Static bending strength and modulus of elasticity in static bending along the height of beech wood (*Fagus sylvatica L.*) obtained from forest thinning

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Abstract: - Beech wood resulted from thinning forest is today, in Romania, an important base of raw material: about 14.53% of the total of beech wood harvested annually (*Romsilva* – National Forestry Association from Romania). Being a wood material somewhat slighted in furniture design, its properties have been little studied. Knowledge of the properties of a material is a condition for a better use of its; these provides valuable information for the technological processes of processing.
In this context, the paper presents the results of testing the bending strength and modulus of elasticity in bending of beech wood (*Fagus Sylvatica* L.*)* with D_{base} = 14 cm. The study was conducted in the context in which wood of beech obtained from thinning can be considered as an alternative wood resource for the furniture industry, in accordance with sustainable development strategies for Romania.
The paper brings new information for the specialty databases and it, also, opens ways for future research concerning wood from thinning.

Key-Words:- beech wood, thinning, bending strength, modulus of elasticity

1 Introduction

Wood is a renewable raw material very important for many branches of national economy. In Romania, beech (*Fagus Sylvatica* L.*)* is one of the most used wood species in wood processing industry. This represent more than a third of the forest of Romania: 36% (*Romsilva* – National Forestry Association from Romania).

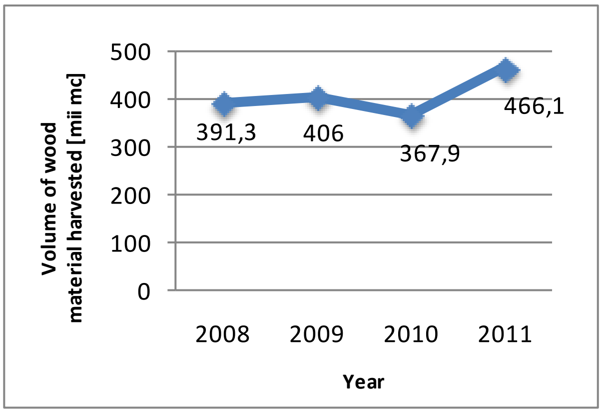

Figure 1. Annual evolution of beech wood harvested from forest thinning.

In general, beech wood resulted from forest thinning present a low interest in the furniture manufacturing industry, although annual is harvest approximately 14.53% of the total volume of beech wood material harvested, according to data from *Romsilva* – National Forestry Association from Romania. From estimates made for 2011, resulted that the volume of beech wood from thinning increased with 26.69% (Fig.1).
It is known that, in general, through thinning operations is removed the trees that are unfit in terms of quality:

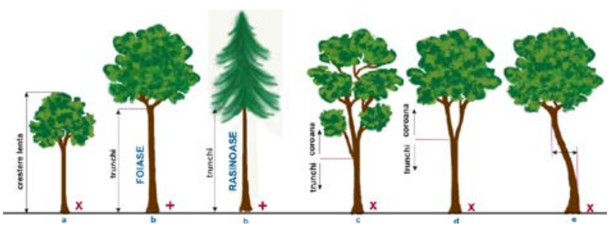

Figure 2. Type of trees resulted from forest thinning. Through thinning is preserved trees with good growth (b) and remove trees with: slow growth (a) branches large developed (c), crotch branches (d), curved stem (e).

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As we can see from forest thinning resulted trees with form defects and implicitly structural defects (Fig. 2).These defects can influence in negative way the wood properties.
From this point of view, in Romania, thin trunks thus obtained are valuable below the operating costs or even left in the forest.
In this context, an *efficient use and at higher level* (Sustainable Development Strategy for Romania 2009*)* of beech wood from thinning, (with D_{base} = 14 cm) for getting ecological structure that can be embedded in product design of furniture, is a priority for Romania, for the furniture industry.
For this, knowledge of the properties of a material is a condition for better use of its; these provides valuable information for technological processes of processing.
Thus, the development of forms of ecological structures of wood more rational, adapted to a modern furniture design which involves aesthetics, economy and safety, requires knowledge of states of strain and tension of that material. Thus, in this paper were analyzed two mechanical properties of thin stem of beech (*Fagus Sylvatica* L.*)*, namely:
bending strength and modulus of elasticity in bending.

2. Experiment

For tests were used samples obtained from 2 thin tree of beech wood (*Fagus Sylvatica L.)* with a diameter of 14 cm. Area of study is UP Valea Cenusii, Romsilva – from where trees have been provided.
The tests were made on the height of tree (Fig.3). Because this kind of wood has a considerable percent of juvenile wood, the authors consider that this method give real information and about its influence on height to the mechanical properties which are studied in this paper.

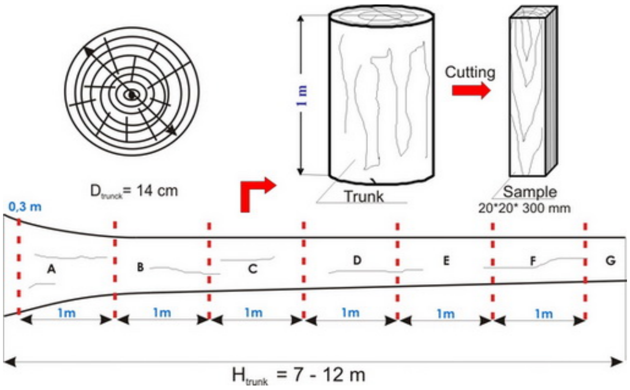

Figure 3. Scheme to obtain samples and type of sample for testing at static bending.

It is known that in bending wood we have a combined loading: stretch and respectively compression. Thus, in stretch area appear normal tension, positive and in compression area appear negative tensions. Through the static bending attempt determine the maximum load which produces rupture of a sample of wood and is calculated wood strength corresponding to this task.
Determination of modulus of elasticity at static bending consists in measuring the arrow of a wood sample subject to static bending loads.
So, trees have been cutting in logs and from each log were obtained a number of 6 samples with form of right prism (Fig.3) with square section, with sides of 20 ± 0.5 mm and length of 300 ± 1 mm, in accordance with ISO 3133 and ISO 3349. Before make the test, the samples were conditioned in a climatic room. Moisture in the moment of testing was 8% and density was determinate on height for each set of sample (Table1, Table2.).
The load was applied tangentially to all set of sample (Fig.4).

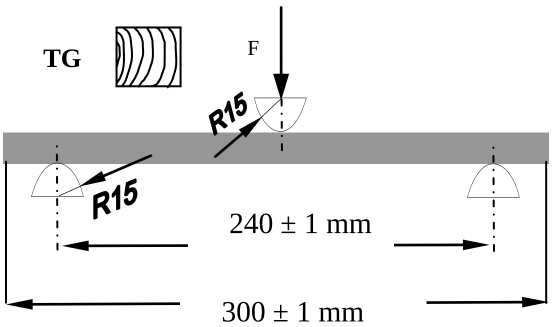

Figure 4. Modality of application of load on wood samples

It is necessary to note that beech wood tested presented some defects of structure such as: twisted fiber, small nodes. These defects are unavoidable at this kind of wood obtained from thinning forest.
Force of loading of ±3N was applied at a constant speed of 7mm/min. Application of load (Fig.4) was made continuously, slowly and progressively, for as breaking samples to be taking place after 1.5±0.5 min from the beginning of request, according to ISO 3133.
The tests were made on a Universal Machine with two columns type Zwick/Roell for testing of wood materials.
Formulas through which we achieved results of the two mechanical properties are:

$$\sigma_i = \frac{3 \cdot P \cdot l}{2 \cdot b \cdot h^2} \quad [\text{N/mm}^2] \qquad (1)$$

where:
σ_i - resistance to bending to the humidity of moment of the test, in [N/mm^2];
P – load of breaking, in [N];
l – distance between centers of backing, in [mm];
b – width of sample section, in [mm];
h –height of sample section, in [mm];

$$\sigma_{i12} = \sigma_i[1+\alpha(W-12)] \quad \text{[N/mm}^2\text{]} \qquad (2)$$

where:

$\sigma_{i_{12}}$ - static bending resistance to humidity of 12%, in [N/mm^2];
α- correction coefficient depending static bending resistance of moisture with the value 0.04 for all wood species;
W- humidity of sample in the moment of test;

$$E = \frac{3 \cdot P \cdot l^3}{36 \cdot b \cdot h^3 \cdot f} \quad \text{[N/mm}^2\text{]} \qquad (3)$$

where:
E - modulus of elasticity in static bending at the humidity of the moment of the test, in [N/mm^2];
P- load, in [N];
l – distance between centers of backing, in [mm];
f – arrow in the pure bending area, in [mm].

$$E_{12} = \frac{E}{[1-\alpha(W-12)]} \quad \text{[N/mm}^2\text{]} \qquad (4)$$

where:
E_{12} - modulus of elasticity in static bending at the humidity of 12%, in [N/mm^2];
α- correction coefficient of module of elasticity depending of moisture with the value 0.02 for all wood species;
W- humidity of sample in the moment of test.

3. Results and Discussions

The results of the tests are shown in Table 1 for bending strength and in Table 2 for modulus of elasticity in bending.

The static bending for normal beech wood (Wagenfuhr 2000) is between 74 - 210 N/mm^2. Compared with this value, in experimental tests, the bending strength for 8% moisture content is between 92 - 115N/mm^2 and for 12% moisture content between 77 - 97N/mm^2. So, the bending resistance for beech wood with D_{base} = 14cm from thinning is within the limits of normal wood. But, the difference is registered on the height of tree: its values are higher in the first half of the tree - to base.

At 8% moisture content the bending strength is higher with 18.55% to base and with 19.48% to peak than at 12% moisture content.

That means the resistance of beech wood from thinning decreases with increases moisture content. The same situation is and for modulus of elasticity at bending strength.

Table 1. Values at bending strength

Beech Wood (*Fagus Sylvatica* L.) - D_{base} = 14 cm					
Tree height	**Direction of load**	**ρ [kg/m^3]**	**F_{max} [N]**	**σi 8 [N/mm^2]**	**σi 12 [N/mm^2]**
A (base)	Tg	**712** (101.71)	2690	**115** (155.40)	**97** (131.08)
B	Tg	**694** (99.14)	2526	**112** (151.35)	**94** (127.02)
C	Tg	**683** (97.57)	2456	**110** (148.64)	**92** (124.32)
D	Tg	**656** (93.71)	2440	**105** (141.89)	**89** (120.27)
E	Tg	**636** (90.85)	2556	**94** (127.02)	**79** (106.75)
F,G (peak)	Tg	**627** (89.57)	2230	**92** (124.32)	**77** (104.05)

In relation to density, the value of force and strength decreases in direct proportion with this on the height. A similar situation is and for value of modulus of elasticity in relation with density.

Table 2. The values of modulus of elasticity in static bending.

Beech Wood (*Fagus Sylvatica* L.) - D_{base} = 14 cm					
Tree height	**Direction of load**	**ρ [kg/m^3]**	**F_{max} [N]**	**E_8 [N/mm^2]**	**E_{12} [N/mm^2]**
A (base)	Tg	**712** (101.71)	2690	**12740** (106.16)	**11799** (98.32)
B	Tg	**694** (99.14)	2526	**11800** (98.33)	**10905** (90.87)
C	Tg	**683** (97.57)	2456	**11770** (98.08)	**10899** (90.82)
D	Tg	**656** (93.71)	2440	**11325** (94.37)	**10756** (89.63)
E	Tg	**636** (90.85)	2556	**11166** (93.05)	**10685** (89.04)
F, G (peak)	Tg	**627** (89.57)	2230	**9240** (77)	**8552** (71.26)

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Value for modulus of elasticity at 8% moisture content is between 9200 - 12700N/mm^2 and at 12% moisture content is between 8500 - 11700N/mm^2. Compared, also, with experimental tests, in normal wood (Wagenfuhr 2000) the modulus of elasticity at bending strength is between 10000 -18000N/mm^2.

We can observe that, in this case, the value of modulus of elasticity is less, in beech wood from thinning than in normal wood: with 8% for E_8 and with 15% for E_{12}. At 8% moisture content the modulus of elasticity at bending strength is higher with 7.9% to base and with 8.04% to peak than at 12% moisture content.

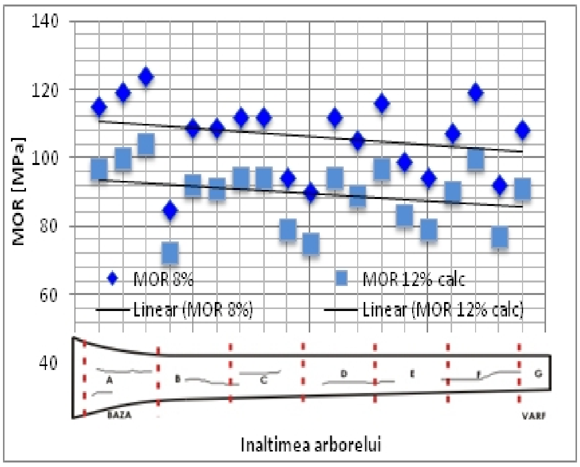

Figure 4. Variation of the static bending on the tree height with diameter by Ø=14 cm, at U=8%

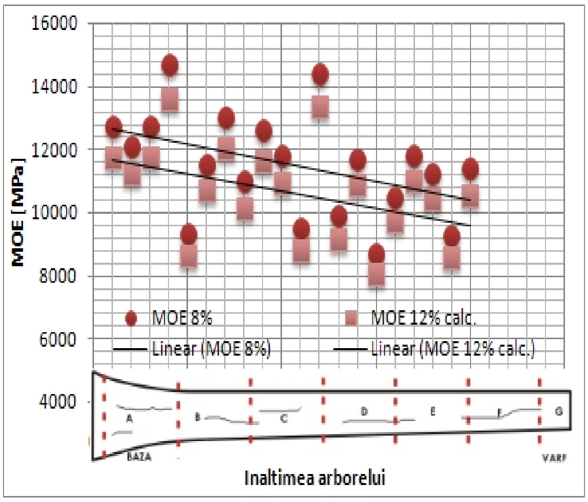

Figure 5. Variation of the modulus of elasticity on the tree height with diameter by Ø=14 cm, at U=8%

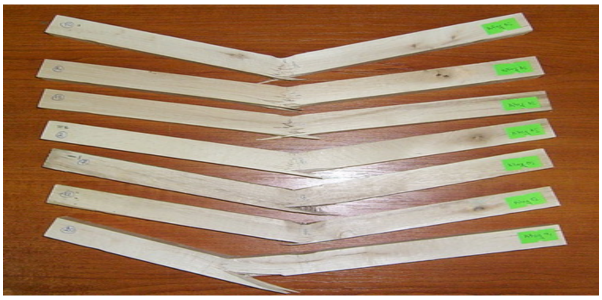

Figure 6 Samples tested and type of rupture: for Ø=14 cm

The samples present short fibers and rupture length varies between 10-20 mm, these observations result from the processing of experimental data.

The way of breaking and bending deflection can be seen and in the figure 5.

An important aspect is the influence of twisted fiber and nodes (Ø = 2 - 8 mm) to bending strength. As we can see in figure 6, the value of bending strength at wood with twisted fiber is less with 9.61% than in wood without these defects.

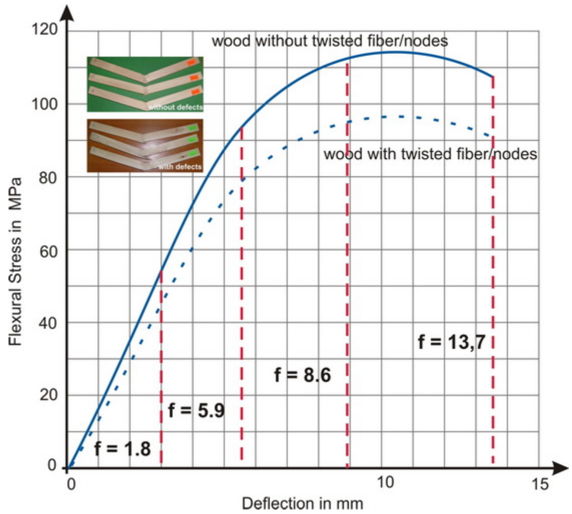

Figure 7. The way of breaking of samples tested and minimum/maximum deflection registered.

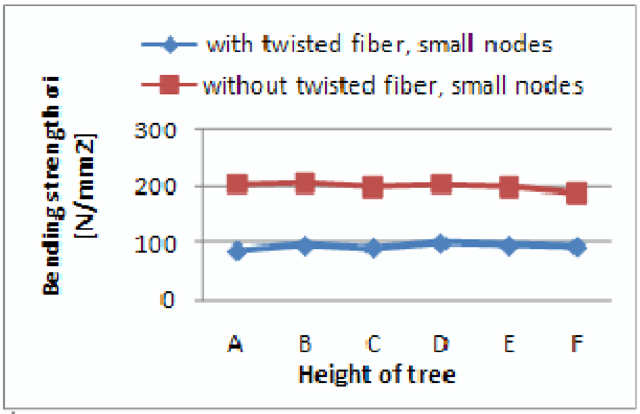

Figure 8. The influence of twisted fiber and small nodes on static bending.

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4 Conclusions

The test made on beech wood from Valea Cenusii with D_{base} = 14 cm, show us that the resistance varies on height and is higher at the base than the top. Modulus of elasticity at bending strength has a similar variation but its value is less than normal wood. These mean that the beech wood from thinning has more elasticity even if it presents twisted fiber or nodes (Ø = 2 - 8mm).

We observed that the bending strength, modulus of elasticity and density decreases on the height of tree from base to peak. These mean that at trees from thinning with D_{base} = 14 cm, proportion of juvenile wood growth to peak and implicitly the properties are lower. So, in this situation, from the industrial processing point of view, we can made a sorting of wood on the height of tree according to requirements.

As you can see in table 1 and table 2 the values of these two mechanical properties registered more decreases from point E. For a trunk with height by 7-12m, mechanical properties decrease from 5-6m.

For a good designing of a product and in accordance with sustainable development, the quality should be checked at each step of a process (Mândru 2011)

So, study on mechanical properties on height of tree allows us to sort wood from thinning in according on the quality required to obtained ecological structure.

In these conditions, beech wood from thinning can be a challenge in furniture manufacturing.

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