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SELECTED CHARACTERISTICS OF NORWAY SPRUCE WITH INDENDED RINGS (HAZEL GROWTH) FOR VIOLINS

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Abstract:

The paper presents the results of an experimental research performed with spruce wood (Picea abies L.) with indented rings (hazel growth), originated from the same forest parcel from the Pitztal valley in Tyrol, Austria. The material was harvested at a sea level ranging from 1450 to 1700m and the wood was air dried for 2-9 years. The supplier evaluated and sold the resonance wood samples at the highest quality grades for violin and/or viola decks. The results showed that the density of 0.407g/cm³ and the ultrasonic velocities of 5684.47m/s in longitudinal, 2174.08m/s in radial and 1546.66m/s in tangential direction are in the range of high quality resonance wood. But the shear strength of 9.63N/mm² in the longitudinal-tangential direction and 9.56N/mm² in the longitudinal-radial direction shows very high values in comparison to literature data of 6.7N/mm². The overall conclusion of this research is that Norway spruce with indented rings selected as resonance wood shows high potential to be used for string instruments, but because of the high shear strength in longitudinal direction, it is more difficult to carve than "standard" spruce resonance wood.

Key words: *spruce; hazel growth; tone wood; acoustical properties; modulus of elasticity.*

INTRODUCTION

The superior sound of some instruments has remained a mystery up to now. On the one hand the delightful sound of famous violins of e.g Stradivari or Guarneri (del Gesú) can be explained by the high quality of the construction and workmanship of these instruments. On the other hand there is no doubt that the selection and quality of the raw material plays an important role (Sacconi 1977).

The different parts of a violin are traditionally made from different types of wood: ebony and rosewood for the fingerboard, maple for the bridge, and spruce for the soundboard of the body (Sacconi 1977). The soundboard amplifies the resonance of the strings and is highly responsible for the tonal qualities of the instruments (Buksnowitz 2006). Opinions among instrument makers as to which resonance wood should be used differs. Some prefer Norway spruce with the grown pattern of indented rings (hazel growth), and others without this feature.

Although the hazel-growth doesn't have perfect aesthetic properties and is often seen as a growth defect, many experts perceive the hazel spruce for instruments as a sound-improving property (Buksnowitz 2006). The research question involves investigating if the quality of resonance wood can be tested objectively in the laboratory.

The present research focuses on the mechanical and, as far as possible, on the acoustical properties of the hazel. For this purpose, a detailed experimental set-up and the specimens from available material were prepared. The objectives of the investigations, the material used, the method used and the measuring instruments used are described below.

OBJECTIVE

The main objective of the present research was to determine relevant properties from Norway Spruce with indented rings, which is selected as high quality tone wood for string instruments. The determined properties are compared to literature data of „standard" spruce and tone wood to extend the knowledge whether this specific grown pattern of indented rings constitutes any benefits when used as tone wood. The results of these investigations should also help to increase the value and acceptance of hazel-spruce as a special tone wood.

MATERIAL, METHOD, EQUIPMENT

Specimens for the characterization of mechanical and acoustical properties were obtained from 12 wedge-shaped spruce samples, which the supplier considered to be of the highest quality grades for violin and/or viola decks. The length of the raw samples were between 50 and 95cm. The provenance was the Pitztal valley in Tyrol, Austria at a sea level ranging from 1450 to 1700m. The wood was air dried for 2-9 years.

For the determination of the properties defect free samples were produced after storing the wedge-shaped samples until the equilibrium moisture was reached. For the modulus of elasticity (MOE) and sound velocity in longitudinal direction, samples with 20x20x360mm³ were prepared. Parts of these samples with the dimension of 20x20x20mm³ were used for the determination of moisture and density values. For the determination of the MOE and sound velocity in radial direction, the samples had the size 20x200 (180 or 120) x40mm³. For the shear strength in longitudinal-radial and longitudinal-tangential direction and sound velocity in all three directions, samples with 50x50x50mm³ were prepared. The schematic material preparation is presented in Fig. 1 and Fig. 2.

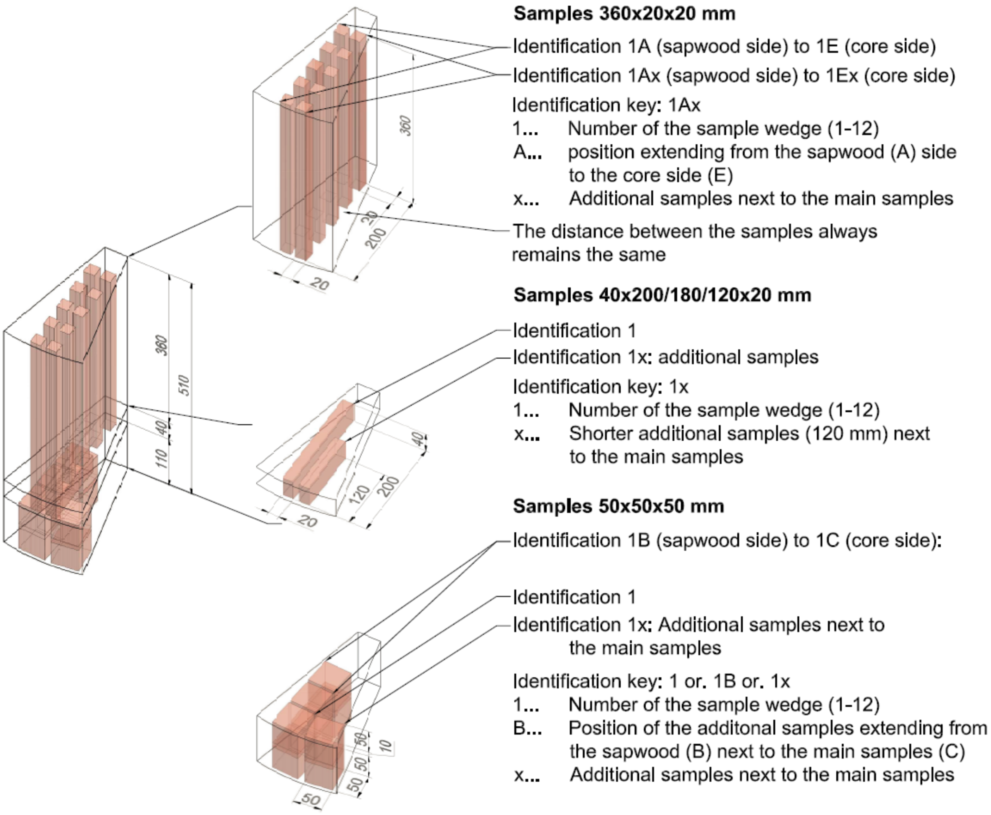

Fig. 1.
Schematic description of the material preparation.

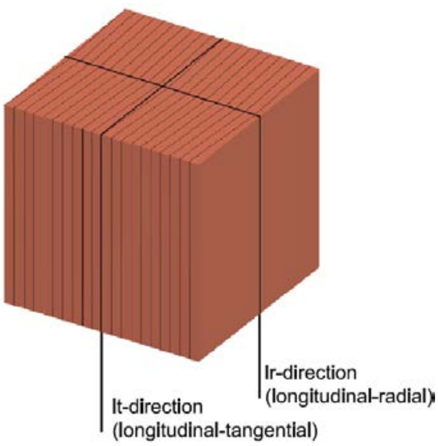

Fig. 2.
Schematic demonstration of the sample for the determination of the shear strength in longitudinal-radial (lr) and longitudinal-tangential (lt) direction.

The determination of the material properties was performed according to the standards for small and defect-free wood samples. The determined material properties were: density, moisture content, modulus of elasticity and shear strength. The specific standards, the number of specimens used for each mechanical test, as well as the devices and some remarks are presented in Table 1. For the determination of the MOE in radial direction, the sample size was altered from the standard to 20x200 (180 and 120)x40 mm³. Therefore the free span was 10mm shorter than the sample with 190, 170 or 110mm.

The material tests were performed at the TVFA (Technische Versuchs- und Forschungsanstalt) at the University of Innsbruck. All tests were performed after storing the material in a climate chamber at 20°C and 65% RH until the equilibrium moisture content (EMC) was reached.

Table 1

Details concerning standards followed, number of samples for each test and the devices used

Test	Standard	No. samples	Devices	Remarks
density	ISO 3131	90	digital measuring slide, balance	balance accurateness 0.001g
moisture content	ISO 3130	90	balance	accurateness 0.001g
three-point bending test	DIN 52185 (1976)	90 longitudinal and 26 radial	Shimadzu Autograph AG-100kN Testing Machine	cross head speed 7 mm/min
shear strength	DIN 52187 (1979)	26 lr and 26 lt	Shimadzu Autograph AG-100kN Testing Machine	test duration 90 ± 30s

The shear strength was determined in longitudinal-radial (lr) and longitudinal-tangential (lt) direction.

Fig. 3.
Test facilities for the determination of the shear strength in longitudinal-radial (lr) and longitudinal-tangential (lt) direction according to DIN 52187.

The sound transmission with longitudinal waves at the frequency of 220 kHz was performed with the ultrasound measuring device Proceq Pundit Lab by using the transceiver S9204A of the company Physical Acoustic Group (Fig. 4).

Fig. 4.
Ultrasound measuring device Proceq Pundit Lab.

RESULTS AND DISCUSSION
Moisture content and density

The mean value of the moisture content was 13.9% and the standard deviation was 1.47%. The mean value of the density was 0.407g/cm³. The range was from 0.351g/cm³ to 0.473g/cm³. The results are given in Table 2.

Table 2

Moisture content and density of the material tested

property	no. samples	mean value	standard deviation	coefficient of variation
moisture content	90	13,87 %	1,47 %	10,6 %
density	90	0,407 g/cm³	0,024 g/cm³	5,8 %

Modulus of elasticity

The modulus of elasticity in longitudinal direction was determined by having the force in the tangential year ring direction as usually required by the standard DIN 52186 and in the radial direction deviating from the standard. The same samples were used for both tests, because the modulus or rupture were not determined and the tests were stopped when the calculated maximum strength of 43% (of the bending strength) was reached. The maximum strength was determined previously with additional samples.

Table 3 shows that the results of the modulus of elasticity, with the force in the tangential direction of the year rings, were about 140N/mm² lower than in radial direction.

Table 3

Modulus of elasticity

testing direction	no. samples	mean value	standard deviation	coefficient of variation
longitudinal: tangential year ring orientation	90	9558.61 N/mm²	984.35 N/mm²	10.3 %
longitudinal: radial year ring orientation	90	9697.50 N/mm²	1049.01 N/mm²	10.8 %

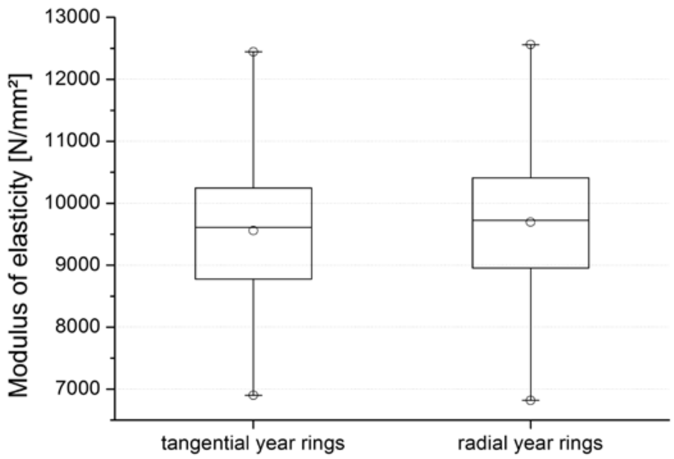

Fig. 5.
Modulus of elasticity in longitudinal and radial direction.

Shear strength

The shear strength was determined in longitudinal-tangential (lt) and longitudinal-radial (lr) direction. The mean value in lt-direction was 9.63N/mm² and in lr-direction 9.56N/mm². Because the testing time was too short, three samples in lt direction and four samples in lr direction were not included in the evaluation.

Table 4

Shear strength

testing direction	no. samples	mean value	standard deviation	coefficient of variation
lt	23	9.63 N/mm²	0.66 N/mm²	6.8 %
lr	22	9.56 N/mm²	1.08 N/mm²	11.3 %

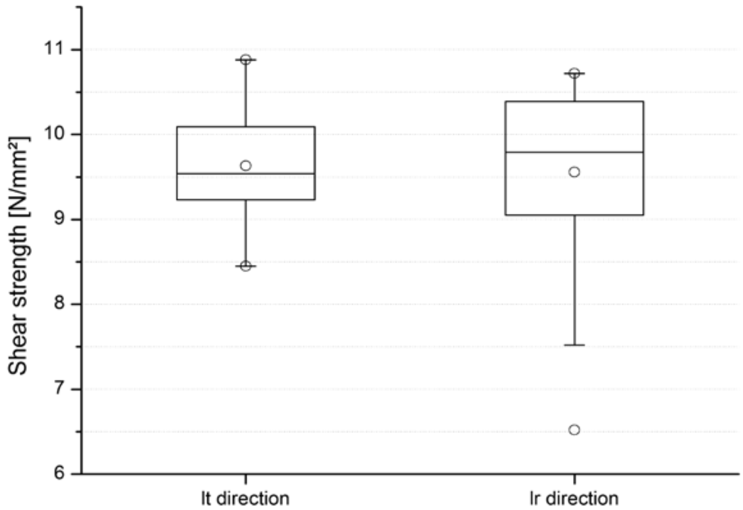

Fig. 6.
Shear strength in longitudinal-tangential (lt) and longitudinal-radial (lr) direction.

The laboratory tests showed that the shear strength of hazel spruce is slightly higher than the shear strength of "standard" grown spruce according to ÖNORM B3012 (6.7N/mm²).

This can be explained by the larger fibre angle, the interlocking of the annual rings, and the greater proportion of medullary rays of hazel-spruce.

Sound velocity

The sound velocity was measured at 220kHz in all three directions (longitudinal, radial and tangential) by using samples with 50x50x50mm³, in the longitudinal direction by using the samples with the dimension 20x20x360mm³ and in the radial direction by using the samples with the dimension 20x200 (180, 120) x40mm³.

Before the tests, the samples were primed until an equilibrium moisture content of 20°C and 65% RH was reached. The transmitter was attached to all samples with constant pressure and no contact medium was used to transmit sound waves from the transmitter to the sample. The sound velocity was calculated according to Eq. 1.

$$v = \frac{l}{t} \quad [m/s] \qquad (1)$$

where: v is the sound velocity [m/s], *l* is the specimen length, path length [m], and *t* is the transit time of ultrasound [s].

Table 5

Sound velocity of the cube sample 50x50x50mm³

testing direction	no. samples	mean value	standard deviation	coefficient of variation
longitudinal	23	5684.57 m/s	187.74 m/s	3.3 %
radial	23	2174.08 m/s	97.48 m/s	4.5 %
tangential	23	1546.66 m/s	90.88 m/s	5.9 %

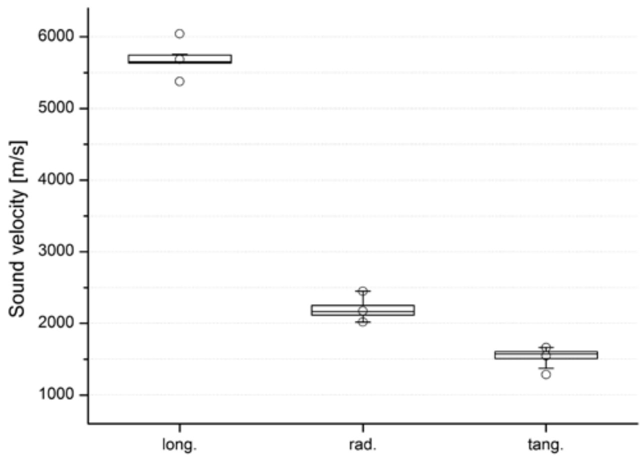

Fig. 7.
Sound velocity in longitudinal, radial and tangential direction.

Table 6

Sound velocity from the bar samples with 20x20x360mm³ in longitudinal direction and with 20x200 (180, 110) x 40mm³ in radial direction

testing direction	no. samples	mean value	standard deviation	coeffizient of variation
longitudinal	90	5525.17 m/s	1890.31 m/s	3.4 %
radial	22	2051.12 m/s	143.54 m/s	7.0 %

CONCLUSIONS

The results of the present research demonstrate that

- the elasticity of hazel-spruce is similar to that of “standard” spruce.
- the raw density of the hazel-spruce samples was smaller than that of the "standard" spruce samples from various literature sources. The reason could be the high sea level (1450-1700m) at which the samples were harvested.
- the swelling properties of the hazel-spruce are about the same as those of "standard" spruce.
- the shear strength is an essential parameter for building violins, as it provides information about the cleavage and the process of the material. Values show that the shear strength of hazel-spruce, due to the indentations and the increased size of the medullary rays, is approximately twice as high as that of “standard” spruce and is thus difficult to split. The cleavability is slightly higher along the tangential surface than along the radial surface.
- the sound velocity of hazel-spruce is in the longitudinal as well as the radial direction higher than that of “standard” spruce as compared to the literature sources.
- with the dynamic elasticity modulus determined from the sound velocity, no significant difference to “standard” spruce can be seen. The resonance coefficient is slightly higher, which indicates good sound properties of hazel-spruce.
- there is a positive correlation between the sound velocity and the flexural modulus, so that the sound velocity can be used for predicting the elastic and resonant properties e.g. violins.

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