MICROWELDING OF STAINLESS STEEL THIN FOIL LAP JOINT USING PULSED Nd:YAG LASER

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Laser welding has currently been used for a variety of thin products and can be performed using either pulsed or continuous lasers [1]. A pulsed laser can be used to create weld seams in thin foils by means of overlapping pulses [2]. Typical problems in lap joint welding of thin foils for sealing components in corrosive environment applications include excessive distortion, absence of intimate contact between couple (presence of gap), melt drop through and high level of residual stress. Pulsed laser processing is expected to be the method of choice because it allows more precise heat control compared with continuous laser processing [3].

Experimental investigations were carried out using a pulsed neodymium: yttrium aluminum garnet (Nd:YAG) laser welding to examine the influence of the pulse energy in the characteristics of the weld fillet. The pulse energy was varied from 1.0 to 2.25 J at an increment of 0.25 J and the pulse length was fixed in 4 ms. The base material used for this study was the AISI 316L stainless steel foil with 100µm of thickness. The welds were analyzed by optical microscopy, scanning electron microscopy, tensile shear tests and micro hardness.

The shape and dimensions of the thin foil weld bead observed in the present work depended not only on the pulse energy, but also on the presence of gaps between foils. Cross sections of macrostructures are shown in Fig. 1. Bead width, connection width and bead depth increased, as the pulse energy increased, and then had the tendency to decrease at the end due to an increase of the burnthrough, as shown in Fig. 2. Ultimate tensile strength (UTS) of the welded joints increased at first and then decreased with the pulse energy increasing, as shown in Fig. 3. The specimen welded with 1.75 Joules attained the maximum tensile shear strength. In all the specimens fracture occurred at the top foil next to the fusion line.

Figures 4 and 5 illustrate typical microstructures of AISI 316L austenitic stainless steel weld joint. Figure 4 shows the heat affected zone of the joint where can be seen the effects of the large thermal gradient in this region. Comparing thin and thick foil welding, it can be concluded that the grains in solid state coarsen with decreasing thickness of the parent metal. It shows that the volume of parent metal plays an important role during the welding thermal cycle. As the material volume decreases, the time to cooling increases and heat affected zone appearance becomes coarsen. Figure 5 shows the fusion line solidification structure of the weld where can be seen the un-melted base metal grains acting as substrate for nucleation of the fusion zone columnar grains (epitaxial growth) witch are perpendicular to the fusion boundary.

SEMs made of fractured surfaces showed different fractographic patterns. Specimens welded with low pulse energy (1.5 Joules) fractured in the weld metal next to the fusion line and displayed a ductile behavior with same porosity, as shown in Fig. 6. Specimen welded with 1.75 Joules fractured in the weld metal and displayed more ductile behavior with reductions of fracture site area and rough fracture surfaces, and also showed minimal or no porosity. Specimens welded with high pulse energy (2.25 J) fractured in the HAZ and showed more brittle behavior with relatively smooth appearing surfaces.

The microhardness is almost uniform across the parent metal, HAZ and weld metal, as shown in Fig. 7. A slight increase in the fusion zone and heat affected zone compared to those measured in the base metal was observed. It has been related to the microstructural refinement in the fusion zone, induced by rapid cooling, and the presence of precipitates in the heat affected zone.

In summary, the results obtained from this study have demonstrated that is fully possible to weld 100 µm thickness AISI 316L thin foils, in terms of microstructural and mechanical reliability, using pulsed Nd:YAG laser system. The better performance showed a joint with full penetration, no underfill and free from microcracks and porosity. It was obtained at an energy pulse of 1.75 Joules, a repetition rate [Rr] of 39 Hz and 4 ms pulse duration. This reflects one of the most notable features of pulsed laser welding compared with other processes, that is welding with small heat input. The work also shows that the process is very sensitive to the gap between couple.

Acknowledgements:

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References:

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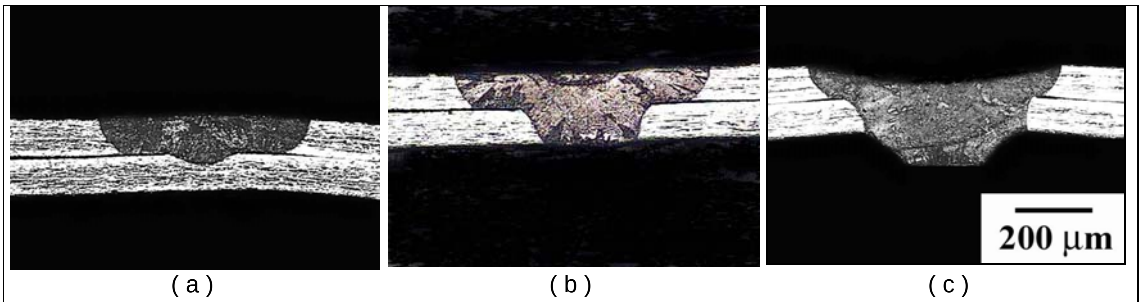

Figure 1 – Cross sections of lap joints made with pulsed Nd:YAG laser welding under different pulse energy (E_p). a) 1.5, b) 1.75 and c) 2.25 Joules.

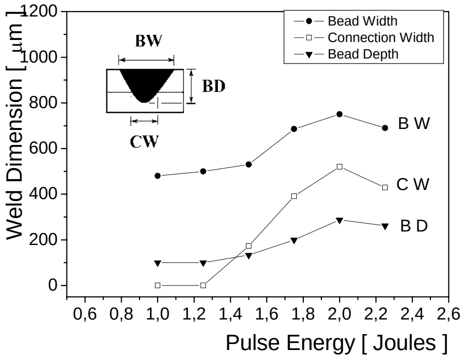

Figure 2 – Pulse Energy [E_p] versus bead width, connection width and bead depth.

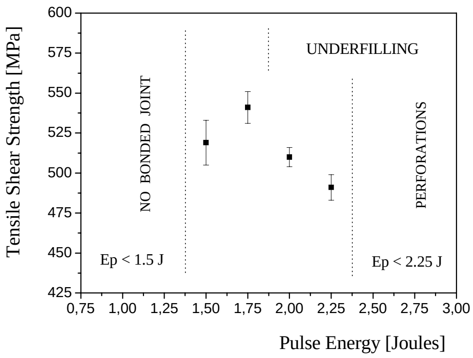

Figure 3 – Relationship between pulse energy and tensile shear strength.

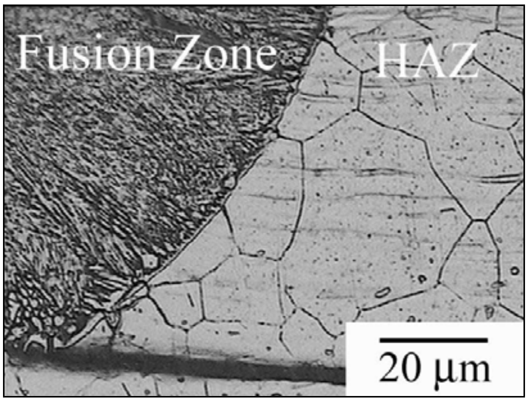

Figure 4 – Optical Microscopy at the fusion line of the specimen welded with 1.75 Joules.

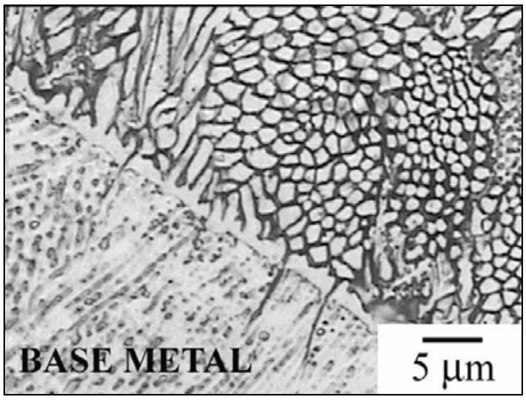

Figure 5 – Optical Microscopy at the fusion line of the specimen welded with 2.25 Joules.

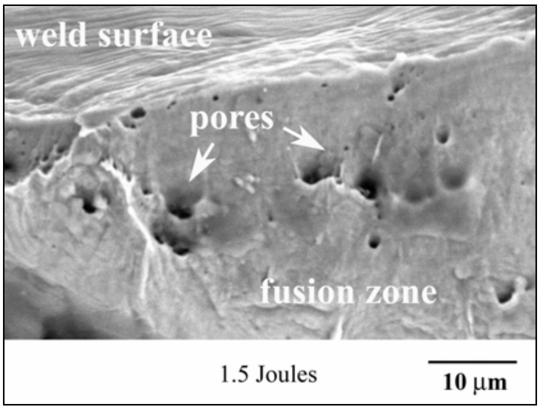

Figure 6 – SEM of fractured suface of the specimens welded with 1.5 Joules.

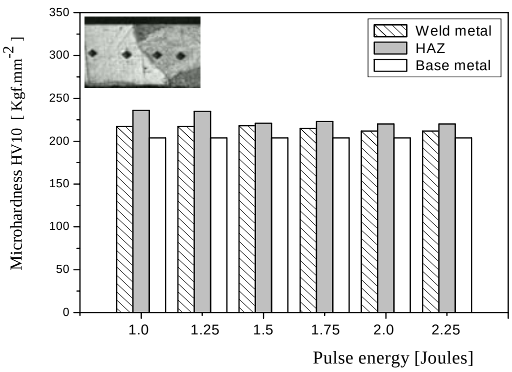

Figure 7 – Hardness profile of the weld joint as a function of pulse energy [E_p].