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CHARACTERIZATION OF SANDWICH STRUCTURAL COMPOSITE WITH EXPANDED POLYPROPYLENE NUCLEUS

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Abstract. *The laminated structures and sandwich structures are widely used because of their high structural efficiency, not only individually but also combined. The present work presents mechanical characteristics of sandwich beams composed of expanded polypropylene, carbon fiber and epoxy resin, aiming the application of this material in the structural development of a radio controlled aircraft, for the participation in SAE Aerodesign Brazil competition. In this Engineering Challenge, undergraduate students are required to develop a complete aircraft design for a small aircraft, including development and selection of materials. The mechanical characterization of the materials under study was performed in the laboratory from bending tests. The composite studied presented satisfactory results, mainly regarding the vacuum lamination method, showing to be relevant as to the possibility of application in aerodesign structures.*

Keywords: *composite, sandwich structure, expanded polypropylene, carbon fiber, epoxy resin*

1. INTRODUCTION

In agreement with Callister (2008), a composite is the combination of two or more individual material, with purpose of to join the best characteristics of each material, creating a combination, which may present a high performance of tensile, corrosion resistance, rigidity, fatigue and especially weight. The composites systems can be divide in three groups: composites reinforced with particles, composites reinforced with fiber and composites structural. Within the structural composites, the most typical structures are the laminates and the sandwich panels/structures.

The sandwich structure, one of the most common in composite materials, is a laminated structure in which the composite is formed by several layers or blades superimposed on each other. The structure consists of two outer layers (low thickness and high stiffness) and an inner layer, the core (greater thickness, lower density and stiffness) (Gama, 2017; Costa, 2017).

Sandwich structures have been used mainly by the need to ally high resistance with low specific mass, encouraging the development of new researches, as in automotive, aerospace and civil construction applications (Almeida et. al, 2010; Mira, 2013; Oliveira, 2015; Toledo, 2016).

According to Lopes (2009), the combination of a matrix that presents low specific weight with a reinforcement of high resistance can lead to the obtaining of a composite of excellent performance. Its properties depend on the properties of its constituent materials and on the interaction between these elements (Carneiro and Teixeira, 2008). As a reinforcing material for sandwich structures, carbon and glass fibers represent the most versatile materials today. While the commonly used resins are epoxy (higher cost but better strength) and polyester resin (lower cost and ease of production). The resin acts on the propagation of the force applied on the composite between each of the fibers (Lopes, 2009).

In relation to the core of this type of composite, this is found in different ways in the research. In the search for materials that result in higher performance structures, there are works that evaluate the core constructed with natural materials, such as bush (Motta et. al, 2016) and balsa wood (Gama, 2017), and with polymeric materials such as polyurethane, polyvinyl chloride and divinycell (Costa, 2017; Belbute, 2010; Gama, 2017).

The Polypropylene (PP) is a thermoplastic polymer that has low cost production potential for its versatility of being used in both extrusion and injection molding. The Expanded Polypropylene (EPP) is a thermoplastic foam obtained from the processing of PP, where it has significant use in the automotive industry, especially in bumpers, due to its high impact

resistance. It can be considered as an inexpensive and viable option for application in aeronautics, due to its low weight and high impact resistance. (Silva, 2017; Souza, 2013).

The development of a sandwich composite occurs through the lamination process, much used in the bonding between the components. Initially, a resin layer is applied over the components to be bonded and then a resin impregnated fiber reinforcement layer is added until the desired thickness is obtained (Carneiro and Teixeira, 2008). In the lamination process, it is important that all the spaces on the surface of the composite are filled with material, avoiding the formation of air bubbles as much as possible, as they may at the end of the process act as discontinuities and, consequently, as places of tension concentration.

According to Cândido, Almeida and Rezende (2000) and Bush (2019), one of the forms of pressing in the lamination is through the application of vacuum in the process, necessary operation to obtain the uniform compacting of the layers, avoiding the formation of porosities or voids and removing excess resin. For this process, it is necessary to make a bag of flexible plastic film whose type of material chosen is compatible with the temperature and curing time of the laminates and is resistant to pressure. In assembling this bag, it is also necessary to use auxiliary materials such as separating fabric, excess resin absorbing fabric, plumbing cloth for removing air, compaction plate, vacuum nozzle and sealant tape to seal the bag throughout its contour.

This work aims to investigate the properties of a composite made of expanded polypropylene, epoxy resin and carbon fiber, intended to be applied in the design of a radio controlled aircraft, developed to participate in the SAE Aerodesign competition.

2. METHODOLOGY

The simplest types of sandwich composites consist of two thin sheets, called faces, with high stiffness and density, usually composed of carbon and glass fibers, separated by a thick layer with a lower density and stiffness called a core, as may be shown in Figure 1 below.

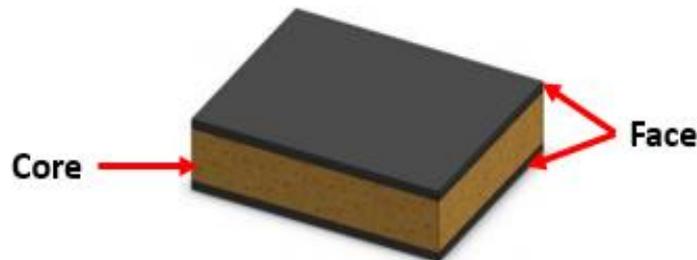


Figure 1. Components of a sandwich structure. Source: Belbute (2010).

The faces, or skins, are composed of thin layers, in which the materials have high stiffness and resistance to flexion and traction. The core has a less dense material and a structural rigidity much lower than the faces of the sandwich structure, but with sufficient stiffness to resist the deformation of the structure.

The composite in which the tests were carried out was a sandwich-type structure with expanded polypropylene core and laminated with one layer the carbon fiber coating (average weight of 200 g/m², 4 wires/cm in the weft and warp) and epoxy resin (resin to catalyst ratio of 2: 1). The composite was laminated through a vacuum system, in curing time of approximately 12 hours.

The vacuum lamination was performed through a vacuum piston pump and a mold constructed of glass and plastic layers, Figure 2. After manually laminating the mold, the system was isolated and generated vacuum through the pump, suctioning the air to remove excess resin.



Figure 2. Vacuum lamination procedure. Source: Authors.

Samples of the composite formed by expanded polypropylene and carbon fiber were submitted to the bending test, following the ASTM C393-00 standard, as can be observed in Figure 3. The tests were performed fully computerized from the Universal Testing Machine model WDW 200-E, shown in Figure 4. Six test specimens were used for sampling and a displacement velocity of 2 mm/min.



Figure 3. Specimens prepared for the test. Source: Authors.

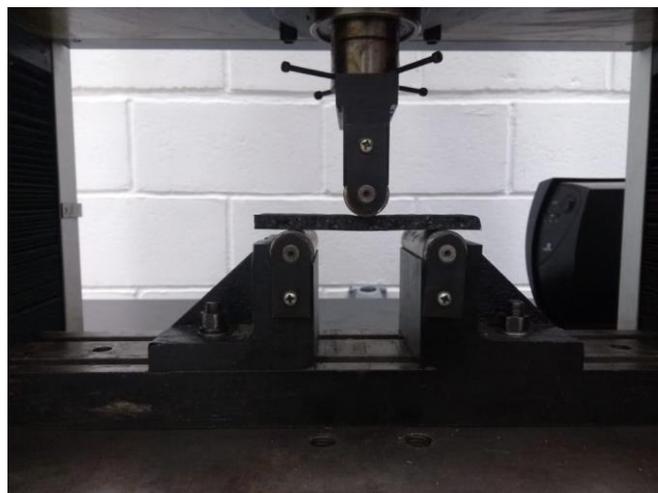


Figure 4. Testing body being tested. Source: Authors.

3. RESULTS

The first line of observation in the post-treatment of the specimens was the type and characterization of the fracture. It was possible to observe in all the specimens the fracture by shear of the nucleus, but without detachment of the faces, as also analyzed in Motta et. al (2016). The Figure 5 shows a visual analysis of one of the test specimens.

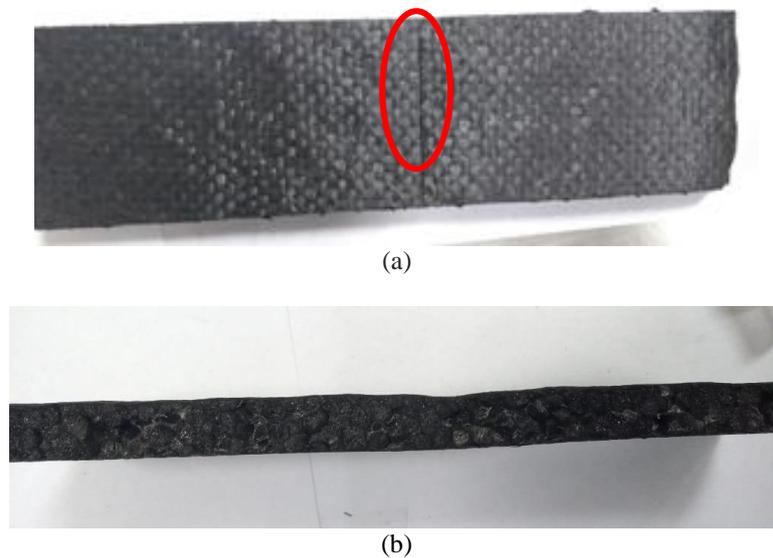


Figure 5. Fractured specimens after bending test. (a) top view. (b) side view. Source: Authors.

The tests were carried out on six test specimens and a mean of the values was obtained. In Figure 6, it is possible to observe the behavior of the specimens during the tests.

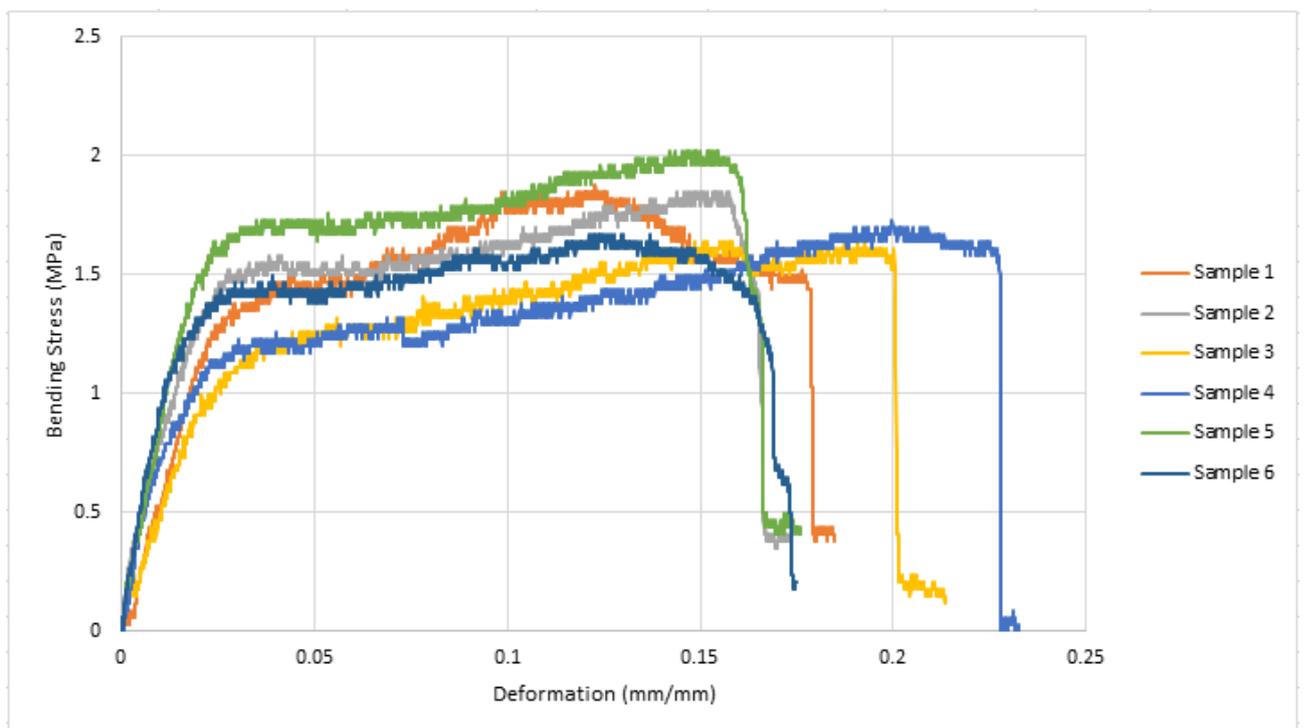


Figure 6. Experimental results for the flexural properties of the composite. Source: Authors.

The Tab. 1 presents the medium values of the physical-mechanical properties of the specimens manufactured.

Table 1. Results of the Bending Test. Source: Authors.

| | Maximum resistance to static bending [Mpa] | Maximum shear stress [Mpa] | Modulus of elasticity to the static bending [MPa] |
|--------------------|---------------------------------------------------|-----------------------------------|----------------------------------------------------------|
| Average | 1.7974 | 0.1815 | 20.2665 |
| Standard Deviation | 0.1444 | 0.0146 | 4.1010 |

The obtained results show that the bending strength of the composite with expanded polypropylene core is small compared to other composites with different cores. Costa (2017) developed polyurethane and polyvinyl chloride core composites, while Gamma (2017) analyzed the properties of a balsa wood core composite and Divinycell H45®, in which both authors evaluated composites with properties superior to analyzed in this research. However, the composite of this work presents superior bending strength to the composites of polyester resin with bush core and composites of epoxy resin with expanded polystyrene core, both laminated with rami wire bidirectional fabric faces (Motta et. al, 2016).

An important parameter when analyzing composites used in aeronautics is the density, which in this study is represented by the planar density observed in the Tab. 2 below.

Table 2. Experimental results of planar density of samples. Source: Authors

| Samples | Mass (g) | Planar Density (kg/m²) |
|--------------------|-----------------|------------------------------------------|
| 1 | 6.30 | 1.03 |
| 2 | 6.49 | 1.06 |
| 3 | 6.59 | 1.08 |
| 4 | 6.30 | 1.03 |
| 5 | 6.32 | 1.03 |
| 6 | 6.49 | 1.06 |
| Average | 6.41 | 1.05 |
| Standard Deviation | 0.12 | 0.02 |

It can be seen that the planar density had an average value of 1.05 kg/m², showing that the composite has an acceptable resistance to density ratio.

4. CONCLUSIONS

We can say that the first experiments with this material were encouraging, we can attribute the reduced resistance presented by the material to the poor sizing of the faces, and a better balance of the properties of the core and faces is necessary in a later study.

In general, it should be noted that the result of the planar density obtained was satisfactory, since the generally used material presents approximately 2.4 kg/m² and the new composite presented 1.04 kg/m², therefore, even though it is necessary to add of thickness on the faces, this laminar density can represent an economy in the final weight of a structure with the alternative material.

As suggestions for future work, the evaluation of the mechanical properties of tensile and compression tests is expected, and the behavior of the composite with the addition of more layers of carbon fiber on the faces is analyzed.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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