SOME PRELIMINARY OBSERVATIONS ON THE EXTENSION OF CRACKS UNDER STATIC LOADINGS AT ELEVATED TEMPERATURES

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The use of linear elastic fracture mechanics to characterize the propagation of fatigue cracks at elevated temperatures has been described in several recent articles [1-5]. Many structures, however, are subjected to static, rather than cyclic, loadings at high temperatures for long periods of time, and a rational method of characterizing the extension of cracks or flaws under such conditions would be very useful. The use of fracture mechanics parameters to characterize crack extension under static loadings in corrosive media has already been demonstrated [6], and a small amount of work has been reported on applying these techniques to high temperature static loadings [1,7]. Popp and Coles [1] studied Inconel 718 at 1000°F (538°C), and Harrison and Sander [7] studied CrMoV steel at 1000°F.

Two specimen designs were utilized in the present study: the ASTM compact tension specimen (CT), and a center notched specimen (CN), and the specimens were fabricated from 20% cold worked AISI type 316 stainless steel (see Figure 1). The specimens were precracked prior to static testing using fatigue loadings lower than those to be applied statically. The specimens were tested at 1000°F in an air-circulating furnace, and the static loadings were applied using a conventional creep machine. Crack lengths were read periodically using a travelling microscope. Crack growth rates were based on the incremental crack extension Δa divided by the corresponding increment of time Δt, and stress intensity factors were based on the average crack length over each growth increment using the conventional formulas.

The results obtained for 20% cold worked AISI Type 316 stainless steel are shown in Figure 2. Also shown are the results of fatigue tests conducted on the same material at 1000°F. The fatigue results are from [5]. The fatigue-crack growth rate da/dN was converted to a time-base using

$$da/dt = (da/dN)(\text{frequency})$$

and the stress intensity factor range ΔK was converted to K_{max} using

$$K_{max} = \Delta K/(1-R)$$

where $R = K_{min}/K_{max}$.

The results of Figure 2 show that, as suggested in [1], the crack extension rate under static loading may be characterized using the stress intensity factor. Two different specimen designs (CT and CN specimens) were utilized in the present study to insure that the stress intensity factor was indeed the rate-controlling parameter, and that we were not merely modelling specimen-geometry behavior.

In addition, the CT specimens were tested at different load levels. Although Harrison and Sandor [7] obtained an excellent correlation between da/dt and K, they preferred to base their correlation upon the net stress in the remaining ligament. The present results tend to suggest that K, rather than net stress, is the rate-controlling parameter.

The fatigue results of [5] appear to correlate well with the static test results. The static results seem to form a lower bound, and one might speculate that fatigue results at frequencies lower than 0.333 cpm would fall between the curve for 0.333 cpm and the static test curve. Testing under this study is continuing in the hope that a superposition model, similar to that of Wei and Landes [8], may be developed to predict crack extension behavior under very general conditions at elevated temperatures.

Acknowledgement: This Report is based on work performed under United States Atomic Energy Commission Contract AT(45-1)-2170 with the Westinghouse Hanford Company, a subsidiary of Westinghouse Electric Corporation.

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22 May 1972

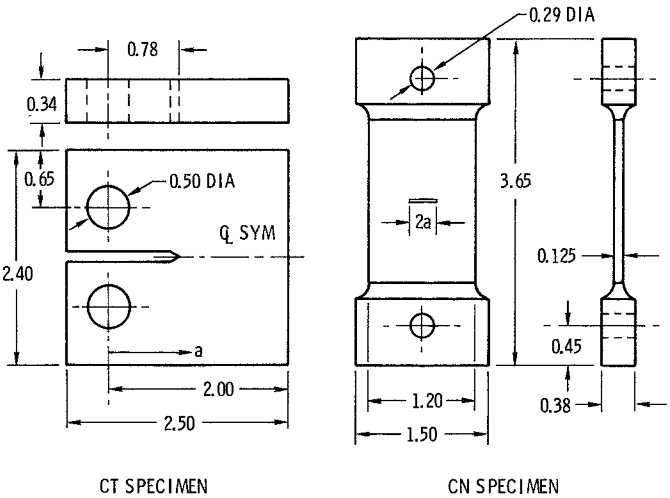

Figure 1. Compact Tension Specimen (CT), and Center-Notched Specimen (CN) Designs. All Dimensions Are in Inches.

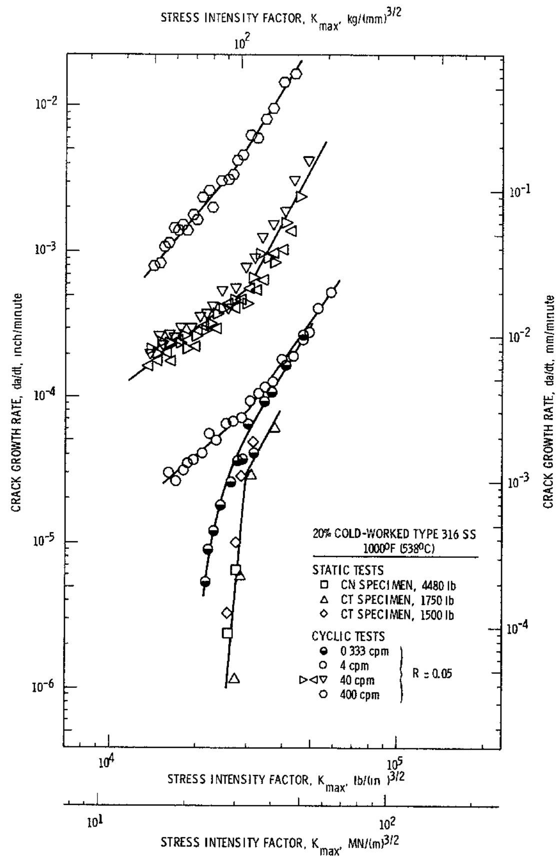

Figure 2. Crack Propagation Behavior of 20% Cold-Worked Type 316 Stainless Steel at 1000°F under Cyclic and Static Loadings.