IMPACT PROPERTIES OF V-4Cr-4Ti LASER WELDMENTS FROM THE GA'S HEAT

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OBJECTIVE

The objective of this task is to assess the quality of both the base metal and the laser weld on V-4Cr-4Ti alloys from the General Atomics (GA)'s heat (832864) and to evaluate the effects of the oxygen content on the impact properties of V-4Cr-4Ti alloys.

SUMMARY

Charpy-impact properties of laser weldments of GA heat 832864 V-4Cr-4Ti alloy were investigated. Impact testing was performed with annealed specimens of the both base metal and the laser weldment in as-machined (by electric discharge machining with water as the flushing fluid) condition. The ductile-to-brittle-transition temperature (DBTT) for the base metal is below –187°C and for the laser weld is about 0°C. Additional microstructure characterization on the laser weld is underway.

BACKGROUND

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 for obtaining high-integrity laser welds of vanadium alloys. The current effort is focused on evaluation of laser welds on ≈4-mm-thick plate of V-4Cr-4Ti alloys. The post-weld characterization includes Charpy-impact testing and microstructural characterization of the welds.

EXPERIMENTAL PROCEDURE

Fabrication of Charpy Specimens

The starting material for this series of tests was obtained from GA heat V-4Cr-4Ti alloy, which was annealed in a high vacuum (better then 3 x 10^{-7} torr) at 1000°C for 1 hour. Laser welding was performed on a Nd:YAG laser welding facility [1, 2]. The laser weldment was produced by butt welding of two annealed plates of ~4.8 mm thickness. Direction of the weld travel was perpendicular to the rolling direction of the plate. Details of the welding procedure are given in Ref. 2.

An electric discharge machine was used to cut all of the Charpy-impact specimens. The specimens were 1/3-size, i.e., 3.3 mm thick x 3.3 mm wide x 25.4 mm long, with a 30°, 0.61-mm-deep, 0.08-mm-root-radius V notch. Notch orientation (i.e., crack propagation direction) was perpendicular to the final rolling direction and into the thickness of the plate. The weld specimens were prepared with the V-notch in the weldment in the thickness direction, as shown in Fig. 1. The specimens were not exposed to other hydrogenous materials (cleaning fluids, etc.) after they were cut.

Impact Testing

In addition to the weld specimens, several base alloy specimens were tested as a comparison. Under standard test procedures, specimens were cut from cold-worked material and then annealed before testing. In addition to the annealing, this procedure would remove any hydrogen that might have been picked up during machining. For investigation of the weld properties, it was necessary to weld annealed material and then machine the specimens.

Charpy tests were conducted with a Dynatup drop-weight tester. The tester was verified before these tests by using a 1/3-size high-energy ferritic steel calibration specimen supplied by Oak Ridge National Laboratory. The calibration showed good agreement (within 1%) between the ANL measured absorbed energy and the published ORNL data [3].

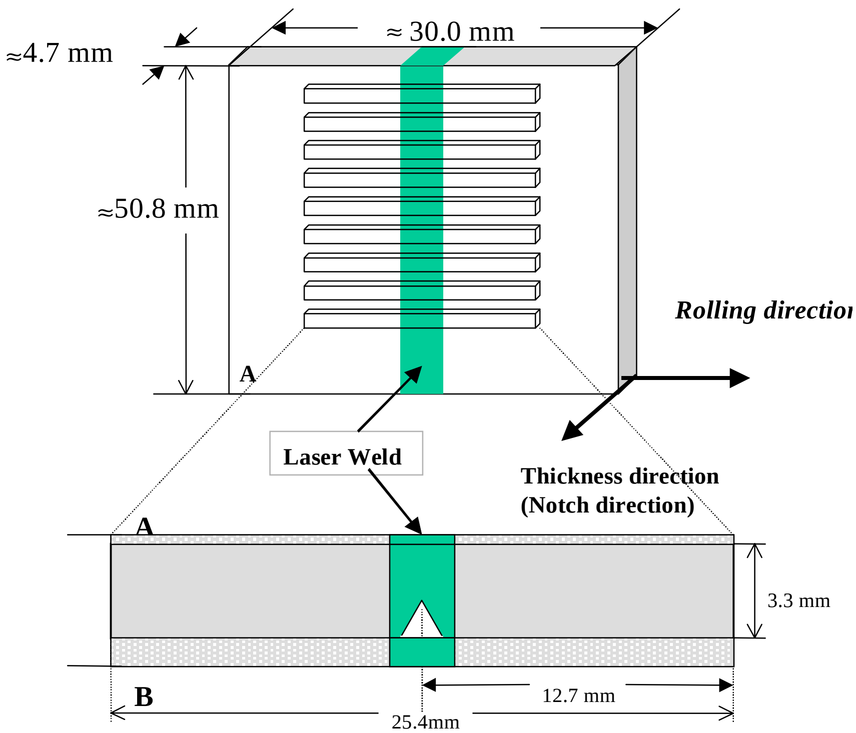

Figure 1. Schematic illustration of the fabrication of Charpy specimens.

Specimen temperature during impact testing was measured with a thermocouple that was spot-welded to the end of the specimen. For tests in which temperatures were above ambient, a hot-air blower provided the heating; for tests in which temperatures were below ambient, argon gas prechilled with a mixture of dry ice, acetone, and liquid nitrogen provided the cooling. In both cases, the specimens were held at the test temperature for a significant period for the temperature to stabilize before the test. Five specimens, three for the base metal and two for the laser weld, were degassed for hydrogen before the impact tests.

RESULTS

Eleven Charpy-impact tests, four for the base metal and seven for the laser weld for GA heat 832864, have been completed this period. The initial series of impact tests was conducted on base alloy specimens to establish the baseline for the weld specimens. Hydrogen-degassed (at 400°C for 1 hr) specimens have been evaluated and reported in previous report [1], thus all impact tests in this report were performed on the nondegassed specimens of GA heat.

Specimens from the base metal and weldments for heats 832864 and 832665 of V-4Cr-4Ti alloys have been tested and the results are included in Figs. 2 and 3. The DBTT of the as-machined base metal from GA heat is below –187°C (see Fig. 2), similar to the DBTT for the H-degassed base metal from the heat 832665. The oxygen content (385ppm) of heat 832864 (4.7mm sheet) is slightly higher than that (324ppm) of the heat 832665 (4.0 mm sheet). Thus our primary results indicate that there is not much difference in the DBTT of the two heats even though there are some differences in the oxygen content [4] and the microstructure [1].

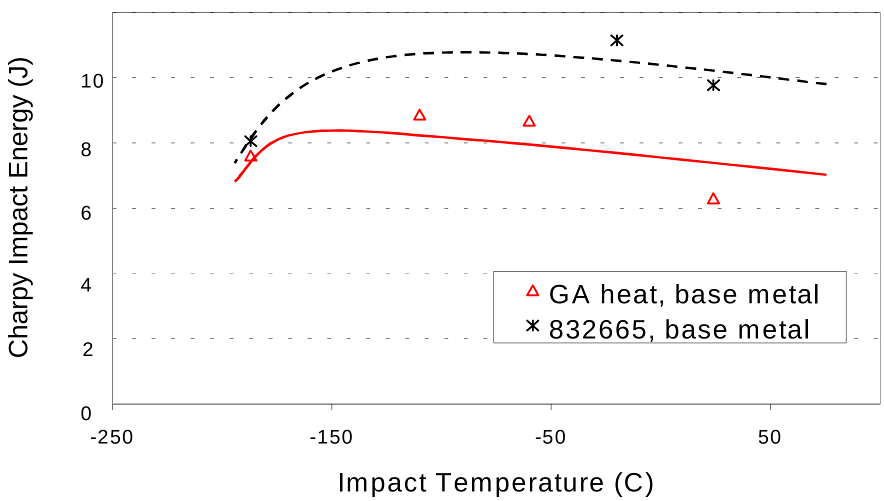

Fig. 2. Charpy-impact data for base metal specimens from GA heat (in as-machined condition) and the heat 832665 V-4Cr-4Ti (hydrogen-degassed at 400°C for 1 hr) showing ductile behavior.

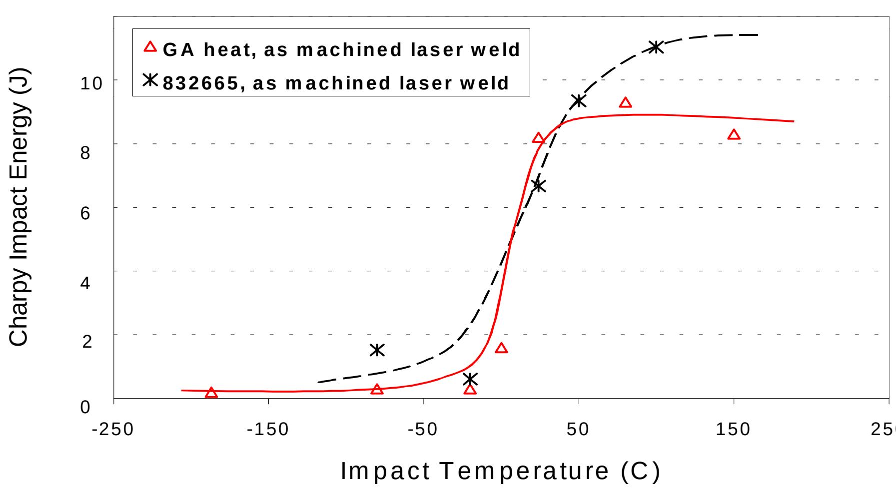

Fig. 3. Charpy-impact data for as machined laser weldment specimens from GA heat (101900I) and the heat 832665 (031300B) V-4Cr-4Ti alloys showing ductile behavior.

Impact tests on the as-machined laser welds indicated that the DBTT of the weld specimens from GA heat is ≈0°C, which is similar to the DBTT of the weld specimens from the heat 832665 (see Fig. 3). Oxygen analyses and chemical analysis are being performed on the weldments to determine the extent of oxygen pickup during the welding and to evaluate effects of oxygen concentration and other impurities on the properties. Further investigations are in progress to determine these various effects on the laser welds.

FUTURE ACTIVITIES

The fracture surface of selected specimens will be examined by scanning electron microscopy to delineate the fracture mode. Oxygen analyses and chemical analyses on the weldments are underway and will be reported in the future.

REFERENCES

[1] Y. Yan, H. Tsai, A. D. Storey, D.L. Smith, and Z. Xu, Microstructural characterization and impact properties of V-4Cr-4Ti Laser Weldments, Fusion Materials Semiannual Progress Report DOE/ER-0313/28, June 2000.

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[4] Y. Yan, H. Tsai, D.P. McGann, and D.L. Smith, Quantitative Oxygen AnalysEs for V-4Cr-4Ti Alloys (this progress report).