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ORIGINAL ARTICLE

INVESTIGATE OF DELAMINATED COMPOSITE LAMINATES WITH SUBJECTED INTERLAMINATE FRACTURE TOUGHNESS

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ABSTRACT: Composite materials are replacing standard engineering metals and alloys for many applications. Their inherent ability to be custom tailored for any application has made fiber reinforced composites. Their superior specific strength and stiffness characteristics have made them very competitive in the industry. The primary limitation of fiber reinforced composites is fracture toughness, specifically delaminating. Delaminating failures are common due to the nature of composite construction. In this study, attempt to distinguish interlaminate fracture toughness of composite laminates along the interface of composite laminates for three type of material. The four end notched flexural (4ENF) test is conducted to investigate the effects of the previous materials on the Mode I and Mode II interlaminate fracture toughness, respectively.

KEYWORDS: Delaminate, Composite Laminate, Finite Element.

INTRODUCTION

Polymeric matrix composites containing reinforcement fibers such as carbon, glass or Kevlar are quite commonly used as engineering materials. These laminated composites are becoming the preferred material system in a variety of industrial applications, such as aeronautical and aerospace structures. The increased strength and stiffness for a given weight, increased toughness, mechanical damper, chemical and corrosion resistance in comparison to conventional metallic materials and potential for structural tailoring are some of the factors that have contributed to the advancement of laminated composites. Among all the possible failure modes, delaminating represents the most serious and important one in laminated composite structures. Delaminating is a commonly observed failure mode in fiber-reinforced composite laminates subjected to static or fatigue tensile or thermal loading that develop due to a variety of factors such as: Free edge effects, structural discontinuities, localized disturbances during manufacture and in working condition, such as impact of falling objects, drilling during manufacture, moisture and temperature variations and internal failure mechanisms such as matrix cracking. Therefore in this part has pointed to some of papers that study in this case. Failure occurs due to a process of damage accumulation caused by characteristic stress concentration at the interface between the inclusion and the composite (Kevin O'Brien, 2008). The delaminated part is less influenced by the deformation of the rest of the laminate. So deformation of the near-surface delaminate part does not necessary follow the deformation of the rest laminate. Consequently, not only the growth of the near-surface delaminate has to be taken into account but also its local stability (Gdoutos, 2005). The concept of stress intensity factor works well for trans-laminar fracture of composites. However fracture in laminate that concept may be more difficult to apply, particularly when different anisotropic properties are present above and below of the plane. For this reason it is customary to characterize interlaminate fracture with energy concepts (Howell, 2009). Rebiere and Gamby, (2008) observed that the second damage mode does not appear in the $[0_2/90]_s$ laminate. For other types of laminates containing a more important number of 90˚ plies, the initiation of a second damage mode is observed. The initiation of delaminate or longitudinal matrix cracking is easier in a laminate containing a thick 90˚ layer. One type of damage observed in a cross ply composite laminate subjected to unidirectional static or fatigue tensile loading, is usually transverse cracking which results an interlaminate stress concentration at crack tips. Delaminate or longitudinal cracking are thus subsequently develops the transverse cracking damage. It is well known and experimentally observed that the stiffness of a composite structure is reduced with the evolution of the transverse crack damage (Rebiere and Gamby, 2004). Transverse cracks are initiated by the connection of micro-voids in the matrix, with de-

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bonds at the fiber/matrix interfaces. The initial crack begins to propagate in the thickness direction at a certain stress level and then propagates in the width direction. Generally, the initial crack does not propagate in the width direction until it is fully extended in the thickness direction. Moreover, it runs through the whole area of the 90° ply as soon as it begins to propagate in the width direction. Thus, the full transverse crack is generated when the initial crack is fully extended in the thickness direction (Okabe *et al.*, 2008). The stress–strain response of the three laminates with increase in angle. So a higher applied load is required to cause matrix cracking, as indicated. Another factor is the ability for the crack to propagate through the thickness of the specimen (Wharmby and Ellyin, 2002). As the angle decreases, it becomes more difficult for the cracks to propagate between individual plies because of fiber bridging of the matrix cracks. The fracture energy is the highest for the unidirectional $[0^{\circ}]_6$ laminate and the lowest for the $[\pm 45]_5$ laminates. The strain energy release rate is presented for the same material properties versus the angle of ply. It is apparent that the strain energy release rate for an angle-ply specimen is minimum when θ is between 0° to 10° (Gordnian *et al.*, 2008).

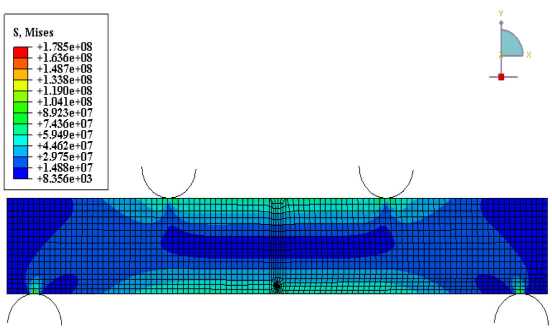
METHOD OF RESEARCH

The ultimate failure of a cross ply laminate occurs by two or three damage mechanisms and fiber breaking. Usually, these three main damage modes are cracking in transverse and later longitudinal delaminate. Delaminate or longitudinal cracking are thus subsequently develops the transverse cracking damage. It is well known and experimentally observed that the stiffness of a composite structure is reduced with the evolution of the transverse crack damage. However angle-ply laminates have been used extensively in industrial applications of polymeric composites because of their superior properties in multidirectional loadings. The most practical applications involve woven reinforced and cross-ply multidirectional laminates where delamination occurs between the plies of different orientations. Therefore, it is essential to characterize the delamination resistance G_{1c} with various stacking sequence along the interface for the development of more accurate design methods. Many studies have already been presented on the interlaminar fracture of laminated multidirectional composites. Interlaminar fracture in filament wound pipes can lead to significant stiffness losses and to increased probability of buckling. Fiber ruptures in tension, fiber buckling in compression, matrix cracking under transverse tension and shearing, and matrix crushing under transverse compression. Damage propagates when the total fracture energy reaches its maximum value G_{cmax} specified by the user as an input parameter. To investigate the effect of interlaminar properties of delamination and crack growth in composites two types of unidirectional Glass/Epoxy and Kevlar/Epoxy laminates of 10 plies are assumed that these specimens were according to ASTM D5528 for mode I, II delamination and mechanical characteristics of material presented in table (1).

Table 1: Lamina engineering constants for the selected materials

Material No.	E_L/E_T	ν	G_{LT}/E_T	G_{TT}/E_{LT}	E_T(GPα)
Graphite-epoxy	40	0.25	0.5	1.0	5.17
Kevlar-epoxy	15.6	0.35	0.56	1.0	5.5

Despite their advantages, composites suffer from layer separation or delamination integrity and most likely to premature failure. The use of three-dimensional finite elements for predicting the delamination of these structures is computationally expensive. So shell elements are employed to study the delamination it gives accurate results with simplicity of computer modeling, which requires relatively lower computer time and space. In the figure1, have been shown contours of stress components (von mises), deflection (spatial displacement) and logarithmic strain components for glass/epoxy model under the four end notched flexural (4ENF) test.



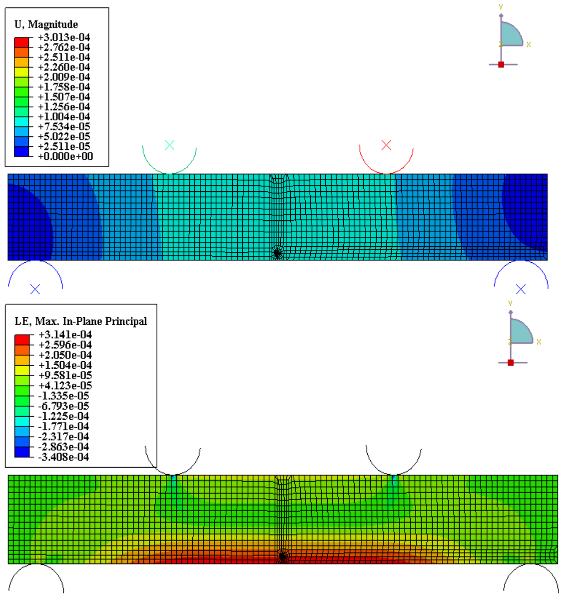


Figure 1: Stress, deflection and strain in type1 of model

So these characteristics for Kevlar/Epoxy presented in figure2 with the four end notched flexural test. This figure shows that lower strength in type2 model rather than type1.

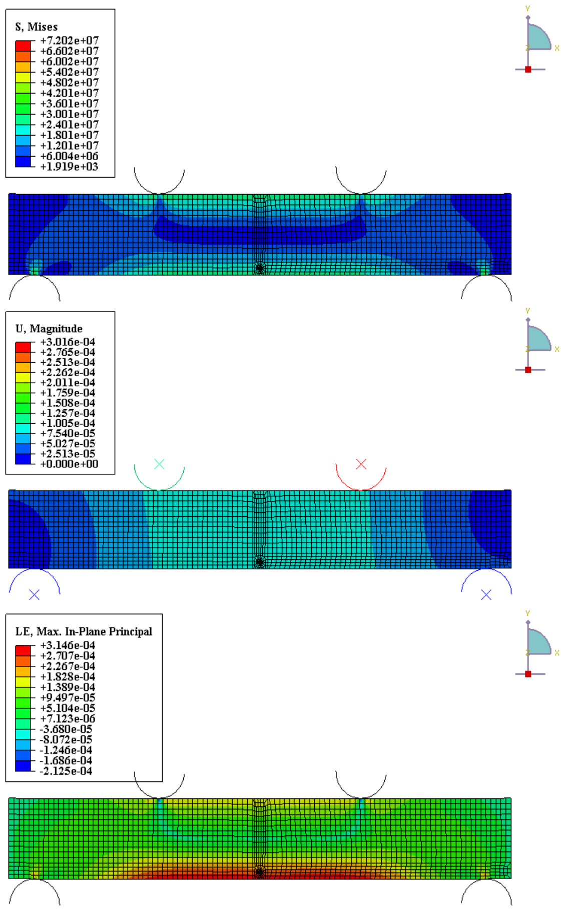


Figure 2: Stress, deflection and strain in type2 of model

Due to which the delamination crack was expected to grow along the midplane of specimen. In the figure 3 to 5 have shown crack propagation direction, J-integral estimated, stress intensity factor K1 and K2 for two type of case study.

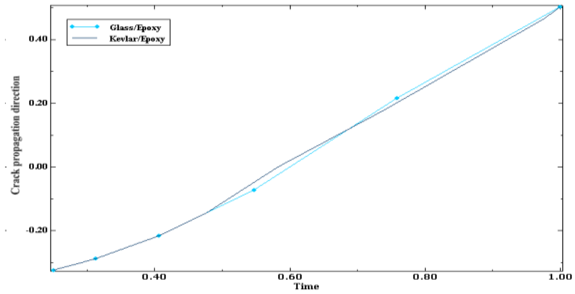


Figure 3: Crack propagation direction of models

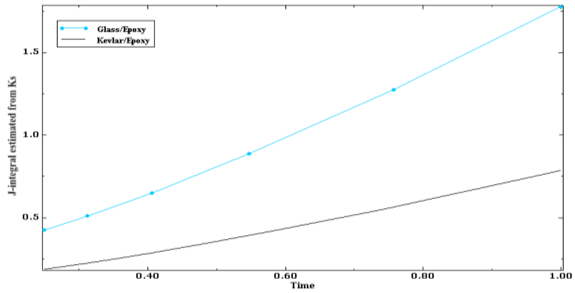


Figure 4: J-integral estimated of models

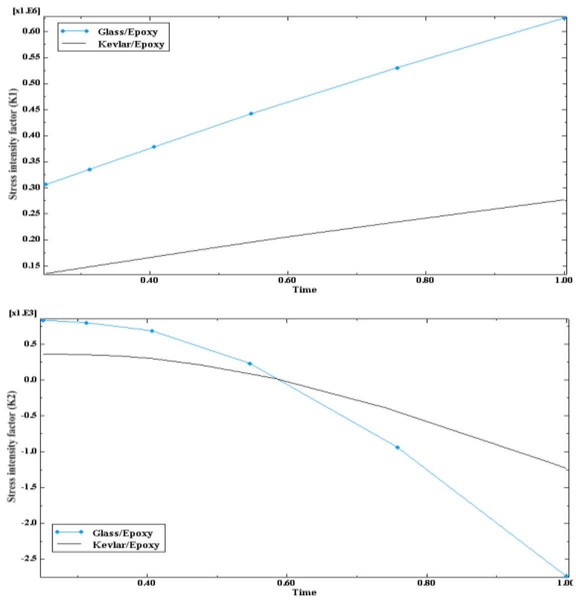


Figure 5: Stress intensity factors K1 and K2 of models

RESULT AND DISCUSSION

The results show that an increase in the J-integral estimated of glass/epoxy specimen around 45% over the of Kevlar/epoxy specimen due to flexibility under the mode II test. The stress intensity factors of specimen type1 exhibits an improvement of nearly 61%

compared with type2 due to resistance of glass/epoxy opposite crack growth but crack propagation direction diagram has shown the similar behavior that represent the flexibility of Kevlar/epoxy can atone shortcoming of strength versus glass/epoxy. In this case, the critical load is not related to the load-carrying capacity of the structure and failure will be due to the delamination growth, which depends on the fracture toughness of the material. Hence, there are stacking sequences that favor delamination growth and others that exhibit high resistance against the crack extension. Therefore, a laminate can be tailored to delamination growth resistance.

CONCLUSIONS

The low interlaminar strength or delamination resistance of composite laminates is one of major disadvantages, which delayed the widespread use of composite laminates in structures. Therefore, delamination becomes one of the most common and dangerous failure modes in composite laminates. For this reason, many efforts have been made to improve the interlaminar strength. In this study, an attempt was made to distinguish the interlaminar fracture toughness of unidirectional composite laminates. Four end notched flexural (4ENF) for mode II test were conducted to evaluate effect of this materials on fracture toughness or delamination resistance.

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