New Hybrid Lignocellulosic Composite made of Epoxy Resin Reinforced with Flax Fibres and Wood Sawdust

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This paper presents a usage method of wood waste as sawdust resulting from sawing processes, by achieving hybrid composite materials consisting of epoxy resin reinforced with flax weave fabrics and wood particles. Mechanical characteristics obtained from tensile testing of the material on both directions of the natural fibres weave fabric used as reinforcement are also presented here. New lignocellulosic composite has application to automotive interior components industry, furniture with complex shapes, etc.

Keywords: wood sawdust, hybrid composite, weave fabrics, natural fibres, tensile tests, automotive applications

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 [1].

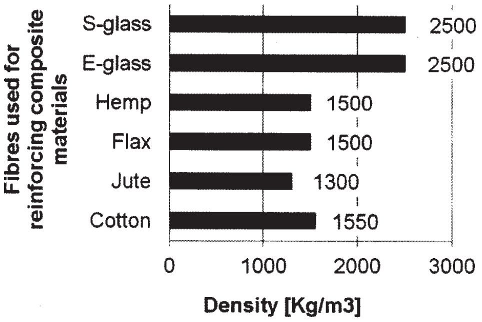

Fig. 1. Density of fibres used for reinforcing composite materials

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 example considerable resistance to mechanical requirements, ease of recycling and availability at a reduced price, is that of interior automotive components [2].

On the other hand price of fibres used to reinforce composites is reflected on the final price of the material obtained. In figure 2 can be seen that energy consumption for natural fibres production is less than the one used for producing synthetic fibres such as carbon or glass fibres [1].

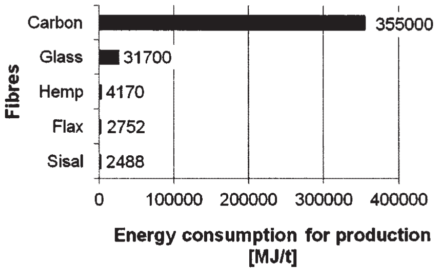

Fig. 2. Energy consumption for production of some fibres

An optimal cost composite can be obtained by embedding in its component the waste from other manufacturing processes or recycled materials [3]. The waste sawdust is an important resource of raw material. A report by FAOSTAT (Food and Agriculture Organization of the United Nations) shows that the amount of wood of different species cut by sawmills in Europe in the year 2010 is about 125.36 million m^3 [4]. The sawdust losses resulting from sawing processes are between 5-11% of the total log volume. At a minimal loss value of 5% results in a volume of 6.27 million m^3 sawdust. So sawdust is an important renewable raw material and can be used in other areas moreover than heating.

In order to obtain high mechanical properties, composite material was reinforced with textile fibres. To reduce the material anisotropy it was used a plain weave fabric with a symmetrical construction on the two directions of yarns.

Although natural fibre weave fabric takes over mechanical stress [5,6], sawdust has the role to fill gaps of the weave fabric increasing the amount of natural fibres used and at the same time increases the thermal and acoustic insulation properties of material [7,8].

The present work focus on comparatively analysis of properties obtained for the both directions of plain weave fabric yarns. The difference between results is given by the difference between tows undulation angle due to the weave fabric manufacturing process.

Experimental part

Materials

In order to obtain automotive interior parts with visible surfaces made by natural fibres reinforcing composite materials a new material with a natural texture was made. The new lignocellulosic material is a laminate having six layers made of epoxy resin reinforced with plain weave fabric of flax fibres and wood sawdust of oak species. The composition of material can be seen in figure 3. To manufacture the plate of composite material a lower forming pressure was used by hand lay-up process. The structure of material can be seen in figure 4.

The epoxy resin is used on a large scale for manufacturing laminated composite materials by using handing lay-up process, and other processes such as

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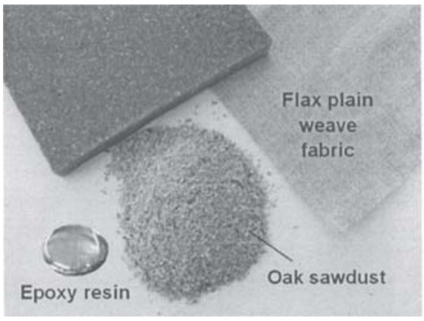

Fig. 3. Lignocellulosic material composition

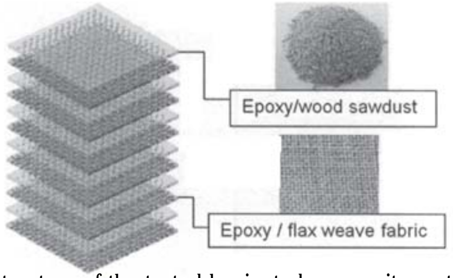

Fig. 4. Structure of the tested laminated composite material

injection with low pressure [9]. Epoxy resin used for the new lignocellulosic material, type Epiphen 4020, has a good behaviour for impregnation of timber with minor effects over natural fibres. The physical and chemical characteristics of the Epiphen 4020 epoxy resin in liquid state are shown in table 1 while the mechanical characteristics of the same resin without reinforcing are shown in the table 2. From the two tables results that the main resin properties are lower viscosity and good mechanical properties.

The plain weave fabric of flax fibres 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 5. Direction of the warp yarns being aligned with the length of the roll of fabric.

The sawdust used was oak waste from sawmills. The oak sawdust particles dimensions are smaller than 1 mm and were separated by sieving. In figure 6 a sawdust sieve analysis method shows that particles smaller than 1 mm have the highest percentage from the amount of particles resulting from sawmill.

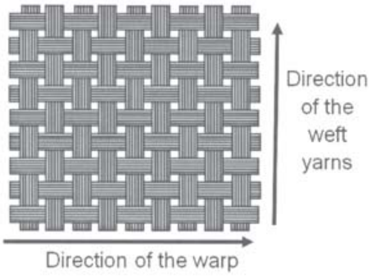

Fig. 5. Warp and weft yarns orientation of the plain weave fabric

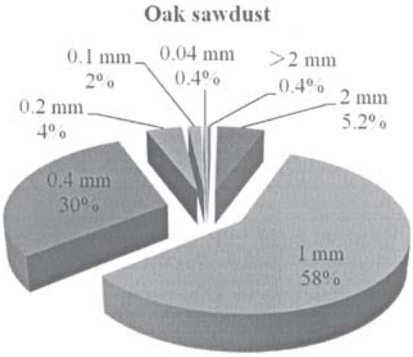

Fig. 6. data results from a granulometric analysis of oak sawdust

Work method

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). 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.

The tests were performed according to European Norms EN ISO 527 on specimens with the shape and dimensions presented in figure 7 [10].

Tensile tests were carried out on a Lloyd LS100 testing machine. In order to measure the specific elongation of the specimen and record the measured data, during the tensile tests an extension measuring instrument was used. Loading speed was 1 mm/min.

Table 1

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE EPIPHEN RE 4020 EPOXY RESIN IN LIQUID STATE

Characteristics	**Value**	**Unit of measure**	**Method**
Density, 25°*C*	**1.15**	***g/cm^3***	**ISO 1675:1985**
Viscosity, 25°*C*	**300**	***mPa·s***	**Brookfield LVT**
Mixture ratio with hardener agent	**(100 pp / 30 pp)**	**%**	**-**
Gel-time, at 20 °*C* (100*g* resin + 30*g* hardener)	**45**	**Minutes**	**-**
Setting time (Hardening time)	**8-9**	**Hours**	**-**
Glass transition temperature	**75**	**°*C***	**ISO 11359:2002**

Table 2

MECHANICAL CHARECTERISTICS OF THE EPIPHEN 4020 EPOXY RESIN WITHOUT REINFORCING

Characteristics	**Value**	**Unit of measure**	**Method**
Tensile strength	**60**	***MPa***	**ISO 527:1993**
Tensile modulus	**3300**	***MPa***	**ISO 527:1993**
Flexural strength	**100**	***MPa***	**ISO 178:2001**
Flexural modulus	**3200**	***MPa***	**ISO 178:2001**
Elogation in tensile test	**5**	**%**	**ISO 527:1993**
Toughness	**85**	**Shore D15**	**ASTM D 2240-97**

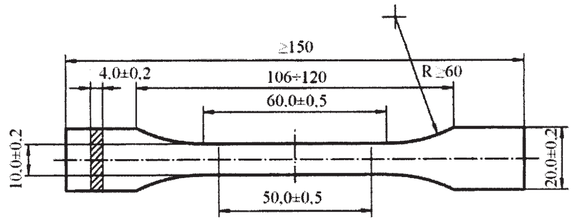

Fig. 7. Specimen for tensile tests according to SR EN ISO 527

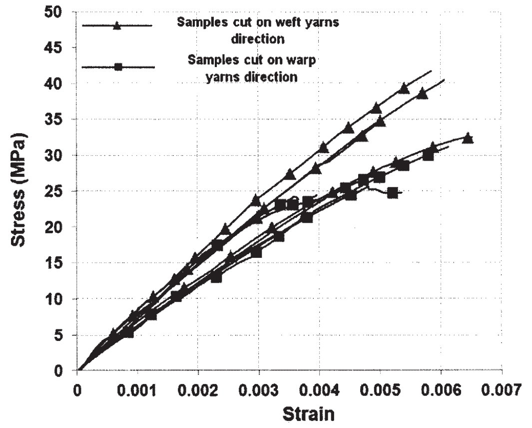

Fig. 8. Stress-strain σ–ε curves recorded in tensile test

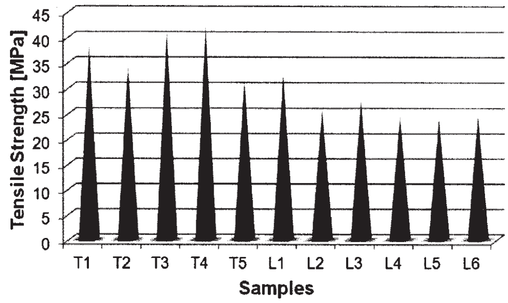

Fig. 9. Variation of tensile strength for both types of specimens (longitudinal and transversal)

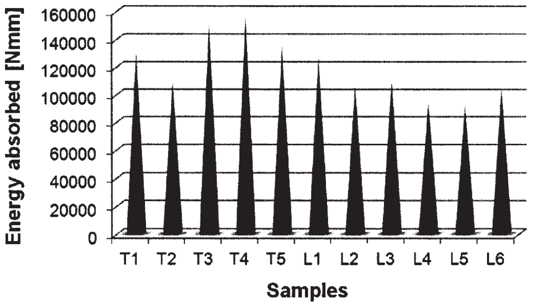

Fig. 10. Variation of energy absorbed for both types of specimens (longitudinal and transversal)

Table 3
MAIN MECHANICAL PROPERTIES RESULTS FROM TESTS

Mechanical properties of lignocelluloses composite material	Average value for the warp direction	Average value for the weft direction
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
Stiffness, *N/m*	7259254.27	9155033.62
Young's Module, *MPa*	8657.566	10417.946

Results and discussions

After processing the machine data, stress-strain (σ–ε) curves were made, as presented in figure 8. Stress varies depending on the direction from where the specimen was cut. For specimens cut on longitudinal (warp yarns) direction stress ranges from 23.89 MPa up to 32.514 MPa and for the ones cut on the weft direction, it ranges from 34.224 MPa to 41.709 MPa.

Figure 9 presents variation in tensile strength of specimens cut on both directions. Tests showed that the material has a better resistance when applied in the direction of the weft yarns fabric used to reinforce composites. On the longitudinal direction of the plate was recorded maximum tensile strength of 32.57 MPa and on the transverse direction of the plate was recorded a tensile strength of 42.03 MPa.

The absorbed energy required to produce fracture, per area unit or mechanical work done during the break, per area unit is equal with area under the curve s = f (r). Tests have shown that the energy absorbed by the specimen is greater when the material is applied in the direction of the weft yarn fabric as can be seen in figure 10.

Table 3 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.

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 were 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 [11].

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