Accepted Manuscript

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PII: S1350-4495(17)30769-7
DOI: https://doi.org/10.1016/j.infrared.2018.07.006
Reference: INFPHY 2620

To appear in: *Infrared Physics & Technology*

Received Date: 18 November 2017
Revised Date: 1 July 2018
Accepted Date: 3 July 2018

Identifying optimal process parameters in deep penetration laser welding by adopting Hierarchical-Kriging model

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Abstract: The quality of welding joints is largely dependent on the laser welding process parameters. In this work, an integrated optimization methodology by combining the Hierarchical-Kriging model and non-dominated sorting genetic algorithm II (NSGA-II) is developed for identifying the optimal process parameters in deep penetration laser welding. Firstly, a three-dimensional thermo-mechanical finite element model is developed as a low-fidelity (LF) model, while the laser welding experiment is taken as a high-fidelity (HF) model. Then, the data sets from these two different levels fidelity models are integrated by Hierarchical-Kriging model to build the relationships between welding process parameters and bead profile and angular distortion. Secondly, the NSGA-II algorithm is employed to obtain the multi-objective Pareto optimal solutions based on the constructed Hierarchical-Kriging model. Finally, the effectiveness and reliability of the obtained optimum are verified by laser welding experiments. Results illustrate that the developed integrated optimal method provides a promising way to identify favorable process parameters for generating a desirable bead profile and reducing the angular distortion in deep penetration laser welding.

Keywords: Laser welding, Finite element model, Hierarchical-Kriging model, Bead profile, Angular distortion

1. Introduction

Laser welding (LW), as a promising advanced manufacturing technology, has been widely used in the aerospace, shipbuilding, energy, and automotive industry. It is prominent over other joining technologies due to its significant advantages such as a high degree of automation, enhanced joint strength, high energy density, and narrow heat-affected zone. In general, the quality of the welding joints is largely dependent on the laser welding process parameters [1, 2]. An improper selection of LW process parameters can bring about the formation of welding defects, such as collapse, incomplete fusion, and upper bead depression, which will significantly reduce the strength of the welded joints [3, 4]. Earlier studies had found that the quantifiable LW bead geometry and welding-induced angular distortion are highly in connection with the functional properties of welded joints [5, 6]. Therefore, the welding parameters can be determined by selecting a desirable LW bead