

Load Rate Effects on Interlaminar Fracture Toughness of Composite Materials

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Abstract. The energy dissipation due to the failure of composites is of particular interest for crash applications involving dynamic loading. Separation of layers or delamination which can occur in opening (mode-I) is one of the key failure mechanisms that dictates the energy absorption. In this investigation, the effects of load rate on the mode-I fracture behavior of laminated composites were studied using quasi-static experiments. The experiments were conducted on laminated beam type specimens with inserts to simulate delamination. The results showed an increasing trend on the fracture toughness for the corresponding increase in the crack extension rate for the Toray Carbon Unitape and scattered response for Newport Fiberglass.

1. Introduction

In the modern world, the composite materials have been utilized mainly for weight saving purposes and also for its load bearing strength. The laminated composites particularly have a poor impact resistance. They generally develop crack from the outer layer which starts extending to the subsequent layers thereby causing total fracture of the material in use. Here we study the behavior of these materials subjected to the opening mode (mode I). The Double Cantilever Beam (DCB) geometry used during this experiment is illustrated in Fig. 1. The fracture toughness which is the energy required to create new surface area is given by (1),

$$\text{Fracture Toughness, } G_I = \frac{3P\delta}{2a} \text{ [lb-in/in}^2\text{]} \text{ (Ref. 1)} \quad (1)$$

where, P = Applied load [lb], δ = Displacement [in], a = Crack length [in]

in the equation (1), the crack length is estimated using the strain gage readings in conjunction with Euler-Bernoulli beam theory. Assuming, the deformations are small, the following equation may be used for obtaining the crack length

$$\text{Crack length, } a^3 = \frac{3\delta eh}{2\varepsilon} \text{ [in}^3\text{]} \quad (2)$$

where, δ = Displacement [in], e = Distance from the hinge center to the gage center [in],

h = Thickness of the half beam [in] and ε = Strain [in/in]

2. Experiments, Results and Discussion

The laminated specimens (6.25"x1" with a = 1.5", e = 0.5") were fabricated using the Newport NB321/7781 Fiberglass and Toray T800S/3900-2B Carbon Unitape prepegs. A layer of DuPont Teflon Film 0.0005 in thick was laid in the middle to simulate the crack. The specimens were then bonded with a pair of piano hinges which were capable of sustaining the applied tensile load. MTS test frame was used to test the specimens at Quasi-Static rates of 0.05 in/min, 0.5 in/min and 5 in/min. The test arrangement as shown by Fig. 2, illustrates the specimen being loaded on the test frame. A load cell of 20lb capacity was used to acquire the values of load. The load, displacement and strain data were recorded during the tests at appropriate data acquisition rates. The delamination propagation and its speed under different loading rates were monitored using strain gage readings on the test specimen in conjunction with the Euler-Bernoulli beam theory. The load-displacement comparisons for NB321/7781 specimens at different test rates have been summarized by Fig. 3 (Ref. 2). The response exhibits a ductile-stable behavior. This data along with crack length measurements were used to determine the fracture toughness (1) and the crack tip velocity (2).

3. Conclusions

For the two materials investigated, the fracture toughness as a function of crack extension rate is plotted in Fig. 4. Based on the limited experimental data, for the range of crack extension rates experienced by the materials, the NB321/7781 material appeared to be insensitive to crack extension speed due the scattered response, while the T800S/3900-2B material showed an increasing trend (Fig. 4).

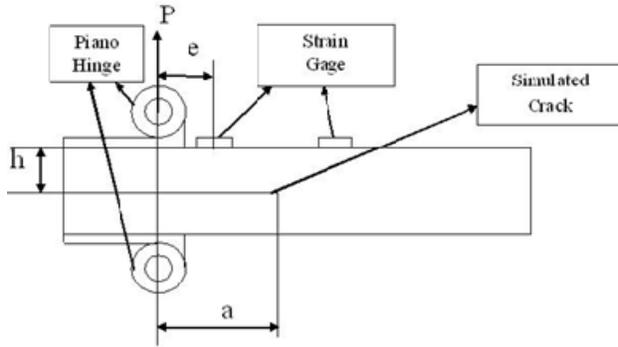


Fig. 1. DCB specimen geometry



Fig. 2. Experimental setup

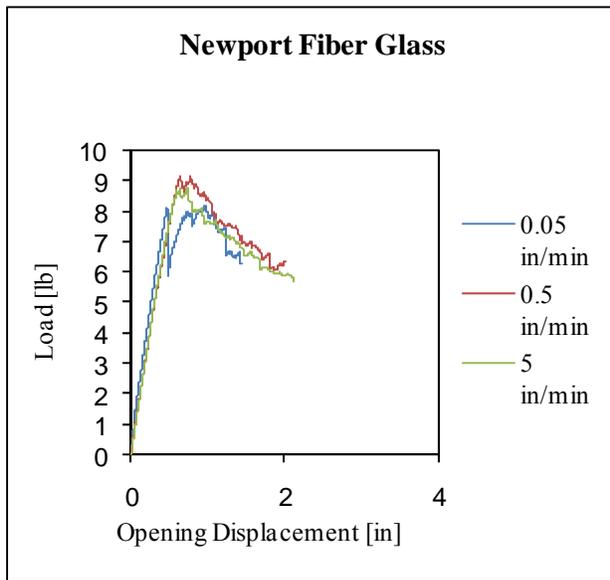


Fig. 3. Load vs. Opening Displacement

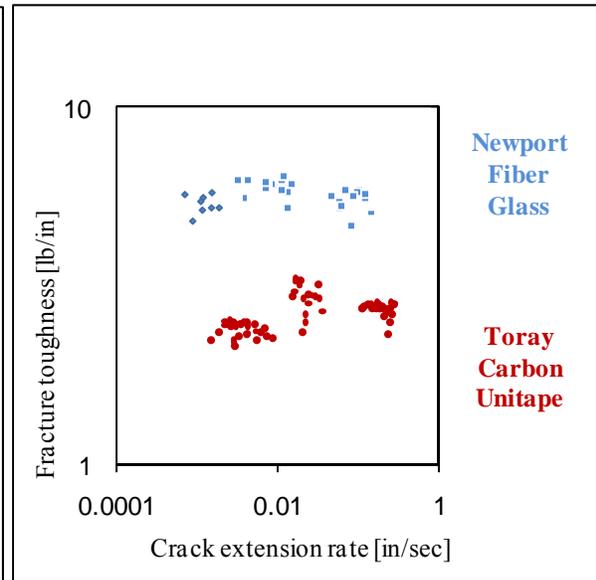


Fig. 4. Rate Sensitivity of Mode I interlaminar Fracture Toughness

4. References

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