layer fashion. At the optimized process parameters, the built components are fully dense and are fabricated in short time. The development of mesh type spacers was taken up through comprehensive experimental investigations for PBF of thin wall geometry with range of process parameter as laser power: 100-200 W, scan speed: 0.03-0.09 m/s and layer thickness: 75 µm. The material used for the above work was commercially available Inconel-625 powder with particle size in the range of 15-45 µm. Inconel-625 is a nickel-based superalloy with Cr, Mo and Fe as major alloying elements. Strength of Inconel-625 is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix; thus, precipitation-hardening treatments are not required. It is a fitting choice for nuclear components because of its high strength, excellent uniform corrosion resistance, resistance to stress cracking and excellent pitting resistance in water at 260-316 °C.

The commercially available machines use layer height of 25 µm for most of the materials during lased based PBF to ensure the quality of the built structures. It is primarily done to achieve superior thermal management and higher track aspect ratio (track width/ track height > 5). In the developed process, higher layer height of 75 µm was selected along with higher laser power for taking the advantage of the geometry to be deposited, i.e., thin walled structure. It facilitated higher deposition rate and shorter fabrication period. The process parameters were optimized using design of experiments. The optimized parameters yielding defect free depositions were identified as laser power: 150 W and scan speed: 0.07 m/s. These parameters facilitated the building of components without comprising the quality. The metrology report of the fabricated spacer using blue light scanner shows that the dimensions are within the tolerance and do not require any post-processing for assembly.

Fig. L.9.2: Assembly of spacers at RED, BARC.

25 number of such spacers were fabricated and sent to BARC for assembly in FRCS. Figure L.9.2 shows the image of assembly of spacers in FRCS at RED, BARC.

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