RESISTANCE WELDING OF V-4Cr-4Ti ALLOY*

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OBJECTIVE

The goal of this task is to further investigate the potential of resistance welding for joining of vanadium-base alloys and to develop a better understanding of the effects of the machine parameters on the weld characteristics.

SUMMARY

More resistance weld samples were prepared on 3.8-mm thick V-4Cr-4Ti alloy plate on a 50 KVA welder with more optimal process parameters. The microstructure of the weld regions were characterized and correlated with the weld parameters. Simplified torque tests were conducted on the test samples to provide a preliminary assessment of the shear strength and ductility of the test welds. Fractography results for the torque samples indicated that the fracture surfaces of resistance welds exhibit ductile characteristics.

BACKGROUD

Continuous resistance welding potentially offers several advantages for fabrication of vanadium alloy for first wall/blanket systems. Current blanket designs for vanadium/lithium systems provide for joining of ~4 mm thick sheet with long weld joints. Previous investigations on resistance welding of vanadium-based alloy [1] indicated that sound welds with minimal restructuring and limited extent of heat-affected zone could be achieved for a range of process parameters. This approach may also reduce the stringent environmental control required to avoid excessive oxygen contamination effects frequently observed in more conventional weld processes.

EXPERIMENTAL PROGRAM

Weld specimens were prepared from 3.8-mm thick V-4Cr-4Ti alloy (heat #832665) in the annealed condition. Specimens were surface polished with a Scotch Brite pad and cleaned with acetone before joining. Lap-type resistance welds on these sheet specimens were produced on a 50 KVA welder at ANL. The process parameters, such as transformer tap settings, preweld squeeze time, weld time, power setting, and post-weld hold time were chosen based on previous experience [1]. All the specimens were made with a pair of weld tips of 5/8" in diameter.

Resistance weld specimens were metallurgically prepared and etched to reveal the microstructural features of the welds. The fractography of torque-broken specimens were obtained. A Nikon MSZ-B stereomicroscope, a Nikon optical microscope and a COHU high performance CCD camera were used for the microstructural evaluation.

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A simplified torque test was used to provide a preliminary evaluation of the weld strength and ductility characteristics. A deflecting beam torque wrench (0 – 150 ft-lbs. torque range) was used to shear the weld joints. The maximum torque as a function of twist angle to fracture was recorded and an estimation of the shear strength was calculated based on the fracture surface area.

RESULTS AND DISCUSSION

The process parameters used to prepare the resistance weld specimens for the microstructural evaluation and torque test are presented in Table 1. Compared to the previous investigations [1], the transformer tap fine setting of the welder was decreased from 7 to 5, which decreased the output power level of the machine. The cross-sectional microstructure of the welds are shown in Figure 1, 2, and 3 for test no. 991203-3, -6, and –7, respectively. The weld zone and heat-affected zone varies considerably for the range of weld parameters shown in Fig. 1 – 3. The maximum torque and twist angles from the torque test for specimens 991203-6 and –9 are listed in Table 2. The large amount of distortion before fracture indicated substantial ductility weld joints. Photographs of the corresponding shear fracture surfaces are shown in Fig. 4 and 5. The fractography results for test no. 991203-6 and –7 show a ductile fracture feature, which is further verified by the large recorded twist angle. A weld specimen with test no. 991203-3 was separated using a wedge. The fractured surface of this weld (Figure 6) indicated some ductile fracture character. An attempt to estimate the shear stress in the welds based on the weld area and the torque values indicated considerably higher than expected values. Calculated results for similar test welds on steel gave reasonable values, although slightly higher than reported shear strength for the base metal. The higher than expected shear strength for the vanadium welds are attributed to some random bonding effects observed outside the primary weld region. Surface roughness created by these effects contribute to the higher torque; however, they should not affect the deformation character of the joint. Additional resistance welds will be prepared with attempts to avoid the observed random bonding effects noted above. Based on results from these types of tests, weld parameters that produce the best weld performance will be used to prepare additional weld specimens for more conventional mechanical tests including Charpy impact tests. Chemical analyses are also being performed on the weld material to determine the extent of any contamination. Those results will be presented in the next report.

Table 1. Resistance welding parameters of V-4Cr-4Ti alloy

Test No.	Transformer tap fine setting	Squeeze (Cycles)	Weld time (Cycles)	Heat (%)	Hold time (cycles)
991203-3	5	30	50	80	30
991203-6	5	30	70	80	30
991203-7	5	30	50	90	30

Table 2. Maximum torque and twist angle to fracture of welds

Test No.	Max. Torque, N-m, (ft-lbs)	Twist angle (degree)	Diameter of fractured and bonded area (mm)
991203-6	67.8, (50)	175	6.5
991203-7	80, (59)	95	6.17
991203-3	Weld join separated by a wedge		

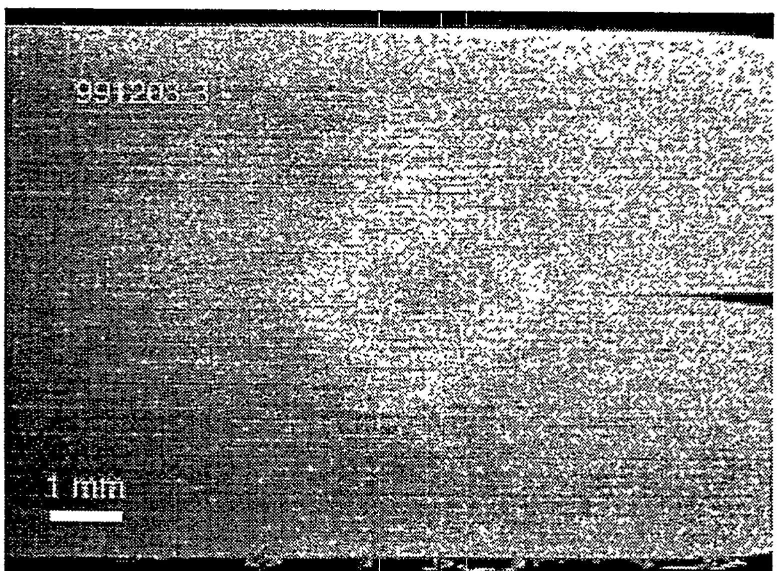

Figure 1 Cross sectional view of resistance weld of V-4Cr-4Ti alloy (Test No. 991203-3 in Table 1) showing minimal structure change of the bond

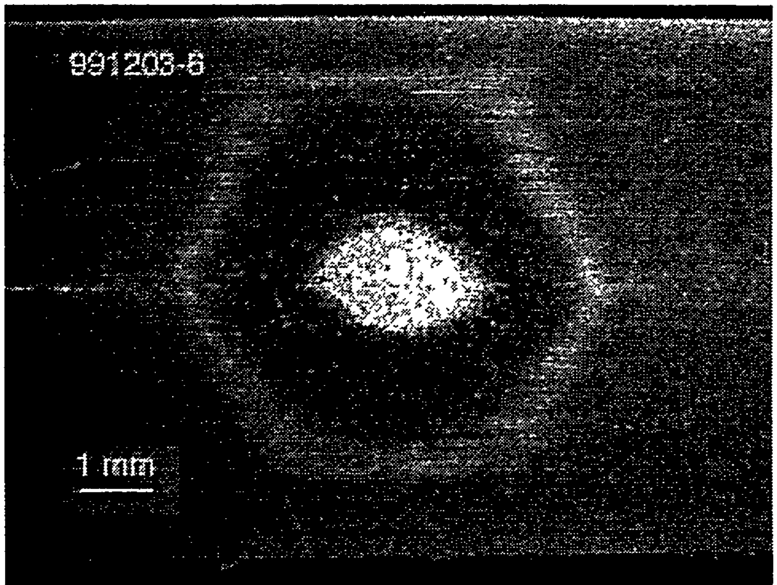

Figure 2. Cross sectional view of resistance weld of V-4Cr-4Ti alloy (Test No. 6 in Table 1) indicating small restructuring zone (white area)

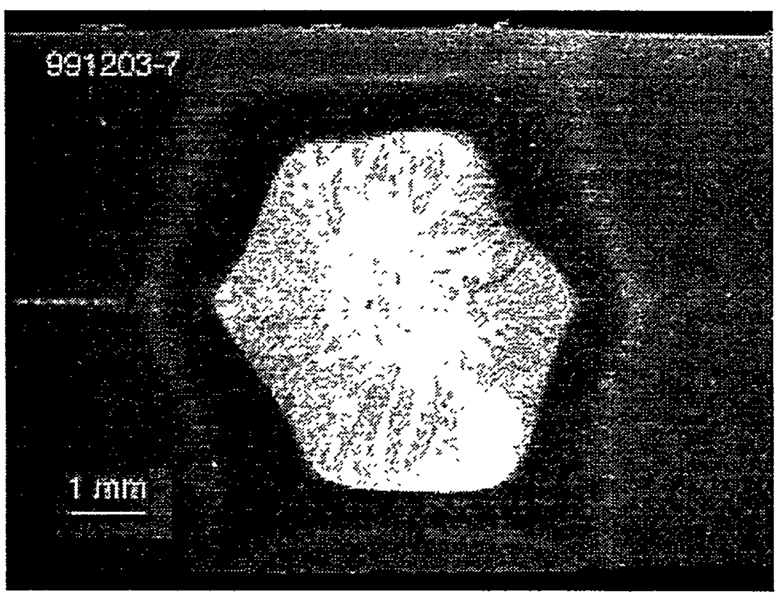

Figure 3. Cross section view of resistance weld of V-4Cr-4Ti alloy (Test No. 991203-7 in Table 1) showing extensive restructuring zone (white area)

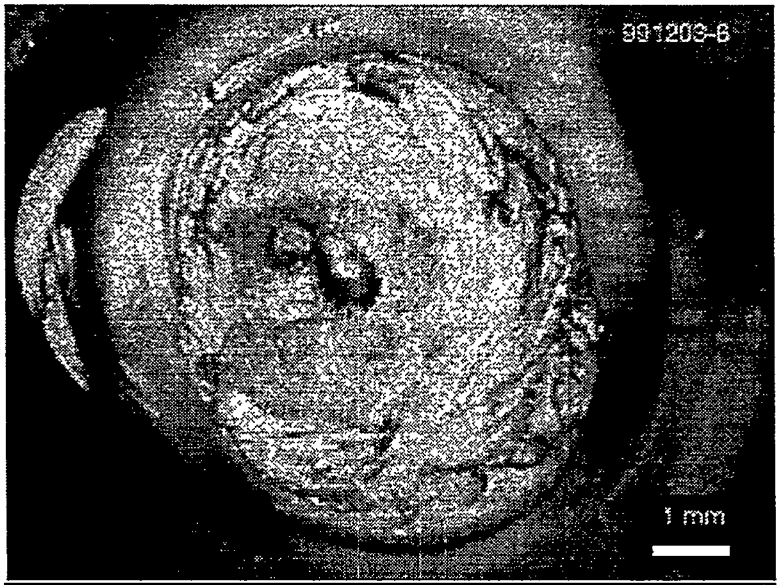

Figure 4. Fractography of torque tested weld (test No. 991203-6) revealing a ductile fracture surface and total bonded area.

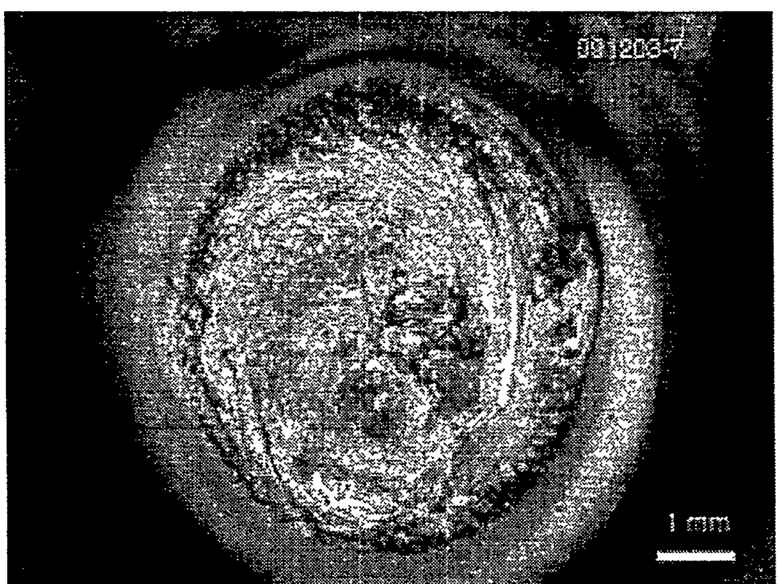

Figure 5. Fractography of torque tested weld (Test No. 991203-7)

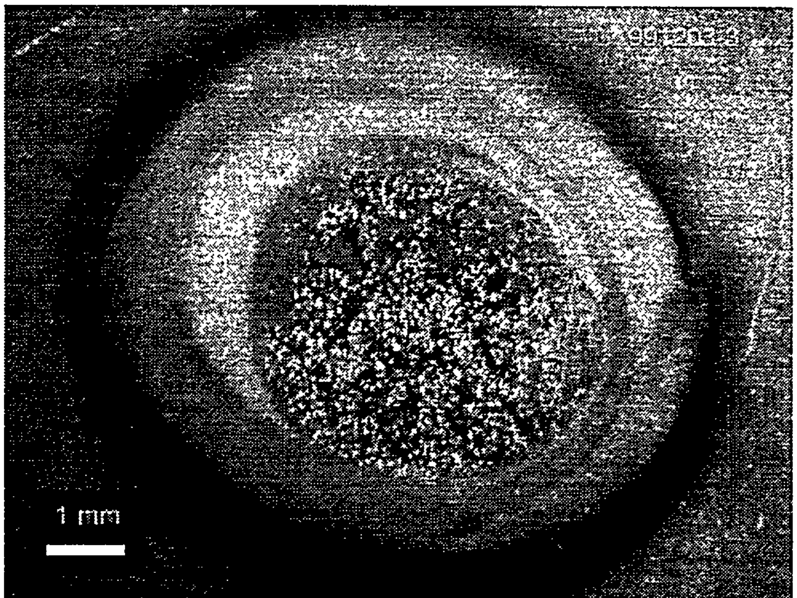

Figure 6. Fractography of the weld (Test No. 991203-3), separated by using a wedge.

REFERENCE

1. Z. Xu, D. L. Smith, and C. B. Reed, "Diffusion Bonding of Vanadium Alloys", Fusion Reactor Materials Progress Report for the Period Ending June 30, 1999, DOE/ER-0313/24.