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MODELING AND ASSESSMENT OF FOLDED THERMOPLASTIC HONEYCOMB CORE SANDWICH STRUCTURES USING A REPRESENTATIVE VOLUME ELEMENT

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1. INTRODUCTION

To achieve the climate targets in transport industry a consistent implementation of lightweight construction is necessary. That's why the use of composites sandwich structures in automotive applications is increasing constantly due to their excellent specific mechanical properties and the resulting weight saving potential. Beside the ecological awareness, the economic effectiveness plays an important role for the choice of the most appropriate material. Sandwich structures with folded thermoplastic honeycomb cores and fiber-reinforced face sheets can be produced in an automated process with short cycle times [1, 2]. Furthermore the meltability of thermoplastics leads to further process relevant advantages like thermoformability and a high recyclability [3]. They are therefore of great interest to the automotive industry. EconCore (Leuven, Belgium) developed a novel and innovative semi-finished material combination which combines the advantages of a sandwich structure with the high specific mechanical properties of a thermoplastic FRP composite which enhances light weight potential and production effectiveness significantly [4].

These novel sandwich materials consisting of a folded Polypropylene (PP) honeycomb core and glass fiber reinforced PP face sheets were investigated in this study. A finite element model was built to simulate the mechanical performance and to validate correlation between mesoscopic honeycomb core structure and overall sandwich behavior. A Representative Volume Element (RVE) of the folded honeycomb core structure was defined in a Finite Element Model. The main objective was the determination of effective material properties for folded honeycomb core sandwich panels.

2. HONEYCOMB GEOMETRY AND PROPERTIES

The regular hexagons resulting in an optimal geometric arrangement of the honeycomb structure are inherently suited for saving material. In Fig. 1 is shown the geometry in principle on the left, the blue marked lines are the double walled surfaces, that are connected in the top and bottom region to the face sheets. On the right side in Fig. 1 is shown the cross section of the honeycomb structure, the L-direction is the stiffer and stronger direction along the double walls, across to them is defined the weaker W-direction. The red marked frame illustrates the selected region of the Representative Volume Element (RVE) for the Finite Element Model.

The folded PP- honeycomb core >THPP< is available form the company ThermHex Waben GmbH with different nominal densities, cell sizes and heights. In this work the densities of 60 kg/m^3 and 80 kg/m^3 THPP60 and THPP80 were investigated. They have nominal cell sizes of 8.0 mm or 9.6 mm and core heights of 10.0 mm and 20.0 mm. Some of these selected honeycomb cores and its mechanical properties are shown in Table 1. The material properties were determined by semi-analytical assumptions for honeycomb cores by Gibson and Ashby [5]. For the RVE model were assumed linear isotropic PP properties with an E-Modulus of 1800 MPa. The face sheets of two unidirectional sheets in 0° and 90° are made of glass fiber reinforced Polypropylene. The properties of the face sheet layers were measured by tensile testing, see Table 1.

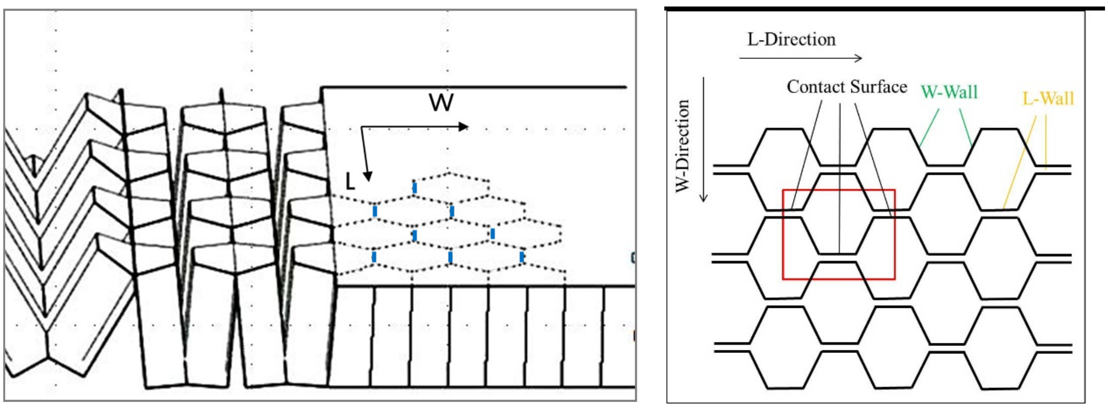

Fig. 1: Geometry of the honeycomb structure with double walls (blue lines left) and cross section of the honeycomb structure with region of RVE (red frame right).

Table 1: Properties of the sandwich components.

Sandwich Elements	E-Modulus [MPa]			Poisson ratio [-]			Shear Modulus [MPa]		
	E_1	E_2	E_3	ν_{12}	ν_{13}	ν_{23}	G_{12}	G_{13}	G_{23}
GFRP-PP face sheet	29˙233	3514	3514	0.33	0.005	0.005	3798	2000	2000
THPP60-10-8 –L	0.247	0.247	98.0	0.99	0.001	0.001	0.137	20.0	12.0
THPP60-10-8 –W								12.0	20.0
THPP80-20-9.6-L	0.583	0.583	130.4	0.99	0.002	0.002	0.320	26.1	16.9
THPP80-20-9.6-W								16.9	26.1

It has been found that the homogenized honeycomb properties are not suitable to estimate the global sandwich behavior in a FE model. That's why a simulation of the mesoscopic structure of the honeycomb core was made.

3. FINITE ELEMENTE MODEL

The overall objective was the determination of the effective material properties for honeycomb core sandwich panels as well as the components of the orthotropic stiffness matrix from 6 experiments (compression, shear, tension, bending) on the RVE model in comparison with experiment and global sandwich simulation.

The complexity of the geometry results from the continuous production process of the folded structure, see Fig. 2 on the left. This creates double walls at certain places as well as top-side caps one the honeycomb structure. The RVE can be arbitrarily laterally put together to expand larger models or provided laterally with periodic boundary conditions, see Fig. 2 on the right. The honeycomb walls as well as the top caps were modeled as shell elements. Between the double walled surfaces, there are defined contact elements in that region they are not glued together. At the face sheets they were assumed to be glued by hot press process during the face sheet application. The face sheets were assumed with linear elastic material properties and modeled as layered shell elements, too.

For the first steps the following load cases were regarded:

(1) Compression in the thickness direction

(2) Shear in W-direction.

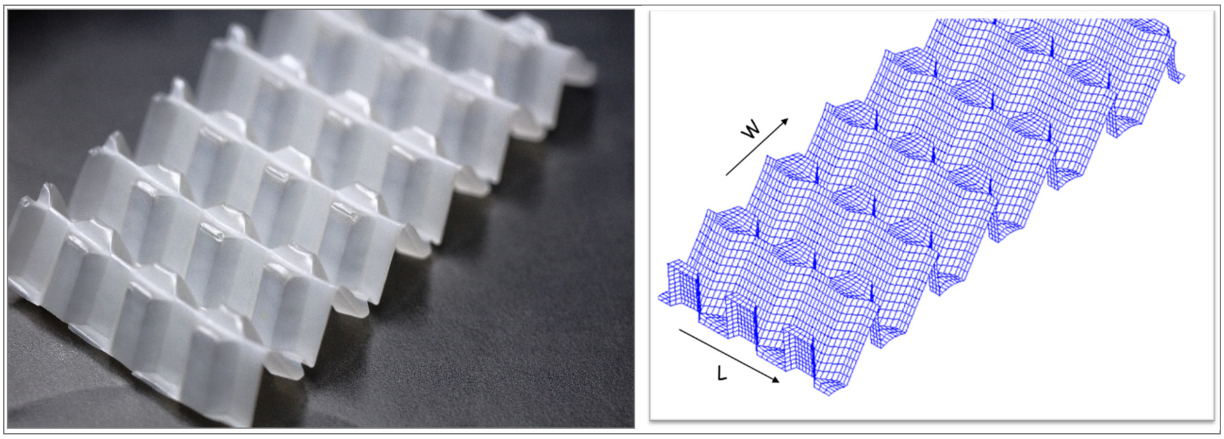

Fig. 2: Folded PP-Honeycomb core (left) and model mesh of 3x6 honeycomb elements without face sheets (right).

4. RESULTS

At first the general deformation behavior of the honeycomb structure was observed qualitatively. In Fig. 3 is shown the displacement of the honeycomb core in lateral direction at compression load of the whole sandwich structure in thickness direction, the core is plotted without top caps and face sheets. It is visible that the double walls of the honeycomb core buckles in s-shape formation.

In Fig. 4 is shown the deformation behavior in case of shear load of the sandwich structure in w-direction. The deformation behavior as well as the force-deflection performance from the simulation has to be compared to experimental results of compression and shear load tests. Depending on these results it has to be decided if a nonlinear material behavior of the PP material has to be implemented. Due to the fact that the folded honeycomb is produced by deep drawing of the PP material, it may happen that in certain areas deviating material properties occur within the PP honeycomb or varying thicknesses could result in varying stiffness's. This has to be proofed for example by computer-tomographic analysis of the honeycomb structure. In addition, it will be investigated which influence the double walls have on the bonding behavior to the face sheet layers.

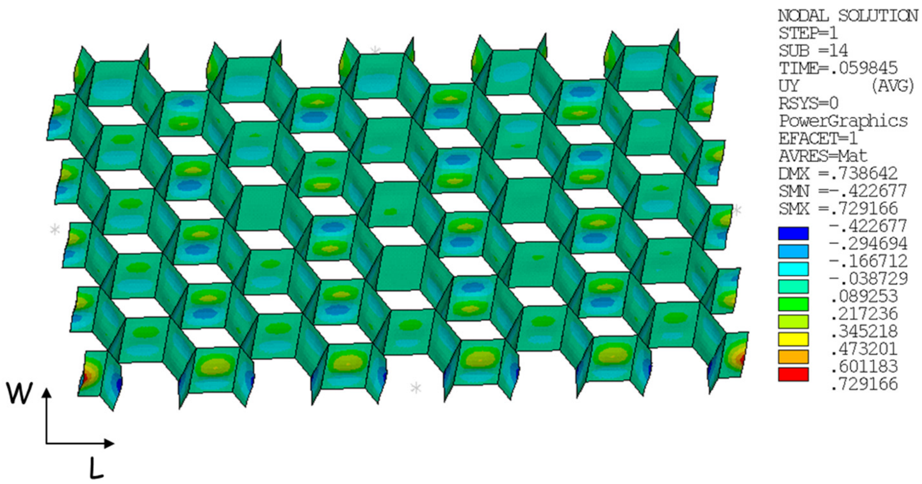

Fig. 3: Nodal Displacement of honeycomb core in lateral direction at out of plane compression load of the sandwich element.

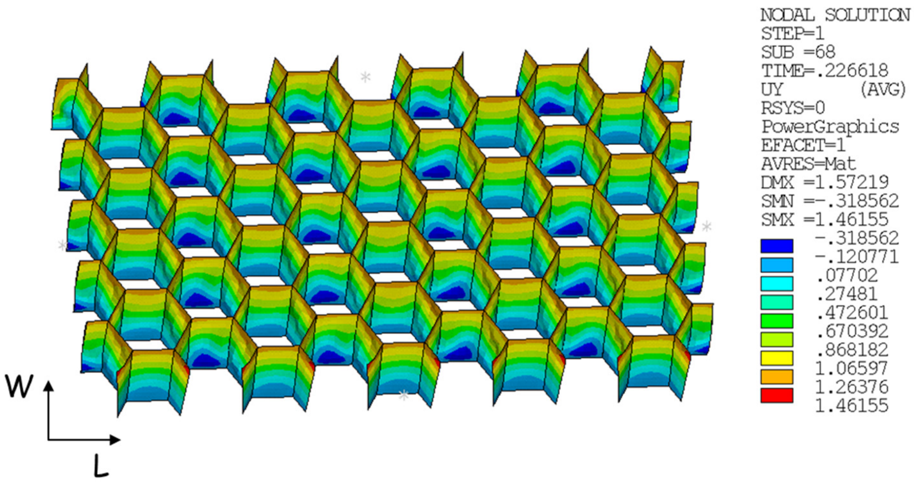

Fig. 4: Nodal displacement of honeycomb core in lateral direction at shear load in w-direction of the sandwich element.

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