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SHEAR STRESS IN MEASURING SECTION OF THE SAMPLE WITH MODIFIED WOOD

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Abstract

The shear strength of anisotropic materials is carried out on the special samples and on the appropriate instrumentation. Research conducted to obtain a homogenous state of the shear stress in the plane sample is difficult, and involve numerous occurrence of additional stress. Therefore, it is difficult to determine the shear strength.

The wood composites are classified as orthotropic materials. In addition, are composed of the layers early wood and latewood. The layers have different thicknesses and exhibit different strength properties. The principal method for determining the shear stress is the trial of twisting of thin-walled tubes. Production of the pipe samples from the wood to determine the shear stress is impossible, due to annual rings.

Beginning of destruction of samples under load was registered by a prototype device. This device makes the realization of plane state of stress in the sample possible. The position of the axis of the sample relative to the direction of the load can be varied. Such configuration axle of the sample to the loading direction, allows to perform, also stretching or compression besides to shear.

The tests were performed for the natural wood and surface modified wood. The paper presents an original method and device designed to determine the shear strength of anisotropic materials on the example of natural wood and a surface modified wood.

***Keywords**: modified wood, mechanical properties, Iosipescu shear test, device to inflict plane stress.*

1. Introduction

Anisotropic materials' research is more complex than isotropic materials due to different material properties for different load directions. Wood is a natural layered composite which structure creates alternating layers of early wood and latewood of very different strength properties.

Shear modules G_{ij}, shear strength T_{ij} and non-dilatational strain γ_{ij} of the composite materials are in an attempt of strength tests. During calculating, the construction with the wood composite is required to take into account the non-linearity between strain and stress [7].

The simple method for determining the shear stress is trial of twisting of thin-walled tubes. However, production of the pipe samples from the wood to determine the shear stress is impossible, due to annual rings. Method of determining shear stress substantially describe Iosipescu standard sample, and concern the synthetic composite materials [12]. In the literature, there is a very little information on the usage of Iosipescu methods for wood testing [11-13].

The paper presents an original method for determining the shear strength, shear/stretching, shear/compression the anisotropic materials on the example of natural and modified surface wood.

2. The test method and material

Production of the cutting stress in the plane sample requires compliance certain criteria. An important feature of the shear test is homogeneity stress in the test area of the sample [1, 2, 8-11].

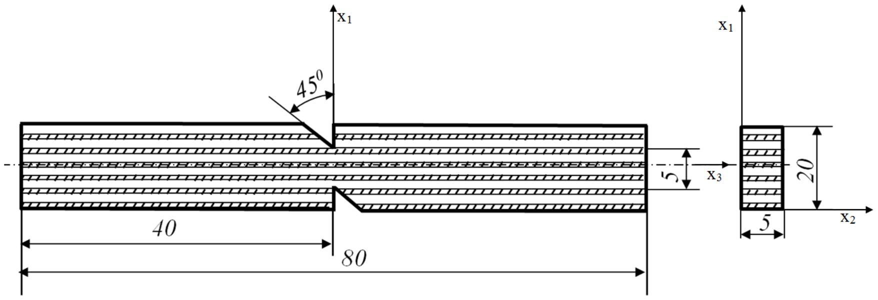

Fig. 1. The shape and dimensions of the sample necessary to determine the shear strength pale layers - early wood - hatched layer – latewood

Currently many researches have been conducted concerning distribution stress in the cross section of the sample with notches for synthetic composite materials [12, 13]. However, for modified wood surface, there is no data on this subject.

The author conducted a number of experimental tests and computational FEM on the basis of which the geometry of the sample has been determined. Such a sample has been used for testing the strength of natural and modified wood. Fig. 1 shows the shape and dimensions of the sample. The bottom of the notched specimen constituted layers of early wood or latewood [5, 6]. The samples were made, with concern that the layers of wood were arranged in parallel and had a constant thickness over its length. Finite element method (FEM) has helped to determine the effect of notch radius on the distribution of shear stress in the measuring cross section of the specimen. For the determination of the notch radius was used dependence [7]

$$r = 2.77\left(\frac{G_{12}}{G_{23}}\right)^{0.23} \cdot \left(\frac{E_{11}}{E_{22}}\right)^{0.37} \text{ mm}, \tag{1}$$

where E_{11}, E_{22}, G_{12}, G_{23} – material constants.

The mechanical testing the pinewood natural and modified was performed using a device, which is described in [5, 6]. In the device shown in Fig. 2, the axial position of the sample relative to the direction of the load F can be varied. Therefore, in the central part of the sample in addition to shear, also stretching or compression can be performed because of the possible rotation the sample [11].

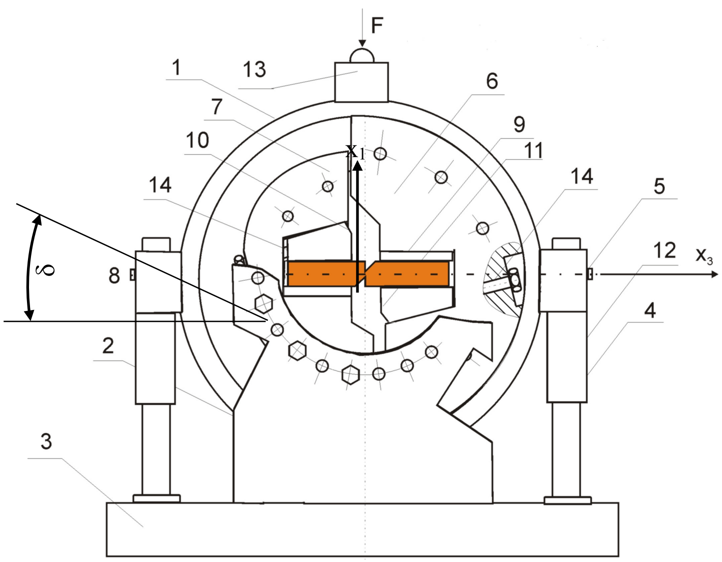

Fig. 2. Device for the strength tests: Casing 2 – cantilever 3 – base, 4 – slide, 5 – sliding funnel, 6 – right holder, 7 – left holder, 8 – insert into the left holder shoe, 9 – insert into the right holder shoe, 10 – left setting block, 11 – right setting block, 12 – slide funnel, 13 – ball fastening and ϕ12 Ball, 14 – M6 Screw

The sample along with holder can be rotated every 15° in the range of -45° to +45°. The rotation of the sample from the horizontal position counter-clockwise direction causes shear and compression of the central portion of the sample, whereas the clockwise rotation causes shear and tensile. In the horizontal position of the sample shear is realized (as in Fig. 2). The device mate with the testing machine which effects a sample with the tension *F*. For the angle $\delta = 0$ (Fig. 2), the state of stress is the closest to a pure shear. For other angles the loading of the sample corresponds to constitutes shear / tensile or shear/compression.

The goal of the work was to determine the shear strength and stress distribution in complex load states (shear / tensile and shear / compression) in the cross-section measuring of the samples of natural and modified wood. Furthermore, the impact surface modification of wood on the rise in strength properties has been defined.

Tests were carried out on samples of natural wood (K0.0) and a modified surface wood (K0.43), which geometry is shown in Fig. 1 and the properties described in the papers [3-6]. Numbers 0.0 and 0.43 means the content of polymer in kg / kg of dry wood [5, 6].

3. Test results and numerical calculations

Depending on the value of the angle between the direction δ load and the longitudinal axis of the sample shear, shear / tensile, shear / compression, and tensile or compression is realized (Fig. 2). In the sample exposed to the stress the distribution stress in the measuring section with notched a length of 5 mm was mainly analysed.

For the angle $\delta = 0$ occurs the sample shear under the influence of an applied vertical displacement along the axis x_1 (Fig. 1, Fig. 2). The force and displacement is recorded by the testing machine. During the shear, displacement of the sample corresponding to the force $F = F_t$,, it is directed along the axis x_1. For negative values of the rotation angles sample in a device (counter clockwise) (Fig. 2), the force *F* causes shear *(F_t)* and compression *(F_c),* in the sample, while for positive angles of rotation (clockwise), the force *F* induces shear *(F_t)* and tensile F_m*).* in the sample.

Figure 3 shows the dependence the load from displacement the samples of natural wood K0.0 and modified wood K0.43 for $\delta = 0°$ (shear).

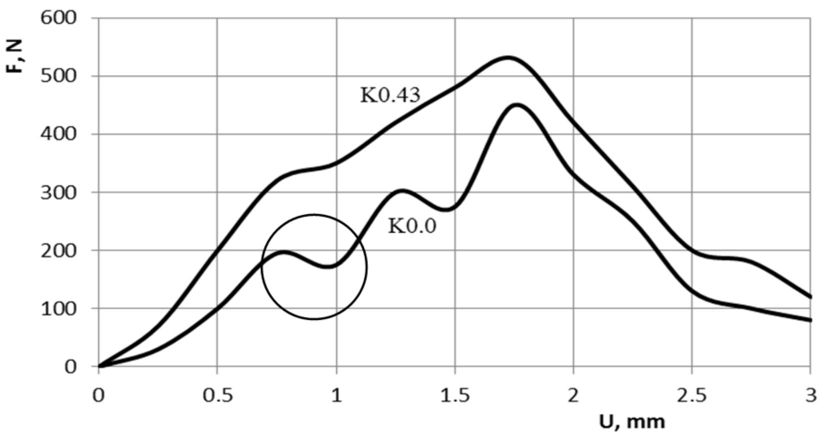

Fig. 3. The dependence the load from displacement of natural wood samples K0.0 and modified wood samples K0.43

Figure 3 shows a characteristic of a periodic change of the transmitted stress by the composite layers of different strength. Latewood layers carry bigger stress and therefore are in bigger effort. The structure of modified wood is more homogenized, a layer of wood has similar strength properties and the curve of the stress is smoother. Furthermore, the modified wood shows substantial increase in strength in comparison for the natural wood.

Numerical calculations have been carried out, used for this purpose elastic constants of the layers early wood and latewood [5, 6]. On basis elastic constants were determined susceptibility matrix of layers of early wood and latewood of the natural wood K0.0 and modified wood K0.43. The ratio the thickness of layers the latewood for early wood adopted as 1/2.

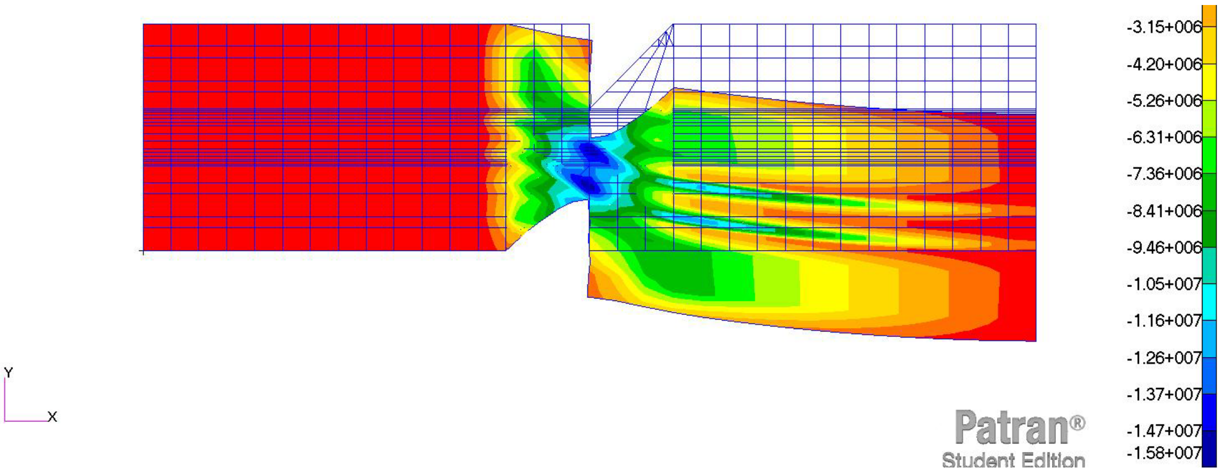

Fig. 4. The distribution of the shear stress σ_{31} in the measurement cross section of the sample K0.0 (deformation of a scale of 20: 1)

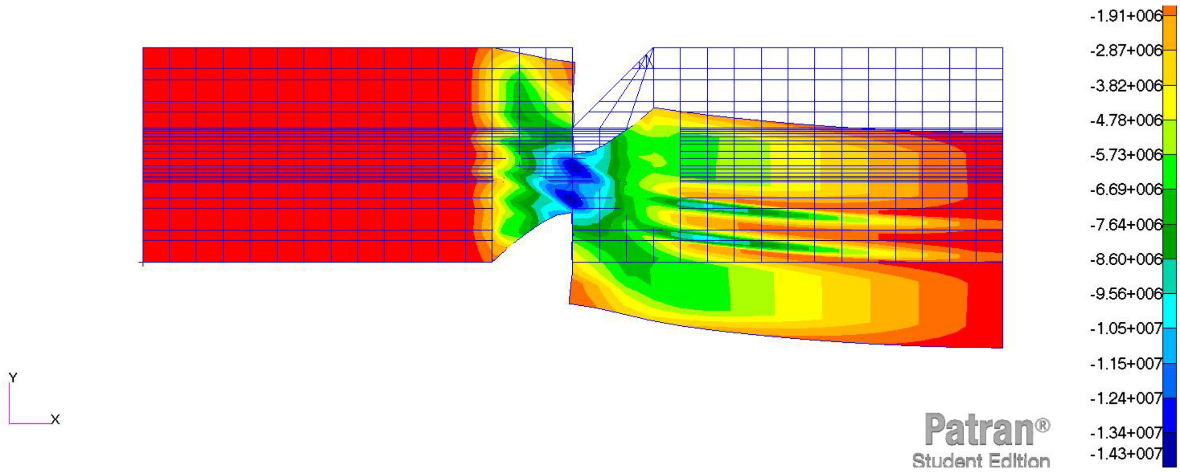

Fig. 5. The distribution of the shear stress σ_{31} in the measurement cross section of the sample K0.43 (deformation of a scale of 20: 1)

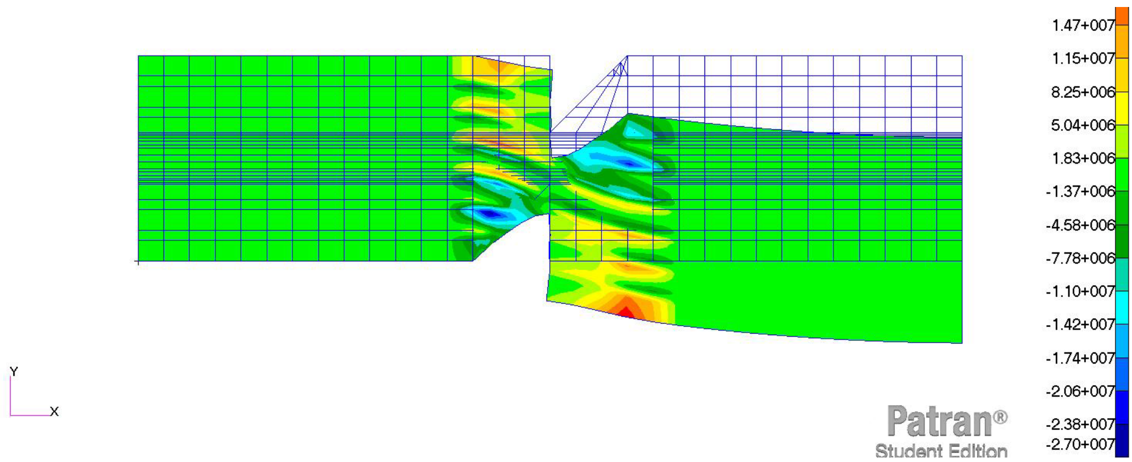

Fig. 6. The distribution of the normal stress σ_3 in the measurement cross section of the sample K0.0 (deformation of a scale of 20: 1)

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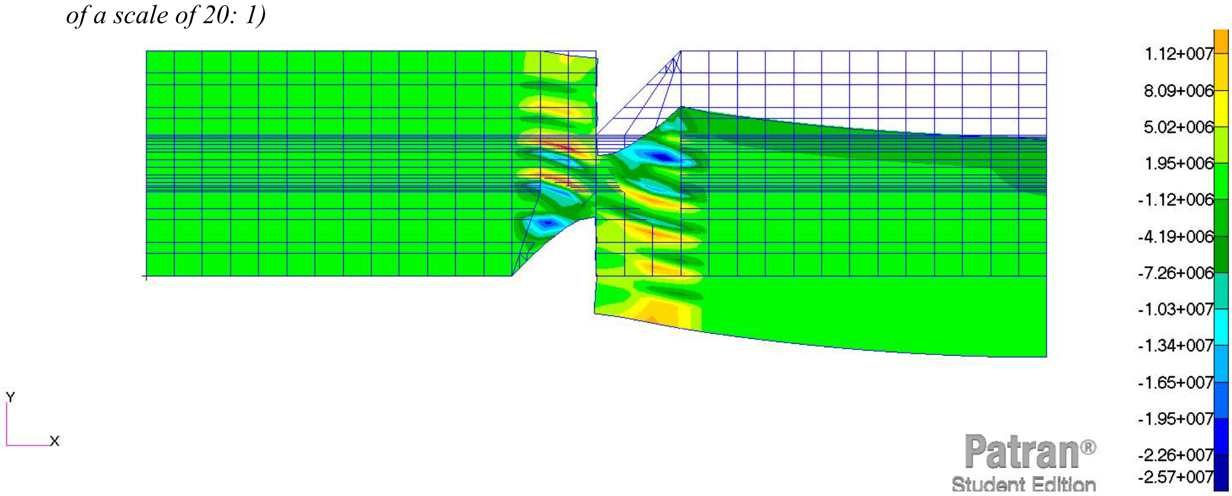

Fig. 7. The distribution of the normal stress σ_3 in the measurement cross section of the sample K0.43 (deformation of a scale of 20: 1)

Figure 4-7 shows the distributions of stress in the analysed cross section of the samples for natural wood K0.0 and modified wood K0.43 for "pure shear" ($\delta = 0^0$). For the angle $\delta = 0°$ corresponding to the pure shear there is a complex stress state.

Obtaining homogeneous stress state for materials "strongly anisotropic" is quite complex issue and requires tools that are more precise. In the modified wood, the distribution of stress is more regular, since the elastic properties of the layers are similar. Modification led the layers of early wood and latewood to be homogenies. Analysis showed that in the sectional measuring samples of the natural wood K0.0, there is a significantly greater effort of the layers of latewood than early wood.

Calculations have shown that in the whole measuring cross-section, the effort of natural wood K0.0 is much higher than the analysed identical measuring cross-sectional of the modified wood K0.43. This is a result of the "homogenization" of the material in the direction of layers latewood. In the natural wood entire load is transferred through the layers of early wood. In the modified, wood both the layers early wood as well as layers latewood have similar properties of strength, resulting in uniform stress distribution in the test section.

4. Final remarks

Determination of the strength characteristics of anisotropic materials is always a complex issue. This particularly applies to the shear strength. Wood is an orthotropic material consisting of layers with different strength properties. The simplification for of calculations is accepted for the material constants and the geometry of the layers.

Wood is a composite natural, which layers intertwine, twist and change of geometry. This all affect the final result. Studies have shown that natural wood has a very diverse effort of the layers in relation to the modified wood. The layers of modified wood have similar strength properties.

The assumption of such sample geometry for the strength tests of the tested materials, on the basis of numerous experiments and calculations, has shown that all of the analysed measuring section the natural wood effort is much higher than a modified one. In studies adopted, the geometry of the sample was appropriate.

Research and calculations have shown that in the entire measuring section the effort of natural wood is much higher than the measuring sectional of the modified wood. This is a result of the "homogenization" of the material in the direction of layers of latewood. The load is spread over the layers of latewood and layers of early wood, which were, strengthen.

Studies have shown that the fulfilment the structure of the wood with a polymer causes a homogenise material. Therefore, the values of the material constants the layers of early wood and latewood are similar.

Finite element method (FEM) has allowed the precise analysis of the stress distribution in the measuring section of the sample. The results allow observing the sensitive areas that are of particular importance in the application of material on the structures.

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