Thermal modeling of Laser Cladding repair process by a simplified two-dimensional semi-analytical approach

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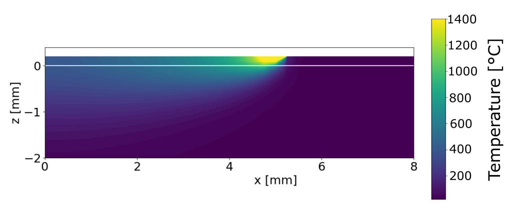
ABSTRACT

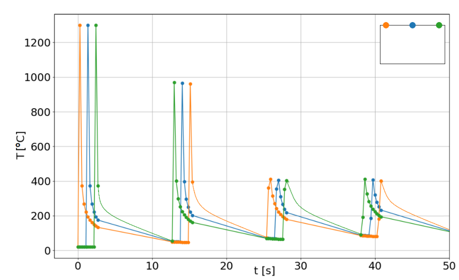
Laser Cladding is one of the leading additive manufacturing technologies enabling the repair of metallic components. The spatial and temporal pattern of the heat flux will conduct to specific spatial temperature gradients and cooling rates, controlling the final microstructure of the repaired component. Optimizing the process parameters to target a specific microstructure requires to have numerical tools to model this complex thermal history. High-fidelity simulations such as the ones described in [1] can be conducted but their computational cost is heavy. However, simplified thermal analyses, based on Rosenthal's solution describing the thermal increment due to a moving heat source [2], offers an interesting alternative to model the repair process of simple geometries.

Our study focuses on modeling the repair of top blades. For simplicity, the blades are represented by a thin plate on top of which a single-bead wall is deposited. This problem is mainly two dimensional as the temperature variation along the thickness of the wall is negligible. The laser path is divided into infinitesimal heat sources and the thermal increment caused by each source is derived analytically, taking into account the convection at the surface of the wall. All those contributions are then summed by numerical integration allowing us to model the transient state of the process. The addition of layers is then conducted by superimposing the heat sources and by diffusing of the heat of the previous layers in the current layer.

As a result, this simplified model gives an evaluation of spatial thermal gradients (Fig. 1a) or cooling rates (Fig. 1b) with low computational times. As suggested in [3], those data can then be used in solidification maps to identify the solidification regime (columnar or equiaxed grains) and to study for example the influence of laser power, laser speed or interlayer dwell time on the part microstructure.



(a) Spatial variation of tempertaure.



(b) Temporal variation of temperature.

Figure 1: Temperature field derived with the two-dimensional semi-analytical approach.

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