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Influence of potting geometry of inserts load-carrying capability in sandwich structure

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Sandwich structure with honeycomb core is widely used in different structural applications in lightweight transportation systems such aerospace industries. Their main advantage is high specific stiffness-to-weight ratio in comparison to conventional materials such as aluminum alloys. The disadvantage of the sandwich structures is the inability of the direct mechanical attachment to other components that required the installation of the special types of fasteners. Threaded inserts bonded to the sandwich structure are universally used for the screws attachment with various other constructions components (brackets, holders, etc.). The load capability of the inserts is the main parameter for design and installation of the sandwich structure. This does not depend only insert type and geometry, but also on the geometrical conditions that are affiliated with the installation (bonding) of the inserts into the structure.

The load capability of the insert bonded into the composite sandwich structure was experimentally tested in case of the out-of-plane tensile pull-out test on the sandwich structure specimens in accordance of the ASTM standard [2]. The principle of the pull-out test is based on the tensile load of the insert over the screwed-in screw, when the upper face sheet of the sandwich specimen is pressed against the steel plate of the testing stand with the central hole with diameter of 80 mm. The two types of the blind inserts with inner threads M5 and M8 bonded into the composite sandwich specimens with the inner dimension of 110 x 110 mm and total thickness 30 mm were tested. The principle of the tensile pull-out experimental setup is shown in Fig. 1. The tested inserts made of titanium were located in the centre of the face sheets of the specimens. The sandwich structure consisted of the two face sheets made of 8 layers of unidirectional carbon prepregs (total thickness of the face sheets is 0.74 mm) and of 5056 aluminum alloy hexagonal type honeycomb core with cell size 3/16” and the thickness 0.001” of single walls.

The numerical simulations were used for the comparison. The numerical model of the sandwich structure with the insert was created in the FEM software Abaqus 6.13. The honeycomb hexagonal core was modeled as a homogenous structure. The individual parts of the sandwich structure and the bonded inserts were connected using tied constraints. The contact without friction was considered between the sandwich structure and the tested steel stand. The computational model was modeled as a quarter of tested specimen due to symmetry with added the appropriated boundary conditions. The computational model is shown in Fig. 2. The non-linear material models with damage were considered for the modeling of the main parts of the sandwich structure. The non-linear behavior of the face sheets was modeled by user defined material model designed by the authors and implemented into the commercial FEM software [1]. The material parameters of the individual parts of the sandwich structure were determined from the performed experimental tensile and compressive test on the separated materials specimens.

The results from numerical simulations were compared with the experimental data in the form of the force-displacement dependencies for the case of insert M5 and insert M8 as is displayed in Fig. 3 and Fig. 4 respectively. In the case of the M5 insert two variants of the potting were modeled in accordance with the fact observed due to experiment, when some specimens had not fully potted inserts at the bottom. This state was created due to incorrect bonding procedure and was manifested by a sharp decrease of the stiffness during loading. That is caused by immediate rupture of the adhesive in a weakened place at the interface of the bottom of the inserts and the honeycomb. The computational model shows a good agreement with the experimental data in the form of the force-displacement dependencies and in the damage which occurred in the sandwich structure with insert during the loading.

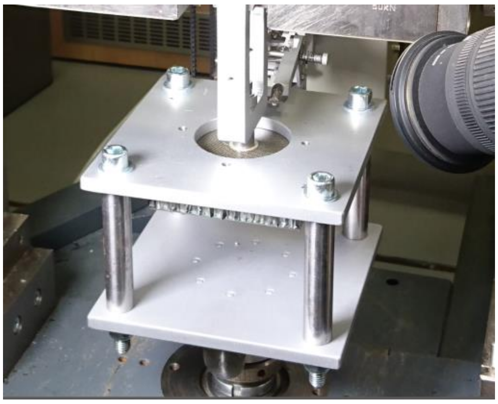

Fig. 1. Tensile pull-out test setup

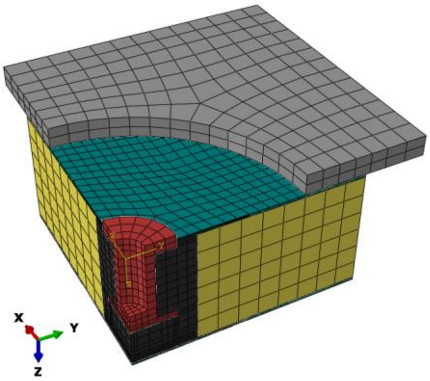

Fig. 2. The FEM mesh of the pull-out tensile test of the sandwich structure with the M8 insert

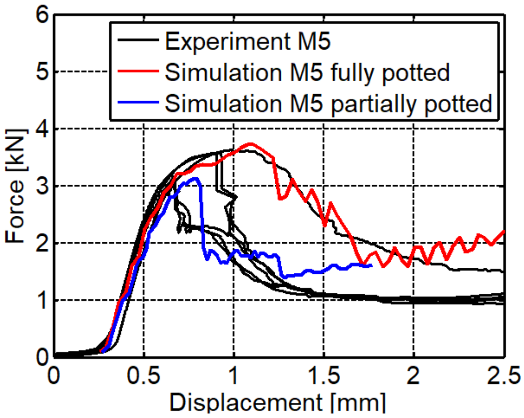

Fig. 3. The comparison of the force-displacement curves between the experiment and numerical simulation for the insert M5. Two types of the potting are compared – fully and partially potted state

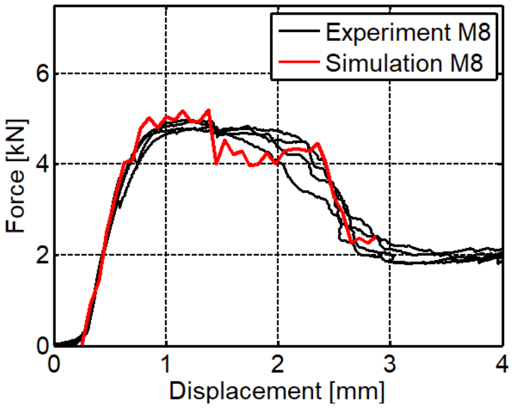

Fig. 4. The comparison of the force-displacement curves between the experiment and numerical simulation for the insert M8

The parametrical study based on the variation of levels of the potting radius r_p of the blind inserts with M5 and M8 thread was performed on the computational model of the sandwich structure in order to specify the possibilities of increase the load-carrying capability of the inserts. The size of the potting radius in the core can be affected by the application of the milling techniques in time of preparation of installation of the inserts in the sandwich structure. The potting radius r_p in the core is obviously equal to the inner radius of the installed insert r_i. The two other sizes of the potting radius in the parametrical study were considered as a 1.25 and 1.50 multiple of the inner insert radius r_i. The influence of the potting radius and the total size of potting in accordance to the hexagonal honeycomb and relevant cell and the comparison of the force-displacement dependencies in case of variation of potting radius for the insert M5 are shown in Fig. 5, in Fig. 6 for the insert M8 respectively.

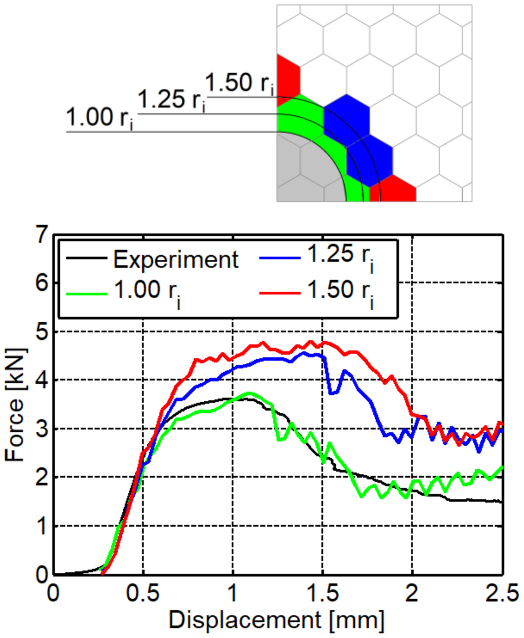

Fig. 5. The influence of the potting radius as a multiple of the inner radius r_i of insert M5 on the force-displacement dependencies

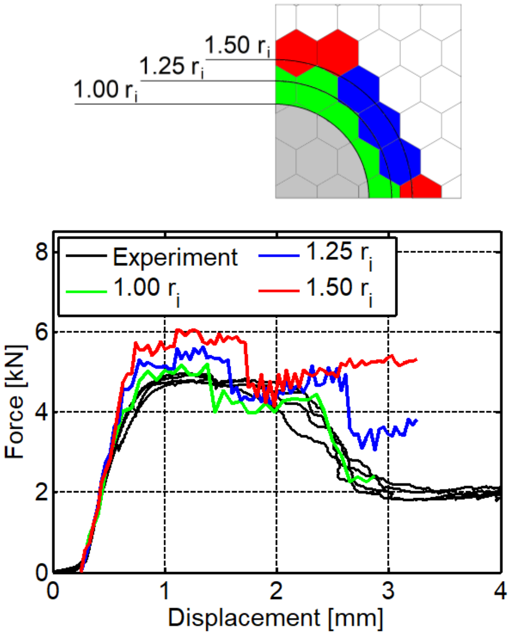

Fig. 6. The influence of the potting radius as a multiple of the inner radius r_i of insert M8 on the force-displacement dependencies

The variation of the potting radius in the hexagonal core showed an increase of the load-carrying capability of the insert potted into the sandwich structure. The most significant effect in the carrying capability was achieved for 1.25 multiple of the inner radius of the insert. The increase of the carrying capability was 19% for the insert M5 and 11% for the insert M8.

Acknowledgements

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