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EVALUATION OF THE MECHANICAL PROPERTIES OF Balsa WOOD AND COMPOSITE MATERIALS

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Abstract. *Balsa wood is a lightweight, tough material and is largely used in the manufacture of radio-controlled aircrafts. By combining low specific mass and high mechanical strength, the material has been proven efficient in its applications. Therefore, it is very common to manufacture composite materials from balsa wood to provide better mechanical properties allied to the wood low specific mass. This paper evaluated the behavior of the mechanical properties of wood as well as confectioned and realize mechanical tests of traction and bending in composites made from a balsa core and coated with carbon fiber coated being varied the resin used during the manufacturing process. The proprieties characterization of the wood and composites shows that, the process of laminating wood with carbon fiber provides a significant improvement in the mechanical properties of the specimen. Moreover, the use of epoxy resin proved favorable to the use of polyester resin, since the first provides a higher limit of traction resistance, flexural resistance and a lower final density of the material.*

Keywords: *Composite materials, carbon fiber, traction tests, bending tests.*

1. INTRODUCTION

Balsa (*Pyramid Ochroma*) is a type of light wood, resistant and widely used mainly in the manufacture of radio-controlled aircraft. By combining low specific mass and high mechanical strength, the material is shown to be efficient in its applications. Therefore, since the woods are generally considered material Anisotropic, rupture plans occur in preferential directions, a fact that requires caution associated to the orientation of their employment in a structure.

The use of advanced composites in structural parts of aircraft increases each year due to the excellent mechanical properties that this material gives to the component being designed and for allowing flexibility in the design of complex parts and with specific local properties (Rezende and Botelho, 2000).

Among the hybrid composites there is the sandwich type consisting of two thin layers of rigid blades of low thickness with a larger core, composed of a material less dense and with less resistance. With this, a composite is obtained with the resistance of its external blades, resistant to traction and compression, and with the characteristics of its core with high resistance to bending and low weight (Gama, 2017).

When working with this type of material, it is expected to obtain an element that has greater rigidity when compared to the materials used as core. The structure obtained in addition to being resistant most often also presents lightness, which makes this type of material widely used in the aeronautical industry, civil construction and various areas of engineering that need to align two or more properties.

According to Tita (2007), the structure created is a special type of laminate. External surfaces tend to withstand the normal tensile, compression, or shear stresses that are associated with flexion. The interior named with nucleus, has the function of keeping the faces apart and must present rigid enough in the direction perpendicular to them, so that the crushing of them is avoided.

One of the most effective methods to evaluate the mechanical properties of a material is conducting mechanical tests of traction, compression, bending, hardness, fatigue, among others. Through them it is possible to raise important data that allow a quantitative evaluation when you want to evaluate and compare two or more types of materials.

The present paper evaluate, by means of traction and bending tests, the mechanical properties of balsa wood and compare them to the matrix of the same material as a carbon fiber laminated composite varying the types of resin applied to lamination process.

According to Callister (2008), the traction test consists of submitting the material to an axial load that tends to lengthen it until the rupture. Such assays allow to know how the materials react to traction efforts, which are the tensile limits supported by the material under study, as well as the necessary load to the body's failure. The bending assay, in turn, consists in the application of an increasing load at a given point, directed perpendicularly to the length of the specimen. It is used to determine the properties of flexural strength, modulus of elasticity, deformation under bending, etc.

2. METHODOLOGY

All the mechanical tests were performed in the universal testing machine in a fully computerized manner, so that, as the specimens were stretched, it was generated through a software aggregate the machine, a database that allowed further analysis through stress curves as a function of deformation. The velocity of the claw displacement used in all assays was 2 mm/min.

2.1 Traction tests

Six balsa wood test specimens were manufactured based on the dimensions presented by ISO 13061:2014 standard. Figure 1 illustrates the specimen with the respective quotas.

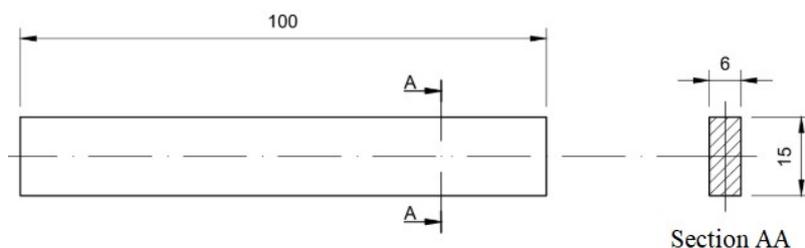


Figure 1. Specimen used on traction tests.

The same number of specimens (with the same dimensions of the balsa wood specimens) was used to test for each composite material configuration. The test methodology was performed on the basis of ASTM D3039.

To obtain more precise and coherent deformation data, ignoring the uncertainties related to the slides or lack of calibration resulting from the universal machine, an extensometer was used to the test body. This instrument was directly connected to the software.

The software connected to the test machine provided the test data relating the force applied longitudinally to the body of proof to the absolute deformation by this suffered. From this it was possible to trace the stress-strain charts of the specimens with the help of Microsoft Excel. Based on the interpretation of the curves data, it was possible to establish the mechanical properties that characterize the material.

2.2 Bending tests

The bending tests were performed based on ASTM C393-00, which presents the methodology, as well as the necessary dimensions to the specimens, as illustrated on Figure 2.

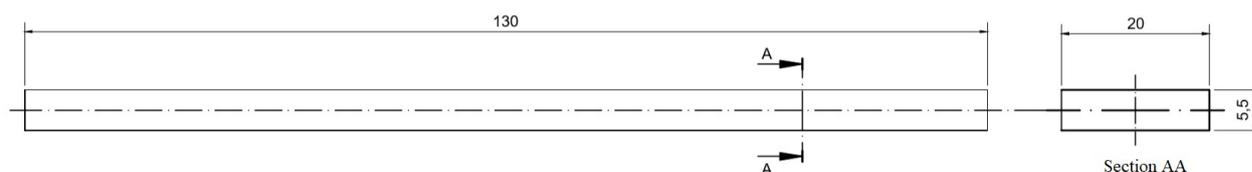


Figure 2. Dimensions of the specimens used on bending tests.

The test body was supported at the ends of the machine and the load was applied at the center of the unit. Figure 3 shows the performance of the traction and bending tests.

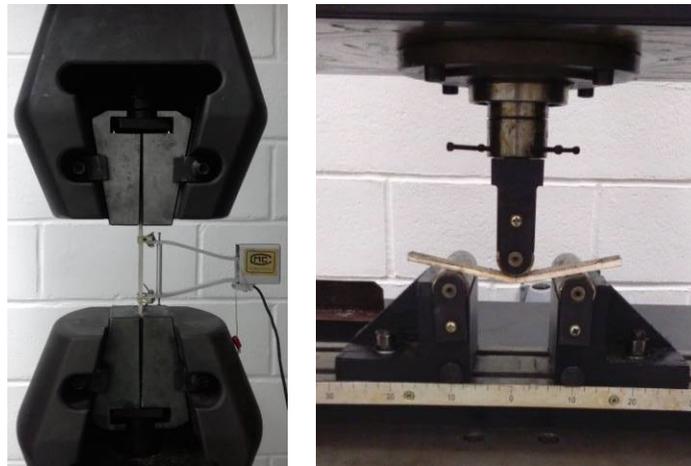


Figure 3. Realization of the traction and bending tests.

3. RESULTS AND DISCUSSIONS

3.1 Results for the traction tests

The curves obtained from the traction tests are showed in this section. Computational resources were used that allowed estimating important properties of the materials. The Fig. 4 illustrates the tension/deformation curve for the balsa wood (BW) used in the tests. Fig. 5 shows the curves obtained for the traction tests of the composite of balsa wood matrix coated with carbon fiber 200 (CF200) and epoxy resin (Ep). Similarly, Fig. 6 represents the curves generated in the tests of the material made from the balsa coated with carbon fiber using polyester resin (Po).

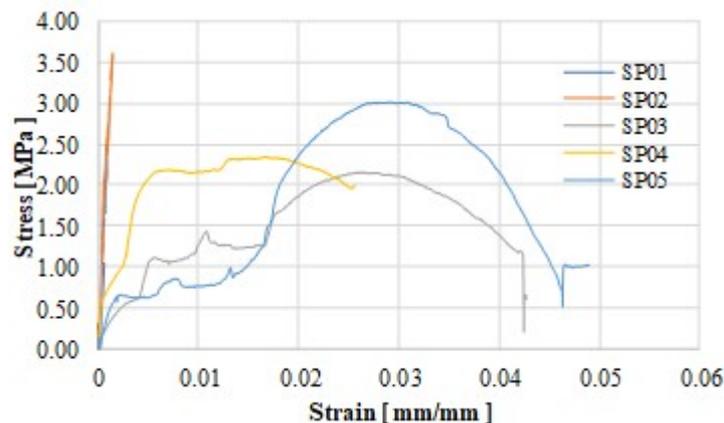


Figure 4. Results from the traction tests of the balsa wood.

As shown in Fig. 4, the curves obtained in the traction tests do not follow a standard behavior of the stress as a function of the deformation. Mechanical characteristics such as limit of tensile strength, Young's modulus and tensile strength vary for each test specimen evaluated. This characteristic can be justified by the anisotropy that the woods, in general, present due to the arrangement of their fibers.

The results of traction tests obtained with balsa wood coated if carbon fiber 200 and epoxy resin stood out when compared with the composite made with polyester resin, since practically all of the specimens of the former exceeded an average voltage value of 30MPa, a fact that is not noticed in Fig. 6, this is due to the fact that epoxy resin has greater uniformity when it is spread through the matrix and has better mechanical properties.

The tests performed with balsa wood coated with glass fiber 200 (GF200) and glass fiber 350 (GF350) using epoxy resin are shown on Fig. 7 and Fig. 9, respectively, that the former achieves higher values of resistance, which was expected because it is a matrix with higher amount of filaments per area, which in turn gives greater resistance to the

element. When dealing with the composites made by balsa wood coated with glass fiber 200 and glass fiber 350 using polyester resin, Fig. 8 and Fig. 10, show that the same fact occurs confirming the previously reported hypothesis. When comparing the results of the composites made by balsa wood coated with glass fiber using glass fiber and different resins, shown in Fig. 7 and Fig. 8, is possible to note that the epoxy resin composites obtains higher resistance values, due to having better characteristics compared to the polyester resin. The results with the composites coated with flass fiber 350, Fig. 9 and Fig. 10, confirms that the epoxy resin meets better qualitative and quantitative characteristics, being mechanical and handling characteristics.

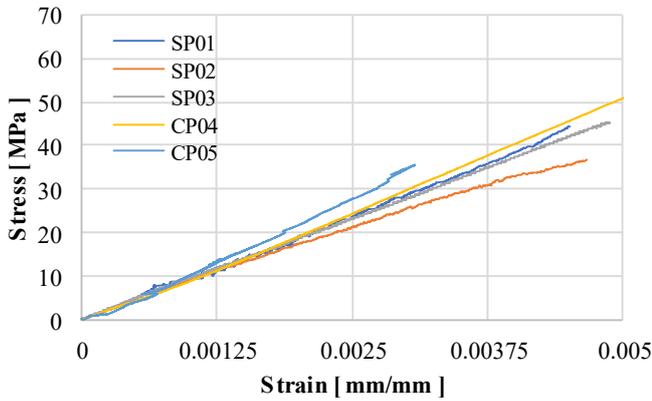


Figure 5. Results from the traction tests BW+CF200+Ep.

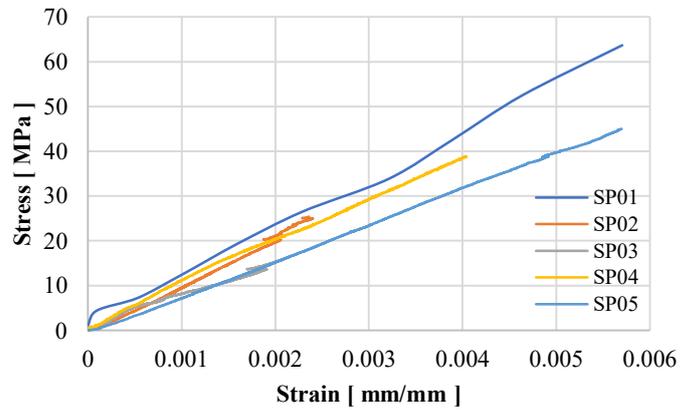


Figure 6. Results from the traction tests BW+CF200+Po.

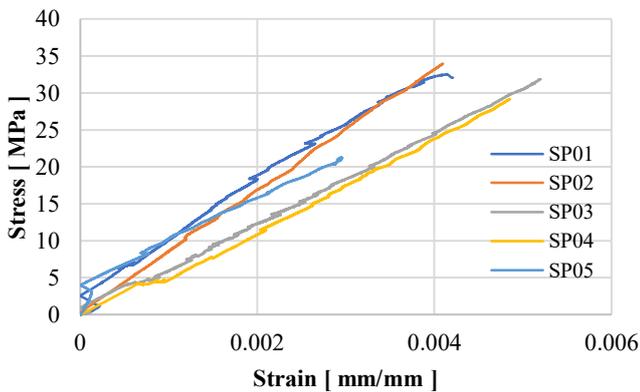


Figure 7. Results from the traction tests BW+GF200+Ep.

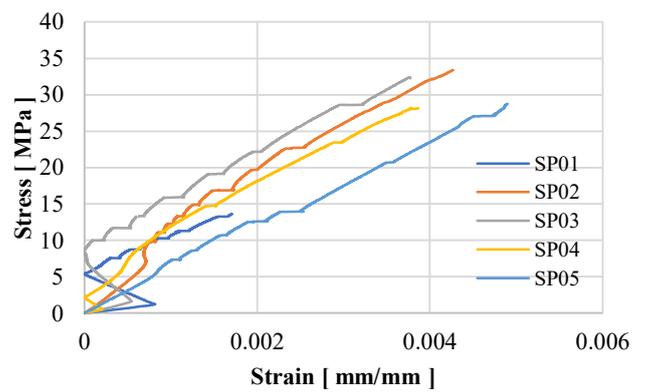


Figure 8. Results from the traction tests BW+GF200+Po.

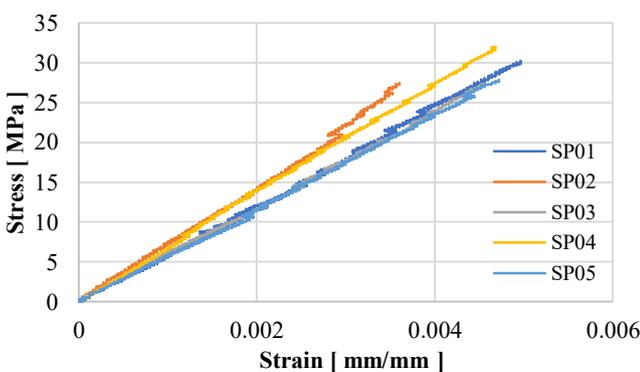


Figure 9. Results from the traction tests BW+GF330+Ep.

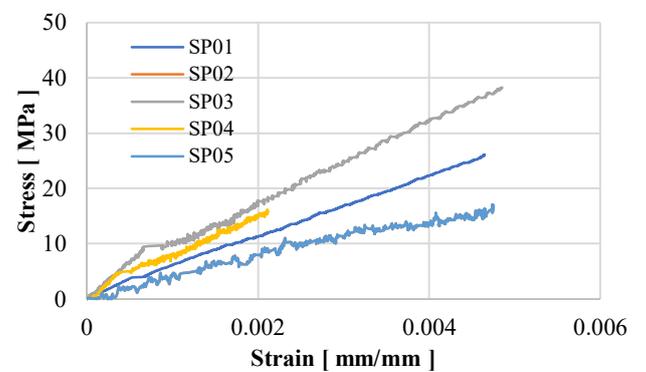


Figure 10. Results from the traction tests BW+GF330+Po.

The results obtained with the mechanical tests were used to calculate an average rupture stress with the respective standard deviation for each material evaluated, as show Fig. 11.

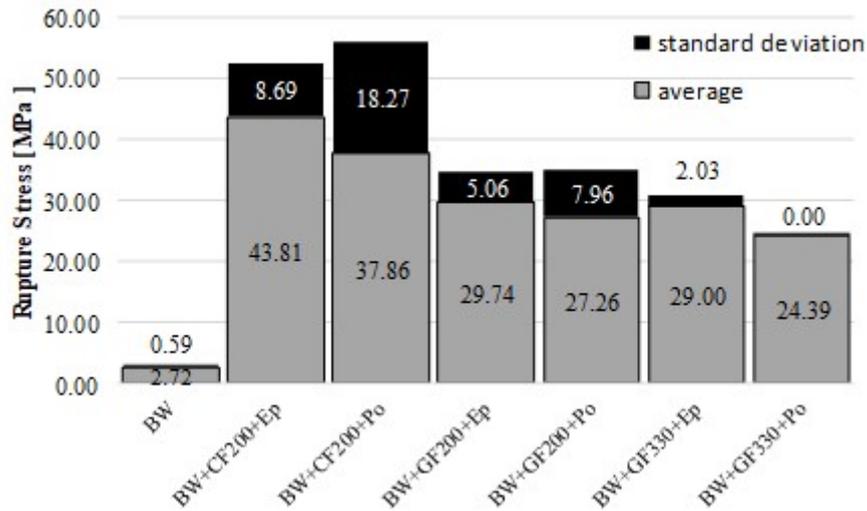


Figure 11. Rupture stress for the materials evaluated in the traction tests.

Figure 11 shows that, when compared to balsa wood tests, there are a significant increase in mechanical strength due to the presence of the fiber and the resin, making the composite slight and resistant for the most diverse applications. Among the composites tested, the one with the highest rupture stress is the composite made by a balsa wood core coated with carbon fiber 200 using epoxy resin.

Like that performed for rupture stress, the average Young's modulus with the respective standard deviation for each material evaluated are presented in the Fig. 12. As observed, the composites confer an increase in Young's Modulus of the material, which is directly related to the rigidity of the material to the mechanical stresses to which the manufactured component may be subjected. The composite that presents the higher average of Young's modulus is the same that have the higher limit of rupture.

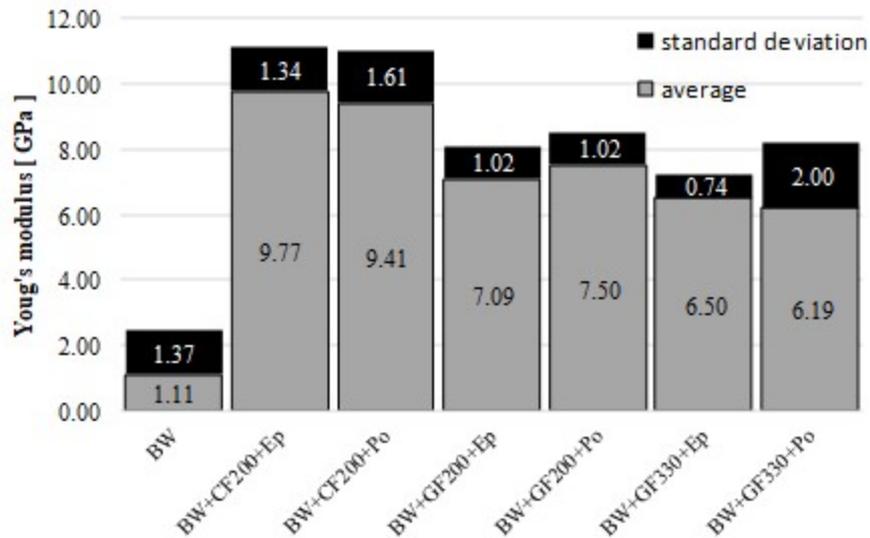


Figure 12. Young's Modulus for the materials evaluated in the traction tests.

3.2 Results for the bending tests

Fig. 13 to Fig. 20 presents the bending tests results for the materials evaluated. When compared to the traction tests, can be observed a different behavior: all the tests presented a maximum stress point, which indicates a flexural strength limit before their rupture.

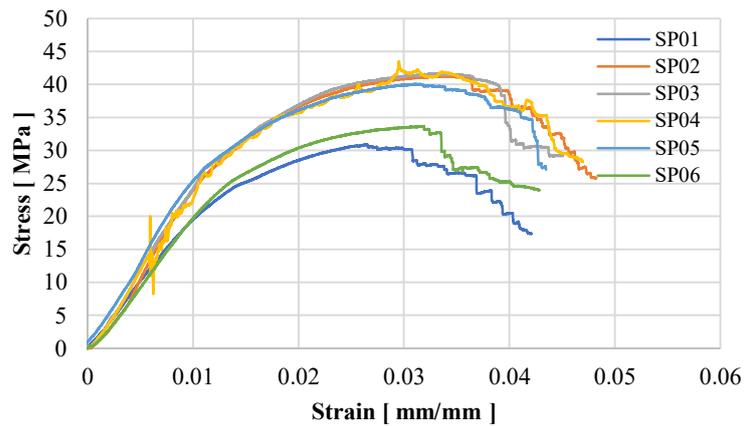


Figure 13. Results from the bending tests of the balsa wood.

Although the typical anisotropic behavior of balsa wood is still observed, bending tests performed with balsa wood (Fig. 13) show a greater uniformity of the behavior of the tension-strain characteristic curves when compared to the tensile tests, allowing a characterization more precise with regard to the mechanical properties typical of such efforts.

A larger sample variance in the behavior of strain-strain curves of the same material is observed in the tests performed with the composites, as shown in Fig. 14 to Fig. 20. This fact can be explained by the non-uniformity in the application of the resin, added to the anisotropic behavior of the matrix, triggers in fragile stress concentrating regions.

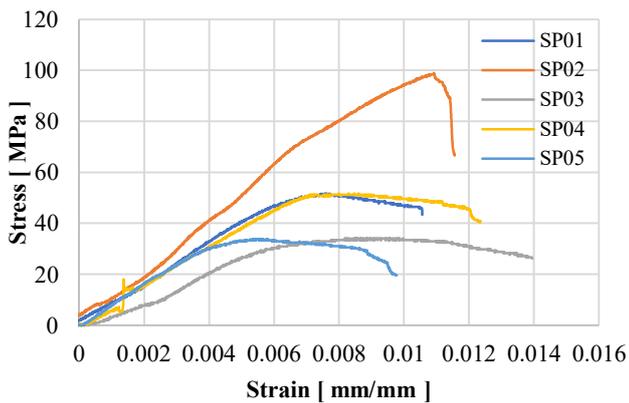


Figure 14. Results from the bending tests BW+CF200+Ep.

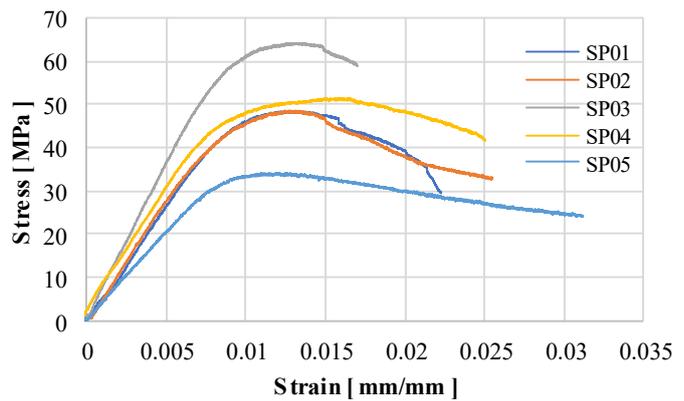


Figure 15. Results from the bending tests BW+CF200+Po.

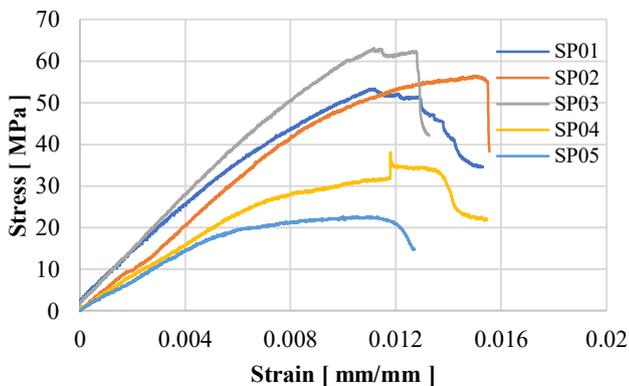


Figure 16. Results from the bending tests BW+GF200+Ep.

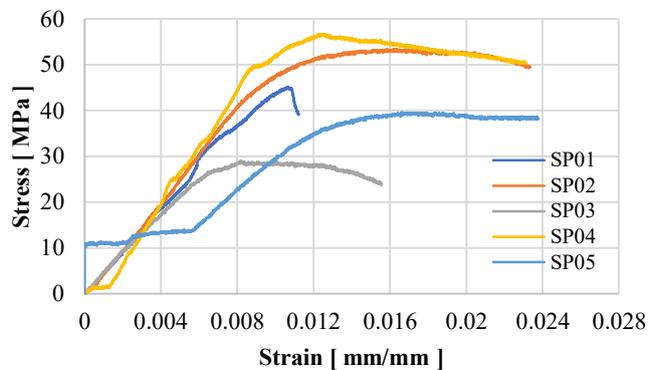


Figure 17. Results from the bending tests BW+GV200+Po.

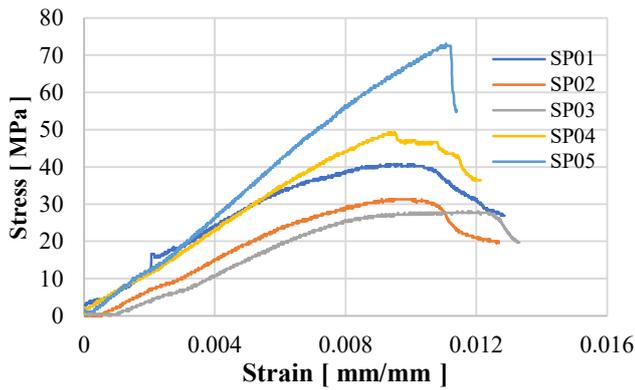


Figure 19. Results from the bending tests BW+GF330+Ep

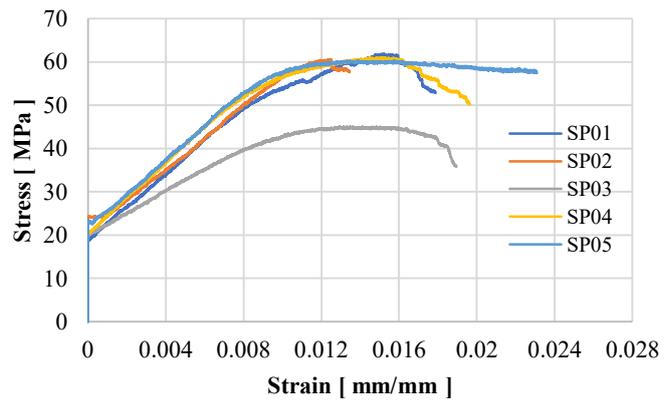


Figure 20. Results from the bending tests BW+GF330+Po.

The average results for flexural resistance and Young's modulus obtained with the bending tests to balsa wood and the manufactured composites, as the correspondent standard deviation, are presented on Fig 21 and Fig 22, respectively.

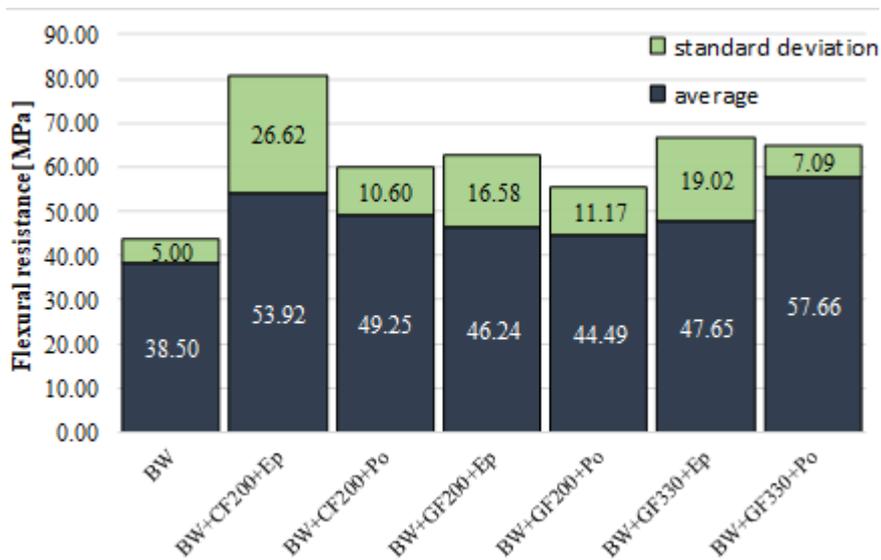


Figure 21. Flexural resistance for the materials evaluated in the bending tests.

According to Fig. 21, the evaluated composite materials showed a slight increase in flexural strength when compared to balsa wood. The composite that presented a higher resistance in this question, although it presented the greater standard deviation among the others, was the balsa wood core coated with carbon fiber using epoxy resin.

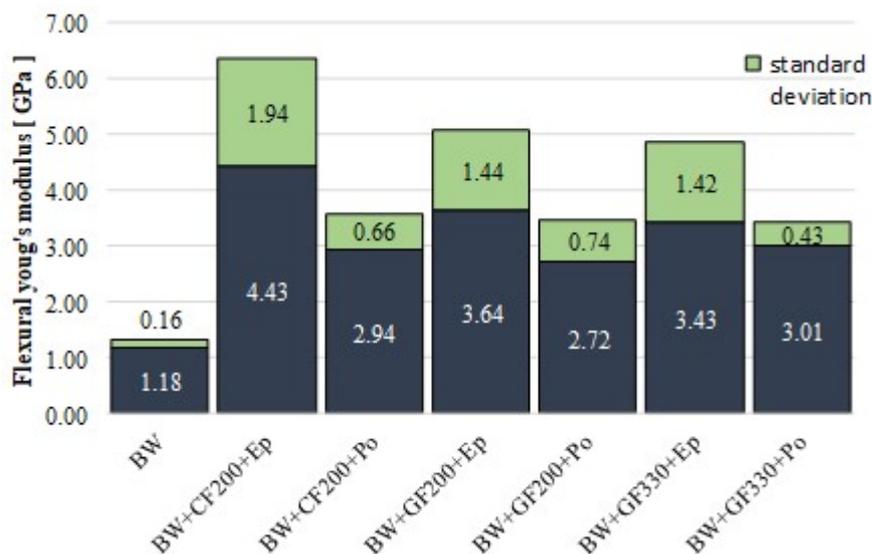


Figure 22. Flexural Young's modulus for the materials evaluated in the bending tests.

As with all mechanical properties evaluated, a significant increase in flexural Young's modulus was also observed, as shown in Fig. 22 when compared to balsa wood tests, the composite made by balsa wood coated with carbon fiber using epoxy resin as being the one with the highest value for the magnitude cited above.

It is noted that different results of Young's modulus are obtained with the performance of the traction and bending tests. This difference is directly associated with anisotropy of the balsa wood, presenting different properties depending of the direction. The Young's modulus showed lower calculated values in the bending tests caused by, during the test, the specimen is subjected to combined traction and shear stresses.

4. CONCLUSION

With the realization of traction and bending tests in balsa wood and composite materials made from a balsa wood and carbon fiber, being varied the resin used in the manufacture of the specimens, it is noticeable that, the wood when laminated together with carbon fiber presents improvements in its mechanical properties. Moreover, when comparing the two types of resins used in the present study, the use of epoxy resin ensures better mechanical properties to the material when compared with polyester resin. In general, the use of epoxy provides greater resistance to traction and flexion, presenting higher limit values of tensile strength, as well as a smaller specific mass that, in most applications, are extremely desired parameters. However, the use of epoxy resin makes the material fragile, being less malleable or deformable. The mechanical tests show that the composite manufactured by a balsa wood core coated with carbon fiber 200 using epoxy resin is the one that presents the highest traction and flexural resistance.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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