Abstract: The paper presents experimental research results and aspects of mechanical characteristics of composite materials reinforced with wood sawdust, subjected to tensile stress. Sawdust, as wood waste resulting from sawing, is an important material resource, natural and renewable. The research sought to determine the influence of particle size on mechanical properties of composite. Like any other natural product, lignocelluloses materials are characterized by high diversity and variability of their properties, which are reflected on structures which incorporate them.

Key words: composites, wood sawdust, tensile tests, polymeric resin, particle size.

1. INTRODUCTION

In recent years there are concerns for the production of wood structures and other materials. To achieve these, one of the requirements is to have compatibility between wood properties (mechanical, chemical) and the other materials that will allow obtaining a new product, with uniform structure and default properties. 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 [1, 2].

The changes that occur during execution of the composite, both for natural fibres and for other components, allow obtaining superior properties of its own, which must be properly identified and used [3].

Experimental studies in the literature have pursued aspects of the structural composition of lignocelluloses materials, namely: the proportion of components, compatibility between components and types and characteristics of the matrix used [4].

Lignocelluloses fibres have a number of advantages and disadvantages compared with traditional glass fibres used to reinforce composite materials. 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.

However certain disadvantages, such as the tendency of agglomeration during manufacture, low resistance to moisture and quality changes due to the seasons of growth, reduce the potential for these fibres [5, 6].

An optimal cost composite can be obtained by embedding in its component the waste from other manufacturing processes or recycled materials. 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$^3$ [7]. 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.

2. MATERIALS AND METHODS

Composite materials are made of polyester resin and oak wood particles. The mechanical characteristics of the polyester resin without reinforcing are shown in table 1.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
<th>Unit of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>50</td>
<td>MPa</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>4600</td>
<td>MPa</td>
</tr>
<tr>
<td>Tensile elongation</td>
<td>1.6</td>
<td>%</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>90</td>
<td>MPa</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>4000</td>
<td>MPa</td>
</tr>
<tr>
<td>Impact strength P4J</td>
<td>5.0-6.0</td>
<td>mJ/mm²</td>
</tr>
<tr>
<td>Volume shrinkage</td>
<td>5.5-6.5</td>
<td>%</td>
</tr>
</tbody>
</table>

Table 1. Mechanical characteristics of the polyester resin used

For these determinations have been used three types of materials using different grains of wood particles: 1 ÷ 2 mm, 0.4 ÷ 1 mm and 0.2 ÷ 0.4 mm.

In figure 1 can be seen that most part of the particles resulting from the sawing process are of the sizes mentioned above.

Fig. 1. Data results from a granulometric analysis of oak sawdust

Particle separation was achieved by sieving, resulting three types of particles shown in figure 2.

An important parameter of composites is the ratio of components. In this study we used fibre volume fraction which is defined as:

$$ V_f = \frac{\rho_m W_f}{\rho_f W_f + \rho_m W_f} $$

(1)

Where: $V_f$ is the volume fraction of fibres; $W_f$ is the weight of fibres; $W_m$ is the weight of matrix; $\rho_f$ is the density of fibres and $\rho_m$ is the density of matrix.

To determine the volume of a certain quantity of particles is very important to know their density. It is known that wood is a porous structure consisting of wood cell membrane and cell lumena as can be seen in figure 3.

Fig. 2. Particle separation device and types of particles results

Fig. 3. Micrographs of spruce wood structure (1000x): a – cross section; b – radial section [8]
Oak density is between 0.71 - 0.75 g/cm³, but wood substance density (without cellular gaps) of the same wood species varies in the range 1.53 - 1.56 g/cm³. Pycnometer method by measuring the mass of liquid displaced by a certain amount of wood particles was used to determine the particle density. The liquid used for these determinations was Petrosin. For each size range of wood particles were analyzed three amounts of wood particles. The average values determined for different types of grains can be seen in figure 4.

Knowing the density of wood particles can calculate their volume, respectively the volume fraction of fibre reinforcement. To determine the effect of wood particle size on mechanical properties of the composite, tensile tests were performed. 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 specimens have the specific shape and dimensions of tensile test composite materials reinforced with fibre, according to ASRO SR EN ISO 527 and were made by directly-moulded. Fibre volume fraction of wood particles was 20% for all three types of specimens. The three types of samples can be seen in figure 5.

The equipment used is a tensile test machine with constant speed of 1 mm per minute, provided with specimen fixing devices. In order to measure the specific elongation of the specimen was used an extension measuring instrument. Specimens fixing in tensile test machine and method of breaking them can be seen in figure 6.

3. RESULTS AND DISCUSSION

After processing the machine data, tensile tests diagrams load-extension were made, as presented in figure 7, 8 and 9.
Fig. 7. Tensile tests diagrams for specimens with 1 ÷ 2 mm wood particles

Fig. 8. Tensile tests diagrams for specimens with 0.4 ÷ 1 mm wood particles

Fig. 9. Tensile tests diagrams for specimens with 0.2 ÷ 0.4 mm wood particles

In figures 10, 11 and 12 strain-stress correlations for the three types of specimens can be seen.

Fig. 10. Stress-strain $\sigma$-$\epsilon$ curves recorded in tensile test for specimens with 1 ÷ 2 mm wood particles

Fig. 11. Stress-strain $\sigma$-$\epsilon$ curves recorded in tensile test for specimens with 0.4 ÷ 1 mm wood particles

Fig. 12. Stress-strain $\sigma$-$\epsilon$ curves recorded in tensile test for specimens with 0.2 ÷ 0.4 mm wood particles
It may be noted that for the same category of specimens there is not a large dispersion of values. The absorbed energy required to produce a fracture, per area unit or mechanical work done during the break, per area unit is equal with area under the curve $\sigma = f(\sigma)$, as shown in figure 13.

Tests have shown that the energy absorbed by the specimens reinforced with particles of size between 0.4 ÷ 1 mm is greater. The average values of energy absorbed for the three types of specimens can be seen in figure 14.

Other properties such as tensile strength and elongation at fracture are also higher for the specimens reinforced with particles of size between 0.4 ÷ 1 mm, as can be seen in figure 15 and 16.

Although the use of smaller particles typically leads to an increase in mechanical properties, in this case it was found that particles of size between 0.4 ÷ 1 mm have a greater length than particles of other sizes and this makes the tensile strength for this category to be greater.

4. CONCLUSION

- With increasing of oak particles sizes, density decreases after the law:

$$y = -0.16\ln(x) + 1.032$$

- Oak particles sizes of 0.4 ÷ 1 mm obtained by sawing are the majority representing a percentage of approx. 58% from the total amount of sawdust. This percentage varies from one species to another and depends on several factors such as wood density, moisture content at the processing, cutting regime etc.
Experimental tests have shown that long particles lead to increased resistance compared to those with comparable sizes (spherical or rectangular).

Maximum strain energy resulted for specimens reinforced with particles sizes between 0.4 - 1 mm.

5. ACKNOWLEDGEMENTS

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59321

6. REFERENCES


7. ADDITIONAL DATA ABOUT AUTHORS

Terciu, O.M. / PhD. Student Eng. / Transilvania University of Braşov – Faculty of Mechanical Engineering / 29 Eroilor Blvd., 500036 – Brasov, Romania / phone/fax: 0040 268 415315/ ovidiu-mihai.terciu@unitbv.ro

Curtu, I. / Proff. Dr. Eng. / Transilvania University of Braşov – Faculty of Mechanical Engineering / 29 Eroilor Blvd., 500036 – Brasov, Romania / phone/fax: 0040 268 415315/ curtui@unitbv.ro

Teodorescu-Drăghicescu H. / PhD. Assoc. Prof. / Transilvania University of Braşov – Faculty of Mechanical Engineering / 29 Eroilor Blvd., 500036 – Brasov, Romania / phone/fax: +40268418992 / draghicescu.teodorescu@unitbv.ro