DEVELOPMENT OF LASER WELDING TECHNIQUES FOR VANADIUM ALLOYS*

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OBJECTIVE

The development of 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, and to evaluate the performance of weldments.

BACKGROUND

Laser welding is potentially advantageous because of its flexibility and the reduced amount of material affected by the weld. Bead-on-plate and butt welds were previously performed to depths of about 4 mm with a 6-kW CO_2 laser on V-4%Cr-4%Ti and V-5%Cr-5%Ti alloys. These welds were made at a speed of 0.042 m/s using argon purging at a flow rate of 2.8 m^3/s. The purge was distributed with a diffuser nozzle aimed just behind the laser beam during the welding operation. The fusion zones of welds made under these conditions consisted of very fine, needle-shaped grains and were also harder than the bulk metal (230-270 dph, compared to ≈180 dph for the bulk metal). A limited number of impact tests showed that the as-welded ductile–brittle transition temperatures (DBTT) was above room temperature, but heat treatment at 1000°C for 1 h in vacuum reduced the DBTT to <-25°C.

Activities during this reporting period focused on improvements in the purging system and determination of the effect of welding speed on welds. A 2-kW continuous YAG laser at Lumonics Corp. in Livonia, MI, was used to make 34 test welds for this study.

EXPERIMENTAL PROGRAM

A YAG laser was chosen for this series of weld tests because its shorter wavelength (compared to that of the CO_2 laser) is expected to provide higher irradiance and thus may improve coupling of the beam with the specimen during the welding operation. Welding speeds of 0.007 to 0.034 m/s were used in making the sample welds. Most of the welds were made with a continuous beam, but a few tests were made while oscillating the beam power as a sine wave function to increase the weld penetration. The amplitude of the oscillations equaled 68 or 90% of full power at repetition rates of 300 and 150 cycles/s, respectively. To reduce oxygen entrainment in the argon purge, the top of the specimen was flooded with argon from two diffusers facing each other, as shown in Fig. 1. The bottom of the specimen was flooded with argon confined in a box, with the exit around the edges of the specimen.

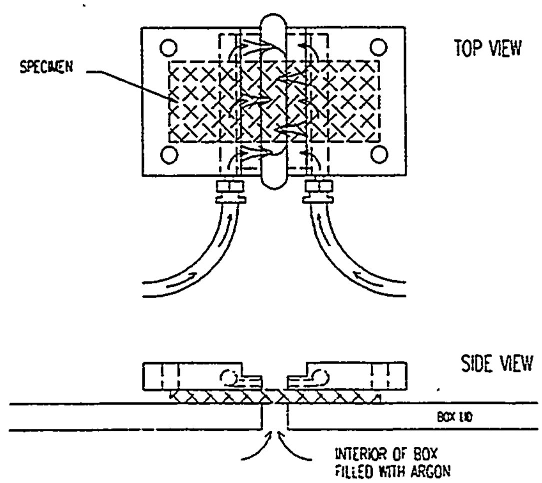

Fig. 1. Schematic Drawing of Argon Purging System

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RESULTS

Metallographic examination and testing of all of the specimens from this series of welds has been initiated. Initial results indicate that the depth of weld penetration and the microhardness of the welds increases as the welding speed is decreased. Use of oscillating beam power also increased weld penetration and weld hardness. The microstructure and grain size of the welds were not changed by the welding speed. The characteristics of the YAG laser weld at 0.034 m/s were essentially the same as those of the CO_2 laser welds at 0.042 m/s.

These results are interpreted as indicating that the "improved" argon purge did not completely prevent the pickup of oxygen during the welding operation. The slower welding speeds resulted in the metal remaining molten longer, which caused greater oxygen contamination than at the higher speeds. Conversely, the weld microstructure is controlled by the solidification rate, which is probably controlled by the thermal conductivity of the alloy and by the purging rate, rather than by the speed of the weld.

FUTURE ACTIVITIES

An enclosure is being fabricated to allow welding in a vacuum or pure inert atmosphere by passing the laser beam through a window. The effectiveness of variations in the gas environment, as well as changes in welding speed, will be assessed by impact testing and by microstructural and microhardness measurements. Postweld 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.