**Prediction of low velocity impact and compression after impact on laminate composite with thermoplastic matrix**

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Composite materials have been increasingly used in airframe and space applications in recent decades because of their advantageous characteristics, such as their low specific weight, enhanced mechanical strength, and high stiffness coefficient when using high performance carbon fiber with intermediate modulus. Nevertheless, during the structure’s life, damage induced in these materials by impacts of minor and major objects, such as hail stones, runway debris or dropped tools, can drastically decrease the structure’s life.

Low velocity impact is one of the most critical load factors for composite laminates. Indeed, for structures submitted to low energy impacts or small dropped objects drops, such as tools during assembly or maintenance operations, composite laminates reveal a brittle behaviour and can undergo significant damage in terms of matrix cracks, fibre breakage or delamination. This damage is particularly dangerous because it drastically reduces the residual mechanical characteristics of the structure, and at the same time can leave very limited visible marks on the impacted surface. Low-velocity impact on composite structures can reduce their strength up to 50% (Fig. 1a) [1, 2].

Since low velocity impact is one of the most detrimental solicitations for composite laminates, there is a strong current trend towards a greater use of tougher matrix for aerospace structures and very high performances can be achieved by using thermoplastics [3]. In this study, unidirectional carbon/PEEK laminate has been subjected to impact and the damage has been studied with C-scan investigations. The experimental results show higher delaminated area than expected [4]. In spite of higher fracture toughness of PEEK resin compared to thermoset epoxy resin, delaminated area is higher than for epoxy/carbon laminates. Moreover the damage morphology is different for carbon/PEEK composite with high delaminated interfaces situated at mid-thickness of the plate, compared to the classic “pin tree” damage for carbon/epoxy composite plate. The high mid-thickness delaminations have also the characteristic to be asymmetric whereas the boundary conditions are symmetric.

Then this paper investigates the capability of a “discrete ply model” (Fig. 1b) [5, 6] to simulate the complex three-dimensional damage patterns in composite laminates with PEEK resin subjected to low velocity impact. The objective is together to simulate the impact damage and to better understand the unclassical damage morphology observed during impact with thermoplastic material.

The results show it is possible to simulate the unclassical damage morphology but it is necessary to use low rate of the mode II interlaminar fracture toughness. This result is coherent with Smiley and Pipes’s results [7] where it is shown that PEEK material exhibits ductile crack growth at low rates and brittle crack growth at high rates. The authors show the change on fracture mechanism resulted in a decrease in GIIC from 1.9 to 0.4 N/mm. It is important to include this rate effect in the damage prediction during impact loading.

Then the model is used to simulate the impact (Fig. 2) and the compression after impact, and the good correlation with experimental results seems confirm the rate effect of the PEEK fracture toughness during impact. Finally an ENF test was done in order to confirm the low value of the fracture toughness when the crack propagation is fast.

 

-a- -b-

Figure 1: Compression after test (a) and principle of the “Discrete Ply Model” (b)



-a- -b-

Figure 2: Delaminated interfaces obtained after impact experimentally (a) and numerically (b)

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