Simulation and Experimental validation for DED-LB/M Additive Manufacturing strategies on Crankshaft Components.

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ABSTRACT

Metallic-based Laser Beam Directed Energy Deposition (DED-LB/M) is increasingly being adopted as a key additive manufacturing (AM) process due to its ability to fabricate complex geometries, enable remanufacturing, perform localized repairs, and even create multimaterial components. Its flexibility and potential for industrial applications make it particularly attractive in sectors such as energy, aerospace, and automotive. However, several challenges still hinder the industrialization of DED-LB/M, mainly due to the high thermal gradients inherent to the process. These gradients often lead to undesirable effects such as part distortion, residual stresses, and local changes in microstructure and material properties. Therefore, predictive tools such as Finite Element Method (FEM) simulation become essential to minimize trial-and-error efforts and guide process optimization.

This work aims to simulate and analyse the behaviour of deposited material using the DED-LB/M process applied on specific zones of crankshaft components. Several process parameters and deposition strategies were numerically tested using macro FEM models to assess their influence on temperature evolution, cooling rates, and stress development. To support and validate the simulation, a set of experimental trials was conducted on smaller-scale specimens. These trials included in-situ monitoring and thermal measurements to calibrate and correlate the numerical model.

One of the main findings of the study is that the crankshaft substrate acts as a massive heat sink, resulting in rapid cooling rates that can adversely affect the final properties of the deposited material. Simulation results were used to propose optimized deposition paths and heat input strategies aimed at controlling the thermal field and achieving more favorable cooling curves. This integrated simulation-experimental approach provides a solid foundation for industrial implementation of DED-LB/M in heavy component applications.