DEVELOPMENT OF LASER WELDING TECHNIQUES FOR VANADIUM ALLOYS*

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OBJECTIVE

Techniques for joining vanadium alloys, and possibly vanadium, to steel will be required for the construction of fusion devices. The primary objective of this program is to develop laser welding techniques for vanadium alloys, particularly for the manufacture of test specimens of welded materials.

SUMMARY

Laser welding is potentially advantageous because of its flexibility and the reduced amount of material affected by the weld. Lasers do not require a vacuum (as do electron beam welders) and the welds they produce have high depth-to-width ratios. Scoping tests with a small pulsed 50 J YAG laser indicated that lasers could produce successful welds in vanadium alloy (V-5%Cr-5%Ti) sheet (1 mm thick) when the fusion zone was isolated from air. The pulsed laser required an isolating chamber filled with inert gas to produce welds that did not contain cracks and showed only minor hardness increases. Following the initial scoping tests, a series of tests were performed with a 6 kW continuous CO_2 laser. Successful bead-on-plate welds were made on V-4%Cr-4%Ti and V-5%Cr-5%Ti alloys to depths of about 4 mm with this laser.

EXPERIMENTAL PROGRAM

Because of the potential advantageous of laser welding, it is important to include laser-welded samples in the materials testing program for vanadium alloys, and laser welding tests on vanadium alloys were begun in late 1994. Initial scoping tests with a small pulsed laser were performed to determine the environment required to make successful welds and the depth-of-penetration capability of this welder. These tests indicated that successful welding of a V-5%Cr-5%Ti alloy would require protection of the molten metal from contamination by interstitial elements (primarily oxygen). Some initial tests have been performed with a 6 kW continuous CO_2 laser and an argon purge to protect the weld. Successful bead-on-plate welds have been made on 1 mm-thick sheet and 4 mm-thick plates. Modification of the purge-stream configuration and adjustment of the welding parameters will be pursued as methods of optimizing these welds. The use of a 1600 W pulsed YAG laser will also be evaluated for making these welds.

RESULTS

Weld beads were generated during initial scoping tests with a 50 J pulsed YAG laser by overlapping individual spot welds. Welds made in air with the aid of an argon purge to protect the welds resulted in welds that contained cracks. However, a crack-free weld was made by placing the sample in a glass chamber filled with argon. In this case, metal vaporized during the individual shots coated the glass and significantly reduced the penetration depth near the end of the bead. These results showed that laser welding was feasible, but that protection of the weld from interstitial impurities was necessary.

Previous experience of the operators of the 6 kW continuous laser indicated that successful welds could probably be made on vanadium alloys by using inert gas purges, which would avoid the complications associated with enclosing the work piece. Initial weld trials have shown that bead-on-plate welds could be obtained to depths of about 4 mm with a power of 5.5 kW and a speed of 4.5 cm/s. Argon at a flow rate of 100 cfh was distributed through a diffuser nozzle aimed just behind the laser beam on the upper surface of the work piece. The rapid solidification rate in these welds resulted in a fine, highly elongated grain structure, as shown in Fig. 1. Results of microhardness measurements (Fig. 2) show an increase from about 180 dph in the bulk material to about 230 dph in the fusion zone.

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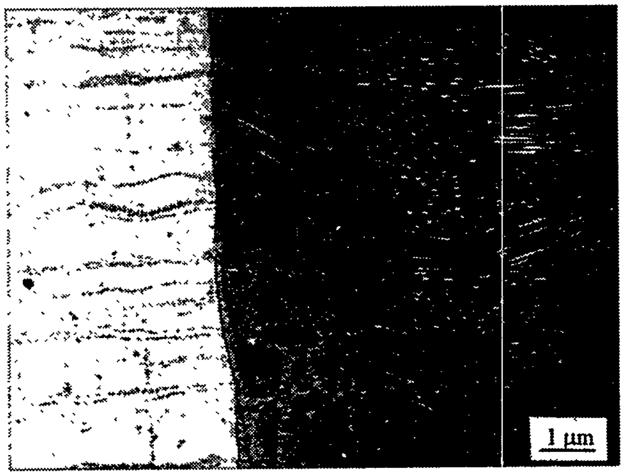

Fig. 1. Microstructure of Laser Weld and Base Material; 100X.

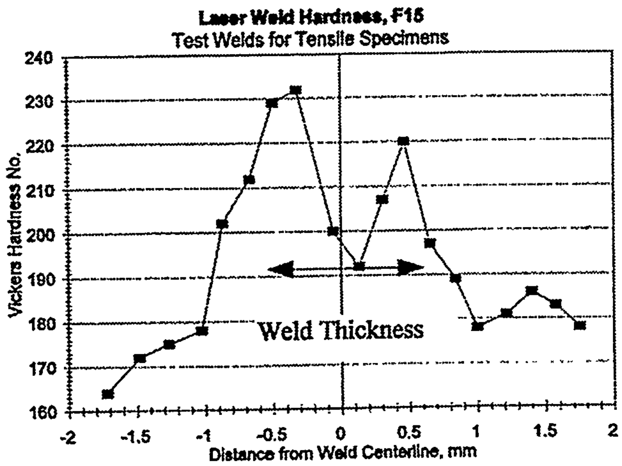

Fig. 2. Microhardness Measurements on Laser Weld and Base Material.

Results of Charpy impact testing on V-4%Cr-4%Ti alloy samples fabricated with the weld located transversely at the notch showed good ductility at 100°C, but poor ductility at -25°C. Only three welded samples were available for testing so no additional data were obtained on the as-welded samples. The third sample was heat treated under vacuum at 1000°C for 1 h and then tested. Charpy testing showed that this sample had good ductility at -25°C. A preliminary interpretation of these results is that the reduction in ductility resulted from the welding. If oxygen contamination were the cause of the reduction in ductility, the annealing operation may have caused the oxygen to precipitate from the matrix in the form of titanium oxides.

FUTURE ACTIVITIES

The next step in the development of laser welding techniques is to evaluate the performance of a 1600 W YAG laser in welding the vanadium alloys. Both improved purging techniques and inert gas enclosures will be included as methods to reduce or eliminate oxygen contamination. Efforts will be made to optimize the power and speeds used to weld 1- and 4-mm-thick material. The effectiveness of changing the welding and cover gas parameters will be measured by mechanical testing, as well as by microstructural and microchemical characterization of samples. Post-welding heat treating will be studied if it is needed to obtain material properties in the weld that are comparable to those in the bulk material.