EFFECT OF ORIENTATION ON EFFECTIVE TOUGHNESS-TEMPERATURE CURVES IN V-4Cr-4Ti

— E. Donahue, G.R. Odette, and G. E. Lucas (University California, Santa Barbara)

OBJECTIVE

The results reported here are part of a larger effort to characterize effective fracture toughness - temperature $K_e(T)$ curves of the program heat of V-4Cr-4Ti alloy as a function of specimen size, geometry and orientation as well as for plates with somewhat different processing histories. The current report focuses on tests of specimens larger than previously studied and in two different orientations with respect to rolling direction.

SUMMARY

Fracture tests were performed on fatigue precracked, 20% sidegrooved 0.26T compact tension specimens in LT and TL orientations under static loading conditions over temperatures ranging from -196°C to -110°C. The effective toughness-temperature $K_e(T)$ curves were similar for both LT and TL orientations. The corresponding 100 MPa√m transition temperature was estimated to be about -155°C. Additional tests to evaluate effects of specimen size, orientation and material fabrication history on the K-T curves are underway.

MATERIALS AND PROCEDURES

Specimens were fabricated from a cold-rolled 6.6 mm thick plate fabricated from the large program heat of V-4Cr-4Ti (#832665) produced by Teledyne Wah Chang [1]. Compact tension specimens (0.26T) were machined in LT and TL orientations, annealed at 1000°C for 2 hours under vacuum, precracked to crack length (a) to specimen width (W) ratio a/W~0.5, and side-grooved to depths of about 10% on each side. These specimens were tested over the temperature range from -196°C to -110°C under static loading conditions. Effective toughness values were calculated from load-displacement traces.

RESULTS

Figure 1 shows the toughness-temperature data for LT and TL orientations. The 100 MPa√m transition temperatures of about -155°C are similar for both orientations as are the lower knee toughness values at around 60 MPa√m. Notably, the $K_e(T)$ curves for these larger CT specimens were shifted up in temperature by about 20-30°C relative to that measured using smaller 3.3 x 3.3 x 25.4 mm precracked three point bend bar specimens [2]. Specimens tested at low temperatures exhibited classical cleavage fracture surfaces, while specimens tested at higher temperatures also exhibited large, transverse fissures.

Fracture Reconstruction (FR) methods have also been used on selected specimens to characterize the sequence of events which lead to fracture. Figure 2 shows the fracture area maps from the FR for a specimen in LT orientation tested at -140°C. It shows limited damage up to a crack tip opening displacement of about $\delta = 100$ µm and then a large pop-in at about $\delta = 130$ µm. This corresponds to a $K_\delta = 137$ MPa√m as calculated from $K_\delta = \sqrt{2E' \sigma_y \delta^*}$ [3,4]. This value is in excellent agreement with the standard $K_e = 130$ MPa√m measured from the load-

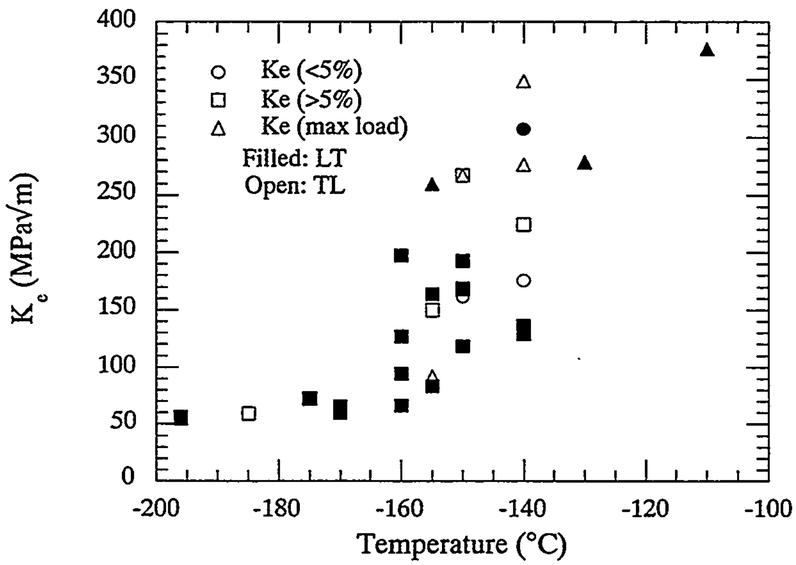

Figure 1. Toughness - temperature data for 0.26T CTs in LT and TL orientations. Toughness was evaluated at the first sign of crack advance if lower than 5% load shed, pop-ins of >5% load shed, and maximum loads in the load-displacement traces. Data shows no effect of specimen orientation on K-T curves.

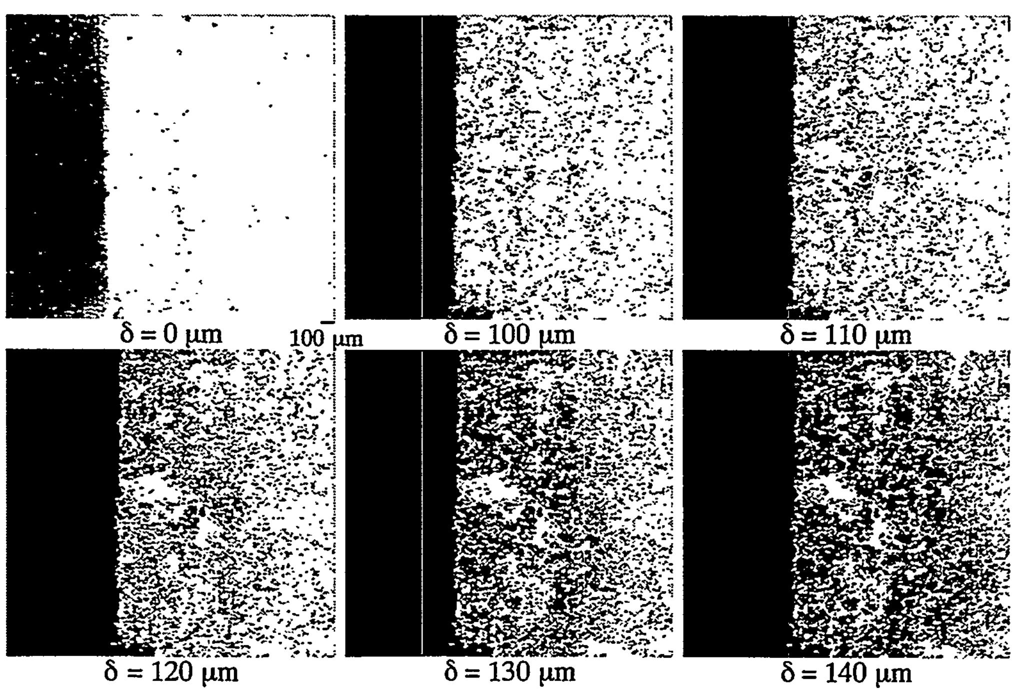

Figure 2. The Fracture Reconstruction for a specimen tested in LT orientation at -140°C. The critical crack opening is about δ = 130μm.

displacement record. The FR shows that damage in the form of isolated cleavage facets was widely distributed prior to reaching the critical displacement for macroscopic fracture.

FUTURE WORK

Future work will involve additional tests of specimens with different orientations, sizes and material fabrication histories. The overall data base, coupled with extensive fractographic and FR studies as well as constitutive models, will be used to develop self-consistent predictive models of cleavage initiation and ductile tearing toughness including the effects of irradiation, loading rate and specimen/flawed component geometry.

REFERENCES

1. Chung, H.M., Tsai, H.-C., Smith, D.L. Peterson, R., Curtis, C., Wojcik, R., Kinney, C., DOE/ ER-0313/17, March 1994
2. Odette, G.R., Donahue, E., Lucas, G.E., Sheckherd, J.W., DOE/ER-0313/20, 1996.
3. K. Edsinger, Ph.D. Thesis, Department of Chemical Engineering, UCSB, 1996.
4. K. Edsinger, G.R. Odette, G.E. Lucas, Proceedings of Miniature Specimen Symposium, KFA Julich, 1995, p 150.