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Effect of Heat Transfer and Fluid Flow on Micro-structure Evolution of Laser Melting based Direct Energy Deposited Components

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Extended Abstract

Additive Manufacturing is a rapidly emerging field that aims to produce components layer by layer, thereby, minimising the wastage involved in subtractive techniques. It boasts of producing complicated geometries and structures, having almost full solid density, particularly in those techniques which involve a complete melting of substrate and the depositing material. Laser melting based Direct Energy Deposition (L-DED) is one such method in which a laser beam scans the surface of the base material to produce a molten pool. On the pool, same material as base plate or a foreign material is deposited, thereby forming an alloyed layer in its wake. Repetition of the process in layers forms the final component. To predict and control the mechanical properties of the component, there is a need to understand the multi-physics phenomena involved in the melting, deposition and solidification processes, as these control the micro-structure of deposited layers. Here, an attempt has been made to study the heat transfer and resulting fluid flow in the molten pool of substrate and bead during the L-DED process, and link them to the micro-structure evolution, thereby, giving the process a predictive capability. A multi-phase three-dimensional computational model has been developed to study the deposition of Inconel 718 on Stainless Steel 316. The transport of energy, mass, momentum and species during the laser melting process, powder deposition, diffusive and convective mixing, and alloy solidification [1] has been studied. The phase change is incorporated using enthalpy technique [2].The model incorporates the differential melting and boiling points of elements in IN 718 being deposited, the progressive melting of substrate due to laser penetration effect, the deformation of free surface to form the bead during deposition using Volume of Fluid technique, Marangoni Convection arising from high temperature gradient driven surface tension gradients, the momentum of shielding gas (N_2), and partitioning at the solidification interface as a characteristic feature of alloy solidification. Experiments for Laser based deposition [3] of IN 718 powders on a SS 316 substrate has been carried out at an array of process parameters by varying the laser power and scanning speed, while keeping the laser spot size and powder feed rate unchanged. The temperature evolution during the process is captured using an IR Camera. The computational results with respect to the temperature distribution and melting isotherm are compared to the temperature data obtained from IR camera. The dimensions of dilution zone and bead obtained from the computations are compared with those obtained from cross-sectional view of experimental samples as observed under an optical microscope [4]. The results are found to be in good qualitative agreement. The cross sections have been observed under SEM to view the micro-structure. At the solidification interface of computationally obtained melt-pool and bead, the species concentration, temperature and cooling rate serve as inputs for a meso-scale microstructure simulation using Phase Field Method. The computationally obtained microstructure has been compared to the experimentally obtained SEM micro-structure with respect to inter-dendritic arm spacing. A qualitative agreement between the two establishes the predictive relationship of the heat input parameters and resulting fluid flow with the final micro-structure of the component layers.

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