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# ACOUSTIC EVALUATION OF VIOLINS WITH MODIFIED GEOMETRIC PARAMETERS

**M. Mihălcică[1], A. Nauncef[1], V. Gliga[2], M. Câmpean[1], M.D. Stanciu[1]**
[1] Transilvania University of Brașov, Brașov, ROMÂNIA
[2] S.C. Gliga Instrumente Muzicale S.A., Mureș, ROMÂNIA
mihalcica.mircea@unitbv.ro, a.nauncef@unitbv.ro, vasile@gliga.ro, campean@unitbv.ro, mariana.stanciu@unitbv.ro

***Abstract:*** *The objective of this study was to evaluate the acoustic quality of 14 violins with modified geometric parameters, the evaluation being performed based on listening to a musical fragment by the musicians / instrumentalists participating in the survey.*
***Keywords:*** *acoustic quality evaluation, musical instruments, modified thickness violins, violin tone, sound clarity, warm sound*

## 1. INTRODUCTION

Both constructively and acoustically, the violin is considered the queen of musical instruments. The constructive complexity starts from the stage of harvesting the resonance wood, considering that its structural characteristics are not acquired genetically, but they result from the combined action of several (climatic, edaphic, orographic, biotic, anthropic) factors, that influence the formation of a special kind of wood, with special acoustic properties. In Romania, the main growth area of resonance spruce trees is in the northern part of the Eastern Carpathians, the most famous being the forest districts Moldovita and Tomnatic. From a constructive point of view, the problem of the violin-makers is to find the optimal ratio between the radii of the longitudinal and transverse arcs, so that, due to the cyclical stresses that appear in the structure of the violins, it does not produce large deformations of the violin body. Establishing the optimum thickness of the plates is also very important. Figure 1 a) presents the constructive elements of the violin. The elements of a violin have both a functional and an aesthetic role. Thus, the violin body, composed of the top plate, the back plate, the ribs and the counter-ribs, has the acoustic role of amplifying the musical sounds emitted during the excitation of the strings with the bow. This subassembly is constructed so that the top and back plates operate as a membrane, capable to transmit and amplify vibrations. For materials strength reasons, the violin body also contains constructive elements that secure the two plates (by means of the counter-ribs and corners) and also elements which support and fix the violin neck. The plates have a spatial shape both in longitudinal and transverse direction. Their thickness varies from the center (the area between the f-holes) towards the edges (Figure 1, b). The violin neck has the primary role of ensuring the required string length, but it also has an aesthetical role, being provided (in the keys area with) a carved shape - generally a scroll, usually made of ebony wood. The tailpiece and the keys have a functional role, ensuring the fastening of the strings. The bridge and the saddle ensure the optimal distance between the strings, the tongue and the violin body. Part of the vibration energy is transmitted through the bridge to the top plate and the fluid inside the violin body. Between the top plate and the back plate, a soundpost is positioned, that has both an acoustic role – that of transmitting vibrations - as well as a resistance role – to ensure the stability of the top and back plates, next to the longitudinal bar, fixed asymmetrically to the left of the instrument.

The strings vibration occurs due to the bow movement over the strings. There is an angle between the bow and the excited string, which horizontally decomposes the force produced by the bow, into a longitudinal component (parallel to the string direction) and a transverse component (perpendicular to the string's direction). The string begins to vibrate both transversally - in the direction of the force applied by the bow, and longitudinally - along the string. The transversal vibrations are transmitted through the bridge to the top plate of the violin and further to the entire air volume inside the violin body. The violin body behaves like a Helmholtz resonator, forming compression and dilation waves between the top plate, the back plate and the ribs, giving rise to intense sound. The intensity of the sound, the acoustic pressure and the timbre of the violin are closely related to the body's ability to vibrate and amplify the sounds. That is why increasing the volume of air inside the resonator box, by changing the thickness of the plates, lead to an improvement of the acoustics of violins.

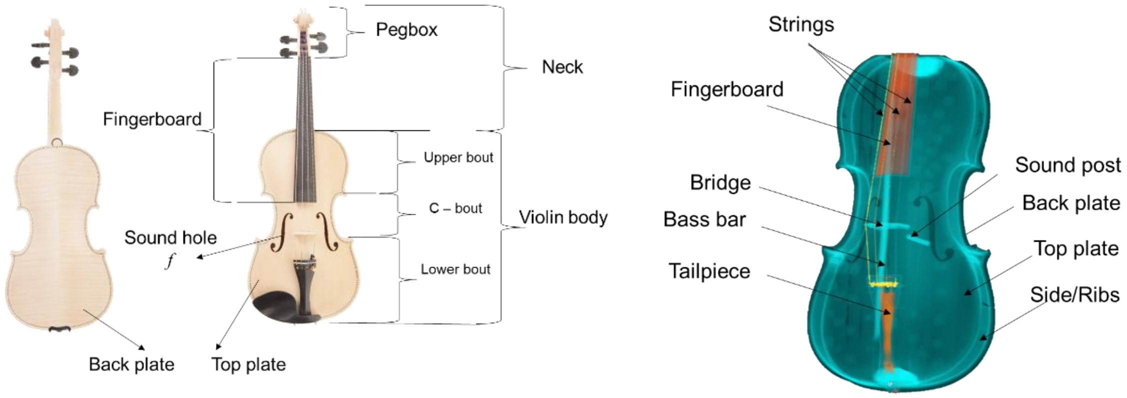



**Figure 1:** The main parts of the violin structure

## 2. MATERIALS AND METHODS

### 2.1. Materials

For this study, 7 violins of class A (maestro) anatomical quality of wood were manufactured, having seven different categories of thicknesses: thus, the nominal thickness (noted by *00*) was set to be the thickness used for the current construction of violins at the factory of musical instruments SC Gliga Instrumente Muzicale SA The coding of violins is based on the following principle: the first letter represents the structural quality class (A), the following code represents the type of thickness (0 - nominal thickness used in the current production of violins; P - increased thickness; M - reduced nominal thickness); the figures represent the tenths with which the nominal thickness has changed (2; 4; 6 - represents the quantity 0.2; 0.4; 0.6 mm which was reduced or added to the nominal thickness). The violins were analyzed in two states: unvarnished, the wood being left in its natural form, having the codes: A00C1, AM2C1, AM4C1, AM6C1, AP2C1, AP4C1, AP6C1 and subsequently, the same violins were varnished according to the manufacturer's specifications, being coded A00C1F, AM2C1F, AM4C1F, AM6C1F, AP2C1F, AP4C1F, AP6C1F.


**Figure 2**: The analyzed violins (courtesy of S.C. Gliga Instrumente Muzicale S.A.)

### 2.2. Methods

The acoustic recording of the violins was made in the concert hall of the Brasov Philharmonic, and the musical interpretation for all violins studied was provided by Nauncef Alina, first violinist at the Brașov Philharmonic and teacher at the Faculty of Music, Transilvania University of Brașov. The performed musical fragment consisted of four parts and was performed on all 14 violins:

- the first part consisted in the excitation of the free strings tuned with the bow (Sol (196 Hz), Re (293.7 Hz), La (440 Hz), Mi (659.3 Hz)).
- the second part consisted in the excitation of the free strings in Pizzicato style (pinching the strings)
- in the third part, an excerpt from Max Bruch - Concerto no.1 in G minor op. 26, PI (first cadence of the solo violin) was played

The choice of this fragment was due to the fact that, in addition to the seductive and sinuous melody, the first cadence includes a wide scope, starting with the lowest tone of the violin, gradually passing from the SOL string to the RE string, where it stops on the octave of the first beginning sound, to continue on the LA string and then ending the musical speech on the crown of the RE sound from the third position, on the MI string. So, the composer chooses from the very beginning that the melody of the violin cadence goes through all the 4 timbres specific to each of the 4 strings of the violin. In this sense, by recording this first cadence, one can reach much clearer conclusions regarding the equality of the sounds of the strings, the sonorities, the dynamics and the timbre of each violin that is recorded.

- in part four, an excerpt from Jules Massenet - Meditation for violin and orchestra from the Opera Thaïs was played

When choosing the short fragment from the Meditation of Thaïs, the lyrical character, which implies a warm, penetrating and sweet sound, which enhances any violin, be it new, master or heritage, weighed a lot. No wonder that this delicate and beautiful song is found in the repertoire of all violinists, but also of almost all musical instruments, for which transcripts and arrangements have been made. The beginning fragment of the recording includes the first 8 measures of the violin, measures that are interpreted, according to the indications of expression of the composer, only on the two strings LA and MI. This short fragment of Meditation was chosen precisely in order to be able to follow the differences between the violin sounds recorded on these 2 strings from the middle and acute register of the violin.
The location of the sound generation and recording equipment was done according to Figure 3, marking the position of the violinist and the microphone stand, in order to maintain the same positions throughout the tests. The professional recording equipment (24 bits, 48000hz) and the special AKG microphone for sounds emitted by the strings were provided by the company A.P. Studio Brasov. The musical fragment composed of the 4 parts lasts about 1 minute, so that the 14 violins can be evaluated, in optimal psychoacoustic conditions.

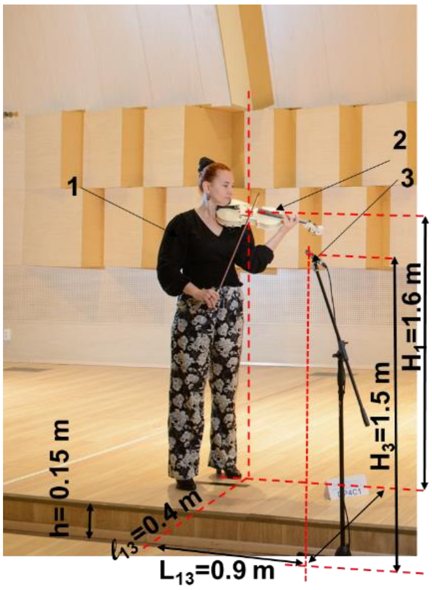



**Figure 3**: The relative position of the performer (1) and the violin (2) in relation to the recording equipment (3)

### 2.3. The acoustic quality evaluation questionnaire

A questionnaire was developed in order to evaluate the acoustic qualities of the violins. The questionnaire was completed by experts in the field (composers, performers etc.), after the audition of the musical sequence  The questionnaire used consisted in awarding grades from 1 to 5 (where 1 - represents the lowest acoustic / worst quality level, and 5 the highest acoustic / excellent quality level), for the following criteria of artistic impressions: sound clarity; warm sound; bright tone; amplitude of sounds; equal sound on strings, criteria that were in turn established on the basis of a survey of opinions to which the respondents were violinists.
From an artistic point of view, the **bright and strong tone** refers to the quality of the sound produced by the instrument, a sound that is very penetrating and open, being able to cover a large performance hall with the harmonics produced. The **sound clarity** is determined by the vibration of the strings that produce very clearly identifiable, isolated sounds, without mixing with the vibrations of other sounds. The **warm, silky sound** is that velvety sound that caresses the hearing and that determines a relaxation and pleasure to the listener. A violin can have both warm, silky and bright sounds, depending on how the musical text is interpreted. But there are also instruments that have soft and warm sounds, but which have the disadvantage of not entering large concert halls. The **amplitude of sounds** refers to the way in which the sounds of the violin are able or not able to go very far, being capable to cover larger or smaller rooms. It all depends on the amplitude of the wave and the distance between the points with the highest vibration and it is measured in units of measurement called decibels (dB). **Equal sound on all 4 strings** - to determine that a violin is sound-wise equal on all 4 strings, each string is

played, one by one, with the same pressure and bow speed, while listening very well if all strings respond the same, with the same color, the same timbre and the same intensity. It is also observed if each of the 4 strings responds just as easily, with the same minimum of effort. The online questionnaire was developed using the Google Forms. For each music sample recorded with each violin, selection boxes in the form of a grid with 5 rows (criteria) and 5 columns (grades) were generated. Additionally, questions on artistic experience, artistic field, gender and age category were added. The questionnaire was completed by the voluntary action of the respondents, whose distribution by gender, age and experience is presented in Table 1.

**Table 1:** General information on the participants in the study

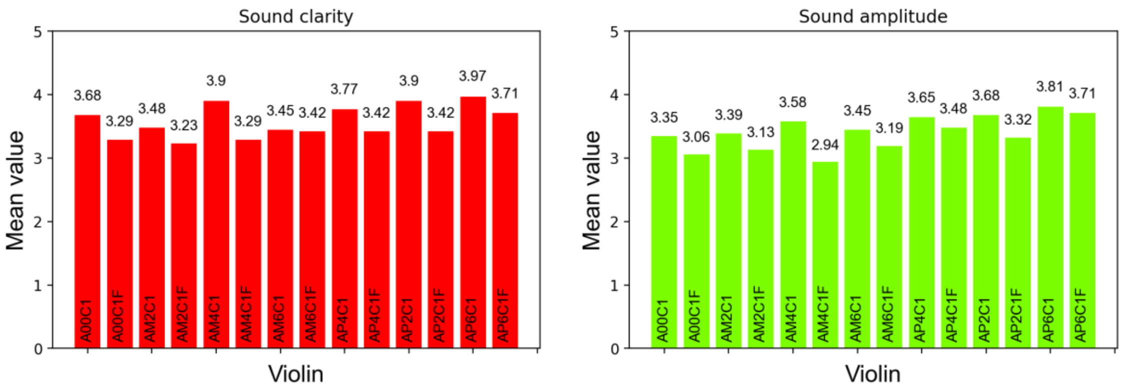
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Male | 10 | | | | | | | |
| Female | 21 | | | | | | | |
| Age category | <17 | 18-24 | 25-34 | 35-44 | 45-54 | 54-65 | >65 | Age category |
| Nunber of participants | 0 | 9 | 7 | 7 | 3 | 3 | 2 | Nunber of participants |
| Experience | <5 | 6-10 | 11-15 | 16-20 | 21-25 | >26 | | Experience |
| Number of participants | 0 | 3 | 4 | 9 | 5 | 10 | | Number of participants |

In the first stage, for each parameter and each violin, the average of the marks given by the respondents was calculated, obtaining a ranking from the point of view of the audience experience, gender and age, for each violin and acoustic criterion assessed. Then, in order to achieve the ranking regarding the acoustic quality of the violins, the averages obtained by each violin in relation to each acoustic criterion were comparatively analyzed. Finally, the global ranking on the acoustic quality of the violins was calculated by summing the averages of the marks given to all the criteria for each violin.

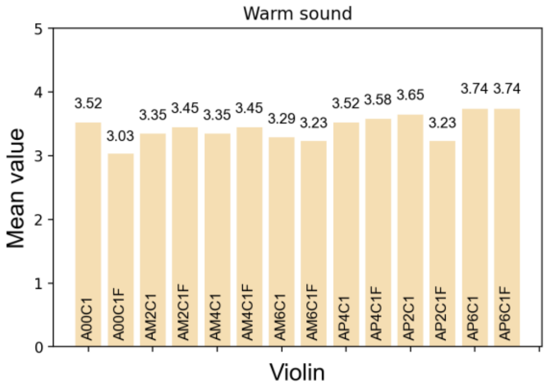
## 3. RESULTS AND DISCUSSIONS

The five characteristics bolded in section 2.3 were evaluated after the data from the questionnaires was processed, and the results are as follows (see also Figure 4):

- **Sound clarity**: the highest values were obtained by the violins AM4C1, AP2C1, AP6C1, values over 3.9 points. The lowest rated were the violins, A00C1F, AM2C1F, AM4C1F (3.23 - 3.29).
- **Sound amplitude**: the highest values were obtained by the violins AP6C1, AP6C1F, and the lowest, by the violins A00C1F, AM4C1F
- The **warm sound** of the violins, after evaluation, led to the following result: the violins rated with warm sound are: A00C1, AP4C1, AP4C1F, AP2C1, AP6C1, AP6C1F (over 3.5 points), and the weakest values are registered in the range 3.0 - 3.29 (A00C1F, AM6C1, AM6C1F and AP2C1F).
- The **equal sound on all 4 strings** was appreciated with high values for the violins AP4C1, AP2C1, AP6C1, AP6C1F, while the violins AM4C1F and AM6C1F obtained the lowest scores.
- The **bright tone** was appreciated with high values for the violins AM4C1, AP4C1, AP2C1, AP6C1, AP6C1F, while the violins A00C1F, AM4C1F were placed on the last places at this criterion




a) b)

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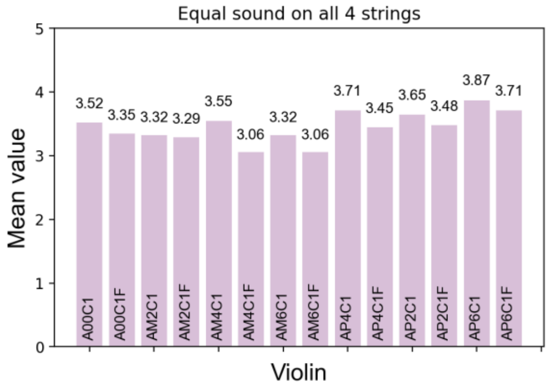


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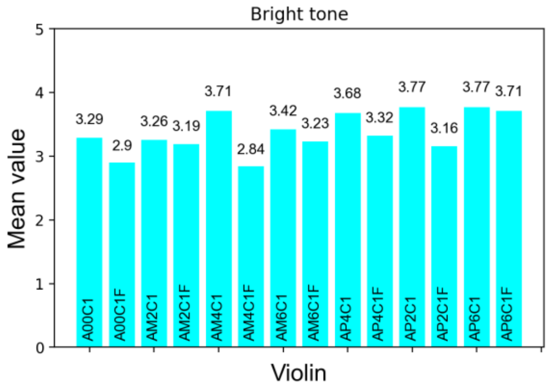


e)

**Figure 4:** The acoustic characteristics for each violin, on a scale from 1 to 5

In the end, an overall "score" of the combined acoustic quality of the violins is highlighted in Figure 5, where you can see the ranking of all the violins in the study.

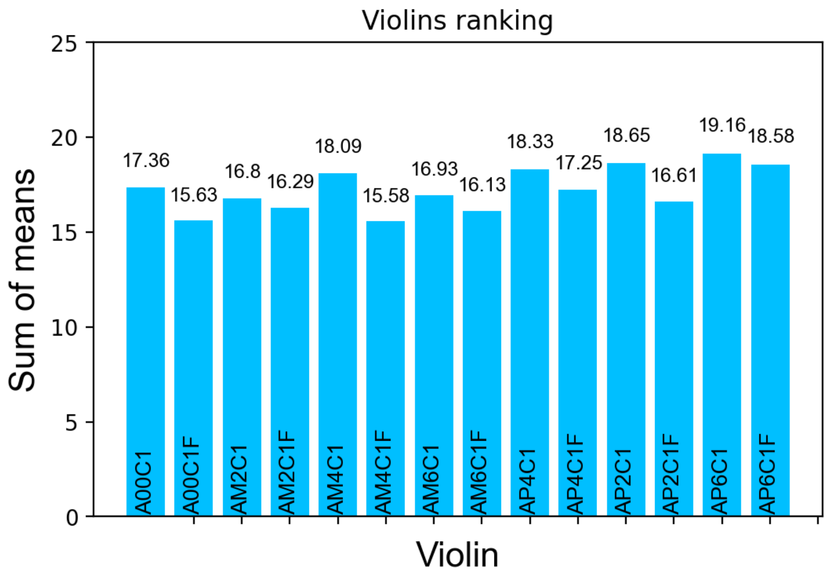


**Figure 5:** The overall score for all the violins in the study, on a scale up to a maximum of 25

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## REFERENCES

[1] Gliga, V.Gh.; Stanciu, M.D.; Nastac, S.M.; Campean, M. Modal Analysis of Violin Bodies with Back Plates Made of Different Wood Species. BioResources 15(4), 7687–7713, 2020
[2] Stanciu, M.D.; Mihălcică, M.; Dinulică, F.; Nauncef, A.M.; Purdoiu, R.; Lăcătus, R.; Gliga, G.V. X-Ray Imaging and Computed Tomography for the Identification of Geometry and Construction Elements in the Structure of Old Violins. Materials, 14, 5926, https://doi.org/10.3390/ma14205926, , 2021
[3] Saitis, C.; Fritz, C.; Scavone, G.P. Sounds like melted chocolats. How muzicians conceptualize violin sound richness. Proceedings of ISMA 2019, International Sympozium on Music Acoustics, 13 – 17 September, Detmold, Germany, 50-57, 2019
[4] Tai, H-C.; Shen, Y-P.; Lin, J-H.; Chung, D-T. Acoustic evolution of old Italian violins from Amati to Stradivari, Proceedings of the National Academy of Sciences, 115(23):201800666, DOI:10.1073/pnas.1800666115, 2018
[5] Giraldo S, Waddell G, Nou I, Ortega A, Mayor O, Perez A, Williamon A and Ramirez R Automatic Assessment of Tone Quality in Violin, 2019
[6] Music Performance. Front. Psychol. 10:334. doi: 10.3389/fpsyg.2019.00334
[7] Saitis, C., Fritz, C., Scavone, G. P., Guastavino, C., and Dubois, D. Perceptual evaluation of violins: a psycholinguistic analysis of preference verbal descriptions by experienced musicians. J. Acoust. Soc. Am. 141, 2746–2757. doi: 10.1121/1.4980143, 2017
[8] Saitis, C., Scavone, G. P., Fritz, C., and Giordano, B. L. Effect of task constraints on the perceptual evaluation of violins. Acta Acust. Unit. Acust. 101, 382–393. doi: 10.3813/AAA.918834, 2015
[9] Zacharakis, A., Pastiadis, K., and Reiss, J. D. An interlanguage unification of musical timbre: bridging semantic, perceptual, and acoustic dimensions. Music Percept. Interdisc. J. 32, 394–412. doi: 10.1525/mp.2015.32.4.394, 2015
[10] Meyer J., Acoustics and the Performance of Music, Manual for Acousticians, Audio Engineers, Musicians, Architects and Musical Instruments Makers, Springer, PPVMedien GmbH, Edition Bochinsky, Bergkirchen, Germany, 2009
[11] Nauncef A.M. *Style and Interpretion in Mozart's piano and violin sonatas*, în Bulletin of the Transilvania University of Brașov, Series VIII: Performing Arts • Vol. 10 (59) No. 2, 2017