Crack Arrest in Laminated Structures

Lanny J. Larson
Department of Engineering Mechanics
U. S. Air Force Academy
and H. F. Brinson
Department of Engineering Mechanics
Virginia Polytechnic Institute and State University,
Blacksburg, Virginia, United States of America

Due to recent advances in bonding techniques such as diffusion bonding, electron beam welding, and explosive welding, it is now possible to design high strength laminated structural components. Since these laminated structures can offer greatly improved resistance to unstable crack propagation, the problem of crack arrest in laminated structures is of great practical importance. This summary describes a dynamic photoelastic investigation of crack arrest and delamination in bonded materials.

Results are presented showing the stress intensity factor for a dynamically propagating crack being arrested by a bond plane in an otherwise homogeneous elastic material. The stress intensity factor is also determined for the case of dissimilar materials joined by a bond plane. The results were obtained using dynamic photoelasticity measurements from a Cranz-Schardin spark discharge camera capable of recording sixteen individual frames at framing rates from 25,000 frames/sec to 1,000,000 frames/sec. The specimen geometries for the experimental program were the double cantilever beam (DCB), the tapered double cantilever beam, and a modified compact tension specimen. Fixed grip loading was used in all cases. Rate sensitivity of the birefringent material used for the study was accounted for by experimentally determining the arrest fracture toughness as a function of crack velocity.

Control specimens (i.e., specimens which contain no bond) were analyzed using both experimental (dynamic photo-elasticity) and existing analytical models. Comparisons of dynamic stress intensity factor and crack velocity was then made between the homogeneous control specimen and a specimen of similar geometry except for the addition of a bond plane. For the case of the bi-material specimen, the control specimen was a single material specimen with a bond plane.

The data is presented in dimensionless form by plotting the stress intensity factor for the bonded specimen divided by the stress intensity factor for the control specimen versus crack position and/or crack velocity. Crack velocity (non-dimensionalized in the same manner as the stress intensity factor) is also plotted versus crack position. The static stress intensity factor for the three specimens geometries with the bond plane was determined experimentally using photoelasticity and holography and compared with the dynamic results.

Conclusions from this study include:

1. The influence of the bond plane on the dynamic stress intensity factor and on the crack velocity prior to arrest.
2. The conditions necessary to achieve arrest and delamination as opposed to continued crack propagation.
3. Comments on the validity of static and dynamic comparisons for the laminated geometry.