CHARACTERIZATION AND IMPACT PROPERTIES OF V-4Cr-4Ti LASER WELDMENTS*

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OBJECTIVE

The objective of this task is to assess the quality of laser welds on various heats of V-4Cr-4Ti alloys and to evaluate the effects of alloy chemistry and microstructure and the effects of weld parameters on the mechanical properties of weldments. In addition, modifications of the alloy microstructure induced by the laser beam provides a sensitive method for evaluating the effects of microstructural and compositional variations on the mechanical properties of these alloys. This effort includes evaluation of methods for controlling the atmospheric contamination of during welding. This activity involves joint work conducted as part of the US/Japan(Monbusho) collaboration.

SUMMARY

The effects of alloy chemistry and microstructure on the Charpy-impact properties of laser weldments of three heats of V-4Cr-4Ti alloy were investigated. The impact properties of all three heats indicate similar behavior with a DBTT of approximately -200^{o}C based on one-third size Charpy specimens in the annealed condition. However, The Charpy impact properties of the weldments, which have a significantly different microstructure, indicate significantly different DBTT's for the three heats. Laser welds or bead-on-plate microstructures obtained with the laser beam provide a unique method for investigating the effects of microsturctural and trace element concentrations on the properties of these alloys. Chemical analyses for several trace elements have been performed on the three heats in an attempt to determine which elements affect the mechanical properties. Further research is in progress to investigate the sensitivity of the V-4Cr-4Ti alloy system to minor variations in trace element concentrations and microstructural variations produced by varying the heat treatment.

EXPERIMENTAL PROCEDURE

A specific objective of this activity is to evaluate the effects of alloy chemistry variations in the various heats on V-4Cr-4Ti alloys on the properties of laser weldments and of variations in the microstructure produced by the laser beam. The starting material for this series of tests was obtained from the 500 kg heat #832665 of V-4Cr-4Ti alloy produced in the US by TWC for ANL, the 1200 kg heat #832864 produced by TWC for GA, and a 30 kg heat of V-4Cr-4Ti alloy produced in Japan for NIFS. Material used for this series of tests was in the form of ~4-mm thick plate annealed at 1000 or 1050^{o}C for 1-2 hr. Chemical analyses were performed on the 4-mm plate and compared with analyses supplied by the vendor. All samples were chemically pickled to remove any surface contamination before sending for analysis. Laser welding was performed on a Nd:YAG laser welding facility [1]. The laser weldment was produced by butt-welding of two annealed plates of ~4-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. 1.

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. The base metal specimens were machined from an annealed plate. 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.

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 [2].

RESULTS

Chemical Analysis

Chemical analysis for selected elements have been performed for the ~4-mm plate used for the welding and the Charpy impact testing. The results of these analyses are presented in Table 1 along with analyses of the ingot materials for each heat. In general, the analyses for the plate material are in good agreement with results from the ingot analyses. The oxygen analyses indicate that contamination of the alloys during the many rolling and annealing steps to the 4-mm plate was negligible. The most notable differences in the impurity concentrations measured are the higher Si content of 832665, the lower Al and Fe contents in NIFS-1, the high Mo content of 832665, and the low Nb content of NIFS-1. The oxygen concentrations in the ~4-mm plate are highest for the 832864 and lowest for NIFS-1; however, these are not large differences.

Table 1. Chemical Analysis of V-4Cr-4Ti Heats

Element	Heat #832665		Heat #832864		Heat NIFS-1		
	Nominal Ingot (wppm)	Base Weld Plate (wppm)	Nominal Ingot (wppm)	Base Weld Plate (wppm)	Ingot 31kg Japan (wppm)	Nominal 6.6mm Plate Japan (wppm)	Base 4.0mm Plate ANL (wppm)
O	310	324*	397	385	181	181	210**
N	85		130	65	103	88	
C	80		37		56	67	
Si	780	570	273	<100	200	200	<100
Al	160	250	193	208	100	100	81
Fe	220	190	227	125	200	200	37
Mo	320	300	<50	30	<100	<100	16
Nb	<60	80	106	114	<100	<100	0.6
Cu		7		6			6
Ni		9		7			<5

*Avg. 4 analyses **Avg. 5 analyses

Oxygen analyses were also performed on selected laser weldments to determine the extent of any oxygen contamination during the laser welding. Results of the oxygen analyses for the weld material are compared with the values for the annealed plate materials in Table 2. In all three materials the oxygen pick-up in the weld region was quite small demonstrating that the inert gas purge system used on the laser welder provided adequate environmental control. This type of environmental control provides high flexibility for laser welding of large components and for field welding.

Table 2. Oxygen Analysis of Laser Weld Joints of V-4Cr-4Ti Alloys

Specimen Number	Oxygen, wppm	
	Weld	Base Metal
832665/ID303/300A	236	324
832665/ID#052500A	313	324
Nifs-1/ID#J031300/JP-B-1	286	210
832864/ID#1019001	469	385

Impact Properties of V-alloy Weldments

The Charpy impact properties of the laser weldments provide a sensitive indication of the effects of chemistry and microstructure on the properties of the vanadium alloys. The Charpy impact properties for the three heats of V-4Cr-4Ti alloys have been measured. The impact properties for the 832665 and NIFS-1 heat are presented in Fig. 1. The Charpy impact properties for 832864, which are presented in a related paper for this Semiannual report period [1], are similar to those for the 832665 heat. The DBTT of the weldments based on the one-third size Charpy specimens are slightly below room temperature, approximately 0^{o}C for both US heats (832665 and 832864). The DBTT of the NIFS-1 heat is below -175^{o}C, which is nearly the same as that of the base material for all three heats.

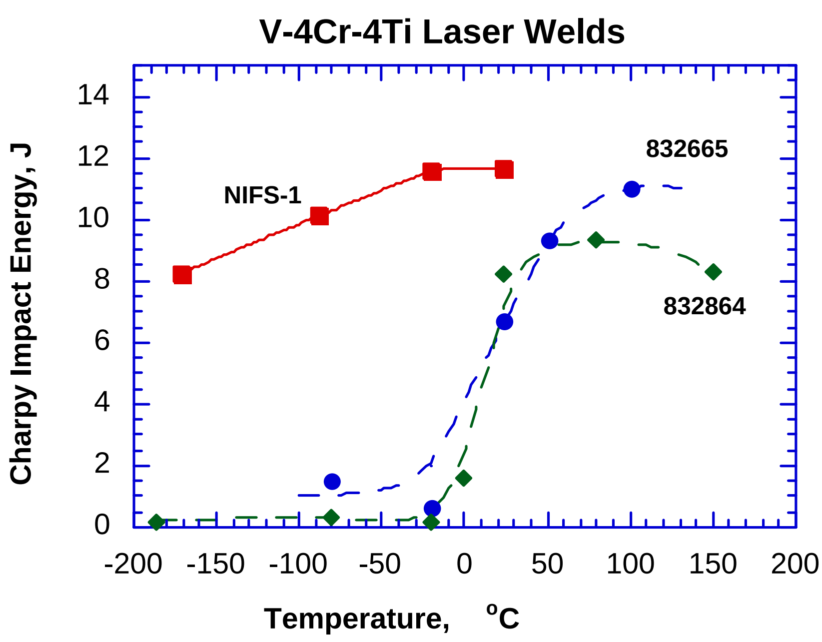

Fig. 1. Charpy Impact properties of Laser weldments of V-4Cr-4Ti alloys

An objective of this task is to determine the basis for the significant difference between the DBTT for the 832665 and 832864 heats compared to that for the NIFS-1 heat. The oxygen content of the NIFS heat is lower than that of the other heats; however, the oxygen content of the 832864 heat differs from that of the 832665 heat by about the same amount as the difference between the NIFS-1 heat and the 832665 heat. As indicated above, the Al, Fe and Nb are all significantly lower in the NIFS-1 heat and; therefore, could contribute to the difference in the impact properties. The Si and Mo contents are significantly higher in the 832665, but the DBTT is similar to that of the 832864 heat, which would indicate that these elements are not the primary contributor to the difference in impact properties. These data would suggest that either the Al, Fe or Nb may be the major contributor to the differences in the impact properties unless some other trace element not included in these analyses is responsible.

Clearly, evaluation of the laser weldments appears to provide a sensitive technique for evaluation of the effects of trace element and/or microstructure on the properties of candidate vanadium alloys. A similar approach using the laser beam as a means of producing various thermo-mechanical treatments of the microstructure provides a unique method for investigating the effects of composition and microstructure on the properties of vanadium alloys. Further investigations using these approaches will be conducted.

References

[1] Y. Yan, et al., Impact Properties of V-4Cr-4Ti Laser Weldments from the GA (832864) Heat (this progress report)