# VARIATION OF SOME PROPERTIES OF THE STEM RADIUS AT RESONANT WOOD

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## ABSTRACT

Many conditions need to be met for producing quality musical instruments. One of them is to have a consistency of structure and properties of wood. It is often difficult, especially for instruments in large dimensions. It is required to be cut large diameter trees.

The article examines variations in the density, compressive strength and flexural strength and modulus of elasticity in the radius of the stem of the spruce. A section for the manufacture of musical instruments is studied in the factory „Kremona AD" – Kazanluk. A section has stayed in dry and heated place more than 12 years. The differences in the properties of the test pieces of juvenile, central and peripheral wood have been established.

**Key words:** resonant wood, spruce, density, compressive strength, flexural strength, modulus of elasticity.

## INTRODUCTION

With the growing age and size of the trees the wood goes through changes. These changes depend on many factors – crown size, age of cambium, etc. Different wood structure means different wood properties, which could be the reason for worsening of the wood quality of certain practical detail. This is really important in the production of acoustic musical instruments. This inhomogeneity could be avoided by procuring trees with bigger radius or by working with smaller details. In that way there is enough space from where could be obtained wood with similar structure.

The aim of the study is the determination of the three zones - juvenile, central and peripheral wood. They can be determined by several methods. The leading one is research of the construction in wood. Here, however, the purpose is to follow the difference in properties and to prove or disprove the belonging of a sampled zone (depending on the radius of the stem) to one of those kinds of wood. The expectations are there properties to be more constant and that to allow the use of any area of the wood separately.

## METHODS AND MATERIALS

Raw material was used for the examination, provided by company „Cremona – AD" Kazanlak. It is obtained by splitting and stored more than 12 years in a dry and heated place (fig. 1). Test pieces were made to determine the acoustic properties with method of resonance (according to ST from SIV 1143-78). From the rest of wood are made test pieces for determining the density of the wood and the ultimate tensile stress.

**Figure 1: General view of the blank (left) and a cutting scheme (right).**

The cutting scheme is the so-called „German arcs“, used in the manufacture of barrels. This method ensures the correct orientation of each test piece. Important role in the study is the describing of the samples (fig. 1). The closest test pieces (those at a distance of 30 to 50 mm of the core) belong to the juvenile wood and the most distant (those at a distance of 180 to 210 mm from the core) - to the peripheral wood. Where is the line between them and can it be determined only by the values of the properties?

To determine that, strips of test pieces, equally distant from the axis of the stem, were tested. Consolidation and averaging of the data was done in several stages. Firstly, the average values were considered strip by strip and then began the separation of groups. The most typical properties of the wood were obtained by the arrangement the data in three groups.

The shown figure (Fig. 1) gives an idea of the size of different parts of the stem, which has a diameter of more than 50 cm. It is noteworthy, the small size of the strip of peripheral wood which should be much larger, and it is not used for production of material for the manufacture of decks.

It has been made an examination of the statistical significance of differences to determine the affiliation of certain test pieces to the species of wood. For determining the density and compressive strength were used 102 specimens. For the determination of flexural strength and flexural modulus were used 72 specimens.

## RESULTS AND DISCUSSION

### Density of wood

The so far obtained values in the country for that property were generally lower than those for Europe [2, 3, 4, 6, 7, 9 and 10]. Kjuchukov, G [1992] and others have established spruce wood density of about 387 kg/m3. This value differs from the tabular (470 kg/m$^3$) by 21 %. [6]. Todorov, M. [1970] has researched changes in the density of wood of the common spruce depending on the altitude and the height of the stem [9]. The author indicates that the influence of altitude is much lower than the situation in the stem of the sampled density. The difference in the values of the first factor was 11.2%, while the second reached 22.0 % (at 1250 m asl) [9, 10].

Furthermore, during the processes of aging the decrease in density is typical. Dragozov and Grigorov [1979] studied the influence of the duration of storage of air-dried spruce wood on cutting resistance. These authors established a decrease in density of about 1.0 % for 3 years, 2.2 % for 5 years and 3.4 % in 10 years [3]. Nikolov and others have conducted a similar study on the influence of storage on physico-mechanical properties of softwoods [7]. The authors found a decrease in density of about 8.6 % to 10 years (compared to the value of 5 years.).

The tested wood shows a gradual increase in thickness with increasing the radius of the stem of 344 kg/m$^3$ (for the sample located from 0 to 60 mm from the axis of the stem) and 405 kg/m$^3$ (for the sample located from 180 to 210 mm from the axis of the stem). The difference between these values of density is 17.7 % (Fig. 2). These values are very close to those pointed out from Bluskova [2]. The author has examined the peculiarities of juvenile wood or as she named it "around the core wood" in the spurce stems. The obtained value for the density of juvenile wood is 341 kg/m$^3$ (at 1000 m asl) and 374 kg/m$^3$ (at 1300 m asl), which the difference is 9.1 %.

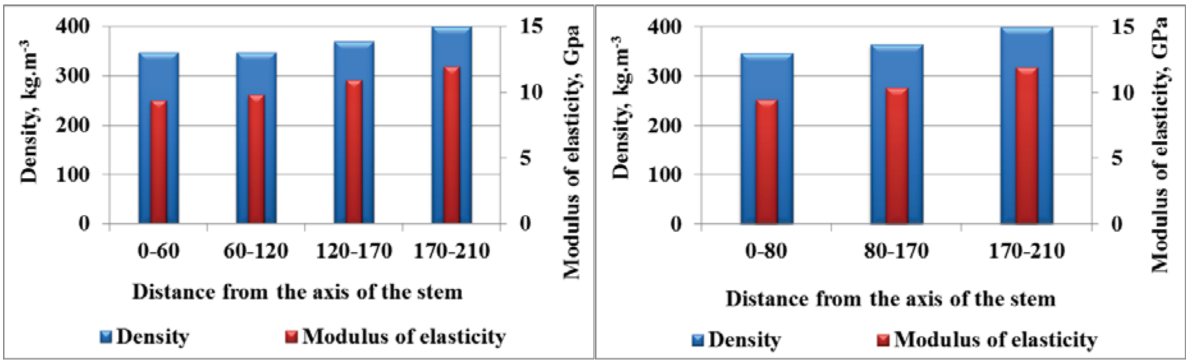



**Figure 2: Average value for the density and modulus of elasticity of wood in four (left) and three (right) samples.**

It is clearly evident, that the nearest and most distant samples have the highest variation. Although the indicator of accuracy does not exceed 2.5% the dispersion is an indicator of homogeneity of the samples density. This gave ground for consolidation, to form only three sets of samples. After verification of the statistical significance of differences of the samples strip by strip, equally remote samples from the body axis of the stem (of the sample at the same distance from the axis of the stem), were determined following three sets of samples on the density of wood (Fig. 2):

- Juvenile wood is spaced to 80 mm out from the axis of the stem and has an average density of 346 kg.m$^{-3}$, having dispersion of 17.8 kg/m$^3$.
- The central wood is situated at a distance from 90 to 170 mm from the axis of the stem and has an average density of 363 kg.m$^{-3}$, having dispersion of 17.8 kg.m$^{-3}$.
- The peripheral timber is located at a distance of more than 180 to 210 mm from the axis of the stem and has an average density of 405 kg.m$^{-3}$, whereas a dispersion of 29.6 kg.m$^{-3}$.

The difference between the values is negligible, varying slightly for both juvenile and central wood. The verification proved that the fourth sample exactly matches the peripheral wood.

**Compressive strength**

The mechanical properties also change with time and position in the stem. A decrease in hardness is shown in referred study by Nikolov, Sv. [1984] and others. The hardness of the along the grain) is reduced by approximately 26.0 %, and transverse to the grain – by 7.7 %. However, other strength characteristics increase. Compressive strength increases by about 16.7 %, flexural strength increased by about 18.0 %, the elastic modulus is increased by approximately 19.4 %. This along with the reduction of the density shows that the increase in the quality coefficients will be even higher.

Quality coefficients representing relation between the mechanical properties and density of the wood. They allow a more precise comparison of the individual test sample. Also on the different materials, and woody species, such as mechanical structures. At coefficient of pressure increase is 26.3% in bending – 28.3 %, while the modulus of elasticity reaches 33.3 %.

Flexural strength of the strongest parts of the test pieces was determined. To help establish the distribution of properties depending on the radius of the stem specimens are made to determine and the compressive strength. After transferring the values of the test pieces, placed after the first sample (at 60–80 mm) were formed three sets of samples (Fig. 3). The conclusion of inspections of statistical significance (A test of Mann-Whitney) of differences confirmed the separation of values.

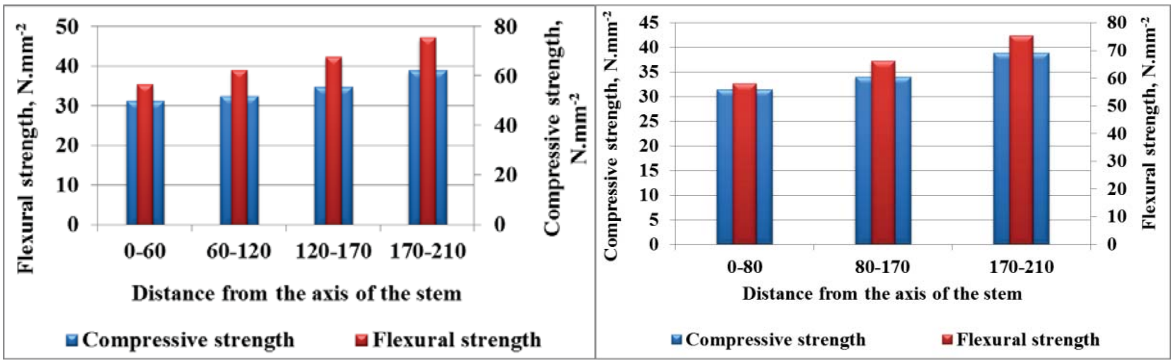



**Figure 3: Statistical indicators for the compressive strength of the wood in four (left) and three (right) samples.**

- First sample (at a distance from 0 to 80 mm from the axis of the stem) is an average value for the strength 31.4 N.mm$^{-2}$, and the dispersion is 2.4 N.mm$^{-2}$.
- Second sample (at a distance from 90 to 170 mm from the axis of the stem) is an average value for the strength 34.1 N.mm$^{-2}$, and the dispersion is 2.9 N.mm$^{-2}$.
- The third sample (at a distance of 180 to 210 mm from the axis of the stem) is an average value for the strength 38.8 N.mm$^{-2}$, and the dispersion is 3.9 N.mm$^{-2}$.

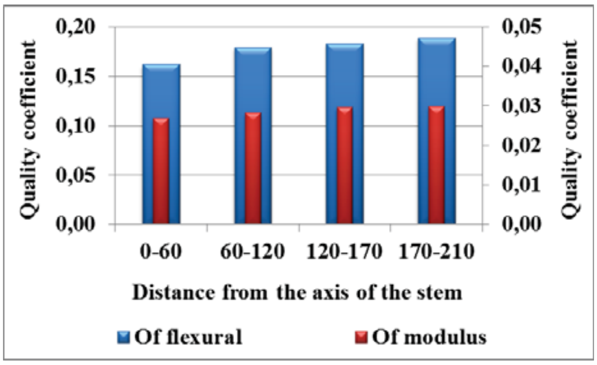
The difference between the values here are also insignificant, while between the dispersions it is 0.16 % of juvenile wood and 0.33 % for the central. Increasing the values is probably due to the greater involvement of the late timber away from the annual rings from the axis of the stem. The increase in the dispersion can be explained by a narrow rings, and the possibility of a wide variety of number of rings (and hence number of zones with late wood) in the samples.

**Quality coefficient**

They are particularly suitable for determining the size of the sample, because on one hand take into account the change of the density, and on other hand – the change in the test property.

When examining of the compressive strength, quality coefficient varies within very narrow limits – from 0.091 (juvenile wood) to 0.096 (peripheral) (Fig. 4).

When the samples were separated into three excerpts and the values of the coefficient of pressure were identical. This indicates that, the spruce wood has the same conduct under load of the pressure, regardless of the type of wood. This can be explained by the fact that both the density and the compressive strength depend most strongly on the thickness of the cell wall. Its change leads to a proportional change in both properties.



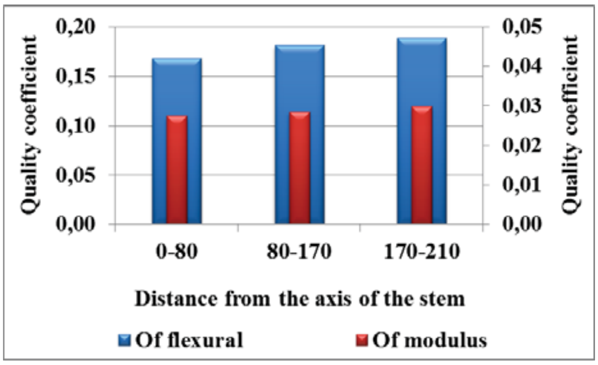




**Figure 4: Statistical indicators for the coefficient of pressure of wood in four samples (left) and three samples (right).**

The dispersion also did not show variation of the values, as in four, and in three samples of values. What should be noted is that the peripheral wood has the lowest dispersion. This could probably be explained by the role of the late wood in determining the compressive strength.

## CONCLUSION

After analysis of the results we came to the following important conclusions and recommendations:

- Peripheral wood has the highest density, but also the highest coefficient of variation (CV, %);
- According to the quality coefficient of the compressive strength there is no difference in the radius of the tree in the behavior of spruce wood subjected to this load.
- With the increase of the radius of the stem, the quality coefficient increases and the variance decreases, which highlights the advantages of this type of wood for the production of musical instruments.
- Depending on the values of the properties, for juvenile can be assumed wood, spaced 80 mm from the axis of the stem and for central - 170 mm.
- Separating the test wood must be verified by the varying the values of anatomical elements in different samples.

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