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EXPERIMENTAL CHARACTERIZATION OF THE DYNAMIC TOUGHNESS OF EPOXY RESIN

Bastien Lammens^{1,2(*)}, Gerald Portemont¹, Julien Berthe¹, Rian Seghir², Julien Réthoré²

¹DMAS, ONERA, F-59014 Lille, France

²GEM, Centrale Nantes, UMR 6183 CNRS, Nantes, France,

(*)Email: bastien.lammens@onera.fr

ABSTRACT

Laminated composite materials used in the aeronautic field can be damaged by impacts, leading to crack propagation. In the literature, the energy release rate (G) is usually estimated from global load measurements. In this paper, full field measurement by digital image correlation (DIC) is used to obtain G and other parameters defining the mechanical state in the vicinity of the crack tip. An experimental setup was designed under quasi-static loading to validate this method for pure epoxy resin specimen. The experiments show that the effects of geometry influence the results and must be taken into account when determining the dynamic toughness.

Keywords: dynamic loading, toughness, digital image correlation.

INTRODUCTION

Laminated organic matrix composites are increasingly used in the aeronautical industry. These materials are subjected to impacts such as bird strikes or hailstone impacts. These impacts can lead to the propagation of cracks that can destroy the structure. The energy release rate (G) is used to characterise the inter-laminar strength. It is determined in mode I using a standardised experimental set-up under quasi-static loading with a Double Cantilever Beam (DCB) sample (Blackman and al., 1996). A global analysis method with an energy approach is applied to analyse this experiment. In the case of dynamic loading, there is no standardised experimental setup. Nevertheless, some authors have developed extensions of the global method used for quasi-static loading. However, the results show differences between the authors for the same material (Mall and al., 1987). Other authors have used a microscopic approach at the local resin scale to determine fracture toughness with stress intensity factors (Joudon and al., 2014). Stress intensity factors can be extracted from Williams series which are analytical solutions of displacement field or stress field at the crack tip. Some authors used non-singular terms from these Williams series such as T or B-stress for others materials. They showed the influence of the geometrical effects of the sample on the stability of the crack propagation, on the toughness and on the non-singular terms (Ayatollahi and al., 2016). The aim of this work is to determine the dynamic toughness of laminated materials in mode I. A microscopic approach on an epoxy resin is employed by adding non-singular terms of the Williams series to take into account structural effects.

RESULTS AND CONCLUSIONS

An experimental investigation under quasi-static loading was carried out on an electromechanical testing machine to validate this microscopic approach. The digital image correlation technique was used with a camera to evaluate the displacement fields. These fields

(near the crack tip) are projected onto the Williams series to evaluate K_I , T and B (respectively the stress intensity factor in mode I, the first and the second mode I non-singular terms). The experimental set-up is represented on Figure 1. Two types of specimens have been used to show impact of structural effects on non-singular terms. The first is a Tapered Double Canteliver Beam (TDCB) specimen and the second one is a triangular specimen. Three crosshead speeds of 0.1 mm/min, 100 mm/min and 500 mm/min were used to show the influence of the imposed displacement speed. The experiments show that the crack propagation is not stable as an unstable phenomenon appears on the load-displacement curve, which is an intermittent crack propagation. Nevertheless, K_I , T and B were obtained for quasi-static crack propagation phases observable between the dynamic propagations. The results show that the values of K_I , are very close for all specimens and for all crosshead speeds to the literature values. For the TDCB specimen, the non-singular terms are close to 0. For triangular specimens, T increases during the experiments while B decreases during the experiments. The drop in B for the triangular specimens is greater than for the TDCB specimens. This has a significant impact on the occurrence of crack instabilities. At these crosshead speeds, no influence of the crack propagation speed on K_I is observed.

Finally, although the stick-slip phenomenon appeared, a microscopic approach using Williams series showed good results. The structural effects were highlighted through their influence on non-singular terms and this approach will be used for dynamic loadings. Another experimental setup was developed using high-speed servo-hydraulic testing machine to determine the toughness and non-singular terms under dynamic loading.



Fig. 1 – Experimental set-up under quasi-static loading.

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