Crack Branching in Homalite-100 Sheets

by
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INTRODUCTION

When a running crack in a brittle material reaches a terminal velocity, the crack normally branches, momentarily decelerates, and then accelerates and branches again. In highly loaded brittle materials this process is repeated many times thus resulting in fragmentation of the material. Branching cracks in glass have been studied by Schardin through the use of high-speed photography with a spark-gap camera (1)*. More recently Clark and Irwin (2) and Sih and Irwin (3) have discussed the dynamic unloading effects and the influence of crack speed on the crack opening displacements.

EXPERIMENTAL PROCEDURE AND RESULTS

The modified Cranz-Schardin 16 spark-gap camera and associated dynamic polariscope used in this investigation were described in a previous paper, (4). The test specimens consisted of 3/8-inch and 1/8-inch thick Homalite-100 plates with 10 x 10-inch test section loaded in fixed grip configuration. As shown in Figures 1 and 2, at fracture load, the crack propagated from a single, edge-notched starter crack and branched several times before propagating through the plate.

DYNAMIC STRESS INTENSITY FACTOR

For a simple branch crack, such as that shown in Figure 1, the dynamic stress intensity factors were determined from the dynamic

*Numbers in parenthesis refer to references at the end of this paper.

photoelasticity patterns using Bradley's approximate procedure (4) which is a variation of the original procedure suggested by Irwin. For a complex branch crack, such as that shown in Figure 2, the dynamic stress intensity factor was determined by fitting a near-field static isochromatics of closely-spaced, parallel cracks to that of the dynamic isochromatics near the crack tips of multiple branched long cracks. The former static isochromatics were obtained through a finite element analysis of an edge-cracked plate of unit width and with a unit edge displacement.

EVALUATION OF DATA

Figure 3 shows the dynamic stress intensity factors and crack velocities of the two main branch cracks shown in Figure 1. Also shown is the static stress intensity factor determined by finite element analysis for a symmetrically branched crack with identical edge displacements.

Figure 4 shows the dynamic stress intensity factors and crack velocities of the left and right major branch cracks for Test No. 5 shown in Figure 2. Static stress intensity factors, although not impossible to compute, were not determined.

DISCUSSION

The dynamic stress intensity factors determined above indicate a branching stress intensity which is approximately 1800 psi$\sqrt{in.}$ and 2200 psi$\sqrt{in.}$ for the 3/8-inch and 1/8-inch thick Homalite-100 plates, respectively. This branching stress intensity factor is approximately 3-4 times larger than the static fracture toughness of the material. Although not conclusive, the branching stress intensity factor is reached prior to major branching and hence prior to the corresponding

static branching stress intensity factor as shown in Figure 3.

As expected, the crack velocity drops to a minimum value at branching and then reaccelerates to high value for another branching. The fluctuating velocities and the minimum values for example, can be related to locations of crack branches.

The surface roughness can be correlated directly with the crack velocity of approximately 14,000 inch/sec in 3/8-inch thick plates. Little surface roughness is observed in the 1/8-inch plate although crack velocities in excess of 14,000 inch/sec were observed in all tests. Perhaps this difference could be attributed to differences in the states of stress due to change in thickness.

Finally as an interesting sideline, Frame No. 11 of Figure 2 shows an isochromatic pattern of Mode II crack deformation at the crack top of the extreme left branch. This Mode II stress intensity factors varied from 210 to 154 psi$\sqrt{in.}$ in Frames 11-12.

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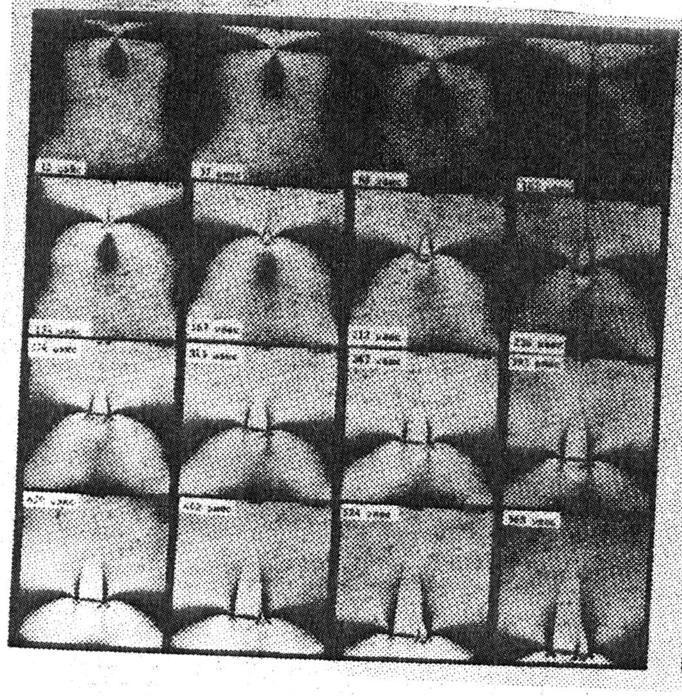

Figure 1. Isochromatic Patterns of Dynamic Crack Propagation for Test No. 1

Figure 2. Isochromatic Patterns of Dynamic Crack Propagation for Test No. 5.

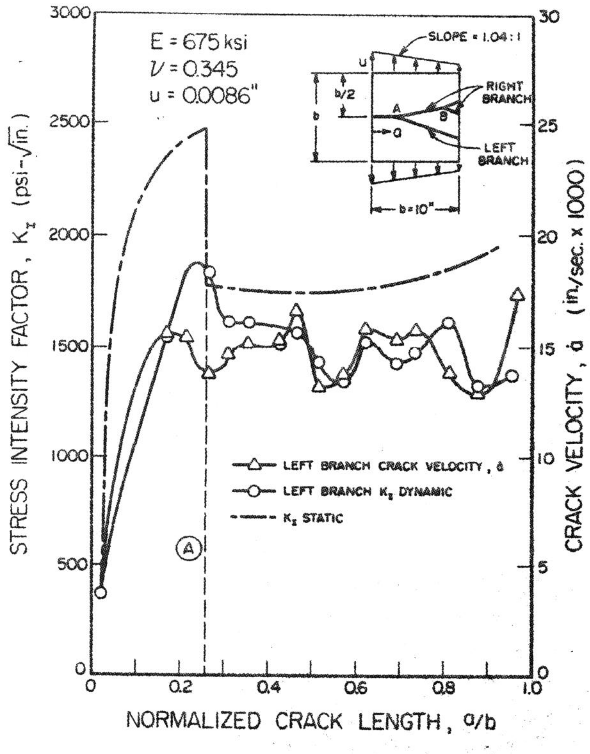

FIGURE 3. STRESS INTENSITY FACTORS & CRACK VELOCITIES IN A SINGLE EDGE NOTCHED PLATE SUBJECTED TO VARIABLE EDGE DISPLACEMENTS, TEST NO. 1 LEFT BRANCH

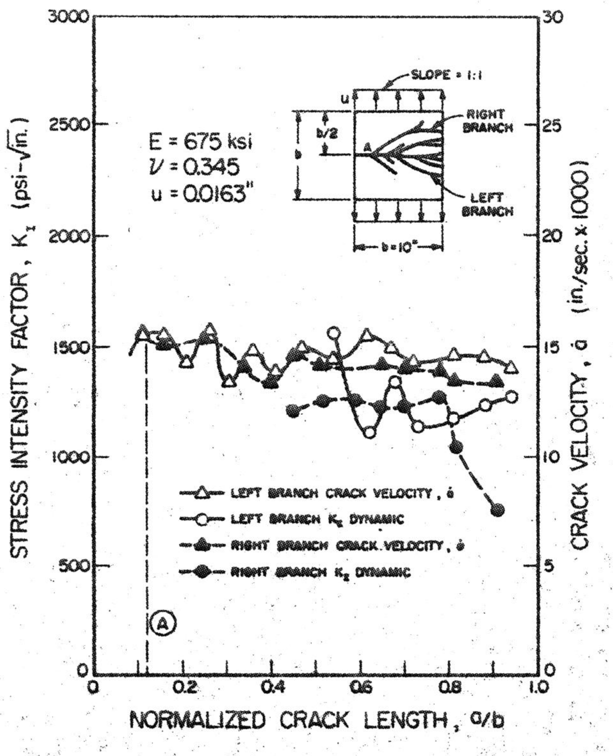

FIGURE 4. STRESS INTENSITY FACTORS & CRACK VELOCITIES IN A SINGLE EDGE NOTCHED PLATE SUBJECTED TO A UNIFORM EDGE DISPLACEMENT, TEST NO. 5