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Slow Crack Growth in Cellulose Film

N. C. HILYARD and J. L. CRUM, *Physics Department, The University of Akron, Akron, Ohio 44304*

Synopsis

A simple photographic method for measuring the slow crack growth in transparent polymer film is described. Framing speeds up to 100 per second have been achieved. Experimental data for a cellulose film with centrally located initial cuts indicate that for $0 < t < 0.8\, t_b$, the crack length c increases with time t according to

$$c = c_0 \exp (Kt/t_b)$$

where c_0 is the initial cut size, K a constant, and t_b the time to fracture.

INTRODUCTION

In many cases a fracture process can be divided into three parts: (a) crack initiation, in which some structural inhomogeneity grows under the action of the applied stress until a small crack is formed; (b) slow crack growth, in which the crack propagates slowly through the sample until a critical crack length is reached; and (c) brittle fracture, in which the crack propagates very rapidly until separation of the sample is achieved.[1–3] In some polymer films slow crack growth is accompanied by considerable plastic deformation.

The greater part of the time to fracture, t_b, is taken up in processes (a) and (b) so that the time dependence of crack initiation and slow crack growth is of considerable interest.

EXPERIMENTAL

A simple photographic method has been used to measure the speed of slow crack propagation in regenerated cellulose film. The samples, containing centrally located initial cuts, were set up in a photoelastic bench[4] and broken using dead weight loading. A General Electric stroboscope (Type 1531A) was used as the light source and photographs of the sample were taken using a 35mm reflex camera. For low framing speeds, up to 1 per 10 sec, the camera was operated in the usual way. For high framing speeds, the film cassette was loaded in the conventional take up position and rewound by hand onto a cassette fitted into the conventional delivery position. The shutter was held open during this procedure. The exposure time and framing speed were controlled by the pulse duration and pulse repetition rate of the stroboscope. The frame size was limited by a rectangular aperture placed in front of the camera. Framing speeds up to 100 per sec have been achieved.

RESULTS

Crack growth in a du Pont K cellulose film, nominal thickness 3.6×10^{-3} cm, is shown in Figures 1 and 2. Figure 1 shows the crack growth over a long period of time and Figure 2 shows the crack growth just prior to the onset of fast fracture. Figure 3 shows the crack length c as a function of the ratio t/t_b, where t_b is the time to failure. The bar on the ordinate

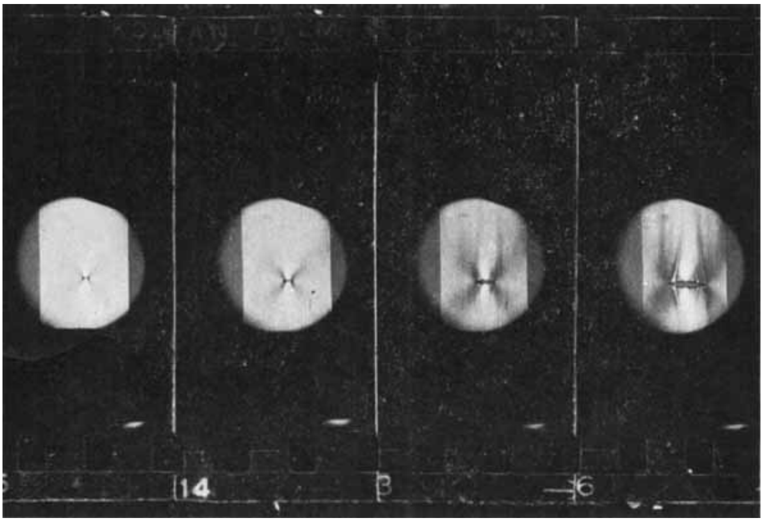

Fig. 1. Crack growth in cellulose film. From left to right, frames at 3, 11, 22.5, and 24.5 min, after application of load. Sample width 2 cm.

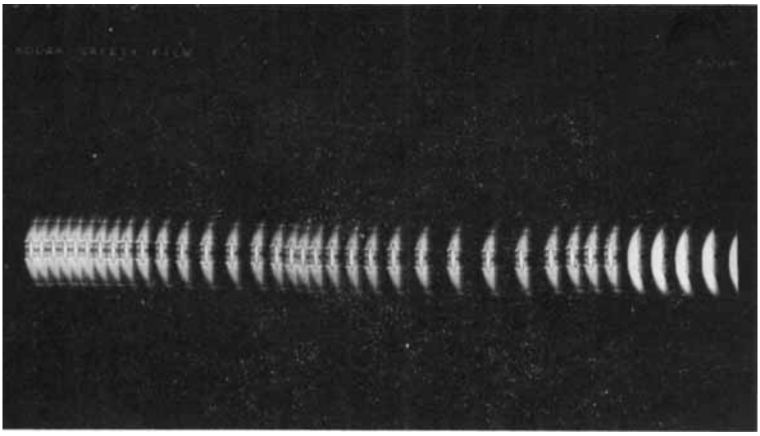

Fig. 2. Crack growth prior to onset of fast fracture. Frames at 10^{-2}-sec intervals.

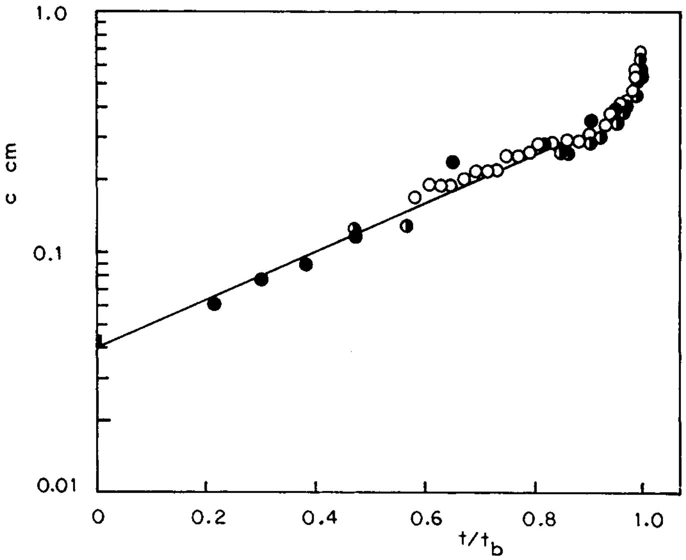

Fig. 3. Variation of crack length c with time t at different loads W; t_b is the time to failure: (●) $W = 5.82$ kg, $t_b = 692$ sec; (◑) $W = 6.10$ kg, $t_b = 64$ sec; (○) $W = 6.40$ kg, $t_b = 24$ sec.

represents the initial cut size, c_0. Within the experimental error, these results can be fitted by an equation of the form

$$c = c_0 \exp (K\ t/t_b)$$

for $0 < t/t_b < 0.8$. K is a constant independent of the load W and t_b decreases with increasing W.

References

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