B. Transport Phenomena and Genetic Algorithm based Window of Welding Variables to Achieve a Target Gas Metal Arc Fillet Weld Geometry

by A. Kumar and T. DebRoy, The Pennsylvania State University

Introduction

Current transport phenomena based welding models are designed to calculate temperature and velocity fields, and other attributes such as the weld geometry. However, in many instances, the desired attribute such as the geometry is known and the correct set of welding parameters need to be determined. The mismatch between the practical need and the capability of the current models has restricted the use of these powerful models. This presentation shows that by combining a numerical thermo-fluid model with an appropriate genetic algorithm based optimization scheme, many possible sets of welding variables that are capable of producing a given weld geometry can be determined.

Procedure

A three-dimensional numerical heat transfer and fluid flow model for the gas metal arc (GMA) welding of fillet joints is combined with a genetic algorithm (GA) based optimization scheme to obtain a window of welding variables. A parent centric recombination (PCX) based generalized generation gap (G3) GA was used. To reduce the computation time, the model is parallelized to run on multiple processors simultaneously. The approach outlined in this paper completely restructures numerical heat transfer and fluid flow calculations and empowers practicing engineers to determine a window of input variables consisting of several sets of welding variables all of which would lead to a target weld geometry.

Results and Discussion

A window of input welding parameters was found by coupling a GMA heat transfer and fluid flow model with a PCX based G3 genetic algorithm. Genetic algorithm is a population based search technique, where a population consists of many sets of welding variables, with each set viewed as an individual in the population. Specifically, each individual represents a set of randomly chosen values of current (I), voltage (V), welding speed (U) and the wire feed rate (wf) with all other welding variables kept constant. To start the calculations, the initial population was randomly selected in the following range of values: I (250.0 to 400.0 A), V (25.0 to 40.0 V), U (2.0 to 8.0 mm/s) and wf (100.0 to 250.0 mm/s). The heat transfer and fluid flow model calculated the weld geometry for each set of welding conditions considering the deformation of the weld pool top surface, additions of the filler metal and the heat transfer by spray transfer of metal droplets. Then the GA produced new individuals (or, set of welding conditions) by minimizing the error between weld geoemtry obtained for these individuals and the target geometry in an iterative manner. The multiple deme (or island) based parallelized GA model used in the present study helped in faster exploration of the window of welding parameters by dividing the search space and migrating the best solutions to other islands. Experiments were also performed in the window of welding conditions obtained by using the proposed model for gas metal arc fillet welding on ASTM A-36 mild steel to check the validity of proposed model. The success of this work shows that the current existing phenomenological models can be reformulted to be used in industry by practising engineers.

Conclusions

Because of recent advances in computational hardware and software, it is now possible to construct a model that can provide window of welding parameters to achieve a target geometry based on scientific principles. Using the window of welding parameters obtained by the proposed model, the calculated shape and size of the fusion zone, finger penetration characteristic of the GMA welds and the solidified free surface profile were similar to those obtained from experiments under similar welding conditions. Good agreement between the model predictions and experiments show that this model empowers practicing engineers to determine a window of input variables that would lead to a target weld geometry.