Additive Repair Processes for High Temperature Materials

Dipankar Banerjee[a], Dheepa Srinivasan[b], Kaustubh Bawane[c], Pooja Srinivas[d], Bhaskar Dutta[e]

[a] Materials Engineering, Indian Institute of Science, Bangalore
[b]INTECH DMLS, Pvt. Ltd., Bangalore
[c]Virginia :Polytechnic Institute and State University, , USA
[d]Indian Institute of Technology, Bombay, Mumbai
[e] DM3D Technologies, Michigan, USA

We describe examples of the development of repair technologies of high temperature materials, using additive processing (direct metals laser sintering (DMLS) and direct metal laser deposition (DMLD)). The additive repair process has been evaluated to examine the feasibility of repair and refurbishment of cast FSX414 components (a solid solution strengthened Co-based alloy extensively used in gas turbine hardware). An optimized DMLS process that eliminates HIP (hot isostatic pressing)was developed for a CoCrMo alloy, and the effect of subsequent heat treatment on microstructure and tensile properties was established. The welding of DMLS CoCrMo to cast FSX414 using Co-based Nozzalloy^{TM} filler wire was demonstrated. We also describe a crack free build-up of directionally solidified (DS) nickel based superalloy MarM247LC via DMLD technology. MarM247LC is an extremely difficult to weld superalloy and undergoes liquation cracking or strain age cracking, during repair and refurbishment. Attempts to restore the MarM247LC structure via conventional processes such as welding and brazing have resulted in, at best, an equiaxed microstructure with cracks. In this study, the DMLD process was used to build MarM247 on a seed of cast DS MarM247LC via a systematic design of experiments, by varying the laser power, scan speed, powder feed and step over. An epitaxial growth of the DMD structure on the cast DS seed was established and columnar grains were seen to grow (with a misorientation of $< 9^{o}$ on the cast seed). Detailed characterization revealed a very fine dendritic structure in the DMD build. A detailed characterisation of the primary dendrite spacing, inter-dendritic segregation as well as precipitate size and volume fraction and tensile properties, was carried out in the as-built condition and after heat treatment.

Both examples demonstrate the ability to use additive manufacturing as a unique technology enabler for repair of high temperature superalloys. The work was carried out as part of collaborative project with GE, Power, Repair Development Center. GE, India Industrial Pvt. Ltd., Bangalore, and while DS was with GE Power, KB and PS were at the Indian Institute of Science.