LASER WELDING OF V-4Cr-4Ti ALLOY

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OBJECTIVE

The objective of this research is to evaluate the potential of laser welding for joining vanadium-base alloys and to determine the effects of weld parameters on the properties of weldments.

SUMMARY

Laser welding offers potential advantages for welding vanadium alloys, including increased flexibility for field and large component welding with acceptable atmospheric control. A pulsed Nd:YAG laser with a fiber optic delivery system is used to conduct a systematic investigation of the weld parameters and environmental control requirements to obtain high integrity laser welds of Vanadium alloys. The current effort is focused on determination of laser weld parameters for welding ~4-mm-thick plate of V-4Cr-4Ti alloys and evaluation of various approaches for providing adequate environmental control. Laser weld specimens have been produced on two heats of V-4Cr-4Ti alloys and preliminary evaluations of weld integrity have been performed. Parameters for obtaining full penetration welds have been defined and weld specimens have been prepared for mechanical testing in a related study. Results from preliminary bend tests on weld specimens indicate good ductility.

EXPERIMENTAL PROGRAM

Materials

The materials used for the study were obtained from the 500 kg heat #832665 of V-4Cr-4Ti alloy produced by TWC and a 30kg heat #PX906 produced in Japan. The 500 kg heat was in the form of 3.8-mm-thick plate cold-rolled and annealed by the vendor at1050°C for 2 hours and the 30 kg heat was in the form of 4.0-mm-thick plate cold-rolled and annealed in Japan at 1000 °C for 1 hour. Small plates of 50.8 x 15 mm in dimensions were saw cut from the plate stock with the short side of the plate along the rolling direction. For the first series of tests the long edges of the plates were mille to provide better edge fitup for butt welds. The microstructure of the as-annealed plate from heat #832555 is shown in Fig. 1

Pulsed YAG laser butt welding

An Electrox 1.6 kW pulsed Nd:YAG laser with fiber optic beam delivery was used for the current laser welding studies. This facility is located in the ANL laser laboratory. The laser schedule power settings were E4L3R66 (Alternative). This indicates that the energy per unit time (E) was 4 Joules/ms, the pulse length (L) was 3 ms, and the repetition rate was 132 /s. The calculated power is E*L*(2R) = 1.58 kW, while the actual measured power is 1.30 kW. The difference is mainly due to losses in the fiber optic delivery and the fact that at low energies (4 J/ms) the laser does not put out full power. The above laser schedule power settings within the capabilities of the equipment were based on previous studies which showed that they produced relatively deep, smooth and stable welds [1]. The two workpieces for a butt weld were mounted on a Wessel 5-axis CNC workstation which moved the workpieces under the stationary laser beam. The seam-line of the two pieces was carefully aligned with the laser beam with the help of a He-Ne alignment laser that is co-axial with the YAG beam. The laser beam was focused by a 77-mm focal length Gradium glass lens (LightPath Technologies, Inc., Albuquerque, NM.). Welds with different beam focal positions relative to the workpiece surface were made to study the effect of focal position on weld penetration. Beam travel speeds ranging from 4 mm/s to 10 mm/s were used. Slight changes of the beam travel speed were used to compensate for the energy loss or gain from the power fluctuations of the laser system.

Environmental shielding technique

Welding of vanadium alloys must be performed in an inert atmosphere to prevent O_2 and N_2 contamination. A major feature of the laser welding approach is the potential to use a flexible containment chamber with an inert gas purge to avoid atmospheric contamination. This capability will allow for on-site welding of large components. An environmental control box (ECB) used in early welding tests provided adequate protection for good welds with a clean silvery weld-bead appearance if flow rates of all the shielding gases were well balanced at the open slit [2]. In this study, a flexible polyethylene containment (Fig. 2) was utilized to achieve consistent prevention from atmospheric contamination. High purity argon (99.995%) was purged into the ECB/bag for 4 minutes prior to welding to displace any air in the ECB/bag.

Weld-bend test

A simplified bend test was performed on selected weld specimens to provide a preliminary evaluation of the weld integrity. A slow strain rate bend of the welded specimen with a standard vice was used to produce a ~90° bend with an inside radius of approximately twice (2t) the specimen thickness (t).

RESULTS AND DISCUSSION

Focal position effect on weld depth

Figure 3 shows the results of a systematic study to investigate the weld depth as a function of beam focal position with respect to the workpiece surface for a fixed laser schedule of power settings and beam travel speed. The maximum weld depth was obtained when the laser beam was focussed at 0 – 0.5 mm into the workpiece. Figure 4

REFERENCES

1. K. Natesan, C. B. Reed, Z. Xu, and D. L. Smith, "Laser-Welded V-Cr-Ti Alloys: Microstructural and Mechanical Properties," Fusion Reactor Materials Progress Report for the Period Ending December 31, 1998, DOE/ER-0313/25, pp. 64-68.
2. Z. Xu, C. B. Reed, K. Natesan, and D. L. Smith, "Improvement of laser weld quality of V-Cr-Ti alloys," Fusion Reactor Materials Progress Report for the Period Ending June 30, 1999, DOE/ER-0313/26.

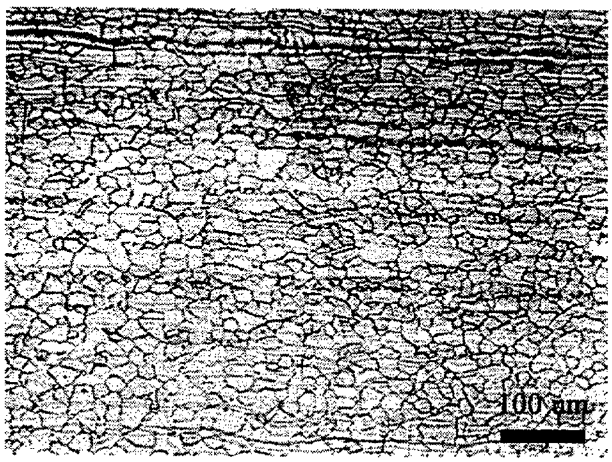

Figure 1. Microstructure of cold-rolled and annealed base metal V-4Cr-4Ti.