WELDING DEVELOPMENT FOR V-Cr-Ti ALLOYS - J. F. King, G. M. Goodwin and D. J. Alexander (Oak Ridge National Laboratory)

OBJECTIVE

A vanadium structure, cooled with helium, is a favored concept for an advanced breeding blanket for fusion systems. The objective of this task is to develop the metallurgical and technological base for the welding of thick sections of V-Cr-Ti.

SUMMARY

The subsize Charpy test results for electron beam weld metal from the V-5Cr-5Ti alloy has shown significant improvement in Charpy fracture energy compared to both gas tungsten arc (GTA) weld metal and the base metal itself. These results are preliminary, however, and additional confirmation testing and analysis will be required to explain this improvement in properties.

PROGRESS AND STATUS

Introduction

The weldability and weldment properties of V-Cr-Ti alloys are being characterized. The reactive nature of vanadium alloys causes concerns with welding the potentially large components of the ITER system, and the selection of weld processes and procedures will have strong economic impact on component fabrication. Several welding processes are being evaluated, with the primary consideration being the effect of interstitial pickup on mechanical properties.

Experimental

A previous report[1] described the conditions for producing GTA welds in ~7 mm thick plate of the V-5Cr-5Ti alloy heat no. 832394. Identical welding conditions were used to produce two weldments (GTA 1 and GTA 2) in a glove box atmosphere containing less than 10 appm oxygen. An electron beam (EB) weld was made in the same plate material. Welding parameters were selected to produce a full penetration weld deposit in the vanadium plate. These were 150 kV accelerating voltage and 20.6 mA beam current at a welding speed of 12.7 mm/s.

One third size Charpy V-notch specimens were machined from the two GTA weldments and the EB weldment. Specimens were notched so that the crack propogated in the fusion zone along the welding direction.

Results

The Charpy properties of the GTA welds were significantly worse than those of the base metal annealed at 1125°C, Fig. 1. Although the number of specimens used was insufficient to define a complete impact energy-temperature curve, the CVN transition temperature of the weldments is clearly 100-150°C higher than that of the base metal. A set of specimens from GTA II was vacuum annealed at 400°C to remove any hydrogen that may have been picked up during welding or subsequent handling. As shown in Fig. 1, the 400°C anneal did not significantly affect CVN properties and it is concluded that hydrogen is not responsible for the poor fracture resistance of the GTA weld. On the other hand, annealing in vacuum at 950°C for 1 hour produced a dramatic improvement in impact properties (Fig. 1). Following the 950°C anneal, the impact properties were similar to those of the base metal.

A section of the completed EB weld was removed for metallographic examination. Examination of the weld cross section (Fig. 2) revealed no indication of weld discontinuities and little evidence of grain coarsening (Fig. 3) in the heat affected zone (HAZ). Hardness measurements were made across the weldment at approximately the middle of the plate thickness. The base metal had an average hardness of 177 DPH. The HAZ exhibited a higher average hardness of 198 DPH with measurements ranging from 180 to 229 DPH. The weld metal was very uniform with an average of 194 DPH. The variation in hardness values is relatively small across the weldment.

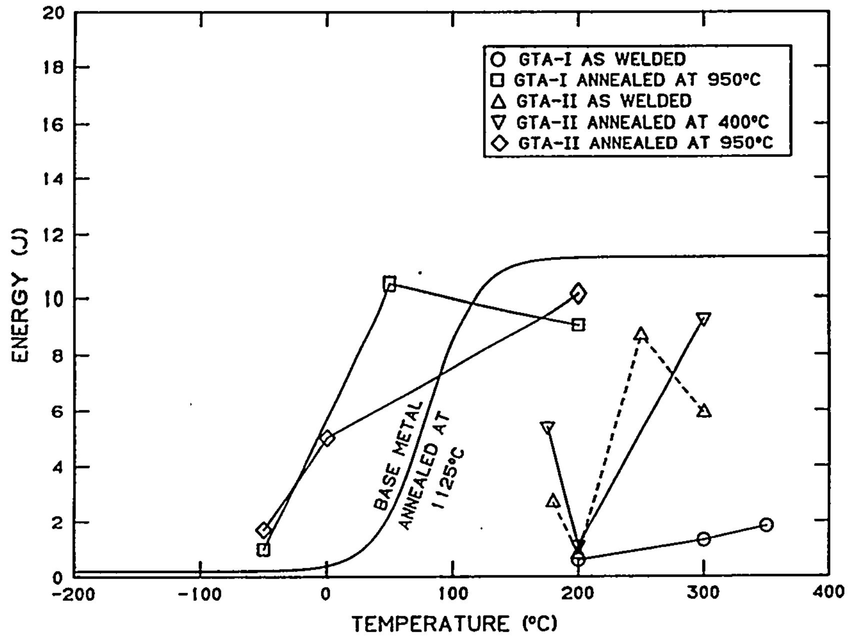

Fig. 1. Subsize Charpy V-notch test result from gas tungsten arc weldments in V-5Cr-5Ti alloy from heat 832394.

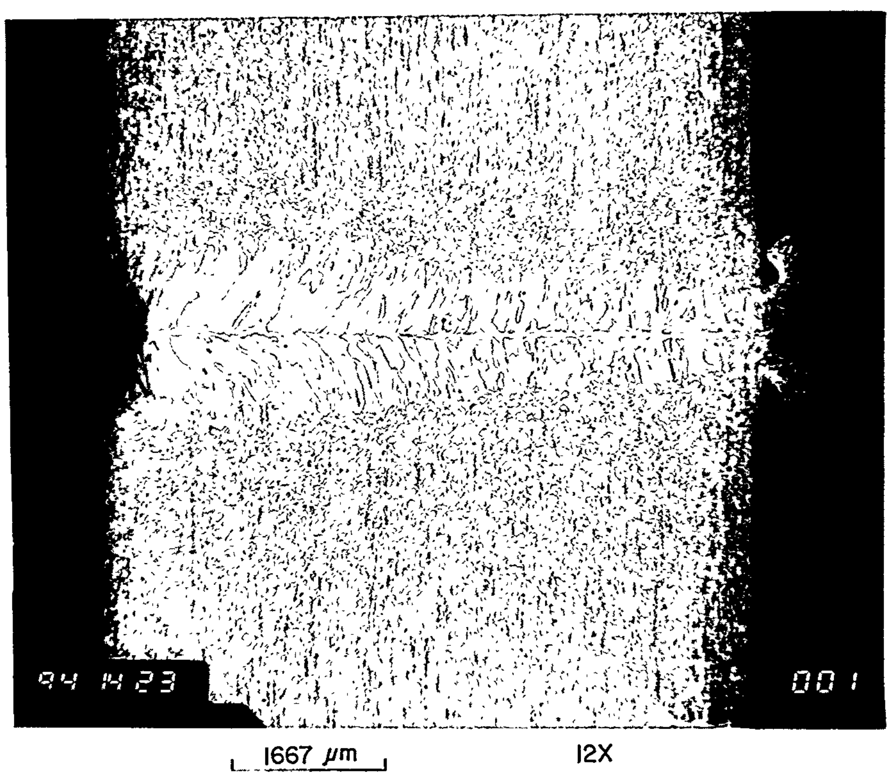

Fig. 2. Transverse cross-section of full penetration electron beam weld in 7 mm thick V-5Cr-5Ti alloy.

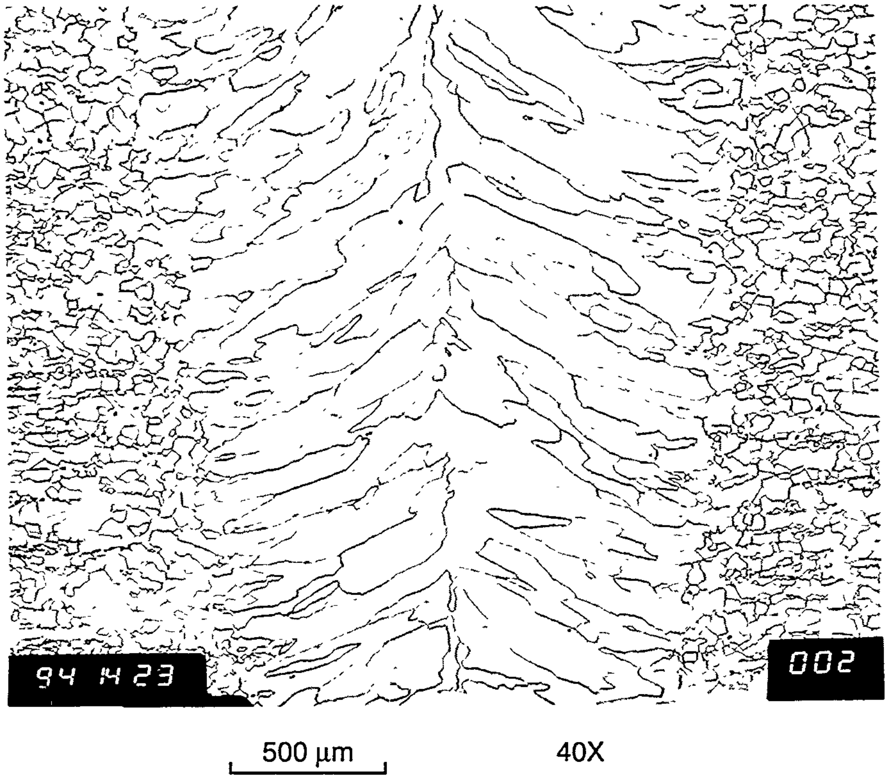

Fig. 3. Transverse cross-section of the HAZ of the electron beam weld in the V-5Cr-5Ti alloy shows little evidence of grain coarsening.

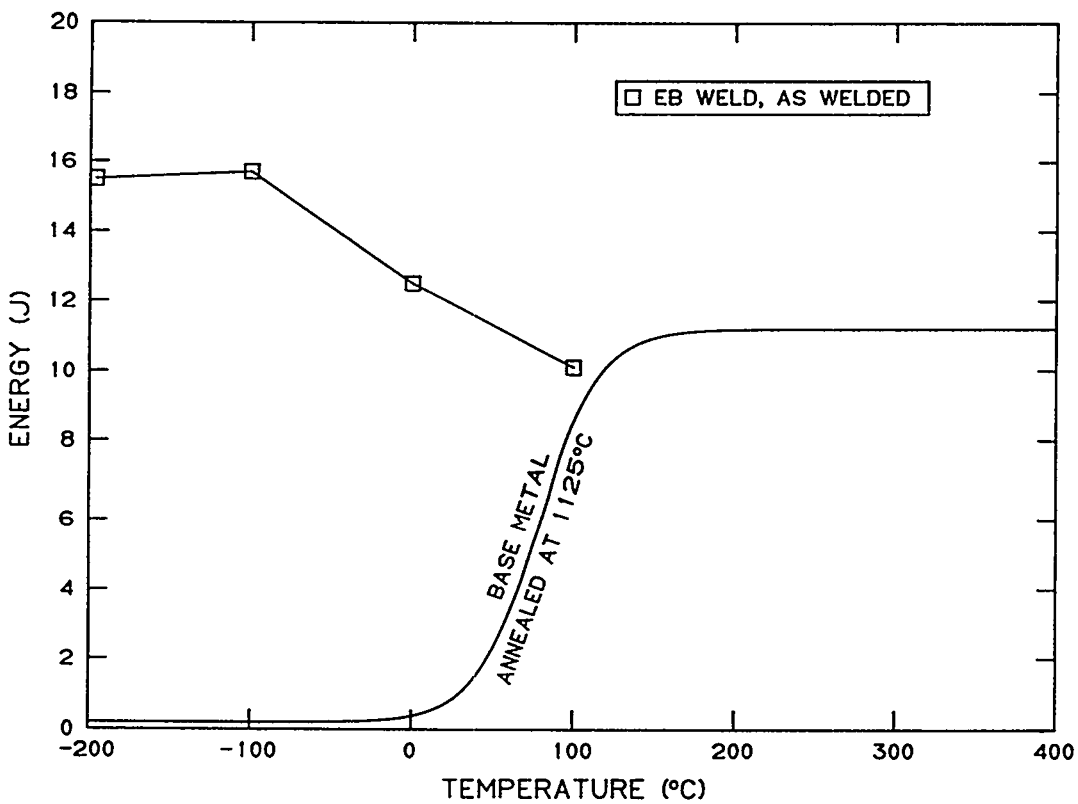

Fig. 4. Subsize Charpy V-notch tests results from earlier electron beam weld (EB-I) and present electron beam (EB-II) in V-5Cr-5Ti alloy from Heat 832394.

Subsize Charpy V-notch specimens were machined from the weldment and notched in the center of the weld fusion zone such that the fracture occurs in the direction of welding. Four of these specimens were tested in the as-welded condition at temperatures ranging from ~100°C down to ~-200°C. At each temperature, specimens failed in a predominantly ductile mode with high values of absorbed energy (Fig. 4). This is a rather surprising result in view of the coarse-grained (~500 µm) microstructure of the fusion zone; and implies that a post weld heat treatment may not be required

FUTURE WORK

SEM, TEM, and Auger measurements are in progress (a) to understand the mechanisms involved in the beneficial effects of the 950°C post-weld heat treatment on the properties of the GTA welds, and (b) to understand the superior properties of the EB weld. Further weld development will focus on the new large heat of V-4Cr-4Ti.

REFERENCES

1. G. M. Goodwin and J. F. King, "Welding Development for V-Cr-Ti Alloys," Fusion Materials Semiannual Progress Report (DOE/ER-0313/16), p. 235.