IMPROVEMENT OF LASER WELD QUALITY OF V-Cr-Ti ALLOYS

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SUMMARY

During this report period, the use of a YAG laser to weld sheet materials of V-Cr-Ti alloys has focused on (a) development of optimal laser welding parameters to produce deep penetration and defect-free welds, (b) integration of a custom-designed environmental control box (ECB) into the laser system to control the oxygen uptake during the processing, (c) examination of the porosity on longitudinally sectioned welds, and (d) analysis for oxygen content of the welds. An innovative method has been developed to obtain deep penetration and oxygen contamination free welds.

EXPERIMENTAL PROGRAM

Vanadium alloy heat #832665, nominal composition V-4 wt% Cr-4 wt%Ti (designated as BL–71) was selected for the study. Bead-on-plate (BOP) welds were produced on 4 mm thick sheets of the alloy using a 1.6 kW pulsed YAG laser with optical fiber beam delivery. Welds made with the same laser parameters but different beam travel speeds were EDM wire cut longitudinally along the centerlines of the welds to comprehensively examine for porosity. A custom-designed environmental control box (ECB) capable of purging with high-purity argon (99.995%) has been integrated with the YAG laser to improve the quality of the welding atmosphere. Figure 1 schematically shows the set-up of the laser system with the ECB. The specimen was placed in the ECB with fixtures. The high-purity argon was purged into the box from both sides and the flow rate was well controlled such that a slow flow of argon out from the slit on the top of the box could be formed This provided a good welding atmosphere to minimize the oxygen uptake during the welding. A shielding disk just above the slit enhanced the shielding effect and also provided a guiding surface for the lens protection gas. The content of oxygen, nitrogen, and carbon of laser-welded samples produced with and without using the ECB were analyzed by Inert Gas Fusion (IGF) method.

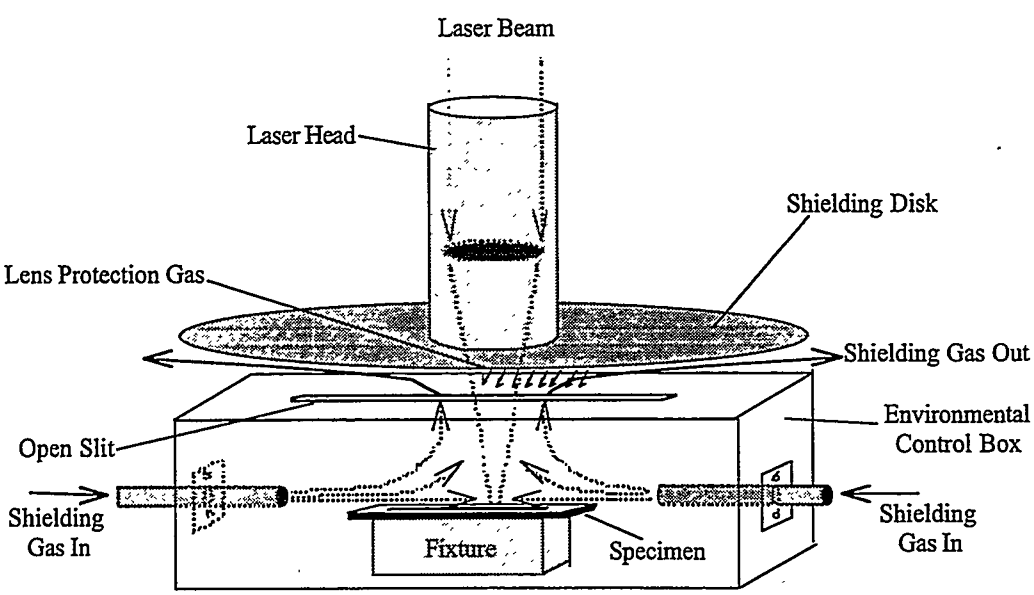

Figure 1 Set-up of the laser welding system

RESULTS AND DISCUSSION

Examination of Porosity on Longitudinally sectioned welds

Cross-sectioned samples of welds with and without root porosity were reported on in the previous report [1]. Cross-sectioned weld samples do not, however, reveal completely the existence of porosity, since the randomly chosen section could be located just between porosities. Table I lists the welding conditions and weld depths of four samples used to examine for porosity in longitudinal sections. The side view of the longitudinal section of the four welds is shown in Figure 2. Detailed views of individual sections are presented in Figures 3 to 6. As it is revealed by the figures, the number of porosities decreases as the beam travel speed decreases. Porosity-free welds were obtained when the weld depth reached full penetration. It appears that full penetration provided a path on the bottom side of the sample for the gas trapped in the welding keyhole to escape, thus eliminating porosity.

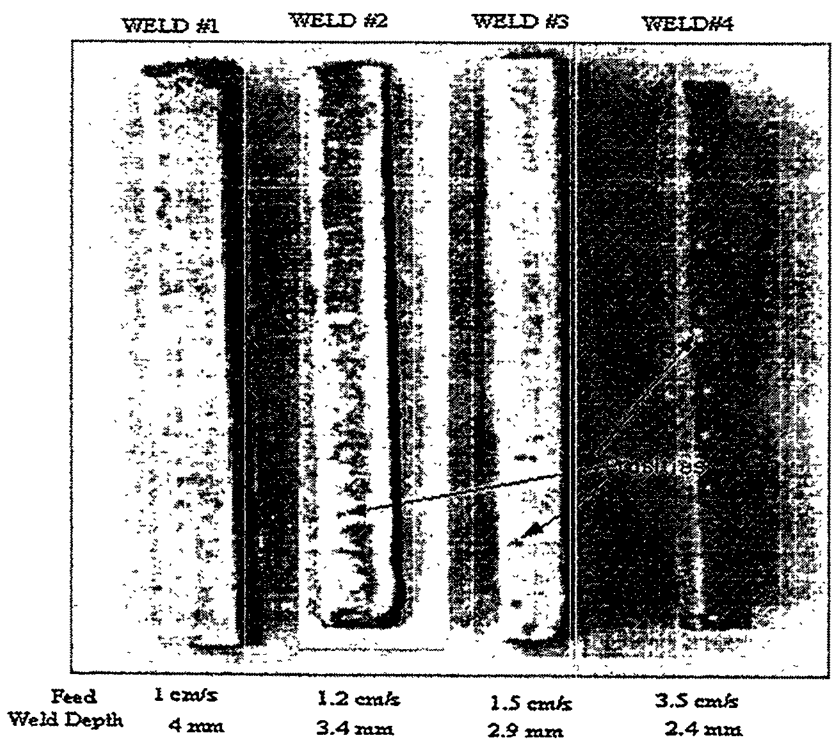

Figure 2. Longitudinal section views of laser-welded samples showing welds with porosity and a full penetration weld without porosity

Table 1. Welding Conditions and Weld Depths

Weld No.	Laser Energy (Joules/ms)	Pulse width (ms)	Repetition Rate (Hz)	Feed Rate (cm/s)	Weld Depth (mm)
1	4	3	132	1	4
2	4	3	132	1.2	3.4
3	4	3	132	1.5	2.9
4	4	3	132	3.5	2.4

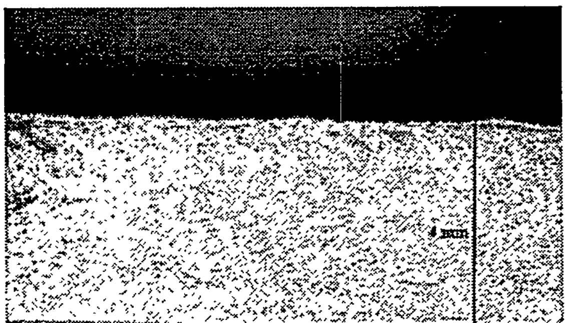

Figure 3. Closeup of longitudinal section view of weld No. 1 in Table I.

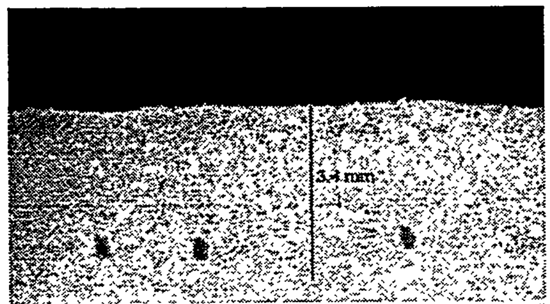

Figure 4. Closeup of longitudinal section view of weld No. 2 in Table I.

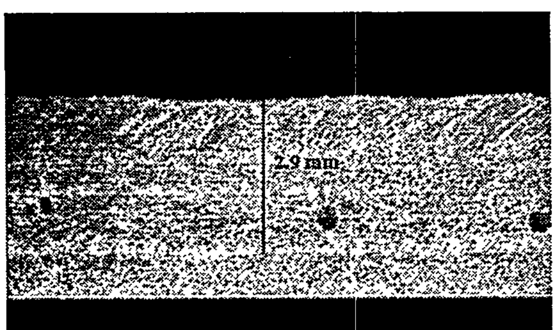

Figure 5. Closeup of longitudinal section view of weld No. 3 in Table I.

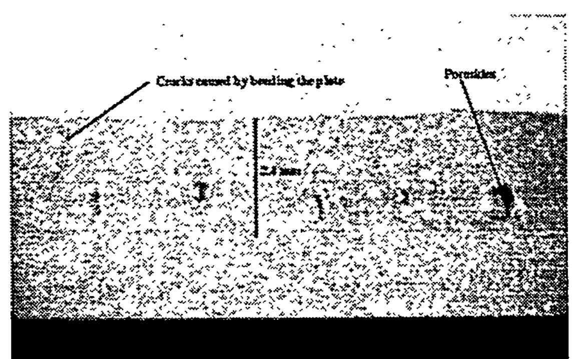

Figure 6. Closeup of longitudinal section view of weld No. 4 in Table I.

Chemical Analysis of Laser-Welded V-Cr-Ti Alloy

Uptake of oxygen leads to embrittlement of the alloy and therefore must be avoided. Table I shows the cleaning and welding conditions used to prepare samples for chemical analysis. The samples were wiped with acetone before and after welding except sample 990709B, which was cleaned in a pickling solution after welding. The chemical analysis results of the welds in Table II by IGF method are shown in Table III; values for the reference heat are also shown for information. The welds produced in the ECB with nearly optimal shielding gas (990712B and 990712C) have the lowest oxygen content. Welds using the ECB but with a less than optimal gas shielding arrangement have higher oxygen content compared to those with nearly optimal shielding. The welds obtained without using the ECB have the highest oxygen content. The O, N, and C contents of welds produced using the ECB with near-optimal shielding gas are essentially the same as the reported values for the reference heat. Oxygen analyses obtained from the chip samples apparently include additional contamination. Subsequent specimens were not milled into chips prior to chemical analysis, but rather submitted as small bars. This approach yielded O, C, and N measurements close to those of the reference analysis for the Heat.

TABLE II. Cleaning and Welding Conditions of Chemical Analysis Samples (Same laser parameters were used for all the welds, laser energy: 4 joules/ms, pulse width: 3 ms, and pulse repetition rate: 133)

Samples	Beam travel speed (cm/s)	ECB used? Y/N	Clean conditions before & after welding	Sample supplied shape
990223A	Base material	Base material	Acetone wiped	Chips
990223B	1	N	Acetone wiped	Chips
990223C	1	N	Acetone wiped	Chips
990709A	0.6	Y, but non-optimal shielding gas	Acetone wiped	Bar
990709B	0.5	Y, but non-optimal shielding gas	Cleaned in pickling solution after welding	Bar
990712B	0.4	Y, near-optimal shielding gas	Acetone wiped	Bar
990712C 990712D	0.25	Y, near-optimal shielding gas	Acetone wiped	Bar

TABLE III. IGF Chemical Analysis Results of Laser-Welded V-Cr-Ti Alloy Samples

Sample	O (wppm)	C (wppm)	N (wppm)	Welded in Environmental control box?
Heat 832665	310	80	85	Reference Analysis
990223A	780	100	80	Base material
990223B	1460	60	1970	No
990223C	1690	80	2710	No
990709A	360	100	180	Yes, but non-optimal shielding gas flow
990709B	390	100	290	Yes, but non-optimal shielding gas flow
990712B	320	100	70	Yes
990712C	320	100	80	Yes

A microhardness profile across the width of weldment 990712D is presented in Figure 7. This profile shows only a slight increase in hardness in the weld metal, in comparison to the adjacent base metal.

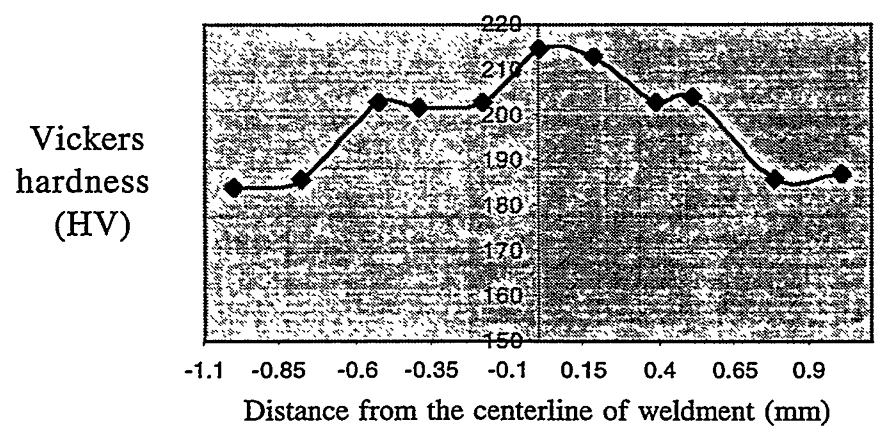

Figure 7. Microhardness profile for oxygen-uptake-free weldment (990712D) at half-width of weldment.

In the next report period, deep penetration, defect free and oxygen contamination free welds will be produced on the vanadium plates using the ECB, then Charpy impact test samples will be cut from the plates and tested. Further work on oxygen pickup and weldment microhardness will be performed in the next report period.

REFERENCES

1. K. Natesan, D. L. Smith, Z. Xu, and K. H. Leong, "Laser-Welded V-Cr-Ti Alloys: Microstructural and Mechanical Properties," Fusion Reactor Materials Progress Report for the Period Ending June 30, 1998, Argonne National Laboratory, DOE/ER-0313/24, p. 87, June 1998.

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