Dynamic-finite-element and Dynamic-photoelastic Analyses of Two Fracturing Homalite-100 Plates

Numerically determined and experimentally established dynamic-energy-release rates show remarkable agreement with each other

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Abstract—A dynamic-finite-element code, HONDO, was used to analyze two single-edged-notch fracturing Homalite-100 plates which had been previously studied by dynamic photoelasticity. A single-edged crack in the finite-element model was advanced in incremental jumps such that the time-averaged crack velocity matched the measured crack velocity in the Homalite-100 plate. Dynamic-energy-release rates were computed for a constant-velocity crack and a crack which arrested after a somewhat constant deceleration. These results were compared with the corresponding dynamic-energy-release rates, which were computed from the dynamic-stress-intensity factors determined by dynamic photoelasticity, and with static-strain energy-release rates. Despite the crude modeling of the running crack, the coarseness of the finite-element-grid breakdown and the differences in the modeled and actual grip conditions, the computed and measured dynamic-energy-release rates, except for occasional large differences, generally agreed within 10 percent of each other.

Introduction

For the past six years, one of the authors and his colleagues1-5 have been using dynamic photoelasticity to determine transient isochromatics in stiffened and unstiffened Homalite-100 plates with single-edged cracks subjected to uniaxial tension with and without impact loading under fixed grip conditions. More recently, dynamic photoelasticity was used to analyze the transient states in dynamic-tear-test (DTT) specimens and wedge-loaded double-cantilever-beam specimens. In the above dynamic-fracture experiments, the running cracks either arrested, branched and/or penetrated through the test specimens. In some instances, the running crack circumvented an open hole straight ahead in its path. In other cases, the crack would run through or arrest between pinned or pinned and bonded stringers which simulated riveted and riveted and adhesively bonded crack arresters. The dynamic photoelastic patterns in these tests were then used to determine dynamic-stress-intensity factors, dynamic-energy-release rates and crack velocities. The corresponding static-stress-intensity factors and static-strain energy-release rates were computed by using conventional finite-element analysis of a model with relatively coarse nodal breakdown. Average dynamic-energy-release rates, which are the total dynamic energies released during crack propagation divided by the total newly created crack-surface areas, were found to correlate with crack arrest and crack branching resulting in proposed crack arrest and crack-branching criteria.6 A controversial conclusion derived through these investigations is that the arrest stress-intensity factor, unlike the critical stress-intensity factor, is not a material property as being proposed by some investigators.7

More recently, Dally et al. conducted dynamic-photoelasticity experiments to determine the fracture-dynamic parameters governing a running crack under static or dynamic loading.8-10 The arrest stress-intensity factor in their investigation was found to be close to the critical stress-intensity factor and tends to verify the postulate that the arrest stress-intensity factor is a material property. In particular, their results agreed with the fracture-arrest concept advanced by Irwin in 1969.11

The above brief survey of the current and past investigations in fracture dynamics using dynamic photoelasticity show that different conclusions can be reached by different investigators possibly due to the differences in experimental setups and photoelastic models which they used. Such differences could imply certain fracture-dynamic parameters, such as the crack-arrest stress-intensity factor, should vary with...
Fig. 1—Isochromatic patterns of dynamic crack propagation for Test No. B2

Fig. 2—Isochromatic patterns of dynamic crack propagation for Test No. B13