Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

COMAT 2020 & eMECH 2020

Brasov, ROMANIA, 29-31 October 2020

STRUCTURAL PATTERNS OF RESONANCE WOOD USED IN VIOLIN CONSTRUCTIONS

M D Stanciu[1*,] F. Dinulica[1], V Gh Gliga[1,2], M Câmpean[1],
-dul Eroilor, 29, Brasov, Romania, mariana.stanciu@unitbv.ro
2 Gliga Instrumente Muzicale S.A., Reghin, Str. Pandurilor nr. 120, Reghin, Mures

Abstract: *In the violin construction are used two main wooden species: resonance spruce and maple. In accordance with macrostructure of wood, the wood samples can be graded in four classes which indicates the quality class of violin. The aim of this paper is to establish the main structural patterns of resonance wood based on measurements of density profiles, width and proportion of latewood and early wood, types of grain in case of maple.*
Keywords: *violin; resonance wood, structural patterns, curly maple, density profiles.*

1. INTRODUCTION

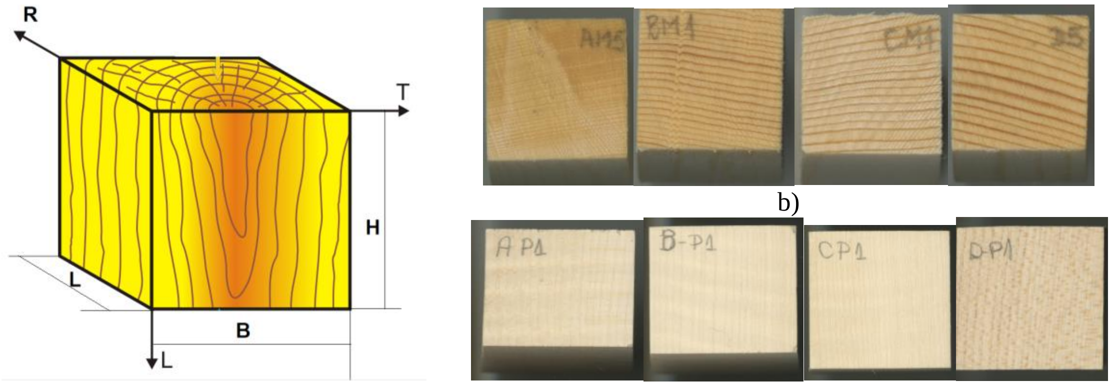
Both in the engineering and heritage area, there are numerous international researches that address the study of heritage violins and current ones in order to understand and re-create instruments with highest quality sound. An interesting aspect for the community of violin producers with regard to sound quality is the characterization of the timbre (tone color) of the heritage instruments and, in particular, the understanding of the sound qualities that make the heritage instruments different from the contemporary instruments. The sound of the heritage violins manufactured by the great masters of Cremona - Stradivari, Guarnieri, Amati - are considered the highest level of violin art for which, even after a few centuries, they are still used as a model by the current violin producers [1-3]. Some studies have highlighted the importance of the quality of the resonance wood used in the construction of musical instruments [4 7], others have analyzed by means of modern techniques the vibrations of the violin body, determining the frequencies and the natural modes [8 - 10], other researches have focused on the acoustic characteristics of the heritage violins determined under both conditions: laboratory as well as in real conditions of use by artists. Some researchers considered that the structural patterns of resonance wood have the main role in the acoustic quality of violin [11 13]. So, the aim of this study is to analysis the macrostructure of resonance wood accordance with the graded made by craft makers of violins.

2. MATERIALS AND METHODS

2.1. Materials

For this study, four types of resonance wood samples, spruce and maple, were prepared for structural analysis. The samples were cube-shaped, cut in the radial direction as can be seen in Figure 1. The main physical parameters are presented in Table 1. The moisture content of wood samples was identical with the one used in violin production, 6 8 %. Concerning wood species, the spruce (Picea Abies) is known as a wood without pores, with fine and uniform structure, with invisible medullary rays on the transversal and tangential sections. The annual rings are distinctly delimited, with the color difference between the early and the late wood; the early wood is light yellowish white, and the latest - light brownish yellow, with gradual color transition.
The maple wood (Acer Pseudoplatanus) is a hardwood with a complex structure, with distinct annual rings, with regular contour, without clear differentiation between early and late wood. Wood with uniformly scattered pores, small, invisible to the naked eye, relatively rare, unitary or in radial rows along the entire width of the annual ring. It is a homogeneous, relative hard and heavy wood. Spruce has long tracheids of about 4 mm and a well-organized structure. This anatomical structural organization of the plate is reflected by symmetrical pattern, with the nodal lines well organized and parallel to the longitudinal axis of the plate, corresponding to L symmetry axis

important in size are the medullary rays, oriented in radial anisotropic direction of wood. When referred to the geometry of the plate, the rays are oriented along its width.



a) b) c)

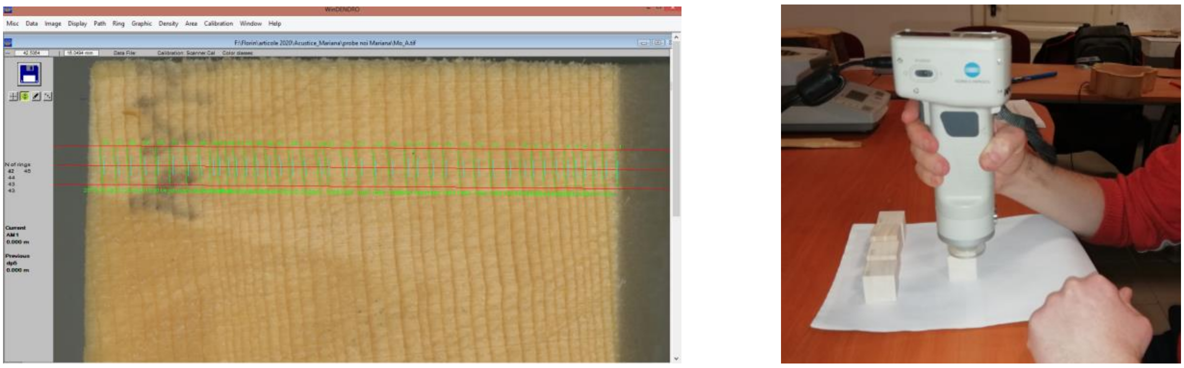
Figure 1. The studied samples: a) the shape; b) the spruce graded samples; c) the maple graded samples.

Table 1. Physical features of samples: spruce and maple

Graded	Code	Wood species	Length L (mm)	Height H (mm)	Width B (mm)	Mass m (g)	Apparent density ρ (g/cm^3)
A	1	Spruce	30.75	30.02	30.24	12.31	0.441
	2	Spruce	30.51	30.35	30.4	12.29	0.437
	3	Spruce	30.50	30.31	30.21	12.23	0.438
	4	Spruce	30.60	30.24	30.38	12.28	0.437
	5	Spruce	29.84	30.13	30.48	11.94	0.436
B	1	Spruce	30.29	30.22	30.02	10.59	0.385
	2	Spruce	30.27	30.25	30.09	10.45	0.379
	3	Spruce	30.73	30.33	30.19	10.60	0.377
	4	Spruce	30.57	30.43	30.02	10.78	0.386
	5	Spruce	30.43	30.36	30.13	10.52	0.378
C	1	Spruce	30.28	30.33	30.49	12.69	0.453
	2	Spruce	30.18	30.34	30.60	12.65	0.452
	3	Spruce	30.13	30.28	30.10	12.09	0.440
	4	Spruce	30.48	30.70	30.82	12.49	0.433
	5	Spruce	30.15	30.33	30.54	12.59	0.451
D	1	Spruce	30.16	30.13	30.53	10.92	0.394
	2	Spruce	30.30	30.31	30.29	11.14	0.400
	3	Spruce	30.35	30.25	30.39	10.96	0.393
	4	Spruce	31.08	30.25	30.35	11.15	0.391
	5	Spruce	30.66	30.48	30.05	11.10	0.395
A	1	Maple	29.26	30.31	30.21	14.90	0.556
	2	Maple	29.41	30.17	30.32	15.07	0.560
	3	Maple	29.84	30.28	30.42	15.29	0.556
	4	Maple	29.25	30.45	30.44	15.07	0.556
	5	Maple	29.81	30.64	30.46	15.43	0.555
B	1	Maple	30.03	30.15	30.17	15.85	0.580
	2	Maple	30.00	30.45	30.31	15.76	0.569
	3	Maple	29.85	30.18	30.15	15.78	0.581
	4	Maple	29.85	30.07	30.10	15.78	0.584
	5	Maple	30.25	30.04	30.24	15.93	0.580
C	1	Maple	29.76	30.25	30.41	15.97	0.583
	2	Maple	29.78	30.21	30.3	15.93	0.585
	3	Maple	29.75	30.44	30.26	16.19	0.591
	4	Maple	29.44	30.34	30.36	16.42	0.605
	5	Maple	29.91	30.14	30.15	15.89	0.585
D	1	Maple	29.66	30.02	30.36	15.54	0.575
	2	Maple	29.52	30.08	30.26	15.32	0.570
	3	Maple	29.85	30.13	30.28	15.36	0.564
	4	Maple	29.15	30.14	30.19	15.13	0.571
	5	Maple	29.50	30.14	30.36	15.11	0.560

2.2. Methods

To determine the qualitative-structural features of resonance wood in terms of average width of the growth rings, latewood width and proportion versus early wood width and proportion, was used the WinDENDRO Density 2006c image-analysis system (WinDENDRO 2007). The samples were scanned at resolutions of at least 900 dpi. The method was applied in previous studies by [11] (Figure 2, a). To establish the color variation of resonance wood from different grades, the chroma meter CR-400 Konica Minolta was used. Measuring results were colour values using the L*a*b* colour system, where L* describes the lightness, and a* and b* describe the chromatic coordinates on the green-red and blue-yellow axes as was described by [12, 13] (Figure 2, b).



a) b)

Figure 2. Experimental set-up: a) WinDENDRO Density 2006c image-analysis system; b) chroma meter CR-400 Konica Minolta;

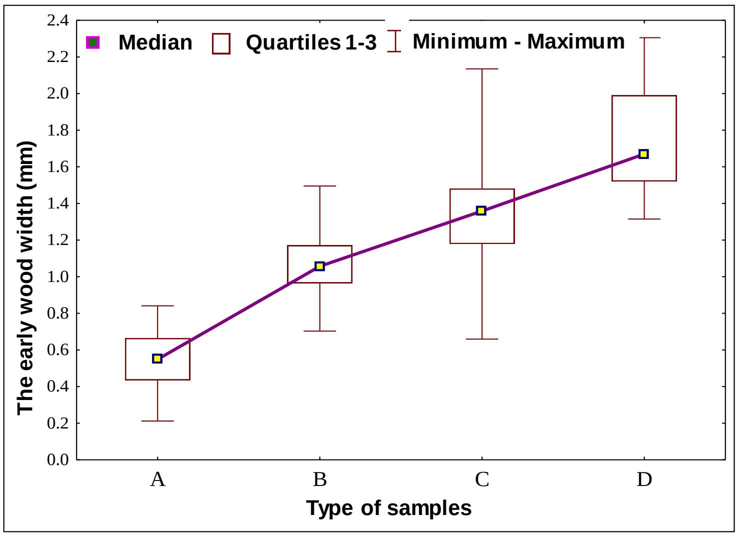
3. RESULTS AND DISCUSSIONS

3.1. Structural patterns of resonance spruce

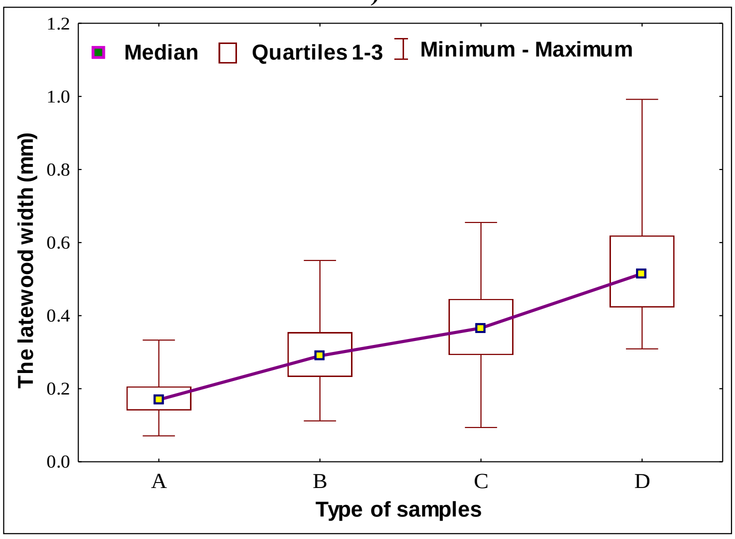
The absolute sizes of the annual ring indicators show a high degree of scattering (coefficients of variation 49-54%), which would allow their stratification. The width of the late wood (with a median of 0.25) is at the limit of visibility (eyepieces) (Figure 3, a). The proportion of early wood is characteristic of the rings (Figure 3, b). Experimental data suggest a trend of decreasing the proportion of late wood with the width of the annual ring, which, although statistically significant, is not sufficiently consistent (R2 = 2.6%). This relationship was pursued at the level of quality classes. It turned out that the inverse proportionality relationship is manifested only in quality class A, while, especially in quality class B, the relationship is positive [11-13]. The density of the wood can be stratified according to the quality class of the sample. Spruce wood from quality classes A and C is heavier, with about 0.600 g/cm3, than wood from classes B and D (Figure 3, c). The color of the spruce wood, especially the lightness (degree of white) shows an unexpectedly low level of variability in the spruce samples examined (Table 2), despite the differences in the configuration of the annual rings. The degree of white (denoted a) is a variable with multimodal distribution and right asymmetry. The existence of several modules suggests color segregation in the examined material.

Table 2. Structural pattern of resonance spruce

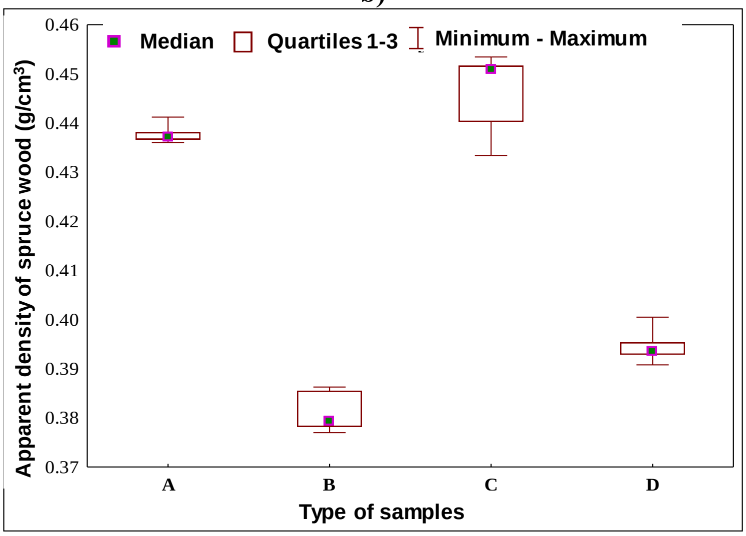
Graded	Data	Annual rings widths (mm)	Early wood width (mm)	Late wood width (mm)	Percentage of early wood (%)	Percentage of late wood (%)	Lightness L	Green-red scale a	Blue-yellow b
A	Average	0.71	0.54	0.18	74.97	25.03	84.15	2.54	19.78
	STDV	0.005	0.011	0.013	1.519	1.519	0.349	0.093	0.573
B	Average	1.38	1.07	0.30	78.53	21.47	83.57	2.97	19.62
	STDV	0.018	0.029	0.013	1.203	1.203	0.398	0.149	0.163
C	Average	1.69	1.33	0.36	78.71	21.29	84.21	2.47	20.02
	STDV	0.045	0.039	0.022	0.895	0.895	0.700	0.202	0.727
D	Average	2.28	1.74	0.54	76.36	23.64	83.65	2.76	20.85
	STDV	0.005	0.029	0.026	1.138	1.136	0.120	0.093	0.223



a)



b)



c)

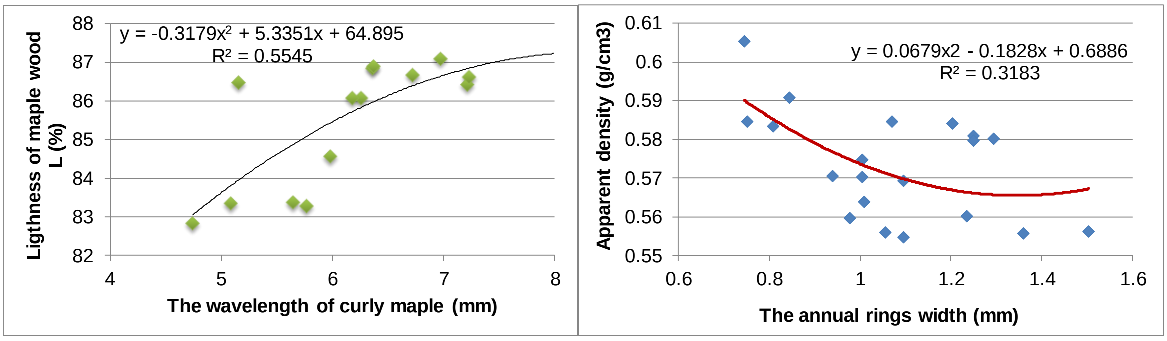
Figure 3. Statistic interpretation of structural patterns of resonance spruce: a) the variation of early wood width< b) the variation of latewood width; c) Stratification of the size of the density of spruce wood according to the quality of the specimens

3.2. Structural patterns of resonance maple

In maple wood samples the tendency is to increase the width of the rings and decrease the wavelength with the improvement of the quality class. The quality class C stands out; in this class the amplitude of the values is also higher. The width of the rings of the maple samples is not normally distributed (ShapiroW test = 0.965, $p<0.0001$), instead the wavelength of the crested fiber is a Gaussian variable (W = 0.977, p = 0.30). The width of the annual rings has a high level of variability (Table 3), which encourages the stratification of its values. The wavelength has a moderate level of variability, but the range of values is quite wide (the amplitude of variation is 9.5 mm). The density of the wood is inversely proportional to the width of the rings and the degree of red, but directly proportional to the wavelength and brightness (Figure 4, a and b) [11-13]. The link between the annual rings width and the color of the maple wood did not exceed the threshold of statistical significance. However, there is a tendency to increase the size of the shade of red and to temper the shade of yellow as the rings become wider. The dense fiber wood is darker, has a higher degree of red and yellow in the color composition.

Table 3. Structural pattern of resonance maple

Graded	Code	Average of annual rings widths (mm)	The wavelength λ	Lightness *L*	Green-red scale *a*	Blue-yellow *b*
A	1	1.504	5.77	83.283	3.630	18.413
	2	1.234	5.089	83.353	3.780	18.523
	3	1.055	5.649	83.373	3.660	18.053
	4	1.359	5.987	84.563	3.237	17.187
	5	1.095	4.746	82.827	3.880	18.350
B	1	1.295	6.257	86.077	2.330	17.067
	2	1.095	5.155	86.457	2.193	17.100
	3	1.250	6.363	86.837	2.187	16.497
	4	1.204	6.976	87.090	2.130	16.370
	5	1.249	6.725	86.670	2.237	16.340
C	1	0.808	6.371	86.887	1.813	17.727
	2	0.752	7.217	86.417	1.953	18.287
	3	0.844	7.233	86.617	1.887	18.220
	4	0.744	6.185	86.063	1.990	18.457
	5	1.070	10.085	86.327	2.230	16.773
D	1	1.004		81.300	4.037	18.290
	2	1.005		81.593	3.567	18.133
	3	1.008		80.837	3.723	18.340
	4	0.939		82.840	3.407	17.713
	5	0.978		84.143	3.383	18.137



a) b)

Figure 3. Statistic interpretation of structural patterns of resonance maple: a) The variation of lightness with increasing of wavelength; b) Variation of density with annual rings width

4. CONCLUSION

The paper presents the experimental investigation of physical features of resonance wood used for violin construction, namely spruce used for top plate and maple used for back plate.
The density, annual rings width, proportion of latewood and early wood, wavelength of grain in case of maple samples, the colour parameters were analysed related to quality grads used in manufacturer of violin.

ACKNOWLEDGMENTS

This paper was supported by Program partnership in priority domains - PNIII under the aegis of Ministry of Research and Innovation and Executive Agency for Higher Education, Research, Development and Innovating Funding from Romania, project PN-III-P2-2.1-PED-2019-2148, no. 568PED/2020 MINOVIS.

REFERENCES

[1] Galamian I 1988 Grundlagen und Methoden des Violinspiels, Ed. Sven Erik Bergh;
[2] Setragno F, Zanoni M, Sarti A, Antonacci F 2017 Feature-based Characterization of Violin Timbre. *The 25th European Signal Processing Conference (EUSIPCO)*, 1903-1907
[3] Trapasso L 2013 Feature-based Analysis of the Violin Tone Quality. Master Degree Thesis Politecnico Di Milano.
[4] Woodhouse J (2014) The acoustics of the violin: a review. *Reports on Progress in Physics*, 77, 11, p.115901. http://iopscience.iop.org/article/10.1088/0034-4885/77/11/115901/pdf.
[5] Stanciu M.D., Cosereanu C., Dinulica F., Bucur V., Effect of wood species on vibration modes of violins plates. Eur. J. Wood Prod. (2020) vol 78, pp. 785-799. https://doi.org/10.1007/s00107-020-01538-5
[6] Gliga V. Gh. Stanciu MD, Nastac S.M, Campean M., Modal Analysis of Violin Bodies with Back Plates Made of Different Wood Species, BioResources, 2020, vol 15(4), pp. 7687 7713.
[7] Meyer HG (1995): A practical approach to the choice of tone wood for the instruments of the violin family. Ctgut Acoust Soc J 2(7), 9-13.
[8] Müller, W., 1969: Resonance wood from Slovenia (in Slovenian). HolzKurier 24, 6-7.
[9] Ono, T., and Norimoto, M. (1984).On physical criteria for the selection of wood for soundboards of musical instruments. Rheol. Acta 23(6), 652-656
[10] Wegst U.G.K., 2006: Wood for sound. American J Bot 93(10), 1439-1448.
[11]
resonance Norway spruce wood used for violin manufacturing. Bioresources 10(4):7525-7543.
[12]
17.
doi:10.3390/polym12020377.
[13] Stanciu M.D., Dinulica F., Cirstea I.C., Physical and mechanical characterization of resonance spruce (Picea Abies L), IOP Conf. Series: Materials Science and Engineering 916 (2020) 012112 IOP Publishing doi:10.1088/1757-899X/916/1/012112.