EFFECT OF THICKNESS AND LOADING MODE ON THE FRACTURE PROPERTIES OF V-4CR-4TI AT ROOM TEMPERATURE - H. Li, R. J. Kurtz and R. H. Jones (Pacific Northwest National Laboratory)*

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EXTENDED ABSTRACT

The effect of thickness on the room temperature (RT) mode I fracture behavior of V-4Cr-4Ti has been investigated. Mode I fracture properties were measured from J-integral tests of compact tension (CT) specimens ranging in thickness from 6.4 mm to 25.4 mm. All specimens were machined in the T-L orientation and vacuum annealed following final machining. Two heats of V-4Cr-4Ti were tested. Specimens 6.4 mm and 12.7 mm thick were taken from ANL Heat No. 832665. The 25.4 mm thick specimens were obtained from GA Heat No. 832864. J-R curves were generated by the single specimen unload-compliance test technique in accordance with ASTM E813. All tests were performed in laboratory air at 25°C.

The RT mode I fracture toughness of V-4Cr-4Ti is very high. ASTM validity criteria for J-R curve determination were not satisfied for any of the specimens tested. Ductile crack growth was observed for 6.4 mm thick specimens, but not for 12.7 mm or 25.4 mm thick specimens. It was found that V-4Cr-4Ti was prone to delaminate in planes normal to the thickness direction. More significantly, the fracture surfaces inside the delaminations indicated the fracture mode was predominantly cleavage. The severity of the delaminations increased as specimen thickness increased. The delaminations were caused, in part, by development of tensile stresses in the thickness direction due to the constraining effect of the material surrounding the crack tip plastic zone, which limits through thickness deformation. The cause of the delaminations is not known yet.

The effect of loading mode on fracture of V-4Cr-4Ti at RT was also studied. Mode I fracture behavior was compared to mixed-mode fracture properties obtained from modified CT specimens. The essential modification of the standard CT specimen is the slanted crack plane. This geometry produces a combination opening (mode I) and out-of-plane shear (mode III). Varying the crack angle varies the ratio of mode I to mode III loading. Crack angles of 0° and 25° were used.

The mixed-mode specimen behaved differently compared to the mode I specimen. During fatigue precracking the crack plane angle rotated from 25° to about 23°. However, during J-testing, the crack plane angle increased from 23° to about 30° when the crack started to grow. After crack initiation, the crack plane angle remained at about 30° until the end of the test. The mixed-mode specimen also exhibited extensive plastic deformation similar to the mode I specimen. The high J-values reached indicated that crack initiation was difficult. The reasons for this behavior are not fully understood. Crack plane rotation prior to crack initiation was one of the factors which contributed to the high J-value for initiation. While the mixed-mode crack was difficult to initiate, it propagated easily. The slope of the mixed-mode I/III J-R

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curve beyond the exclusion line was only 140 kJ/m^2/mm, or about one-third of that for the mode I specimen.

Fracture of V-4Cr-4Ti under mixed-mode loading conditions showed the same trend observed previously for V-5Cr-5Ti and for other tough materials [1]. For materials which fail by microvoid coalescence, the addition of an out-of-plane shear loading component introduces incompatibility stresses at particle interfaces in the trajectory of the crack. These incompatibility stresses cause particle/matrix decohesion or particle fracture which leads to void formation that limits the mode I plastic flow field. The present results demonstrate that fracture of V-4Cr-4Ti is sensitive to the addition of shear loading components and that mode I fracture toughness tests may not give the most conservative measure of resistance to ductile fracture.

REFERENCES

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