B. Determination of Unknown Welding Parameters for GMA Fillet Welding Using a Smart Model

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Introduction

Numerical heat transfer and fluid flow models of fusion welding require prescription of several parameters such as the arc efficiency that cannot be accurately prescribed from fundamental scientific principles. If the model predictions of weld pool shape and size or cooling rate do not agree with the experimental results, no systematic method exists now to tune the unknown or relatively uncertain welding parameters. The goal of this presentation is to propose and demonstrate a new approach where a GMAW heat transfer model can learn from a limited amount of experimental data to improve the predictive capability of the model.

Procedure

A three-dimensional numerical heat transfer model for the gas metal arc (GMA) welding of fillet joints is combined with two multivariable optimization schemes to determine several unknown or uncertain welding variables. The heat transfer model can provide weld geometry and the shape of the solidified weld reinforcement surface using the energy minimization technique. The technical approach is to use a small volume of experimental data on weld pool shape to estimate how the arc efficiency varies with input power, the effective thermal conductivity in the weld pool, and the radius of the volumetric heat source.

Results and Discussion

The model was used to determine the arc efficiency, effective thermal conductivity of the molten weld metal and the diameter of the internal cylindrical heat source. The cylindrical heat source represents a region where most of the heat from the droplets is deposited inside the weld pool. Using the proposed bi-directional model, a linear relation between the arc efficiency and the input power was obtained. For the conditions of fillet welding parameters studied, the effective thermal conductivity was found to be 12 times the molecular value of thermal conductivity of the liquid metal. The diameter of the cylindrical heat source was found to be about 2.7 times the average diameter of drops.

An important difference between the commonly used heat transfer and fluid flow models of GMA welding and the proposed model is the ability of the proposed model to provide welding conditions to achieve certain attainable geometric parameters. This is done by coupling a GMA heat transfer model with two optimization schemes, the conjugate gradient method and the Levenburg-Marquardt method. The new ability is computationally intensive and requires several days of calculations in a 3 GHz P4 PC while one run of the numerical heat transfer model for GMA takes on the order of only 10 minutes in the same PC. The speed of convergence depends on the initial choice of the welding parameters.

Conclusions

Because of recent advances in computational hardware and software, it is now possible to determine several unknown welding parameters based on scientific principles from experimental data using a numerical heat transfer model coupled with a

suitable optimization routine. Using the unknown parameters determined by the new model, the calculated shape and size of the fusion zone, finger penetration characteristic of the GMA welds and the solidified free surface profile were calculated for several welding conditions. Good agreement between the model predictions of leg length, the penetration depth and the actual throat and the corresponding experimental data for various welding conditions show that this approach is promising.