Characterisation of Honeycomb Core Crush Behaviour by Discrete/Finite Element Coupling

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The application of polymeric composite sandwich structures in aerospace industry has been continuously increasing since new fibre types, resin systems and lightweight core materials have been developed and introduced into the market. Numerous studies on the performance of sandwich structures and improvement of their behaviour under different load cases have been conducted. A critical loading case in aircraft structures is impact from birds, hailstones and foreign objects and the designer needs reliable methods for predicting impact damage in wing and fuselage components.

Structural sandwich components have low resistance to impact due to the thin outer composite skins and undergo different fracture processes depending on their absorbing capacity. Most common damage mechanisms in composites, such as matrix cracking, debonding and fibre failure, may appear individually or interact resulting in complex failure modes. After fracture of the skin, the impacting object may damage and penetrate into the core. If impact speed is low, sandwich panels may respond by bending and no damage occurs if the kinetic energy of the impacting object is accommodated by the elastic strain energy level of the panel. At higher impact velocities a critical condition is reached when local contact stress exceeds local strength which leads to laminate bending failure, core compression strength failure and core/skin interface delaminations [1].

Core deformation and failure are decisive factors for the energy absorption capability of sandwich panels [2]. Modelling of impact in sandwich panels leads to numerical problems such as element distortion in skin and the core and may cause critical instabilities and error termination. Some computational techniques using adaptive meshing with optimization of mesh size and different discretization types can additionally create domain coupling problems.

Some studies have suggested the Element Elimination Technique (EET) as an alternative to conventional methods. It consists in removing the finite elements on reaching a threshold stress or strain value. Considering the case of impact, the failed material is contained mostly in the impact damage zone and contributes to the damage resistance even after the initial failure. Since EET progressively removes the damaged elements from the impact zone, it cannot model realistic impact load cases. Additionally, small increments in the element elimination threshold may change the impact failure mode completely, leading to wrong numerical results.

This study focuses on a novel modelling approach for the crush behaviour of typical core materials in sandwich panels which overcomes the numerical problems inherent in the EET method. It is based on a previous experimental work conducted at our institute on aramid paper honeycomb core, namely NOMEX™. In the experimental component of this study, a series of tests were conducted, including quasi static-compression and shear; with sandwich specimens fabricated with NOMEX™ core and carbon fibre fabric/epoxy facings. The results of the quasi-static compression tests show that the crush response consists of three phases: elastic buckling of cell walls followed by a plastic buckling, debonding fracture at cell interfaces and fracture of phenolic resin layer. This local failure has been simulated in detailed unit cell models using shell elements, see [3]. However, these methods are not appropriate for larger aircraft structures.

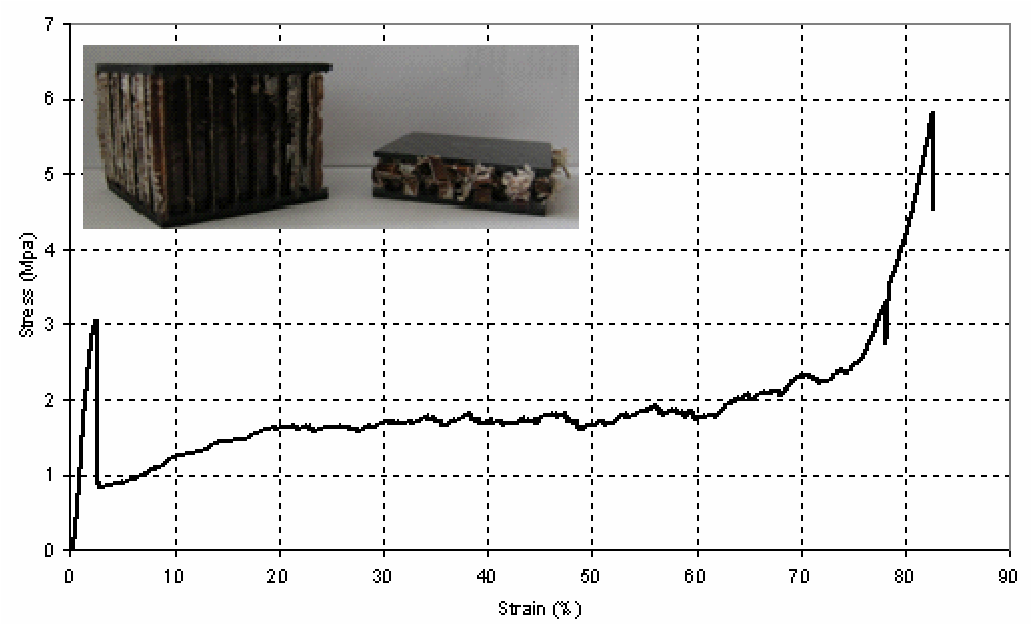

Fig. 1: Compression behaviour of NOMEX™ core.

To model this behaviour more efficiently a semi-adaptive numerical coupling technique is proposed to characterise the NOMEX™ core material and to model its complex crush behaviour. This technique consists in replacing the finite element mesh by a discrete particle formulation in the failure region or damage zone. It has the advantage that by replacing elements with particles, these may be compacted under compression stresses, allowing stable computations, avoiding element elimination and lost of contact force information.

The numerical studies were performed in the commercial finite element package PAM-CRASH™. The honeycomb structure is substituted by a homogenized volume model which combines discrete and finite elements. The solid finite elements characterise the orthotropic core stiffness properties and the discrete particles represent the fragmented material at failure.

In this work experimental and simulation results for the damage behaviour of this homogenized volume model are presented and discussed in detail. Finally the experimental and numerical crushing behaviour of aramid paper honeycomb materials are compared along with previous numerical and experimental investigations.

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