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Weld Procedure Development with OSLW — Optimization Software for Laser Welding

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Abstract

Weld procedure development can require extensive experimentation, in-depth process knowledge, and is further complicated by the fact that there are often multiple sets of parameters that will meet the weld requirements. Choosing among these multiple weld procedures can be hastened with computer models that find parameters to meet selected weld dimensional requirements while simultaneously optimizing important figures of merit. Software is described that performs this task for CO_2 laser beam welding. The models are based on dimensionless parameter correlations that are derived from solutions to the moving heat source equations. The use of both handbook and empirically verified thermophysical property values allows OSLW to be extended to many different materials. Graphics displays show the resulting solution on contour plots that can be used to further probe the model. The important figures of merit for laser beam welding are energy transfer efficiency and melting efficiency. The application enables the user to input desired weld shape dimensions, select the material to be welded, and to constrain the search problem to meet the application requirements. Successful testing of the software at a laser welding fabricator has validated this tool for weld procedure development.

Introduction

Finding the best automated welding parameters to achieve a specific weld size on a new material is usually an expensive and time consuming task. To determine a weld procedure in a logical manner, one must consider many competing factors including productivity, thermal input, defect formation, and process robustness. The tradeoffs between these factors can be substantial as well as hard to quantify. For example, we might expect that process robustness is inversely proportional to productivity, but in fact, the result depends on the defect we are concerned with. Humping and undercut are defects that occur primarily at high feedrates, however thermal damage and base metal distortion are deficiencies that are reduced at high feedrates. The development problem is complicated by the fact that there are often multiple sets of parameters that will meet the weld size requirements. Identifying the preferred set of parameters for an application can require extensive experimentation and keen process insight.

Choosing among numerous weld procedures can be hastened with computer models that find parameters to meet selected weld dimensional requirements while simultaneously optimizing important figures of merit. Two fundamental figures of merit for fusion welding processes are the energy transfer efficiency and the melting efficiency. Energy transfer efficiency indicates what fraction of the energy incident on the workpiece is actually absorbed by the metal. Melting efficiency quantifies the fraction of net heat input to the workpiece that is used to produce melting rather than unnecessary heating of the metal that can lead to thermal damage and distortion. Other figures of merit which we may wish to consider are the physical extent of the heat affected zone or the fusion zone size tolerance to a changing base metal temperature. Desktop computer models to quantify these and other figures of merit for the numerous welding processes in use today present a formidable task that has only recently been undertaken. (Ref. 1,2,3)

For laser beam welding, a dimensionless parameter model (Ref. 4) has been shown to be effective in relating melting to power, speed, and the material thermophysical properties. By combining this thermodynamic based relationship with additional correlations for penetration depth, weld shape, spot size, and energy transfer efficiency, a computer model of the continuous wave CO_2 laser welding process has been developed called OSLW (Optimization Software for Laser Welding). The application is written in MATLAB*, which provides integrated numerical computation, graphics, and a graphical user interface. A description of the construction of OSLW, features of the graphical user interface, and example problems will be presented.

The Model

Usually, analytical weld models require the weld procedure parameters to be input in the problem statement, the model then calculates the weld dimensions and other material responses such as temperature. OSLW solves the more universal engineering

* The MathWorks, Inc. Natick, MA 01760-1500