C. Identifying Uncertain Material Parameters in Weld Pool by Integrated Modeling

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Introduction

The values of effective thermal conductivity and effective viscosity of liquid metal in weld pool are not known beforehand since they depend on specific weld pool characteristics. Traditional weld pool simulation undertakes those values usually in a probabilistic manner. The present work reports a deterministic approach to identify those parameters by integrating a phenomenological heat transfer and fluid flow simulation in weld pool with an iterative multi-variable optimization technique. The optimization technique minimizes the error between the predicted and the measured weld dimensions by considering the sensitivity of weld dimensions to each of the unknown parameters. The integrated model could successfully identify those unknown parameters based on a few measured data.

Technical approach

The phenomenological heat transfer and fluid flow simulation in weld pool is carried out by simultaneously solving the law of momentum conservation, continuity and the energy transport with appropriate boundary conditions. The optimization technique is based on the Levenburg-Marquardt procedure that involves the minimization of an objective function, which depicts the difference between the computed and measured values. The sensitivities of the computed weld dimensions to the unknown parameters are evaluated numerically by carrying out several heat transfer and fluid flow simulation within the framework of the integrated model. The overall calculation starts with a set of initial guess that is iteratively updated until the error between the computed weld dimensions and measured data for all sample welds is minimized.

Results and discussions

A set of laser welded samples made with varying combinations of laser power and welding speed are used in this work. A non-dimensional heat input index corresponding to each sample is calculated as a ratio of absorbed heat input per unit volume and the enthalpy change required to bring a unit volume of the metal from room temperature to melting temperature. The objective function is constructed as the summation of the square of error between the computed weld dimensions and corresponding measurements in non-dimensional form for all six sample welds. The effective thermal conductivity and effective viscosity of liquid metal in weld pool are considered in non-dimensional form. An initial set of numerical experiments are performed to realize the patterns of sensitivities of computed weld dimensions with effective thermal conductivity and effective viscosity. As the effective thermal conductivity increases, the penetration increases while the weld width is reduced. The effective viscosity has depicted similar influence on computed weld dimensions. These results are consistent with the fact that the enhancement in viscosity reduces radial material flow and thus convective heat transport in radial direction. Consequently, weld width reduces and the peak temperature increases. The penetration improves subsequently due to enhanced downward heat conduction owing to higher temperature gradient. Increase in effective thermal conductivity enhances overall conductive heat transfer and thus, penetration improves. However, higher heat conduction also reduces surface temperature gradient that leads to reduced convective heat flow and hence lower weld width. It is observed further that the extent of such interacting influence of effective thermal conductivity and effective viscosity on weld dimensions is also related with the absorbed heat input. The solution of the integrated model has finally predicted an increasing trend of effective thermal conductivity and effective viscosity as a function of non-dimensional heat input index.

Conclusions

An integrated modeling tool that can simultaneously learn values of uncertain weld pool parameters and analyze heat transfer and fluid flow in weld pool with greater accuracy has been developed. Based on only a few measurements of weld pool dimensions, the integrated model has calculated the values of effective thermal conductivity and effective viscosity for weld pools made with varying heat input. It is further established that the effective thermal conductivity and effective viscosity follow an increasing trend with absorbed heat input.