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NUMERICAL MODELLING OF NOMEX HONEYCOMB CORES FOR LOCAL ANALYSES OF SANDWICH PANEL JOINTS

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Due to their excellent weight specific stiffness and strength, honeycomb sandwich structures have become a standard material in many lightweight design applications. However, one of the major short comings of sandwich structures in general is their inability to bear localized loads [1]. This weakness is due to the inherent functional principle of two stiff face skins separated and supported by a relatively weak core structure. As a result, sandwich structures need to be locally reinforced in order to withstand local load introductions for instance at joints of sandwich panels. Such reinforcements naturally lead to stress concentrations and therefore require particular attention when designing and dimensioning sandwich structures.
In order to determine the strength and failure behaviour of a particular sandwich panel joint, manufacturers of honeycomb sandwich structures currently still depend on extensive testing. During the last few years, first attempts have been made to virtually test panel joints using advanced non-linear Finite Element Methods with the objective of creating a better understanding of the prevailing failure mechanisms [2-3]. This objective could be achieved, however, it is not reported that these first studies have concluded numerical models that are actually applied to reduce the current high testing effort for characterizing sandwich panel joints. It is therefore assumed that further research on the validation of numerical models of sandwich panel joints is needed, in order to successfully perform virtual tests on these joints.

One of the main issues when developing a detailed numerical model of sandwich panels in general, is the accurate representation of the weak core structure. This particularly applies for honeycombs, since their thin walled cells easily buckle when locally loaded. In the literature, countless studies on the failure behaviour of honeycomb sandwich cores under local impact loading can be found. The most recent of these studies model the honeycomb cell walls accurately using two-dimensional or even three-dimensional elements (meso-scale), thus enabling realistic cell wall deformations of the core [4]. This level of model detail requires accurate material data as well as suitable material models for the applied cell wall material.
Due to its excellent mechanical and flammability properties, the trademarked Nomex© aramid paper impregnated with phenolic resin has become a well established honeycomb base material. However, this material has also proven to be particularly complicated to be implemented in a meso-scale honeycomb model. The main reason for this is the phenolic resin coating on the Nomex paper. It leads to a layered material with an orthotropic ductile center layer (Nomex) and two isotropic very brittle outer layers (phenolic resin).

In the literature three main approaches can be found to account for this composite material. The first and most simplistic approach uses an isotropic linearly elasto-plastic material model, thus neglecting not only the orthotropy of the composite but also its layered structure.

Secondly, the Nomex paper can be modelled using a single layer orthotropic linearly elasto-plastic material model, which is more difficult to implement but at the same time gives more freedom in modelling the directional mechanical behaviour. Lastly, there is the approach of considering the multi-layer structure of the material by implementing a three-layer property set with an isotropic material model that allows brittle failure for the phenolic resin coating and the orthotropic material model from the second approach for the inner aramid paper.

The present study reviews and compares the different material property data and material models found in the literature in order to eventually recommend a suitable approach for the detailed numerical analysis of sandwich panel joints. As benchmark serve proprietary test results from standard flatwise compression and shear tests of honeycomb Nomex sandwich specimen (cell size: 3.2mm, density 48kg/m³). These tests are remodelled in a virtual testing environment using the commercial explicit FE-solver RADIOSS. Each presented approach is implemented in this virtual test environment and the model performance is evaluated by matching the stress-strain curves of simulation and test results.
The conclusion of this study is that the first approach is easily implemented while being capable of modelling the non-linear compressive behaviour of the Nomex honeycomb reasonably well (Figure 1). However, it is not possible to fit the material model for both, the compression and shear test results, simultaneously. Therefore, the first approach seems not suited for the proposed application, as a correct directional mechanical behaviour of the honeycomb cell walls is crucial for modelling sandwich panel joints. The second described approach enables the consideration of the directional material behaviour by applying an orthotropic material model. However, its single layer setup neglects the brittle fracture of the phenolic coating, thus leading to a wider peak in the stress-strain plot. The third described approach enables the representation of the brittle failure, leading to the best model performance of all three approaches. However, due to the high implementation effort of this three layered setup, it is recommended to apply the second approach for meso-scale models of Nomex honeycomb sandwich panel joints. The single layer orthotropic elasto-plastic material model is capable of reproducing the test results reasonably well also in the non-linear regime. It provides a good compromise between implementation effort and model performance.

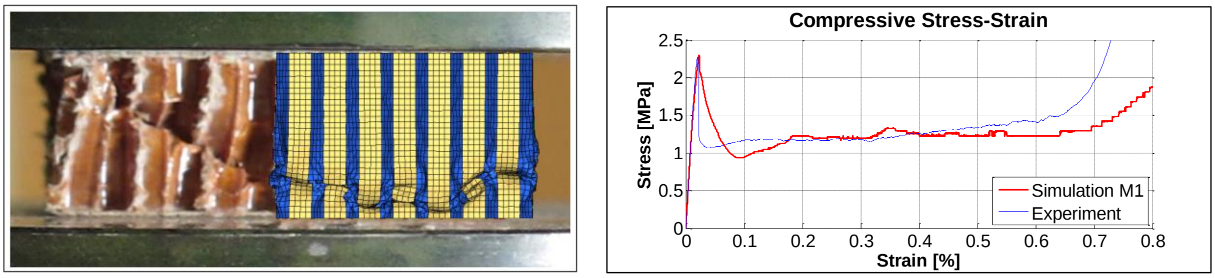

Figure 1 Comparison of compression in test and simulation in case of the simple isotropic elasto plastic material model

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