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Efficient Damage Tolerance Assessment of Composite Sandwich Structures

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1 INDRODUCTION

Multi-functional and weight efficient shell constructions are highly aspired for aircraft design. Composite sandwich structures satisfy this demand by the combination of two thin, stiff face sheets and an intermediate lightweight core, which provides thermal and acoustic damping. Low-velocity impact, however, can considerably reduce the load bearing capacity of sandwich structures by causing damages in face sheet and core. To reliably assess the damage resistance and the damage tolerance of such double-shell constructions, efficient methodologies are needed for the design process. Concerning this objective, appropriate methods are proposed to simulate the impact and the compression after impact behaviour of sandwich structures. An experimental test program, which was conducted at Dresden University (ILR), acts as referee for the validation of the simulation methodologies. The studied sandwich plates consist of two 0.63 mm and 2.71 mm thick CFRP face sheets and an embedded 28mm thick honeycomb core. The panels were impacted with energies from 1 J to 15 J. After evaluating core and skin damages by ultrasonic scanning, the specimens were loaded in uniaxial compression to measure their residual stiffness and strength.

2 IMPACT SIMULATION

Since frequent design loops require a quick analysis, efficient deformation and failure models are needed. To achieve a rapid and accurate stress analysis, a three-layered finite shell element [1] is used in combination with the Extended 2D-Method for three-layered shells [2]. The failure behaviour of core and face sheets is modelled by stress-based failure criteria and stepwise linear degradation models, which have been deduced from experimental investigations [3], [4]. As a result, core damage is assessed by upper and lower bounds, which cover the experimental core damage sizes very well. Furthermore, the skin failure model is suitable to predict the onset of face sheet tearing. Overall, the comparison between experiment and simulation shows a very good agreement in the dynamic deformation behaviour as well as in the size of core damage and in the onset of skin cracking for all studied impact energies from 1 J to 15 J. Moreover, short computation times demonstrate the high efficiency of the simulation. Thus, a new methodology is available for the design process, which can rapidly and reliably assess the damage resistance of sandwich structures.

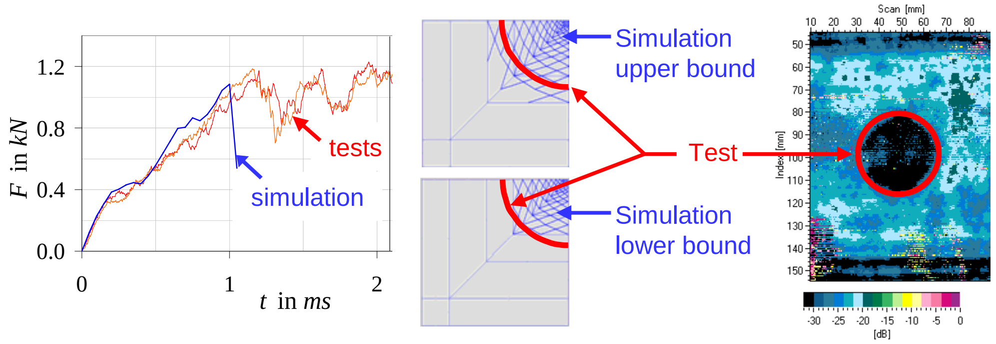

Fig. 1: Force-time history and core damage size caused by a 4J impact.

3 RESIDUAL STRENGTH PREDICTION

To assess the damage tolerance of sandwich structures, the compressive failure behaviour of the impacted specimens was evaluated. The missing support of the impacted face sheet in the area of core damage allows the impact dent to grow under in-plane compression, which in turn causes a propagation of core damage. Ultimately, the damage propagation leads to collapse of the impacted face sheet. The ultimate load is largely controlled by the initial core damage size and less by the size of the impact dent. The failure is reproduced by finite element simulations using a 1D material model for the honeycomb core and 2D shell elements for the impacted face sheet. Progressive damage growth in the honeycomb core is modelled by combining stress-based failure criteria with a stepwise linear stiffness degradation approach, which has been deduced from combined transverse shear and compression tests [3]. Comparative studies with a detailed FE model using solid elements for the honeycomb core have shown that the simplified 1D core model is sufficiently accurate to compute the residual strength of the investigated structures. Moreover, the experimental validation of the approach showed a very good agreement between test and simulation results and, thus, confirmed the applicability of the methodology to unsymmetrical sandwich structures [5].

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