FAILURE OF SANDWICH COMPOSITE FOAMS AND MICROSTRUCTURAL ANALYSES OF THEIR BEHAVIOUR

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Abstract: In the development of a new generation of advanced sandwich composite materials with special destinations, the mechanical testing is a prerequisite for a better understanding of their behaviour as to be able to calibrate the constants of the material. Without this step any modelling and simulation will be useless in the development of inovative structural components and structures. The refinements of the microstructural analyses are presented hereby for a better understanding of the response of the materials to different loadings.

Keywords: composite foams, mechanical testing, failure, microstructure

1. PRESENT EXPERIENCE AND PROPOSED THEORETICAL APPROACHES

Tensile tests, three and four points bending, and mode I, mode II and mixed mode fracture tests have been made previously, for different composite combination. By an interdisciplinary research, with the help of materials science specialists, analyses have been performed to put into evidence particularities of damages formation, depending on material and load. The results targeted were the set up of theoretical models, specific to each material and the formulation of calculation models and numerical simulation models of the damages extension that will lead to propagation rules meant to establish new laws for controlled damage and better durability and reliability. In the research that started to be done new theoretical and experimental approaches will be used, new high complexity types of tests will be performed and new structural components will be designed in a more appropriate manner. Finally, the likely possibility is to design specific composite materials for a certain application. The cracks initiation and propagation in active materials that can adapt to loads by continuous changes of properties will be analysed.

Thus, the results targeted is the analysis to a scale between the micromechanic one (at the fiber and matrix level) and the macromechanic one (laminate level). The appropriate working theory should be named *the mesomechanic theory of damage of composites* and its origin lies in a new mechanic area, named *damage mechanics*. Basically, once the damage is produced, the material loses its initial stifness and shows a unlinear behaviour. The nonelastic response is given by a remanent strain after the removal of load. Because such a process is irreversible, a parameter must be find for the best description of the damage.

More than that, in recent years, the cohesive zone modelling approach has emerged as a popular tool for simulating fracture processes in materials and structures due to the computational convenience. In the cohesive zone approach, it is assumed that, ahead of the physical crack tip, there exists a cohesive zone which consists of upper and lower surfaces (cohesive surfaces) held by the cohesive traction. The cohesive traction is related to the separation displacement between the cohesive surfaces by a cohesive law, or *cohesive zone model*. Upon the application of external loads to the cracked body, the two cohesive surfaces separate gradually, leading to the physical crack growth when the separation of these surfaces at the tail of the cohesive zone (physical crack tip) reaches a critical value. Although the cohesive zone model was originally proposed for Mode I fracture, for the purpose of removing the crack tip stress singularity, this condition has not been strictly observed by many researchers who employed the finite element method for numerical solutions. It has been shown that the necessary condition to eliminate stress singularity at the tip of the cohesive zone is that the cohesive traction must have a nonzero value at initial vanishing separation displacement. By allowing the existence of the stress singularity at the cohesive zone tip, additional fracture energy dissipation mechanism is present besides the fracture process in the cohesive zone. Moreover, it is often assumed that the fracture energy in the cohesive zone model is the same as the critical energy release rate in LEFM. This assumption is true only when the cohesive zone size is vanishingly small. For cohesive laws with initial zero traction that have been widely used the results showed that the cohesive traction first increases from a nonzero finite value at the beginning of separation, quickly reaches the peak, and then decreases with further increasing separation displacement.

2. EXPERIMENTAL EVALUATION OF MECHANICAL PROPERTIES FOR COMPOSITE FOAMS

With the financial help provided by sponsored research it was possible to acquire a modern computer controlled generation testing machine LRX Plus produced by Lloyd Instruments. The maximum force is of 2.5 kN and the software NEXYGEN plus allows real time data acquisition and statistical analysis.

Up to date traction, compression and three-point bending tests showed with a high level of refinement the behaviour of the tested foams and glass or carbon fibre skins. Only as an example, we present in figure 1 the characteristic curves obtained in traction for the polyurethane foam with density 200 kg/m^3. The influence of the resin which impregnates the foam is evident in the non-linear domain, in such a way influencing the cohesive zone model parameters.

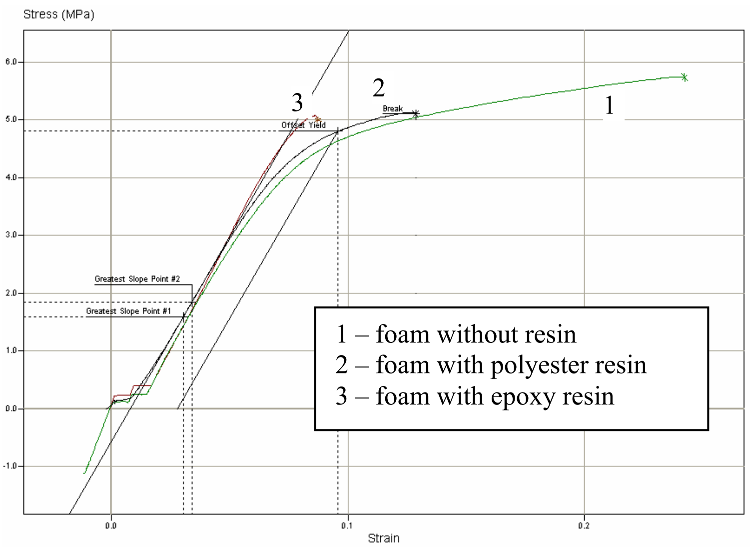


Fig. 1. Characteristic curves for polyurethane foam.

3. MICROSCOPIC ANALYSES OF SOME FOAMS

In order to be able to understand the behaviour of a layered or sandwich composite it has ben found to be necessary to understand the microstructure of each constituent and its mechanical properties. The design of a specific composite can be tailored only in such circumstances. We concentrated our investigations on different foams that form the core of sandwich composites as we believe that such composites have a huge potential in practical engineering applications.

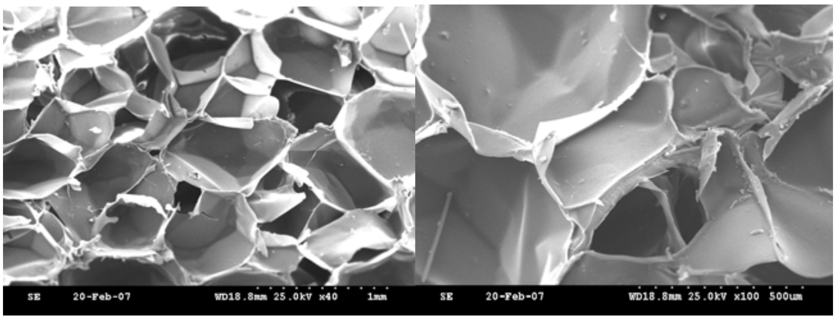
The SEM investigations of different types of composite materials were done by using an equipment HITACHI S2600 which has also a dispersive energy analysis system. The specimens which were examined are notated as follows:

Table 1. Foam specimens analysed through SEM.

Specimen no.	Material
1	PVC foam
2	Coremat
3	Extruded polystirene
4	Polyurethane foam with density 200 kg/m^3
5	Polyurethane foam with density 40 kg/m^3
6	Expanded polystirene
7	Glass fibre woven fabric
8	Carbon fibre woven fabric

The SEM examinations established the morphology, the dimensions and arrangement of the microstructural entities as to corelate them with the microstructural characteristic properties. Untested and tested specimens were analysed as to be able to observe the changes in the microstructure at the very intimate level. As the composites are non-conductive from electrical point of view all specimens were covered with a silver thin layer of thickness as 5-6 A. By also taking into account the high level of light chemical elements (C,H,O, etc.), the only element on which was done a local qualitative microanalysis with X rays was the Coremat specimen.

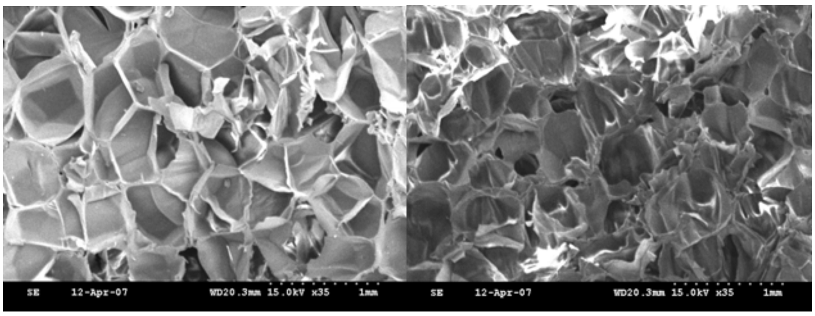
Only as examples, we show the pictures obtained on the PVC foam and the Coremat core. The untested PVC foam specimens have voids of about 200-500 μm and a wall thickness of 3-4 μm; these are smooth with no striations. Figure 2 shows the microstructure of the foam.



a b

Fig. 2. Specimen no. 1. Voids have dimensions in between 200-500 μm.
Wall thickness of 3-4 μm (a-x40; b-x100)

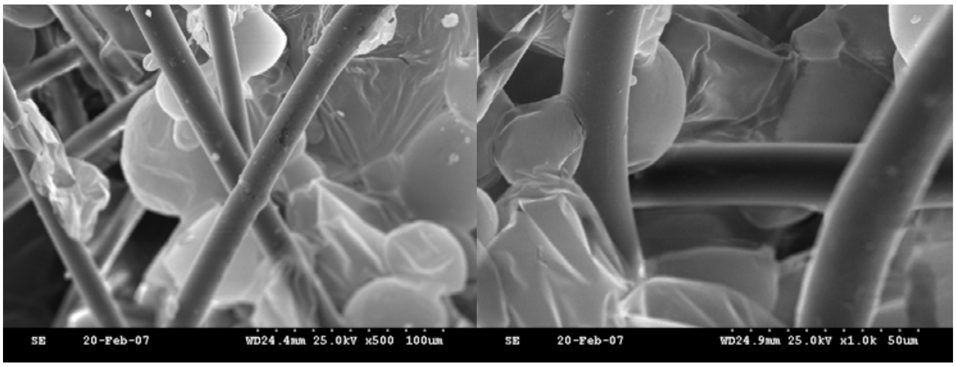
After being tested in compression (the only possible loading to be applied in this case) the specimen behaved mostly elastically as the voids kept their poliedral shape after the removal of the loading, but reduced their size. However the walls showed some wrinkling in a consistent way for all tested specimens (Fig. 3).



a b

Fig.3. Specimen no.1: a - untested; b - tested in compression. Wrinkling of walls due to loading (x35).

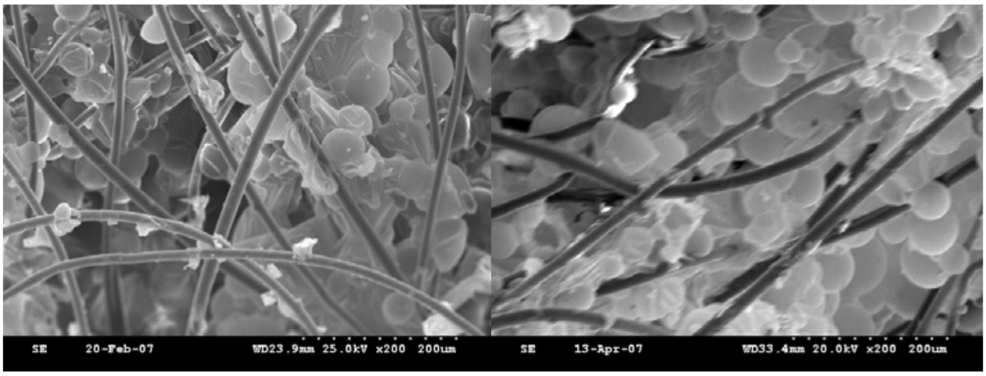
For the Coremat core (very much used for sandwich composites) the fibres of diameter 10 -12 µm have a random orientation with the spaces in between fibres partially occupied by rounded particles, some of them even spherical (Fig. 4). Qualitative X rays analysis showed chemical elements as Si, Cl, Ti with traces of Cu.



a b

Fig. 4. Microstructure of specimen no. 2 (Coremat). Fibrous structure with voids filled with rounded particles, some of them sherical. (a-x500; b-x1000)

The loading in traction gives the extension of the fibres and their orientation along the direction of loading, the separation of the conglomerations of spherical particles and the failure of the fibres together with the formation of bigger microcracks. In figure 5, pictures of a – untested and b – tested specimens are not taken in the same location, therefore the inclination of fibres is different. Such a specimen could be tested only in traction as the delivered material is of thickness of about 3 mm.



a b

Fig. 5. Microstructure of specimen no. 2 (Coremat): a - untested; b - tested in traction, for same magnification (x200).

4. CONCLUSIONS

Damage initiation and formation of microcracks is investigated at micromechanical level together with a more refined mechanical testing. The effects at macroscopic level are to be seen as a result, and encourage us to pursue our investigations. These preliminary experimental observations lead us to the conclusion that a careful design of a composite as to obtain specific properties is possible, but has to be done with care. Without this, any modelling and simulation will be useless in the development of innovative structural components.

REFERENCES

http://www.lloyd-instruments.co.uk/ products/ materialsoftware.cfm