Porosity Characterization for Nd:YAG Laser Welds: Investigating the Effect of Square Wave Modulation

J. T. Norris, M. J. Perricone; Sandia National Laboratories, Albuquerque
C. M. Ellison, K. M. Faraone; Honeywell FM&T, Kansas City

Introduction

Weld porosity is a prevalent artifact of laser beam welding. Although its presence is not necessarily catastrophic, it remains undesirable and poses not-easily-quantified risks - weld strength being a main concern. The extent to which strength is reduced depends upon the weldment's intended application, weld joint type, loading forces, and most importantly porosity characteristics: size, frequency, and location. Assessing weld reliability in the presence of these pores can be difficult. The present study seeks to identify mechanisms using square wave modulated and continuous wave lasers to minimize and/or eliminate pore formation in an effort to predict and control pore formation characteristics.

Technical Approach

A Lumonics 1000 W fiber delivered Nd:YAG laser was used to create standing-edge welds on 304L stainless steel. Welds were produced in both continuous wave (CW) and square wave power modulated modes. Weld samples were 4 X 1 X 0.050" with weld lengths of approximately 3½ inches. Power, percent modulation, modulation frequency, spot size, and weld speed were systematically varied. Weld porosity was quantified in terms of nominal pore diameter, frequency, and location via X-ray radiography and metallographic analysis. Thermocouple measurements were taken from bead-on-plate welds 0.200" from the weld's centerline. Analysis for CW laser beam welds was conducted correspondingly.

Results/Discussion

Welding parameters were chosen to represent a reasonable working space for 304L stainless steel. Visual appearance was the main criteria for this basis. By modulating laser power, pulse overlap was controlled and bead width was not allowed to extend beyond the corners of the standing edge geometry. Preliminary visual inspection showed that at higher peak powers and smaller spot sizes (shorter focal length lenses) weld appearance suffered as the weld bead narrowed and exhibited increased top surface convexity. With higher weld speeds, evidence of this behavior increased and was accompanied by weld pool elongation (tear drop appearance). In contrast to previous work performed on CW laser beam welds, square wave modulation of laser power allowed for improved coupling and greatly reduced weld heat input particularly at low weld speeds. Initial x-ray radiographs revealed a chaotic formation of weld pores of small diameter and displaying no location preference within the weld. When contrasted with trends observed in CW laser welding, these data suggest a variation in weld pool dynamics between the CW and power modulated processes. Results of microstructural analysis will be presented to correlate weld aspect ratios to welding parameters. Also, attempts to rationalize these differences in the context of previous work will be discussed.

Conclusion

Pore formation behavior in square wave modulated and continuous wave laser beam welds have been characterized. Temperature measurements comparing square wave modulated laser beam welding to continuous wave and correlations between processing parameters and porosity formation have been completed. Disparities in pore forming tendencies between the two modes of laser welding have been identified. Data analysis has targeted operational space in which weld porosity is minimized allowing optimal weld strength and reliability of laser welds.

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