HYPERVEROLOCITY IMPACT
Dynamic Fracture Behavior of Brittle Polymers

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Introduction

How do things break when hit by a shooting star? 

Hypervelocity impact induced fracture behavior of brittle polymers was experimentally investigated using a unique two-stage light-gas gun at speeds averaging 6 km/s (13,400 mph). Resulting mode I or opening mode crack tip stress intensity and energy release rates were analyzed using the optical techniques of caustics and dynamic photoelasticity.

Dynamic Fracture & Impact Physics

The process of hypervelocity fracture at the impact site can be regarded as a multiple-scaling phenomenon initiated at the free surfaces. Upon impact at vi two shock waves propagate away from the interface, i, one towards the end of the impactor, si, and one towards the rear side of the plate, S2. Rarefraction waves are then transmitted toward the axis of symmetry of the impactor, and later at the ends of the impactor and plate causing spectra to form at the impact site and cracks to propagate in the plane of the plate (Figueroa right) [2]. The mode-I or crack opening dynamic stress intensity factor can be described by the singular stress solution and is directly related to the energy release rate ahead of the moving crack [3].

Impact site of Homalite 100 and Mylar are compared side-by-side. Each was hit with a 45 mm right cylindrical slug 1.8 mm in width and diameter or approximately 5 km/s. Notice that the Homalite 100 has almost identical dynamic behavior, whereas the Mylar site has a slight time delay from impact. This could be due to the fact that the thermal conductivity of Mylar is about 200 times lower than Homalite 100. Additionally the size of the impactor holes in both materials are greater than the diameters of the hypervelocity projectiles.

Optical Methods & High-Speed Photography

High speed photography (100 million frames per second) is used to capture the instantaneous fringe pattern and crack propagation during impact. A high speed video camera with 100 m/s sensitivity and 2500 frames per second has been used. The experiments were performed at five different impact conditions: 35 km/s and 35 μs before impact, 35 km/s and 5.2 μs before impact, the projectile is closer to the plate, and the two impact velocities of 5.2 and 13 km/s, respectively.

Crack Tip Fracture Behavior

Mylar has smooth and flat crack path appearance, whereas Homalite 100 exhibited branching crack paths. This is due to the fact that the lower Young's modulus and higher shear modulus of Homalite 100 cause it to be more brittle than mylar, and consequently the cracks did not experience any complex wave interaction from reflection at the plate boundaries. Homalite 100 cracks propagated in the instantaneous local plate (shear) direction and only branched when crack speed reached about half of the material longitudinal wave speed. Average branching apex was approximately 45°.

Acknowledgements & References

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