Doctoral Dissertation
Doctoral Program in Managment, Production and Design (36thcycle)

Characterization of Directed Energy Deposition Laser Beam Powder (DED-LB) through experimental and simulation approach

By

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Summary

The explosive rise of additive manufacturing over the last decades has caused a widespread shift in industry priorities, with many increasingly emphasising the use of innovative technology in their operations. This development has resulted in an increase in scholarly interest as researchers devote their efforts to expanding these technologies, diving into both scientific breakthroughs and the pursuit of manufacturing practises that are both cost-effective and environmentally sustainable. In this evolving landscape, one technology that has captured considerable attention is Direct Energy Deposition (DED). Positioned as a cutting-edge metal technology, DED has emerged as a focal point for numerous investigations. The spotlight on DED can be attributed to its relatively recent introduction and its potential applications, particularly in the realms of component repair and the rapid creation of large, customized components. The technology's ability to facilitate the production of intricate and tailored components within compressed time-frames has ignited interest across various sectors, positioning DED as a game-changer in the realm of additive manufacturing. Furthermore, the environmental consequences of additive manufacturing technologies, such as DED, are becoming more prominent in research efforts. Scholars are actively investigating ways to improve the sustainability of these technologies, with the goal of reducing the environmental footprint connected with manufacturing processes. This environmental commitment is consistent with broader worldwide efforts to migrate to greener and more sustainable industrial practises. Finally, the rise of technologies such as DED in additive manufacturing indicates a dynamic and disruptive age in the industrial world. The interaction of scientific

advances, cost-effectiveness, and environmental awareness demonstrates a dedication to innovation that goes beyond mere technological capability. As businesses and researchers continue to explore the full potential of additive manufacturing, it is clear that DED is at the forefront, poised to rethink component repair and the fabrication of large, customised components in the pursuit of a more efficient, sustainable, and adaptable manufacturing future.

The primary objective of this thesis is to analyse the technology and identify the key limitations that now hinder the widespread use of the process in industrial settings. Two main factor were recognized of vital importance: process parameters and scanning path. For these reasons, the study started single tracks analysis. A set of linear single tack was deposited and examined being a linear track a first step of the deposition process. An experimental campaign examined how process parameters affected track and temperature field attributes was executed. After that, a grey-box model was created to computationally predict process outcomes while process parameters changed. The model predicted results accurately, especially under ideal conditions. These criteria were then tested using circular and squared examples in order to test the model and study the track characteristics when changing laser path. The simulation findings improve this scenario's prediction. The data also show that scanning path variation greatly affects deposition height. After that, process parameters and scanning procedures on more massive components were studied. The initial experiment examined thick wall samples to see how factors affected structural element deformation. The simulation method used in this case was a macro-scale Finite Element Method (FEM) model. Netfabb Local Simulation was used to analyse the component's thermal and mechanical characteristics. The results show that high energy density, especially at high power levels, distorts the final component. The data show that temperature gradients in the early layers cause most deformation. To reduce temperature gradient, heat distribution must be effective. Next, scanning procedures' effects on the thermal field were examined. The study examined eight polyhedron configurations using experimental and numerical analysis. Finally, 3DExperience software was used to simulate a real scale component to forecast deformations with different scanning strategies. After the numerical result the component with the greatest deformations was made for comparison. Preliminary results show that the software can predict component deformation, although with a large margin of error. Further evaluation of the boundary conditions and consideration of the suitable time step improves the results.