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COMPARISON OF MECHANICAL AND ELASTIC CHARACTERISTICS BETWEEN SOLID WOOD AND LIGNOCELLULOSIC COMPOSITE

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Abstract:
A report by FAO (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*. So sawdust is an important renewable raw material and can be used in other areas moreover than heating. Wood combined with other materials has multiple benefits and utilities, becoming a subject of active research area, with new ideas that are to be examined and then developed. The paper presents experimental research on elastic properties of lignocellulosic composite with different sizes of grain and type of reinforced material (hemp and flax) determined with tensile test. A new material with a natural texture was made. Then, the results were compared with elastic properties of solid wood from references*. *The fracture behavior in case of weft direction of samples is brittle, while the warp direction is ductile due to successive ruptures of reinforcement elements. By adding wood particles between layers of fabric, the material anisotropy was improved resulting decreasing of longitudinal elasticity modulus on the warp direction of only 14.8%, compared to the longitudinal modulus of the material in the weft direction. By embedded the wood particles in gaps of fabrics, the compaction of the material increase and mechanical properties of the composites are improved. In this case breaking behavior for tensile test is brittle too.*

Key words: *lignocellulosic composite; tensile stress; strain; solid wood.*

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INTRODUCTION

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. 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. Wood combined with other materials has multiple benefits and utilities, becoming a subject of active research area, with new ideas that are to be examined and then developed (Bismark 2006). Lignocelluloses fibres have a number of advantages and disadvantages compared with traditional glass fibres used to reinforce composite materials (Hadar 2006, Curtu and Stanciu 2010). Their ecological character, biodegradability, low cost, non-abrasive nature, safe handling, use with various possibilities as fillers, processing with low power consumption, important specific properties, low density and a large number of types of fibre are very important factors for their acceptance in markets where a large volume of materials is needed such as automotive industry (Curtu and Stanciu 2011). In this respect, the research was carried out a new type of composite material made from wood fibers mixed with resin and reinforced with flax or hemp fabric. New lignocellulose was tested for applications in the automotive industry as a door panel, floor to buses and trucks. Being integrated into a complex structure, it was necessary to determine the mechanical properties of the composite by standardized tests. The results were compared with the characteristics of solid wood to determine the advantages and disadvantages of using these composites in various applications that could replace wood. The paper presents experimental research on elastic properties of lignocellulosic composite with different sizes of grain and type of reinforced material (hemp and flax) determined with tensile test.

MATERIALS AND METHOD

Firstly, lignocellulosic specimens were prepared containing particles with different sizes (1 ÷ 2mm, 0.4mm and 0.2 ÷ 1 ÷ 0.4mm) of different wood species (beech, oak, poplar and spruce). It is known that size and shape of wood particles from sawdust varies from: wood species, moisture content etc. The grain sizes of sawdust ware determined by a sieve analysis, using a sieve particle separation device produced by FRITSCH. In Fig. 1 are presented the correlation between grain size of wood particle and density, in accordance with analyzed wood species. As the wood particle sizes are smaller, density is higher. Increasing particle size embedded in composite leads to decrease density. Density of particle with size of more than 2mm approaches that of solid wood (Fig. 1).

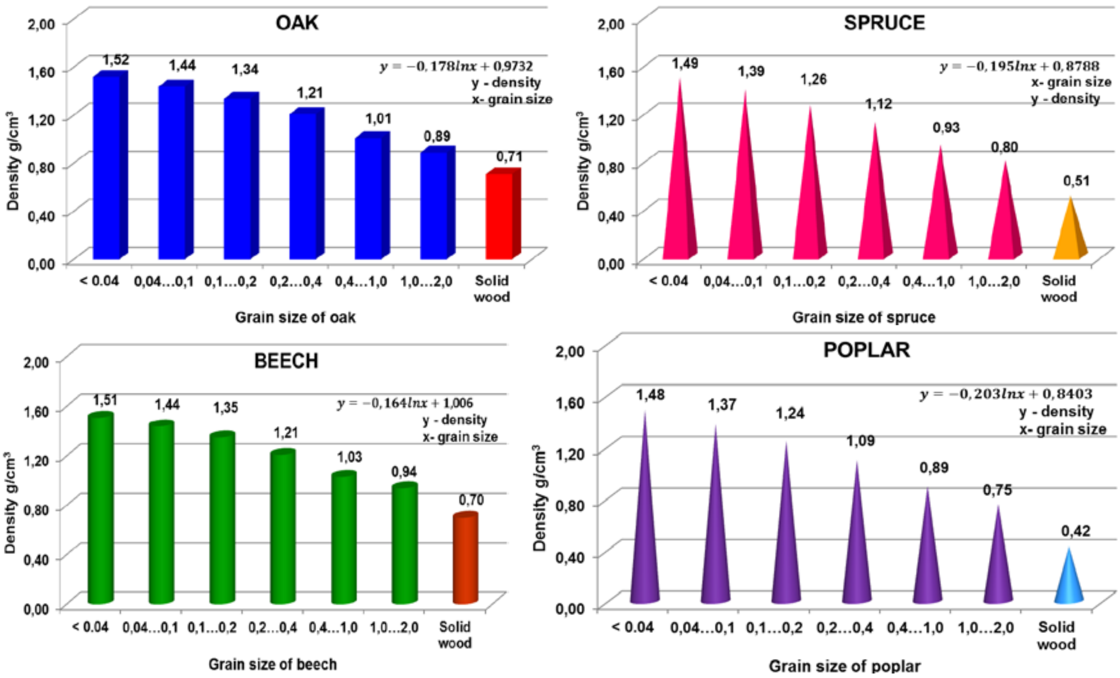


Fig. 1
Density variation depending on particle size from different species (oak, spruce, beech, poplar) compared to solid wood.

Secondly, the lignocellulosic material was obtained as a laminate having six layers made of epoxy resin reinforced with plain weave fabric of flax fibres and wood sawdust of oak species (Fig. 2). The plain weave fabric of flax fibres has a density per unit area of 220g/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 Fig. 2, direction of the warp yarns being aligned with the length of the roll of fabric. It was chosen the oak species due to high density and its resistance to aggressive environmental factors.

It is known that wood is a porous structure consisting of wood cell membrane and cell lumena as can be seen in Fig. 3. Oak density is between 0.71 - 0.75g/cm^3, but wood substance density (without cellular gaps) of the same wood species varies in the range 1.53 - 1.56g/cm^3. Six specimens were carried out for each direction of fabric - the cut in the warp direction denoted FOUPU and the cut on weft direction denoted FOUPB. In Table 1 are presented dimensions of samples.

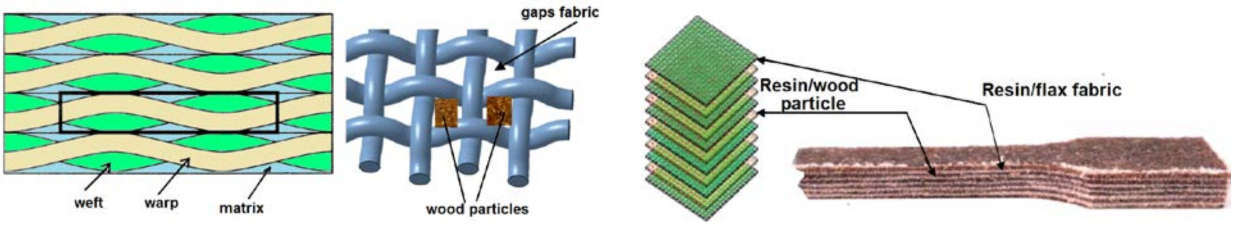
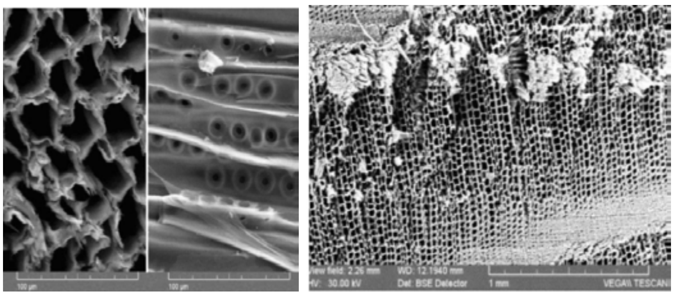


Fig. 2
Types of yarns orientation in reinforcement fabric.



a. **b.**
Fig. 3
Micrographs of spruce wood structure (1000x):
a – cross section; b – radial section (Szmutku 2011)

Table 1
The dimensions of the test specimen cross section with six layers of fabric reinforced by the particles of wood and oak

Samples	Width b_1 *[mm]*	Thickness h *[mm]*	Area *[mm^2]*	Samples	Width b_1 *[mm]*	Thickness h *[mm]*	Area *[mm^2]*
FOUPU1	10,26	6,52	66,8952	FOUPB1	10,38	6,51	67,5738
FOUPU2	10,12	6,81	68,9172	FOUPB2	10,21	6,47	66,0587
FOUPU3	10,22	6,71	68,5762	FOUPB3	10,29	6,86	70,5894
FOUPU4	10,24	6,71	68,7104	FOUPB4	10,15	6,9	70,035
FOUPU5	9,92	6,54	64,8768	FOUPB5	10,29	7,1	73,059
FOUPU6	10,32	6,9	71,208				

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. The tests were performed according to European Norms EN ISO 527 on specimens with the shape and dimensions presented in Fig. 4a. Tensile test were carried out on a Lloyd LS100 testing machine (Fig. 4). 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 1mm/min.

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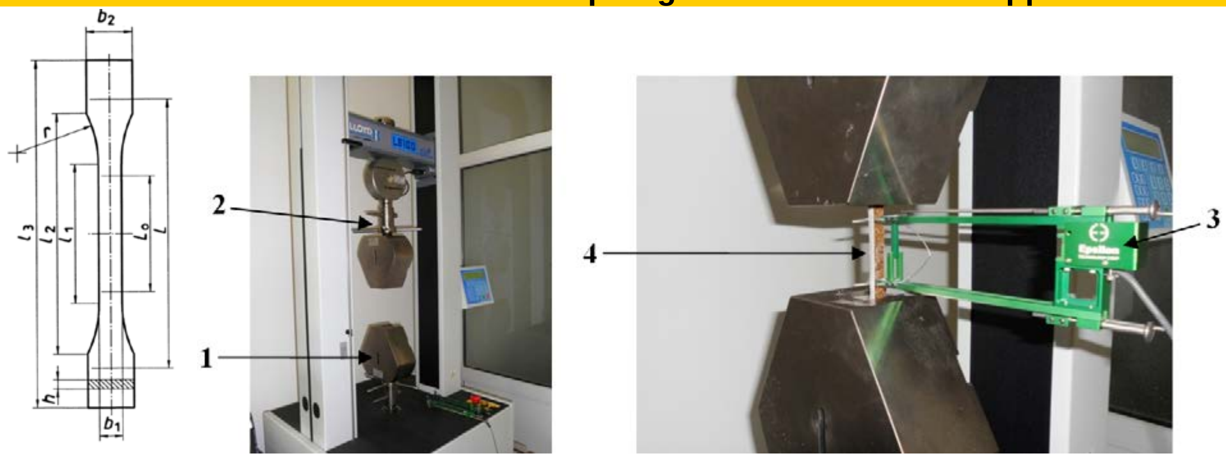

a. ***b.*** ***c.***

Fig. 4
Experimental set-up:
a – sample of tensile tested; b - Tensile test machine LS100 Lloyd's Intruments;
c - extension measuring instrument: 1 – fixed part; 2 - movable part; 3 - extension measuring instrument; 4 – composite material specimen.

RESULTS AND DISCUSSION

After tensile tests, stress-strain σ-ε curves for samples cut on warp and weft direction are obtained and presented in Fig. 5. It can be noticed that all specimens behave almost linear until breaking. From rheological point of view, this behavior characterized the elastic - plastic materials compare to solid wood which is elasto-visco-plastic being simplified as Burgers body by some researchers or N Kelvin body by others (Moutee 2006, Ferry 1980, Macosko 1994).

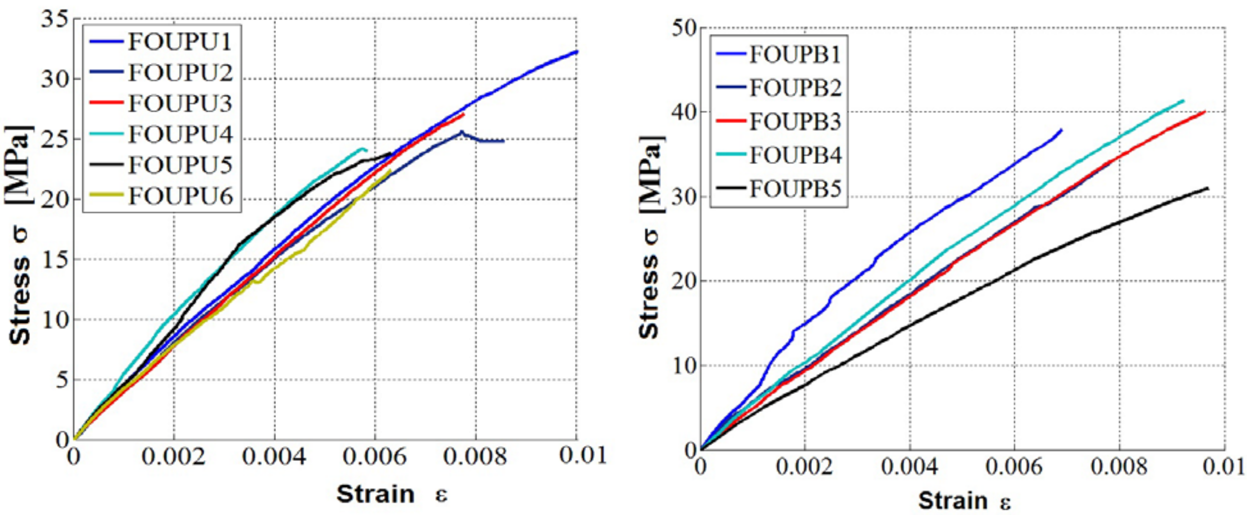

Fig. 5
Stress-strain σ-ε curves recorded in tensile test
(FOUPU cut on warp yarns direction; FOUPB - cut on the weft direction).

In Fig. 6 are shown the breaking shapes of samples. These fractures are brittle and present snatching fiber in the warp direction. In case of samples cut on warp direction, the matrix yielded on full-length. Although the fabric theoretical has the same features on two directions, the test showed a strong anisotropy of the material. This behavior is because the manufacturing of the fabric, the warp and the weft have been strained differently, resulting in a higher ripple angle of the warp direction.

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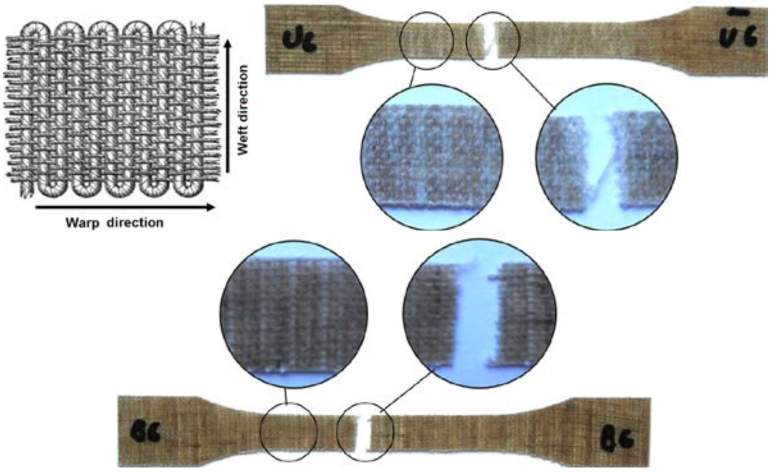

a. b. c.

Fig. 6

Fracture behavior of specimens cut in warp and weft direction: a - to the two directions of the fabric; b - failure of sample on warp direction; c - failure of sample on weft direction.

From stress-strain curves, the elasticity modulus can be determined. In Fig. 7 is presented the comparison between solid wood and lignocellulosic composite regarding elasticity modulus E. It can be noticed that the elasticity modulus of composite samples is lower than solid wood in longitudinal direction. So, the values of elasticity modulus for composite vary between 2501MPa and 4894MPa. The maximum values are obtained for all type of laminate regardless number of layers, but cut in weft direction and reinforced with flax. In previous studies, the lignocellulosic composites with one lamina and with different type of fabric (hemp and flax) were researched (Terciu 2011, 2012). Comparing with lignocellulosic composite, solid wood is characterized by low elasticity modulus in radial direction almost 2 times and 4.5 times in tangential direction.

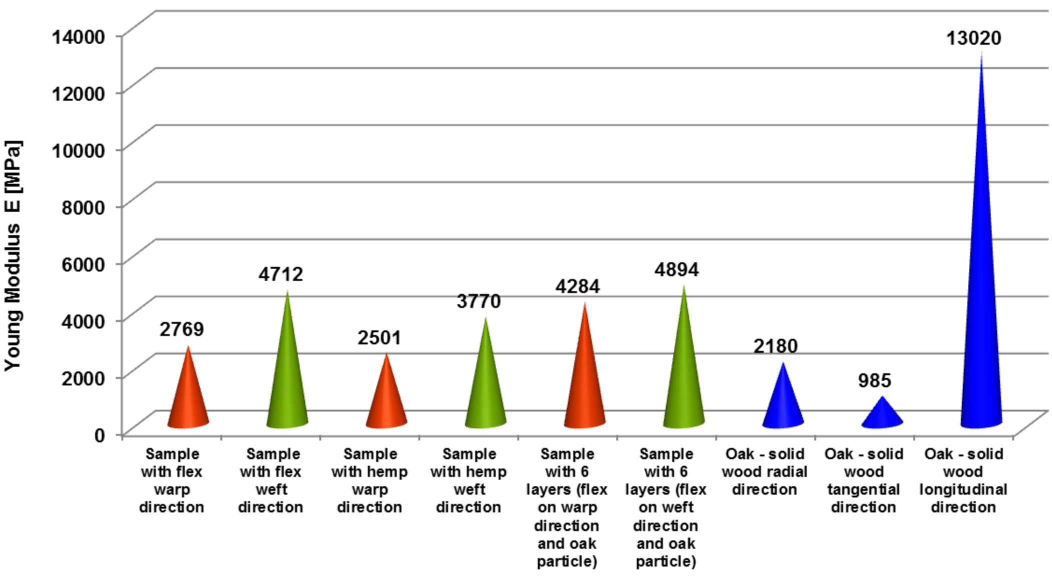

Fig. 7

Comparison between solid wood and lignocellulosic composite regarding of Elasticity Modulus E (Curtu 1984 – Values of Elasticity Modulus of solid wood).

Tensile strengths of the composites in weft direction are higher by about 55-60% compared to the warp direction. Unlike solid wood, tensile strength is less than about 4 times the warp direction, regardless reinforced fabric (hemp, flax) and number of layers. Compared with transverse strength of solid wood, composite strengths are 8-10 times higher. From the two graphs (Fig. 7 and 8) it can be seen that by adding wood particles between layers, anisotropy in the two directions of reinforced fabric material is improved and the mechanical properties are improved. Even just fabric reinforced materials in multiple layers, the arrangement of the layers affect the mechanical properties of the composite. This is shown by Barbero (1998) in one of his books, which reported that by ordering phase layers improved mechanical properties of the composite layer.

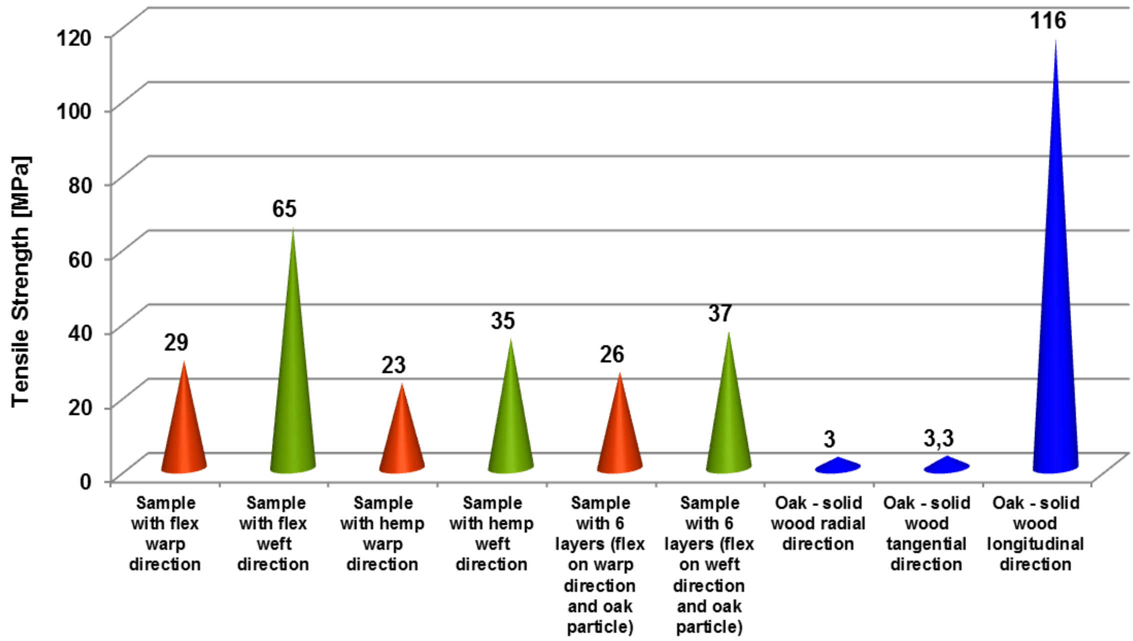

Fig. 8
Comparison between solid wood and lignocellulosic composite regarding of tensile strength.

CONCLUSION

The fracture behavior in case of weft direction of samples is brittle, while the warp direction is ductile due to successive ruptures of reinforcement elements. By adding wood particles between layers of fabric, the material anisotropy was improved resulting decreasing of longitudinal elasticity modulus on the warp direction of only 14.8%, compared to the longitudinal modulus of the material in the weft direction. By embedded the wood particles in gaps of fabrics, the compaction of the material increase and mechanical properties of the composites are improved. In this case breaking behavior for tensile test is brittle too. In conclusion, for some application, lignocellulosic composite represents an efficiently alternative of solid wood and of synthetic composite (glass, carbon etc.), being characterized by a satisfactory and economical values of resistance.

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