B. Effect of temporal pulsing shaping on cracking susceptibility of AA 6061-T6 Aluminum Alloy Laser Beam Welds

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Introduction

Pulsed laser beam welding (LBW) of 6xxx series commercial aluminum alloys will typically exhibit severe solidification cracking when a normal rectangular on-off laser pulse is employed and no filler material is used. Although temporal pulse shaping of the laser beam pulse has been shown to be capable of reducing or eliminating solidification cracking for some simple binary aluminum alloys, the suitability of this technique with ternary Al-Mg-Si wrought aluminum alloys has not been accessed. In this experimental study, the effects of temporal pulse shaping on solidification cracking susceptibility of AA 6061-T6 aluminum alloy pulse Nd:YAG laser welds was evaluated.

Technical Approach

In this study, a Lumonics JK-702H Nd:YAG pulsed laser welder was used to make bead-on-plate seam welds in AA 6061-T6 aluminum alloy sheet. Various specimen surface conditions, i.e. as received, acid cleaning and wire brushing, were evaluated. A series of welds were made at different focal positions with normal rectangular pulses at various peak powers. Non-dimensional heat flux number, ξ, and Fourier number, F_o, were used to characterize LBW process parameters. The effects of temporal pulse shaping were evaluated using laser pulses with a main welding sector followed by a range of ramp-down sectors. These pulse shapes were used to investigate the combined effects of ramp-down rates and peak power of main welding sector on solidification cracking susceptibility. Topographies of beads were examined for evidence of solidification cracking. Transverse sectioning was done for measuring weld dimensions as well as total crack lengths and cracking areas to characterize the cracking severity.

Results and Discussion

The four different surface conditions of the AA 6061-T6 specimen were found to have no effect on the weld dimensions or the transition conditions between conduction-mode and keyhole-mode welds as well as welding and drilling. Therefore, specimens with "as received" surface were used for all subsequent experiments. The threshold between surface heat marking and conduction-mode welding occurred when the non-dimension heat flux number, ξ, reached about 1, independent of the F_o number (focal position). As soon as ξ reached about 7.2, a transition from conduction-mode to keyhole-mode welds occurred. This also was independent of F_o. All welds exhibited geometric similarity if ξ and F_o were the same.

It was not possible to avoid solidification cracking when using the conventional rectangular pulse shape. However, the total crack length per unit area of weld metal was observed to decrease linearly with increasing power density.

The ramp-down temporal pulse shape was used to control the rate of solidification of each pulsed laser spot weld. For all levels of peak power of the main welding sector used, as the tailing ramp down rate was decreased, there is a clear trend from severe continues solidification cracking, to intermittent cracking, to no cracking, and then a return to intermittent cracking again. With lower peak power of the main welding sector (1.26 kW peak power and 4 ms main welding sector width), the range of ramp-down gradients that produced crack-free welds was from 137 kW/s to 47 kW/s.

With higher peak power of the main welding sector (1.7 kW peak power and 4 ms main welding sector width), the ramp-down gradient range that produced crack-free welds shifted from 137 kW/s to 71 kW/s. It was possible to produce crack-free laser seam welds in AA 6061-T6 aluminum alloy using an optimized temporal pulse shape. Furthermore, the solidification cracking susceptibility was affected by both the ramp-down gradient and the peak power of the main welding sector.

Conclusions

The effect of temporal pulse shaping on cracking susceptibility of pulsed Nd:YAG laser seam welds in AA 6061-T6 aluminum alloy had been examined. It was impossible to avoid solidification cracking if a conventional rectangular pulse shape was employed. In this case, however, the total crack length per unit area of weld metal decreased linearly with increasing power density. It was possible to produce crack-free laser seam welds in AA 6061-T6 aluminum alloys using temporal pulse shaping. The severity of cracking decreased with decreasing ramp-down gradient; however, cracking returned when the gradient was too low. The solidification cracking tendency was not only affected by ramp-down gradient, but also appeared to be related to the peak power of the main welding sectors.