# Fracture mechanics of hybrid composites with ductile matrix and brittle fibers: Influence of temperature and constraint effect

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In the late eighties, the elevated-temperature dependence of fracture energy mechanisms of hybrid carbon-glass fiber reinforced epoxy composites was studied by Munro et al [1], who concluded that the work of fracture increased with temperature and glass fiber content.

In the present study, the fracture behavior of hybrid composite consisting of 14 carbon-PEEK 5HS (Harness Satin) woven plies with two outer glass-PEEK woven plies obtained by consolidation process is investigated. On the one hand, single-edge-notch bending tests (SENB) and single-edge-notch tensile tests (SENT) have been conducted at room temperature (RT) and at 150°C (i.e. slightly higher than $T_g$ as the ductile behavior of PEEK matrix is exacerbated) to study the influence of both the constraint effect and the temperature on the strain energy release rate in laminates with ductile PEEK matrix and brittle fibers. As failure is primarily driven by fibers breakage in tension and bending, it turns out that a temperature increase has very little influence on the critical translaminar fracture toughness though the ductility of PEEK matrix is exacerbated at $T>T_g$. It also appears that the constraint effect has very little influence on the critical mode I fracture energy as SENT and SENB specimens have virtually the same mean value (about 45MPa.$\sqrt{m}$). With increasing ratio a/w (a: initial notch length – w: specimen's width), the strain energy release rate increases gradually in SENT specimens whereas it slowly increases and suddenly decreases in SENB specimens, due to edge effects (see Fig. 1). SENB being characterized by a gradual failure, the crack extension has been obtained from DIC measurements and compared to the crack growth resulting from the gradual compliance loss. Finally, the G-R curves have been derived from the computation of the compliance and crack extension in agreement with the ASTM standard E1820 [2].

The use of the Linear Elastic Fracture Mechanics (LEFM) to describe damage as the propagation of a single dominant crack may be not always self-similar in heterogeneous composite materials depending on its stacking sequence [3]. Thus, the translaminar crack growth resulting from an initial transverse notch is usually self-similar in quasi-isotropic brittle laminates [4]. Thus, this idealization of a damage zone, which extends in a self-similar manner, allows a global analysis based on a global strain energy release-rate that can be calculated solely on the applied tensile loading [5].

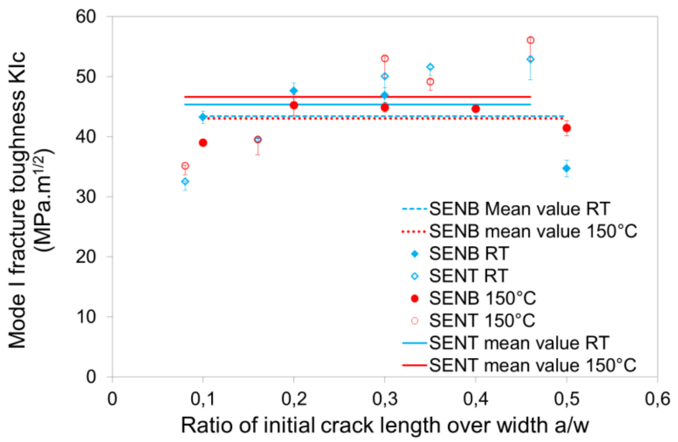


Figure 1 – Influence of temperature and constraint effect on the mode I fracture translaminar toughness of QI laminates in SENT and SENB specimens

A simple numerical model consisting of a failure criterion based on fracture mechanics was tested to account for the dissipation of the critical energy release rate in opening mode (mode I) due to fibers breakage. The crack extension obtained from Digital Image Correlation (DIC) measurements was compared to the crack growth resulting from the gradual compliance loss as well as the crack growth predicted by the model (see Fig. 2). From this comparison, it turns out that this simple model is able to capture the mode I translaminar fracture behavior of TP-based composites at $T > T_g$ when ductility of PEEK matrix is exacerbated.

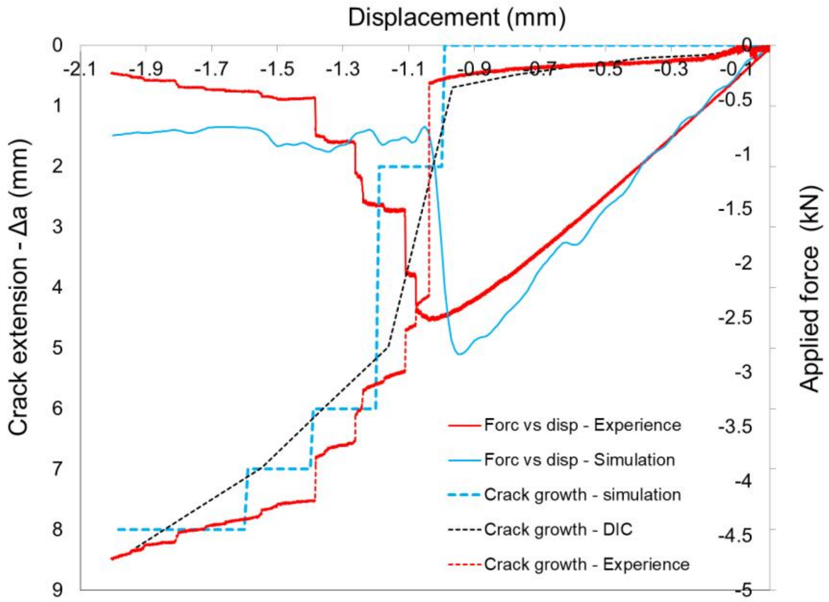


Figure 2 – Comparison of the crack growth along with the applied force in SENB specimens (with a ratio a/w=0.3) at 150°C: experience vs numerical modelling

**References**


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