A 2D DAMAGE MODEL FOR IMPACT ON PRE-STRESSED COMPOSITE PLATES

Fabian Ehrich *, Lorenzo Iannucci*, Jesper Ankersen* and Michel Fouinneteau †

*Department of Aeronautics
Imperial College of Science, Technology and Medicine
London SW7 2AZ, UK
e-mail: fe109@imperial.ac.uk

† AIRBUS France
e-mail: michel.fouinneteau@airbus.com

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Summary. This paper outlines the effect of in-plane compressive loads on the impact resistance of laminated fibre composites. Further, a two dimensional damage model to predict the impact damage of plates under initial in-plane loading is presented. The predictions of the damage model are compared to the experimental results.

1 INTRODUCTION

Due to their high specific mechanical properties, fibre reinforced composites are widely used in aerospace applications. However, impact loads can cause substantial damage in these materials reducing strength and stiffness significantly. Impact damage in fibre composites has been studied extensively in the literature. Although a real structure subjected to impact loading is most likely to be under additional loads, only very few studies have analyzed impact on pre-loaded structures [1, 2].

This paper presents an energy based damage model to predict impact damage on plates under initial compression. The predictions are compared to impact experiments carried out on carbon-epoxy composite plates under in-plane compression.

2 EXPERIMENTAL RESULTS

Low velocity impact experiments were carried out on carbon/epoxy composite plates. Prior to impact, the plates were pre-loaded uniaxially in compression. Pre-strains were observed to reduce the peak load and increase impact duration, energy absorption as well as delamination area. While plates under moderate pre-strains of 1500µε responded in a similar manner to unloaded plates, high pre-strains of 3000µε caused a change of failure modes and resulted in a very different force-time response. The resulting delamination extent is shown in Figure 1.
3 DAMAGE MODEL

The damage model proposed here is a two dimensional plane stress model for shell elements [3]. It is based on a continuum damage mechanics approach with five damage variables accounting for damage in matrix and fibres. After damage initiation is detected, corresponding material properties are progressively degraded according to a fracture mechanics based constitutive law. Thereby it is assumed that the energy dissipated during material degrading equals the fracture energy of the same failure mode:

\[
\frac{1}{2} \sigma_c \varepsilon_{\text{max}} = \frac{G_c}{l^*}
\]  

Introducing the characteristic length \( l^* \) enables to compare the volumetric strain energy and the critical fracture energy \( G_c \) and ensures that the results are independent of mesh size.

4 MODELLING METHODOLOGY

Simulations were performed using the commercial software ABAQUS/Explicit. The plates were discretised with a stacked shell approach consisting of continuum shell element layers representing sub-laminates connected with cohesive elements to model delamination damage. The model predictions for contact force, displacement and delamination damage were compared to the results obtained from the experiments.

5 CONCLUSIONS

In-plane loads can alter impact damage in composite materials significantly. The presented damage model can predict the impact response and damage accurately without being sensitive to mesh size.

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