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2D THERMAL MODEL FOR LASER HEATING PROCESSES: A FINITE ELEMENT APPROACH

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ABSTRACT

For laser-based additive manufacturing, the process parameters are central for the quality of the produced pieces. This manuscript presents a 2.5D Finite Element simulation of the laser-induced metal deposition, which produces the history of temperature in a cross section of the metallic substrate, taking into consideration the laser trajectory normal to the cross section. Particular focus is set on the effect of the geometry of the power density of the laser on the process upon the thermal response of the substrate. Three laser intensity distributions are considered: Gaussian, uniform circular and uniform squared.

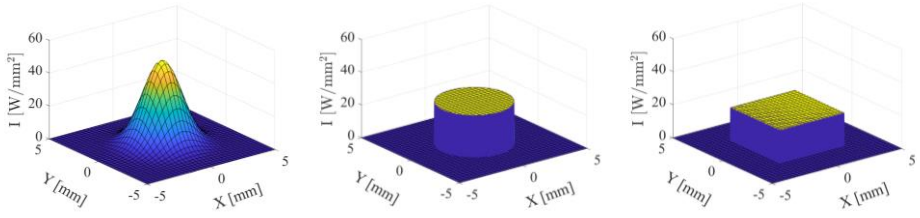
INTRODUCTION

Laser-based Additive Manufacturing (LAM) has important applications in repair, reconditioning, coating and remanufacturing of high-valued industrial pieces [1]. Consequently, LAM is an open field of research. Recent studies focus on the analysis of three process variables: laser power, process speed and powder feeding rate [2,3]. In this work, we study the impact of the geometry of the laser intensity distribution (absent in other publications) in terms of the temperature field and the shape of the heat affected zone (HAZ).

METHODOLOGY

The energy provided by the laser is modeled as a time dependent heat flux boundary condition. At every time step, we calculate the total influx through the boundary of each element on top of the domain.

We simulate the influence of three laser intensity distribution functions on the thermal behavior of the substrate: (a) Gaussian, (b) uniform circular and (c) uniform squared. Fig. 1 shows a graphical representation of the corresponding laser intensity distributions to a laser power $P = 500$ W and a laser radius $R = 2.5$ mm.

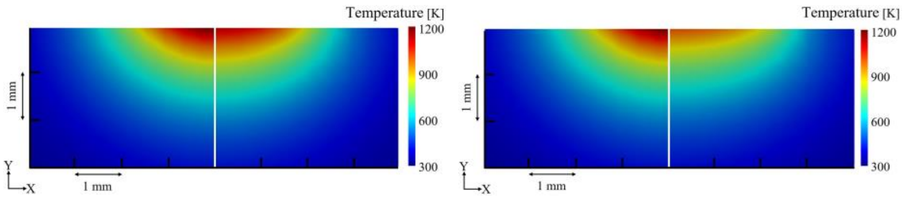


(a) Gaussian (b) Uniform circular (c) Uniform squared

Figure 1. Laser intensity distributions: Gaussian, uniform circular and uniform squared.

RESULTS AND CONCLUSIONS

Fig. 2 shows a comparison of the temperature field in a cross cut of the substrate for (a) Gaussian vs. uniform circular, and (b) Gaussian vs. uniform squared intensity distributions. The maximum temperatures reached are 1210 K, 1141 K and 1014 K for the Gaussian, uniform circular and uniform squared distributions, respectively. These temperature differences stem from the peak present in the Gaussian distribution, which in turn causes an energy concentration on the center of the HAZ.



(a) Gaussian vs. uniform circular (b) Gaussian vs. uniform squared

Figure 2. Comparison of the temperature using different laser intensity distributions.

Fig. 2 shows that the HAZ of the uniform squared laser has a larger width and a smaller depth than the HAZ of the Gaussian and uniform circular lasers. This difference arises from the geometry of the laser power distributions (Fig. 1). Our implementation shows influences of the laser power density on the HAZ shape and history. It also opens opportunities in considering convection and radiation effects.

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