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Three-dimensional thermal analysis of multi-layer metallic deposition by micro-plasma transferred arc process using finite element simulation

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Abstract

Manufacturing of complex 3D-parts by micro-plasma transferred arc (µ-PTA) powder deposition process involves repeated heating and cooling at the same location causing thermal distortion and residual stresses in the substrate and deposited material. Simulation of temperature distribution, thermal cycles and temperature gradient can be helpful to predict thermal distortion and residual stresses. This paper describes 3D-analysis of temperature distribution and thermal cycles in multi-layer metallic deposition by µ-PTA process by finite element simulation using temperature dependent properties of the deposition material. Analysis was also done to study influence of deposition direction on temperature distribution and temperature gradient in multi-layer metallic deposition. The simulated results were experimentally verified on the µ-PTA process experimental apparatus developed for temperature measurement depositing powder of titanium alloy (Ti-6Al-4V) on substrate of the same material. Good agreement is observed between the simulated and experimental results. The results showed that temperature increases with increase in the deposition height and the temperature gradient in parallel deposition is higher than that in back and forth deposition. This implies that parallel deposition exhibits better heat diffusion than back and forth deposition. This work will be helpful in selection of optimum heat input, process parameters and deposition direction in multi-layer metallic deposition by µ-PTA process.

Keywords: Mutli-layer metallic deposition; Micro-plasma; 3D-thermal analysis; Finite element simulation; Ti-alloy; Additive layer manufacturing.

Research highlights:

- 3D FES of temperature and thermal cycles in multi-layer deposition by µ-PTA process
- Study of effect of deposition direction on temperature and thermal gradient
- Experimental verification using Ti-6Al-4V powder deposition on substrate of same material
- Parallel deposition showed better heat diffusion than back and forth deposition
- Useful in optimizing heat input, process parameters and deposition direction
- Will help in minimizing thermal stresses and thermal distortion