Joint Tolerance and Process Sensitivity in Laser Welded Lap Joints

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Introduction

Laser weld lap joints in sheet materials can be made in several configurations, including (AWS C7.2, Recommended Practices for Laser Beam Welding, Cutting, and Drilling) lap, seam, and fillet. Although these joints are ostensibly designed for similar loading, they are significantly different in terms of their sensitivity to fit up and gap tolerances, laser absorption, the relative complexity of laser beam orientation and joint tracking, and inspection requirements. As a result of these differences, it is not always clear which joint type is preferable for a given application. A quantitative means for determining the most appropriate joint type is desirable.

Procedure

An experimental matrix of lap welds was produced between 1.6 mm thick PH 13-8 Mo and 3.2 mm thick 304L stainless steels by using a Rofin Sinar CW015 continuous wave Nd:YAG laser in three joint configurations. These configurations included a fillet type with the beam oriented perpendicular to the lap plane, a fillet type with the beam oriented at a 60° angle to the lap plane, and a seam (piercing) weld through the PH 13-8 Mo. Independent variables in the experiment were laser power, gap, and focus position (spot size). Weld travel speed was held constant. Response variables included weld volume (cross-sectional area) and weld area (length) in the plane of the lap.

Results and Discussion

Because of the significant differences in the lap weld procedure types, a simple experimental matrix in which joint and welding parameters are identically varied cannot be used. Thus, the following experimental design was adopted. At sharp focus, constant travel speed, and zero gap, a baseline laser power was determined that produced equivalent fusion zone cross-sectional areas for all three weld types. The matrix variations in power were then centered around this baseline set of procedures for each type and included 90, 100, and 110%. Variations in the other two independent variables, gap, and focus position, were equivalent for all three weld types. In this way response surfaces were constructed, and the relative sensitivity to process variations about a standard set of conditions was evaluated.

In general, the three weld types were sensitive to gap variation, with the piecing weld demonstrating the greatest sensitivity. This sensitivity results from the significant changes in heat flow which accompany increases in gap spacing, and can be demonstrated with analytical assessments of the heat flow conditions. The 60° angle fillet weld was found to result in an increase in weld size when the joint gap was increased slightly. This increase in weld size was attributed to increases in beam absorption due to multiple reflections in the joint gap.

The influence of other factors, such as machining tolerances, material weldability, part motion capabilities, and fixturing requirements, will be discussed in relation to the sensitivities determined in this work.

Conclusions

Three types of lap joints for laser welding were evaluated and the relative sensitivities to processing variations such as laser power and beam size were determined. Weld joint gap was also varied for each weld joint in order to determine the sensitivity to variations in piece part tolerances that are inevitable in production applications. In conjunction with other considerations, these sensitivities provide a basis for determining the most appropriate lap weld procedure for a given set of application requirements.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000