RESEARCHES REGARDING THE STRENGTH AND STIFFNESS OF LIGNOCELLOSES COMPOSITE REINFORCED WITH NATURAL FIBRES FOR AUTOMOTIVE INTERIORS PARTS

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Abstract: This paper presents the experimental investigation of a laminated composite material reinforced with weave fabrics of flax fibres in order to obtain the main mechanical properties. Specimens made of epoxy resin reinforced with weave fabrics of flax fibres were tested using a tensile test machine and a digital image correlation system. Tensile test is known to be the most important and most used static tests to obtain the strength and stiffness characteristics. The aim of the research is to determine the influence of warp and weft directions of natural fibres weave fabrics on mechanical properties of composite material. The laminate was manufactured by a process known as hand lay-up. In order to improve thermal and sound insulation the new material contains oak wood flour. These materials were designed in order to be used in the automotive industry to achieve interior components with visible surfaces and natural textures.

Keywords: mechanical properties, composite materials, weave fabrics, natural fibres, automotive applications

1. INTRODUCTION

Environmental concerns have resulted in a renewed interest in sustainable composites focusing on bio-based fibres [1]. Although natural fibres have lower mechanical properties compared to synthetic fibres, in Figure 1 is apparent that they have a lower density than glass fibres for example [3].

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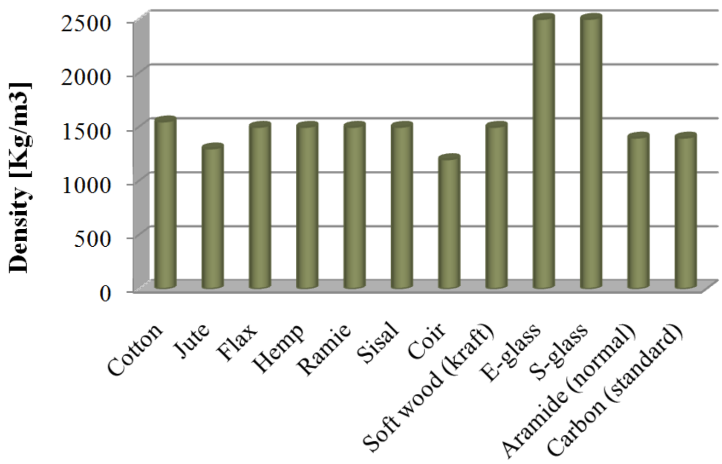


Fig.1. Density of fibres used for reinforcing composite materials

This makes fibres reinforced materials to be valued in areas where weight of the components has major importance. Such areas where low density materials are needed, which also possess some properties for examples considerable resistance to mechanical requirements, ease of recycling and availability at a reduced price is that of interior automotive components [5]. In Figure 2 we can see energy consumption for each life cycle stages of a family car. As can be seen most of the energy is consumed during the utilisation stage. Due to the closely related vehicle mass with fuel consumption materials weight influences energy consumption.

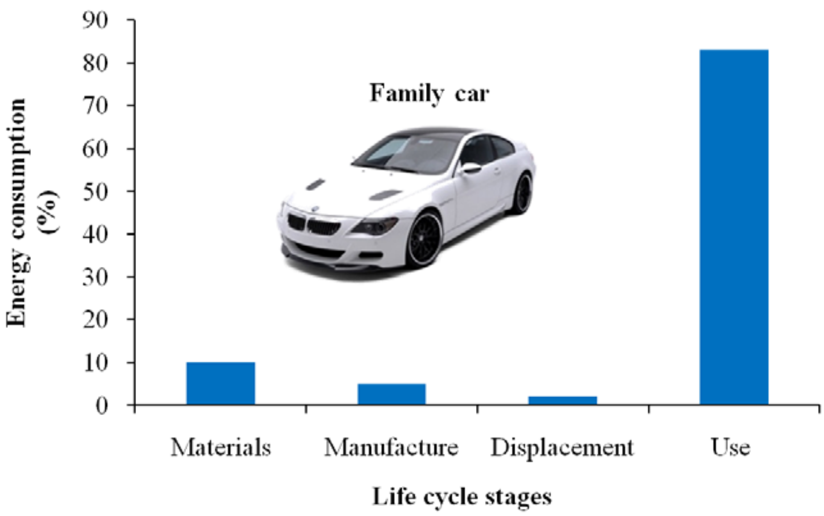


Fig.2. Energy consumption for each life cycle stages of a family car

On the other hand price of fibres use to reinforce composites is reflected on final price of material obtained [3]. In Figure 3 can be seen that energy consumption for natural fibres production is less than that for producing synthetic fibres such as carbon or glass fibres.

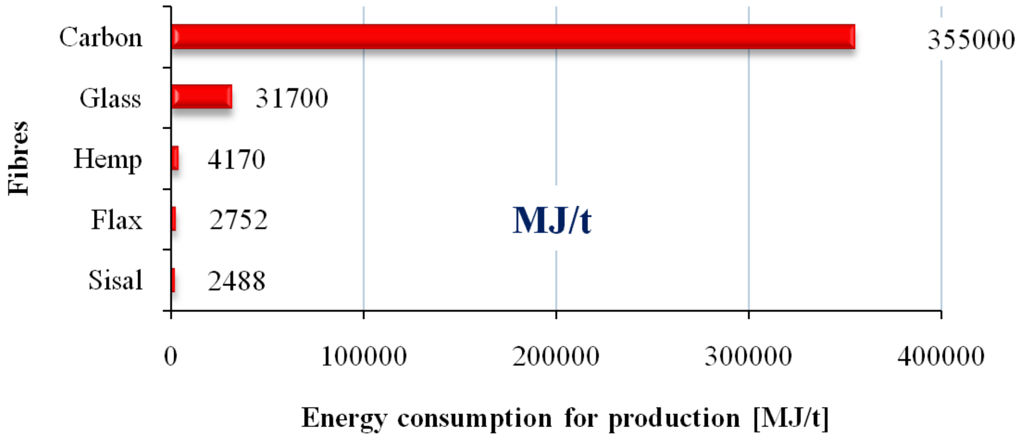


Fig.3. Energy consumption for production of some fibres, adopted from [1]

In recent decades automotive interior parts manufacturers, for example Johnson Controls Company, are looking for sustainable solutions to replace the excessive use of plastics [4], by incorporating vegetable fibres into their products (Fig. 4).

Fig.4. Carriers for covered door panels made of natural fibres with polymer resin [6]

2. MATERIALS AND METHODS

In order to obtain automotive interior parts with visible surfaces made by natural fibres reinforcing composite materials a new material was made. The new lignocelluloses material is a laminate having six layers made of epoxy resin reinforced with plain weave fabric of flax fibres and wood flour of oak or spruce species (Fig. 5).

Fig.5. Material composition: 1 - wood flour (oak and spruce species); 2 - weave fabric of flax fibres; 3 - epoxy resin; 4 –composite materials

The plain weave fabric of flax fibres (Fig. 6.b) has a density per unit area of 220 *g/cm*^{2} and number of yarns per unit length is 14 yarns / *cm* for both directions of warp and weft yarns. The two directions of a fabric can be seen in Figure 6.a. Direction of the warp yarns being aligned with the length of the roll of fabric.

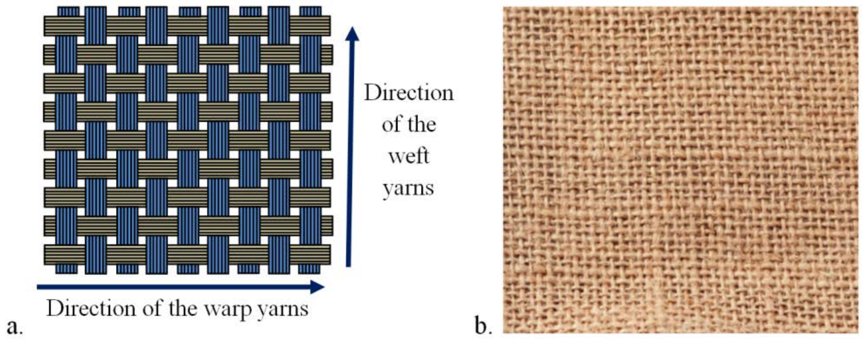


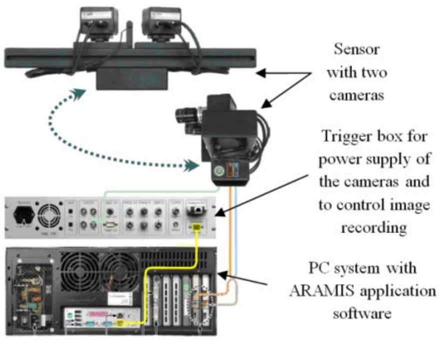
Fig.6. Warp and weft yarns orientation of the plain weave fabric (a) and plain weave fabric of flax fibres used as reinforcement (b)

In order to determine the main mechanical properties of new natural fibre reinforced composite material, it has been tested to tensile stresses. Tensile test is known to be the most important and commonly used static test due to the procedure's simplicity on obtaining the strength and stiffness characteristics.

Mechanical characteristics of the new material are needed to simulate the behaviour of parts made of these materials by finite element method (FEM). Plates from which were taken samples were manufactured by handing lay-up process of 6 layers reinforced with weave fabrics of flax fibres, arranged in the same direction, towards the longitudinal direction of the plate. From the composite plates were cut for tensile tests, six samples in longitudinal direction of the plate and five samples in transverse direction of the plate, and other two sets of five specimens for determining Poisson's ratio. The samples have the specific shape and dimensions of tensile test composite materials reinforced with fibre, according to ASRO SR EN ISO 527 [2].

The equipment used is a tensile test machine with constant speed, provided with specimen fixing devices. In order to measure the specific elongation of the specimen was used an extension measuring instrument and in order to determine Poisson's ratio was used digital image correlation (DIC) method.

a.



b.

Fig.7. Tensile test machine used (a) and digital image correlation system (b)

Digital image correlation (DIC) method offers an optical solution for deformations measurement. For these tests specimens tested using the ARAMIS system have been previously painted with a layer of white paint and over this a layer of black dots arranged randomly was applied, as can be seen in Figure 8.

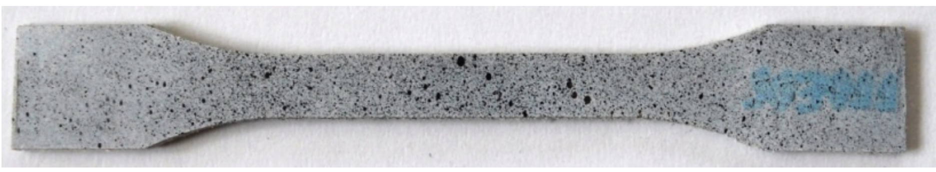


Fig.8. Specimen used to determine Poisson's ratio by DIC method

3. RESULTS AND DISCUSSION

After processing the machine data, tensile tests diagrams (*F-ΔL*) were made, as presented in Figure 9. Breaking force varies depending on the direction from where the specimen was cut. For specimens cut on longitudinal (warp yarns) direction the force ranges from 1.53 *kN* to 2.18 *kN* and for the ones cut on the weft direction, it ranges from 2.42 *kN* to 2.94 *kN*.

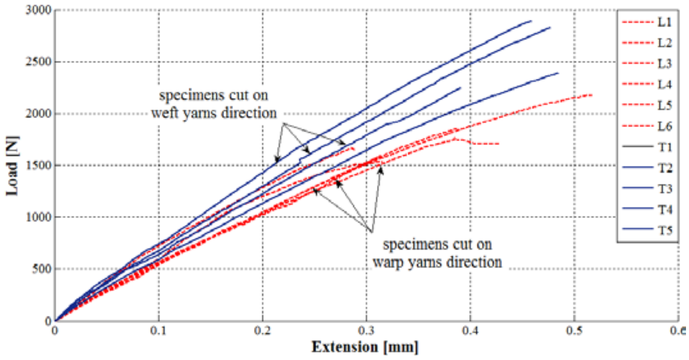


Fig.9. Tensile tests diagrams obtained for both directions of the weave fabric used for reinforcing composite materials

Poisson's ratio is defined as the negative value of ratio of transversal contraction over the longitudinal strain of specimen, as follows:

$$\upsilon = \frac{\varepsilon_y}{\varepsilon_x} \quad (1)$$

This was determined after traction tests, where the specimen was stressed on longitudinal direction and due to the Poisson effect results a contraction on the transversal direction, as can be seen in Figure 10.

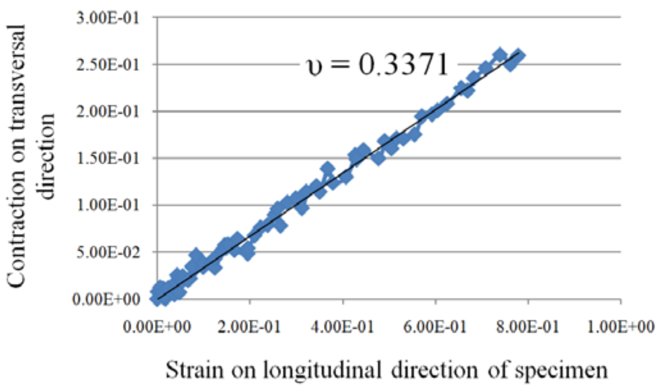


Fig.10. Poisson's ratio determination

Table 1 presents the main mechanical properties obtained of the material, for the two-way direction of stresses applied, both longitudinally and transversally. Although natural fibre weave fabric has a symmetrical construction on both directions, type 14/1 (14 yarns/ *cm*), tests revealed significant differences in mechanical properties of the two directions.

Table 1 **Main mechanical properties results from tests**

Mechanical properties of lignocelluloses material studied	Average value for the warp direction	Average value for the weft direction
Stiffness, *N/m*	7259254.27	9155033.62
Young's Module, *MPa*	8657.566	10417.946
Stress at Maximum Load, *MPa*	26.3973	37.3317
Strain at Maximum Load	0.00403	0.003698
Energy absorbed by the specimen, *Nmm*	105569.098	135815.622
Load at Break, *kN*	1.7774	2.6033
Stress at Break, *MPa*	26.0802	37.1255
Poisson's ratio	0.3371	0.3395

4. CONCLUSIONS

Experimental tests showed significant differences between mechanical properties of the composite material on the two directions of the fabric due to the weave fabric manufacturing process;

Even if the same type of tows was used on both directions of the weave fabric, the tows undulation angle has a great importance on the mechanical properties of the composite;

Knowledge of mechanical properties on both directions of composite materials reinforced with natural fibre fabrics is very useful to designers, to make advanced structures, with applications to interior automotive components with complex shapes. One of the advantages of the proposed composite material is that it can make automotive interior components with visible surfaces and a natural texture and changing colour of material can only be achieved by replacing the wood species used as filler particles.

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