ADVANCED HYBRID BIO-COMPOSITE REINFORCED WITH NATURAL FIBRES USED IN THE FABRICATION OF LAMINATES

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Abstract: *The use of natural fibres as a replacement for traditional glass fibres and carbon fiber in composites has gained increasing importance in recent years as environmental concerns have led to a quest for sustainable alternatives. This paper presents the results of studies undertaken to evaluate various mechanical properties of hybrid carbon - hemp composites and fiber glass - hemp composites to assess the suitability traditional carbon and glass fibers used in composites composition. Hemp fibres, in the form of non-woven mat, randomly oriented in two dimensions, glass fibres in strand mat form and carbon fiber were used. The matrix was a polyester resin with rapid hardening characteristics - DERAKANE resin . The combination of a hand lay-up method, followed by compression moulding, was used in the fabrication of laminates*
Keywords: *Natural fibers, Composite, Structure, Mechanical properties.*

1. INTRODUCTION

Generally, a composite consists of a reinforcing fibre which is the strongest and stiffest component, embedded in a continuous matrix. The main functions of the matrix are to transmit externally applied loads to the fibre and to protect the latter from external mechanical damage. Fibre volume fraction is one of the most important factors controlling the strength, stiffness and many other mechanical properties of the composites. [1]-[4]
The use of hemp fibers as reinforcement in composite materials has increased in recent years as a response to the increasing demand for developing biodegradable, sustainable, and recyclable materials. Hemp fibers are found in the stem of the plant which makes them strong and stiff, a primary requirement for the reinforcement of composite materials.
The mechanical properties of hemp fibers are comparable to those of glass fibers. However their biggest disadvantage is the variability in their properties. Composites made of hemp fibers with thermoplastic, thermoset, and biodegradable matrices have exhibited good mechanical properties.
One method of increasing the mechanical properties of natural fiber composites is by hybridizing them with another synthetic or natural fiber of superior mechanical properties. The synthetic fiber mostly used for this purpose is glass fiber. Although the biodegrability of the composite is reduced, this can offset the advantages gained by the increase in mechanical properties.

2. MATERIALS AND METHODS

Two types of hybrid composite materials were made: carbon-hemp and hemp-hemp, which were subjected to both static traction loading and at the dynamic load (Fig. 1). These types of composite materials have been made from 4 layers of thermosetting resin reinforced with carbon fabric with 40% volume of carbon fiber and a hemp fiber volume fraction of 20%. For the bottle-hemp hybrid, the mat fiberglass has a fiber volume fraction of 35%. The process for obtaining such hybrid composite materials, carbon-hemp and the hemp-glass composite consists of the fact that for the layers that have been formed, a manual formation technology has been used, that provides the use of a hand roller to impregnate the carbon (glass) fibers and hemp fibers with the resin. [1]-[10]. The mechanical characteristics of the thermosetting resin hardener are: tensile tension $\sigma_t = 86MPa$; modulus of elasticity $E = 3200MPa$; impact resistance $K = 40kJ/m^2$.

The layered composite panel is made of: the first carbon layer (mat glass) having a thickness of 1.5 mm alternating with a second layer of hemp cloth with a thickness of 0.5 mm, and repeating the operation until a composite plate consisting of four layers is obtained. Finally, the laminated composite panel thickness is 4 mm.

The panel obtained by using this method was kept at room temperature for two weeks after which 8 samples were made (the samples have a form suitable for tensile testing according to EN ISO 527-2). The glass-hemp hybrid composite was made in a similar manner, should only be noted that the glass fibers have a volume fraction of 35%. The samples were coded C-Cnp (in the case of the hybrid composite carbon-hemp) and S-Cnp (in the case of the hybrid composite glass-hemp) and have been tested at static traction.

Figure 1. Sectional view of the composite hybrid C-Cnp (a) and the composite Hybrid S-Cnp (b)

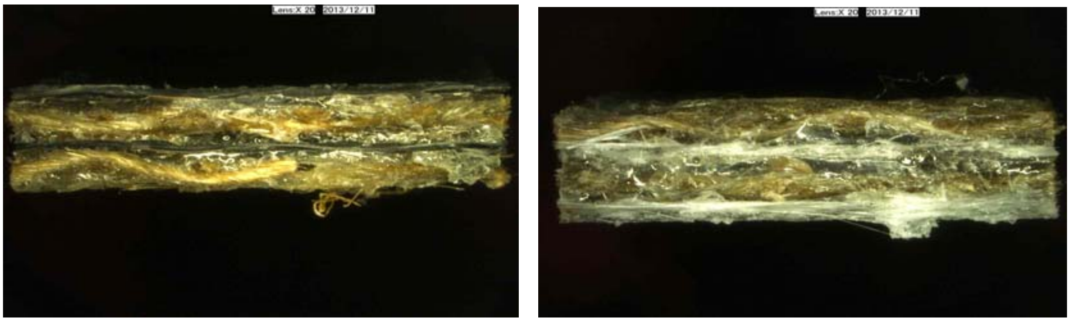


Figure 2. Microscopic view of the composite hybrid C-Cnp (a) and the composite hybrid S-Cnp(b)

After the static tensile stress was applied, the experimental data obtained for both the carbon-composite hybrid hemp and for the glass-hemp hybrid composite were centralized for capitalization.

Table 1. The mechanical properties of the composite S-Cnp

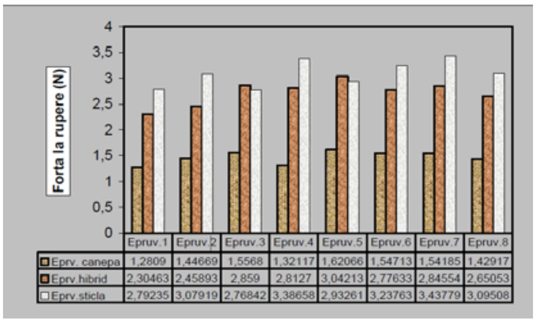
Characteristic	Value
The force at max. loading (kN)	2.7776
The tearing force (kN)	2.7768
The elasticity modulus (MPa)	6000.5
The tensile strength (MPa)	70.845
The tensile strain (MPa)	70.825
The elongation at tearing (-)	0.016927
Deformation of the machine at max loading (mm)	0.84357

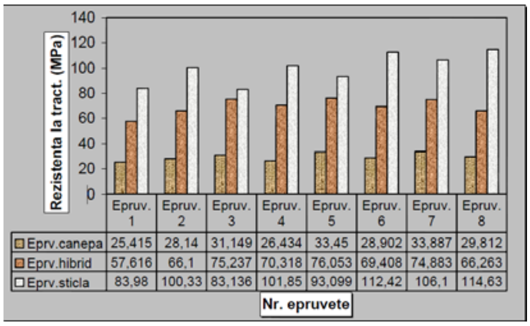
Table 2. The properties of the hybrid composite C-Cnp

Characteristic	Value
The force at max. loading (kN)	6.1639
The tearing force (kN)	6.1635
The elasticity modulus (MPa)	11791.0
The tensile strength (MPa)	154.10
The tensile strain (MPa)	154.09
The elongation at tearing (-)	0.013225
Deformation of the machine at max loading (mm)	0.62712

3. RESULTS AND DISCUSSIONS

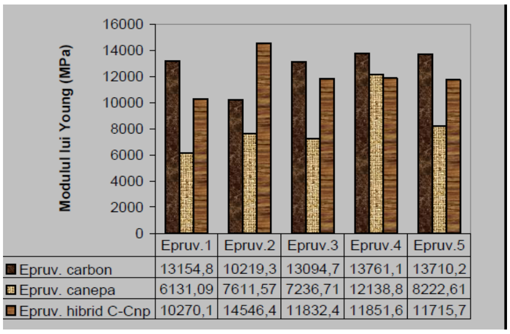
If we analyze the experimental data of the tested composites, their interpretation has led to some graphical representations and comparisons of the two types of hybrid composite S-CNP and C-Cnp.. In the first stage, the mechanical properties of the composite hybrid S-Cnp were revealed in comparison with the mechanical properties of the component materials, glass-mat and, respectively, hemp fabric.(fig.3) The centralization of the experimentally obtained data allowed the graphical representation of the main mechanical properties for the composite hybrid C-Cnp in comparison with the mechanical properties of the constituent materials, with the carbon fiber based composite and, respectively, hemp fabric.(fig.4)

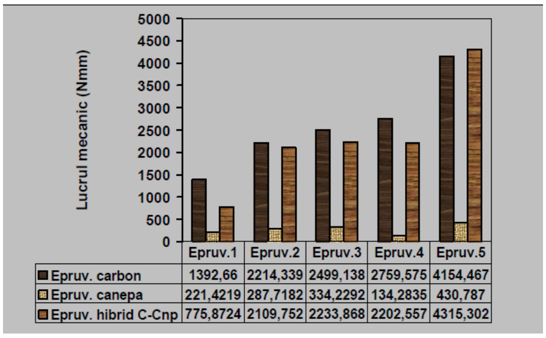




a) **b)**

Figure 3. Variation of tearing force and tensile strength in the case of composite mat glass, hemp and hybrid S-Cnp

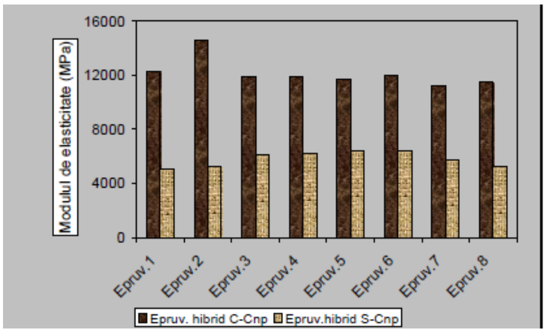


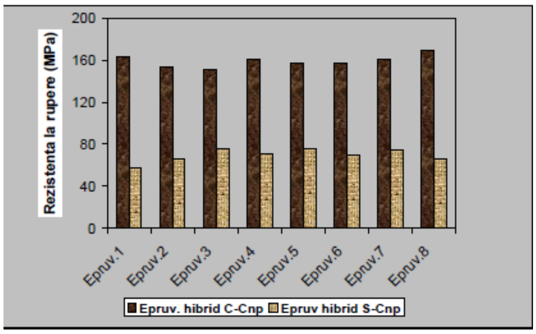


a) **b)**

Figure 4. Distribution of the elasticity modulus a), and tensile consumed work b) for the carbon composite, hemp fabric and hybrid C-Cnp

Last but not least, an interesting and representative graphical representation was possible, showing the mechanical properties of the two types of hybrid composite S-Cnp and C-Cnp (Fig.5-7)





a) **b)**

Figure 5 The distribution of the elasticity modulus a) and tearing strength b) in comparison for the composites S-Cnp and C-Cnp

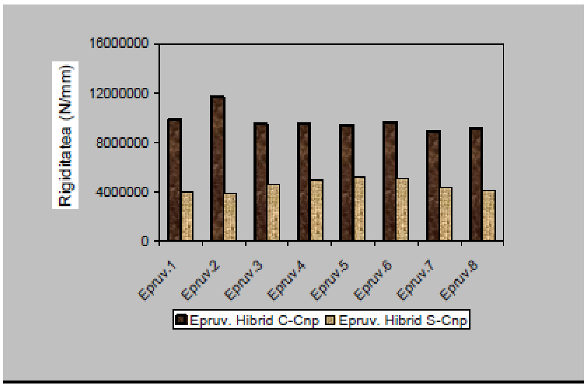


Figure 6. Stiffness distribution for the composites S-Cnp and C-Cnp

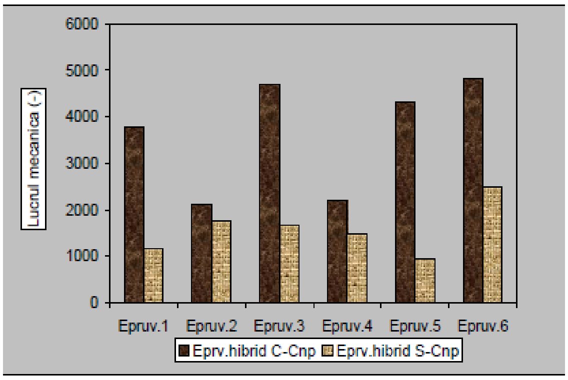
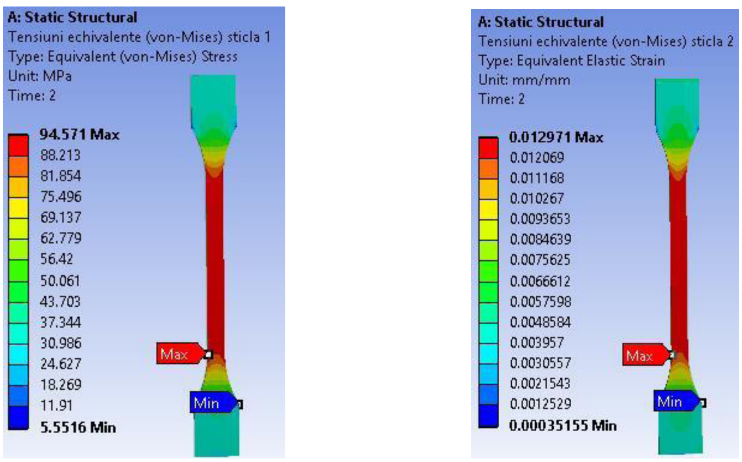


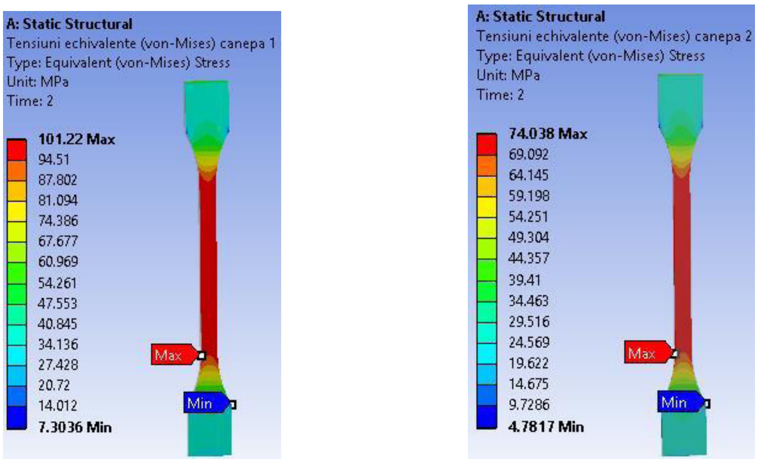
Figure 7 Distrubution of mechanical work for the composites S-Cnp and C-Cnp

Minimizing the mass of the composite laminates can also be addressed by balancing the layer thickness from the cross-section so that the destruction of the layered structure as a result of mechanical stress occurs simultaneously in all layers and not one after another. The tests on specimens, combined with other modern methods of calculation and analysis, allow for a rapid design and optimization of the analyzed structures . In comparison with the conventional methods, the finite element analysis of composite parts allows for a significant reduction in the time required to find a laminated composite structure. Also, by successive runs with different layering (having different numbers, order and orientation of different layers) reaching an optimal layered composite can be done very quickly and inexpensively. The following charts represent the von Mises stresses in the studied specimens, which were subject to static tensile stress:



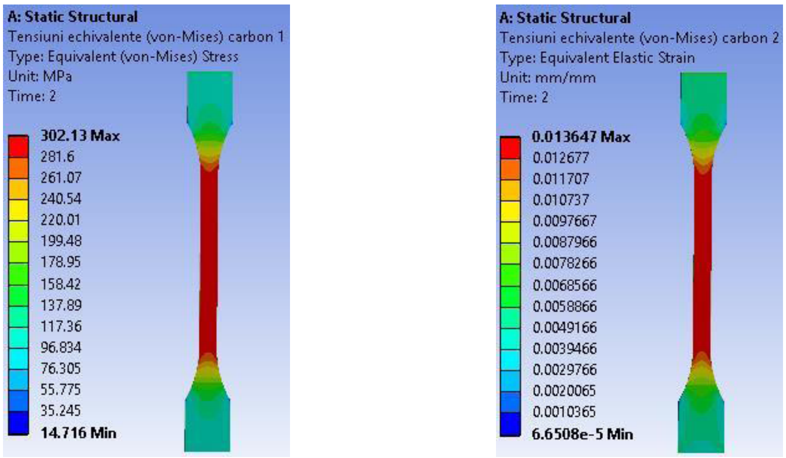
a) **b)**

Figure 8. The total von Mises equivalent stress in the first glass (a) layer and third glass (b) layer of the hybrid composite, S-Cnp



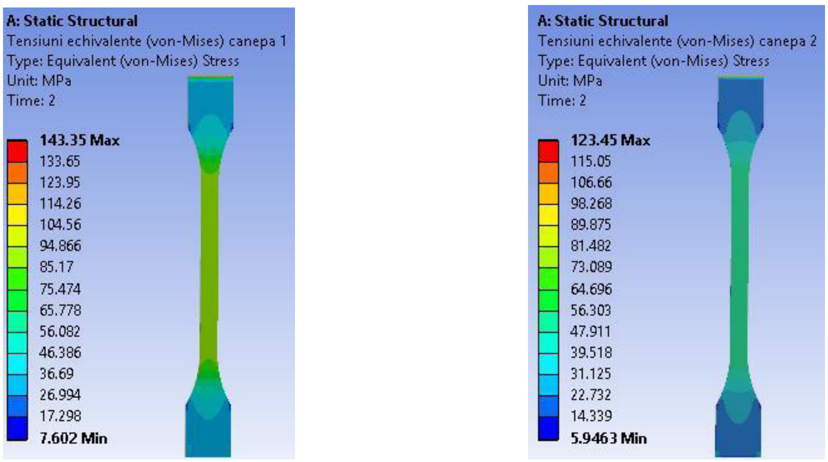
a) **b)**

Figure 9. The total von Mises equivalent stress in the second layer (a) and last layer- hemp (b) of the hybrid composite S-Cnp



a) **b)**

Figure 10. The total von Mises equivalent stress in the first layer (a) and third carbon layer (b) of the hybrid composite C-Cnp



a) **b)**

Figure 11. The total von Mises equivalent stress in the second layer (a) and last layer-hemp (b) of the hybrid composite C-Cnp

4. CONCLUSION

As expected, after analyzing the graphs shown in Fig . 3-7 , it can be seen that the C - Cnp hybrid composite behaves much better , having much better mechanical properties than the hybrid composite S - Cnp . Also, the mechanical properties for both hybrid composites S - Cnp and C - Cnp can be found in the range of values determined by the properties of the composites that make up the hybrid material. On the other hand, the substitution of a 0.25% of carbon or glass fiber mat with fabric hemp leads to both an improvement of the mechanical properties of the composite hybrid and to a reduced cost .

From the graphs in Figure 8-11 , it is observed that, for the same loading , the modulus of elasticity has a major influence on the results. Lower values for tension are observed at small values of the modulus of elasticity, whereas at high values of the elasticity modulus, an increase of the von Mises stress is observed . This can be explained by the fact that the material with a lower modulus is less elastic , therefore the stresses lead more to the increase in deformation than in the increase of tension. On the other hand, the high modulus materials are very rigid , not allowing for the deformation of the specimen and introducing additional efforts.

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