Analysis of welding simulation results using DOE methodology

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The presented article focuses on the analysis of the results of laser welding simulation performed using the Design of Experiments (DOE) methodology. The aim was to evaluate the influence of selected characteristics of the conical heat source model on the shape (dimensions) and quality of the weld pool. A fully factorial design of type 2^3 was used for the design of the simulation experiments, which allowed to investigate not only the main effects of the three input factors: laser power (P), upper base radius (re) and lower base radius (ri), but also their possible interactions. The repetitions necessary for statistical processing of the results were obtained from simulations at the center point of the selected experimental area.

Numerical simulations were performed in the ANSYS 18.2 program using the 3D element SOLID70 using a conical volume model of the heat source with a Gaussian heat distribution. The input parameters ranged from P = 1200-1500 W, re = 0.3-0.7 mm and ri = 0.3-0.5 mm. The output responses included the weld pool width and the molten zone density, which are considered critical for the weld quality.

Statistical analysis of the simulation results showed that the interaction effects of the selected parameters on the observed weld pool width response were not significant and could therefore be excluded from further consideration. All factors examined significantly affected the weld pool width, with laser power (P) and upper base radius (re) having a positive effect, while lower base radius (ri) showing a negative effect.

Regarding the molten zone density, laser power (P), lower base radius (ri) and the interaction of lower and upper base radius factors (ri*re) were identified as significant factors. The laser power (P) shows a significant positive effect. The effect of the lower base radius (ri) factor on the density of the molten zone is negative and is smaller than the laser power (P). The effect of the interaction of the base radius (ri*re) is comparable to the effect of the lower base radius (ri). Although the positive effect of the upper base radius (re) on the response to the density of the molten zone according to the results of the statistical analysis is not significant, due to the hierarchy of the regression model it was retained in the model. The center point was also included in the model due to the required curvature.

The developed regression models achieved high significance and accuracy, no lack of fit and high correlations with high R^2values, which indicates their suitability for predicting the values of the studied weld characteristics.

This article presents a DOE-based approach for numerical simulations of laser welding and provides recommendations for the selection of geometric parameters of the heat source and laser power in order to optimize the weld quality.

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