Delamination effect on compression loadings of hybrid sandwich composite

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Abstract: *The idea of hybrid sandwich structures made of polymeric sheets and RVC foams represents a new research topic which is directly related to the interaction between thermal shock wave and structural insulation panels, dynamics of thermal motions, delamination effect during the compression loads and fracture mechanism of the structure. The RVC (reticulated vitreous carbon) foams are very attractive for aerospace industry, especially for impact absorption. Development of hybrid sandwich system made from polymeric composite materials presumes a high degree of complexity. Aspects such as the conception, design and construction of both the materials and the product itself are corroborated taking into account the properties of the materials and the functional need. The technical approaches of this paper are mainly focused on the compression behavior of the hybrid sandwich composite structure, being the first step in finding an optimal structure for the system. The behavior will be analyzed using the microscopy technique.*

Key Words: *delamination, compression, hybrid, sandwich, RVC foam*

1. INTRODUCTION

Reticulated vitreous carbon foam (RVCs) with open pore structure are attractive materials for applications in the aerospace industry (super-light structural materials or core sandwich materials from thermal protection systems [1], [3]), due to their physical, chemical and mechanical properties, low density (up to 0.05-0.03 g/cm^3) and very high operating temperatures (up to 2000°C in non-oxidative environments). These permeable structures allow the cooling medium to circulate through the sandwich core structure and are not affected by vacuum or decompression environment conditions [4].

RVC foams with open pores can be made by pyrolysis in inert medium at over 1000°C of precursor foams previously made from various resins (phenolic, epoxy, furfuryl alcohol) [4-11]. The resulting material is transformed into carbon, retaining its cellular structure, except for small volumetric changes, being a material with a density of about 2/3 of that of graphite, but with superior mechanical properties [4, 5].

The most well-known process for making precursor resin foams is by replication. The replication method approached by the RPMI partner involves several steps of impregnating a cross-linked polyurethane foam support (PUF) with an ethanolic bakelite solution (thermoreactive phenol-formaldehyde resins).

The PUF support is immersed in the bakelite solution and centrifuged to remove excess solution, leaving a thin layer of PUF on the substrate, the thickness of which can be controlled from the concentration of the bakelite solution.After drying, the impregnation can be repeated to increase the thickness of the layer.

The density range thus obtained is of 0.07-0.35 g/ cm^3. The RVC foam resulting from the pyrolysis of the structure has the structure shown in the figure below. The porous structure is composed of fully interconnected open cells in which the connecting elements are the edges of the agglomerated polyhedra [4].

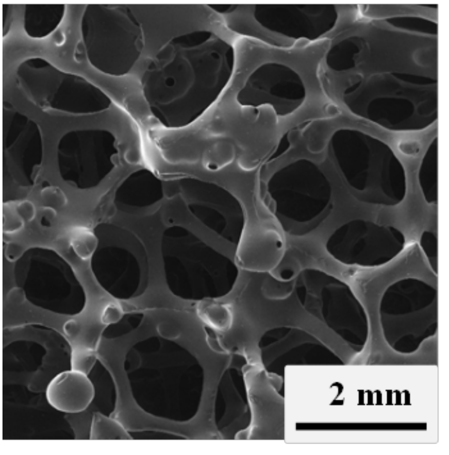

Fig. 1 The structure of an open cell reticulated vitreous carbon foam obtained by PUF structure replication [4]

The RVC foams are suitable for sandwich composites system used especially in the aerospace industry.

The main advanced feature of the sandwich structures are the properties adjustment according with technical requirements in choosing the component materials. The CFRP's faces are the latest trend in structural sandwich system with foam core. [3]

2. EXPERIMENTS

Materials

Three types of RVC (Fig. 2) obtained by PUF structure replication were used for the experimental part.

The realization/ development and characterization of the core from VC (reticulated vitreous carbon foam - RVC) was provided by the partner RPMI from Belarus. The difference between them is the density of the final material.

According to the preliminary mechanical testing results given by the Belarusian partner, the foam with the lowest density has the minimum compressive strength:

- RVC 1 (Fig.2.a)): Density = 0,173 g/cm^3, Compression/ compressive strength (approx.) <1 MPa;
- RVC 2 (Fig.2.b)): Density = 0,175 g/cm^3, Compression/ compressive strength (approx.) <1 MPa;

- RVC 3 (Fig.2.c)): Density = 0,399 g/cm^3, compressive strength (approx.) <3 MPa.

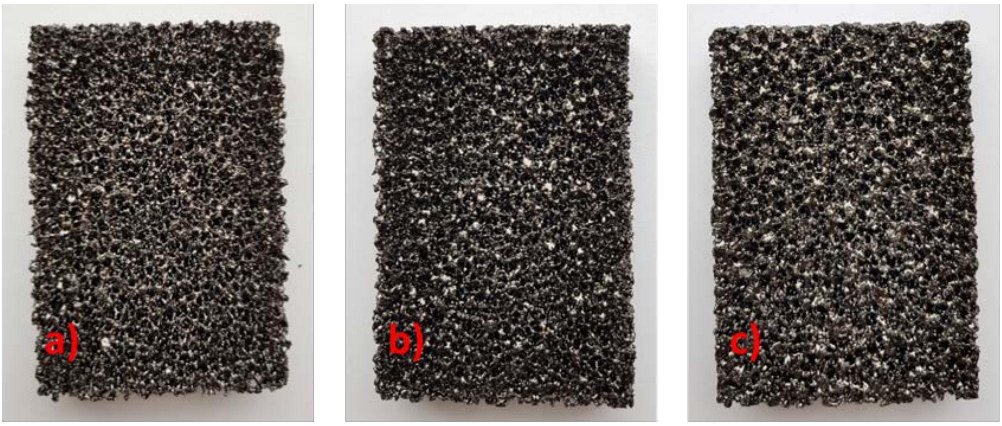

Fig. 2 The three types of RVC used for the experimental determination

These materials were used as core for sandwich structures with composite material skin from 3 carbon fiber (3FC) reinforcement and epoxy resin (epoxy) matrix.

Fig. 3 The three types of sandwich structures obtained by INCAS using 3 FC / epoxy skin and RVC core

Processing and testing methods

The manufacture of fiber composite and epoxy matrix based on carbon fiber fabric was carried out using the technology of the pressing mold, using a hydraulic press (Carver) with heated platens. The technology of making composites was performed under the conditions imposed by the technology of this class of material (reinforced fabric) and pressing temperature technology.

The testes were carried out on the sandwich structures samples (Fig. 3). To evaluate the mechanical properties, the sandwich structures were subjected to mechanical testing using INSTRON 5982 machine.

The sandwich samples with different formulations were mechanically studied at room temperature according to ASTM C 365 Standard test method for flatwise compressive properties of sandwich cores (Fig. 4).

Table 1. The average of samples dimensions used for mechanical testing

Sample no.	**Carbon foam density [g/cm^3]**	**Specimen width [mm]**	**Specimen length [mm]**
1. (fig. 3.1)	0,173	15.750	34.250
2. (fig. 3.2)	0,175	15.500	34.900
3. (fig. 3.3)	0,399	15.500	34.000

Fig. 4 Compression testing of sandwich structures made of 3FC / EPOXY and RVC foam core: before testing, during testing and after compression testing

Fig. 5 The three variants of sandwich structures made of 3FC / EPOXY and RVC foam core after compression testing

3. RESULTS AND DISCUSSIONS

Mechanical compression testing of sandwich structures

Following the mechanical compression test of the three types of sandwich structures (Fig. 5), a clearly superior behavior is observed and the resulted values for both compressive stress and modulus are directly proportional to the density of RVC foam used as core (Table 2). For each batch of samples, values outside the mean range were eliminated.

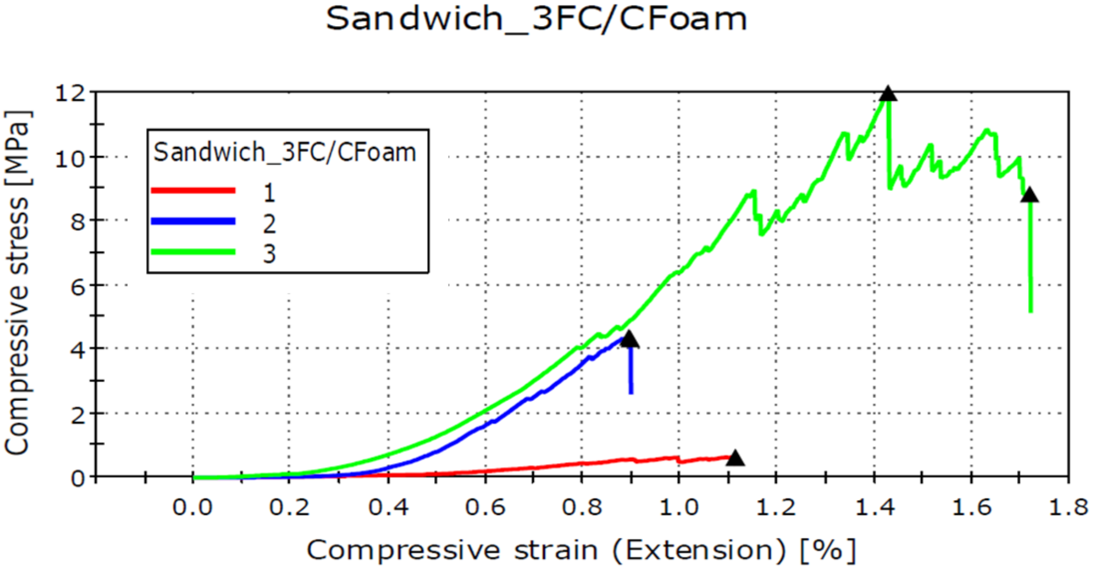

Fig. 6 Compressive strain-stress diagram

Table 2. The average results of compression tests on 3FC/VC foam sandwich structures

Crt. No.	Load [kN]	Compressive stress [MPa]	Modulus [MPa]	Compressive strain (Extension) [%]
1.	0.346	0,641	0,154	1.11
2.	2.360	4,362	1,177	0.89
3.	6.301	11,955	2,067	1.43

Electron microscopy structural analysis

The morphological characteristics of the foam were investigated by SEM using a QUANTA 250 FEI scanning electron microscope equipped with an EDS module, in low vacuum conditions. The samples were analyzed morphologically to study the adhesion between the faces and the RVC core.

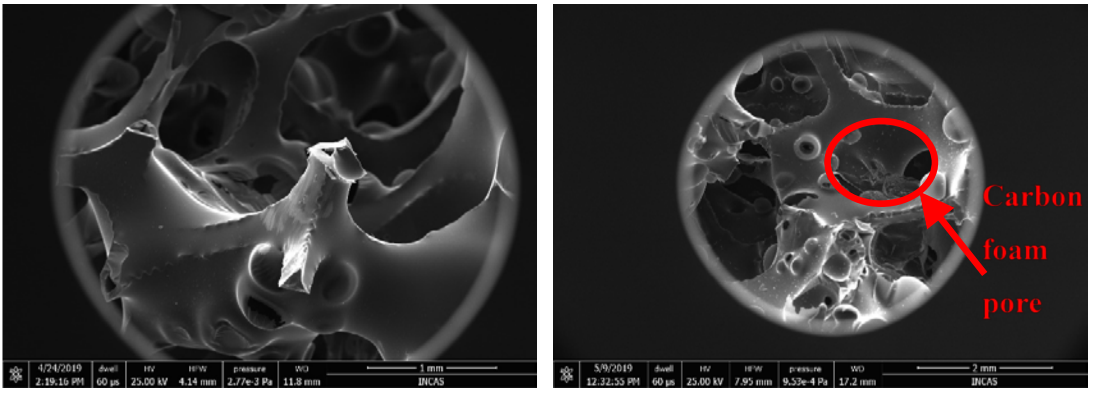

Fig. 7 FEM results for ILSS delamination prediction

From the microscopic analysis it is observed that there is a very good adhesion at the RVC foam - CFRP's faces interface presenting a fragile behavior inside the VC foam structure.

4. CONCLUSIONS

The present paper presents the results of compression tests on the type of sandwich samples made of CFRP faces and three RVC cores with different density to study in particular the adhesion to the interfaces.

The composite materials were subjected to mechanical compression tests, after which they were analyzed microscopically using electronic technique. The foam was mechanically tested and analyzed morphologically to see the compressive strength and to easily set the parameters for making hybrid sandwich composites. The results were corroborated with the results of hybrid sandwich composites that were mechanically tested and morphologically analyzed using optical microscopy technique.

Considering the results of the experimental studies, it should be mentioned that the manufacturing process and the geometry may interfere in the delamination process.

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