C. Development of a Distortion Test for Laser Welding

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Introduction

The selection of laser welding process parameters for critical applications requires consideration of a large number of factors, including: structural requirements (penetration), heat flow and thermal constraints, distortion, appearance, and productivity. Of these, one of the most difficult to analyze quantitatively is weld distortion. Although sophisticated modeling approaches for assessing distortion are available, distortion is most often addressed by experience and/or trial welding of actual assemblies. Thus, a simple test for comparison of distortion, as a function of laser and joint parameters, is desirable.

Procedure

A distortion test was developed, characterized, and used to compare weld schedules in 304L stainless steel. The sample consisted of a thin rectangular bar and a slotted thick block. The narrow end of the bar was seam welded to the block, which was designed to allow for unconstrained movement of the free end. Statistically designed experiments were conducted to compare the deflections generated by continuous and pulsed seam welding, and as a function of joint gap. The distortions of interest, the axial deflections, were determined by using height gage measurements. Restrained measurements using a load cell were also conducted.

Results and Discussion

The predominant distortion of interest in this test consists of a cantilever deflection (rotation) of the bar about an axis defined by the weld centerline. Because of the bar length, this deflection is magnified at the opposite end, and is easily measured. For the geometry used (0.25” by 1.25” by 0.063” thick), the free end displacement was on the order of 0.040”. This deflection results primarily from both the lateral contraction on solidification and thermal contraction during subsequent cooling. A much smaller secondary distortion also develops, and essentially consists of a rotation about an axis parallel to the bar long axis. This secondary displacement results primarily from the longitudinal contraction of the weld as it traverses the bar, but is minimized by the short length of the bar in the travel direction. Finally, very small shape changes, of lesser interest in the current work, also occur in the bar. These can be measured for use in validating advanced simulations by using more extensive characterization methods.

The results of the statistically designed experiments indicate that the test is useful for direct experimental comparison of process parameters, and highlight the differences between continuous and pulsed welding at similar penetration. The deflections can be correlated by using analytical models developed for arc welding which consider the heat input and weld cross-sectional size and shape, without the need to resort finite element models. Thus, the results provide a convenient basis for assessing a range of process parameters prior to initiating full scale process development. Although the test greatly simplifies many of the factors associated with residual stress development and distortion, it is believed that the unconstrained distortion relates in a direct way to the residual stresses developed in restrained welds, and these are also compared with analytical models and correlations developed for arc welding.

Conclusions

A simplified test for rapidly assessing the effects of processing parameters and joint gap on distortion has been developed and characterized. The test utilizes an unconstrained cantilever bar to magnify the lateral distortion and minimize the longitudinal distortion, and can be correlated with geometrical analyses of the weld. The test provides a basic means for comparison of distortion during process development, and is also potentially useful for model validation.

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