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Documentation of Double Bass Plate Modes Using the Scanning Laser Vibrometer

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Abstract

In spite of its importance in classical and jazz music, the double bass has remained largely unstudied by musical acousticians. The documentation of double bass plate modes and frequency response can be seen as a first step toward making quality judgments of basses using objective measurements. This study documents significant modal patterns and resonance characteristics of two double basses using laser vibrometer area scans and input admittance measurements. The instruments tested were made especially for this study and differ only in the form of the back plates. The combination of methods gives clues to important components of the vibrating structure and how these components can be manipulated by makers to influence the response of instruments. Findings indicate that while flat and round back plates do not have modal patterns in common, the top plates of the test instruments resonate similarly and to some degree independently of the back. The round-backed model shares modal shapes with the violin, while the flat back shows unique, viol-like patterns.

1. Introduction

Of the modern, Western bowed instruments, the form of the double bass is the least standardized. While the violin, viola and violoncello are clearly members of the violin family, many double basses possess some formal elements, such as sloping shoulders, blunt c-corners, and a flat back, which are attributable to the viol family. Since basses in use today do not adhere to standards of size and form, all sorts of instruments may yet be found on the concert podium. Because of this variety of forms an exact definition of types is not straightforward, but for the purposes of this study the form types of double bass may be divided into two kinds: that with a flat back plate and that with a round (arched or carved) back plate. Most basses have either a viol-like flat back plate with a unified thickness, upper break or slope of the back, and three or four inner braces, or a violin-like rounded back plate with variable thickness, no break and no inner braces. It is not clear whether one type is more prevalent at this time.

The form of flatbacks and roundbacks double basses are somewhat rooted in regional instrument-making traditions, which were influenced by individual makers at certain points in time. The definition of the double bass as a large violin or as viol has recently been the subject of some controversy among historians. This paper may shed some light on this subject, at least from the acoustical point of view.

2. Experiments

The basis of this investigation is a pair of new, unvarnished double basses made to identical specifications and wood, differing in theory only in the form of the back plate. The string length is 104 cm, the calculated air volume is approximately 0.204 m^3 or 20,412 cm^3 (without the arching), the area of both the f-holes is 0.0101 m^2 or 101 cm^2, and the thickness of the top plate at their opening is approximately 3.5 mm. The accessories including setup of the bridge, soundpost and strings were kept as identical as possible. The instruments are identified as Pfb (poplar flatback) and Prb (poplar roundback).

Measurements with the Polytec scanning laser vibrometer were made at the Technical Museum, Vienna, in a relatively small room (4 m * 8 m * 4 m = 128 m3) with smooth concrete walls and floor. The instrument and shaker B&K 4810 were mounted on a stone plate at a distance from the camera of approximately 3.5 m. A periodic chirp from 5-2000 Hz was used, the bridge was driven on the treble side and the strings were not dampened. No additional audio data was collected. The unvarnished state proved to be an advantage for measurements with the Polytec scanning laser vibrometer because reflections from glossy finishes tend to cause errors in the analysis. A special cello with a flat back with three braces was also tested. Laser data were also correlated with separate response data from an anechoic chamber.

3. Results of Laser Vibrometry Measurements

The main result of laser vibrometer analysis is that in spite of the common usage of both types, the flatback and roundback basses are acoustically significantly different instruments. Laser analysis shows that flatbacked basses share many top plate modes with the roundbacks, but the back plates show completely different operational deflection patterns throughout the entire measured frequency range of 80 Hz to 2000 Hz.

The implication is that basses with round backs can be classified as large violins, while flatbacks belong to the viol family. This study resulted in a quantity of pictures of modal patterns, many of which are presented below (Fig. 3). Note that the flatback back, flatback front, roundback back and roundback front are presented from left to right, in two columns, and F is labeled in Hz above each pattern.

3.1. Modal Patterns

While the roundback model compares favorably to the literature on violin instruments, the flatback does indeed resemble Ågren's "magnum" treble viol [1].

Due to technical difficulties, the laser measurements under 80 Hz are only of limited value, so the first corpus bending modes and tailpiece resonances that should be found around 50 Hz [2] could not be observed by this method. Also the A0 mode, which was determined at 65 Hz (by combined radiation response and input admittance measurements) falls into this range and is not well visible.

In the band from about 80 Hz to 115 Hz, the top plates of the flatbacked and roundbacked bass show similar patterns, while the back plates are different. The T1/A1 mode is very clear at 115 Hz in both basses, corresponding to illustrations from related literature. The suspected C3 is found in the roundback Prb at 155 Hz, as shown in Fig. 2.

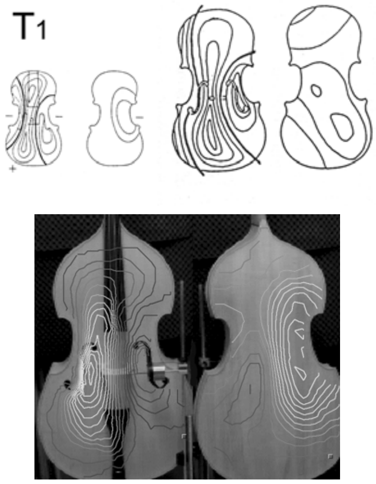


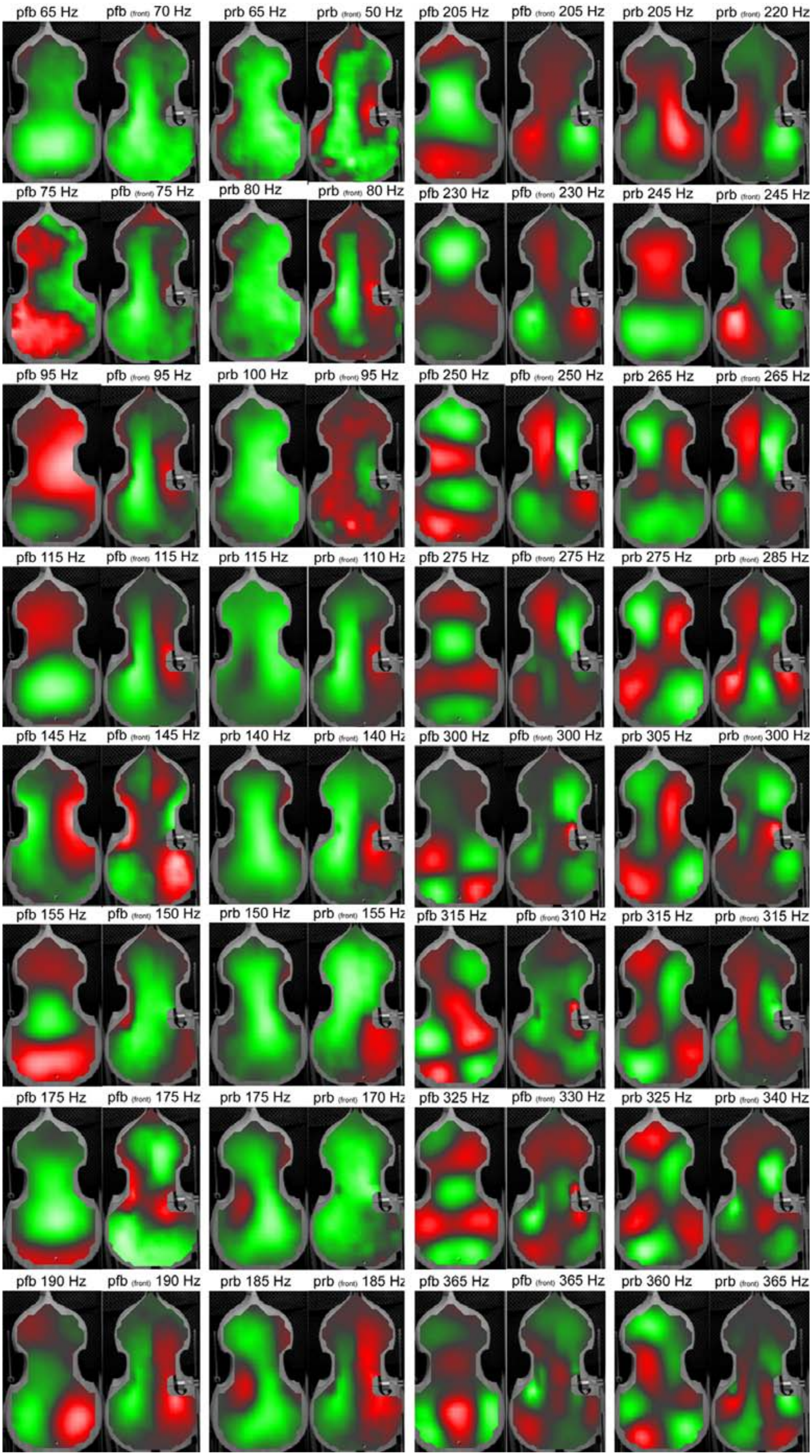
Fig. 1: (above) The T1, or main top plate resonance: violin 460 Hz [3], violoncello 219 Hz [4] and Prb at 110 Hz.

Fig. 2: Comparison of cello C3 mode, 219 Hz [4] and Prb, 155 Hz.

An RMS averaged over the entire measured bandwidth shows that the flat back plate generally vibrates symmetrically along the vertical axis, divided into sections by the braces, while the rounded back shows asymmetrical patterns along the length of the back [5]. A ring pattern in the round back plate is present at a lower frequency (125 Hz) relative to the violin (650-700 Hz), and remains dominant in a broad band reaching to 160 Hz. Correlating this asymmetrical pattern with radiation response data shows that the broad band, asymmetrical mode of the round back plate from 125 Hz to 160 Hz is a major contributor to the smoother radiated response curve in that band and suggests that the arched back plate causes the instrument to radiate more efficiently and as a 0-order radiator in this bandwidth (in the bridge plane). The flat back, in contrast, goes through a rapid transition within narrow bandwidths between deflection patterns. This bass type has a significant directivity, which may be caused by narrow-bandwidth modes that radiate poorly, for example at 150 Hz, and by cancellations from the symmetrical deflection areas, for example at 300 Hz (Fig. 3). The pattern of the flat back at 145 Hz is also characteristic of flat back plates, and was found at 190 Hz in the analysis of a flatbacked cello. This motion, known as "C-Bout vertical translation" is known to have a high mobility but low radiation efficiency [2].

3.2. The Braces

It is clear that the resonances of the individual braces in the flatbacked bass are responsible for the unevenness of the flatback's response. These resonances can be easily isolated with impulse response tests done on the outside of the back. The four braces of the flatbacked bass Pfb are numbered from top to bottom. Brace 1 has the highest Q factor peak and is quite isolated, while the other braces have more complex vibration modes. Consequently the "knocking tone" of Brace 1 is very clearly a "B" natural, if a bit flat at 240 Hz. The resonance of Brace 2 is yet dominated by the strong peak of Brace 1, but has eigenfrequencies at 335 Hz and 405 Hz. The "knocking tone" of Brace 3, or soundboard, is less easy to hear when knocking, depending on exactly where the plate is struck. This brace is presumably of primary importance because it is directly coupled to the top plate through the soundpost, and consequently to the main radiation source. Brace 4, being the longest and proportionally thinnest, has the lowest eigenfrequency at 85 Hz.

4. 

pfb 65 Hz
pfb (front) 70 Hz
prb 65 Hz
prb (front) 50 Hz
pfb 205 Hz
pfb (front) 205 Hz
prb 205 Hz
prb (front) 220 Hz
pfb 75 Hz
pfb (front) 75 Hz
prb 80 Hz
prb (front) 80 Hz
pfb 230 Hz
pfb (front) 230 Hz
prb 245 Hz
prb (front) 245 Hz
pfb 95 Hz
pfb (front) 95 Hz
prb 100 Hz
prb (front) 95 Hz
pfb 250 Hz
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pfb 115 Hz
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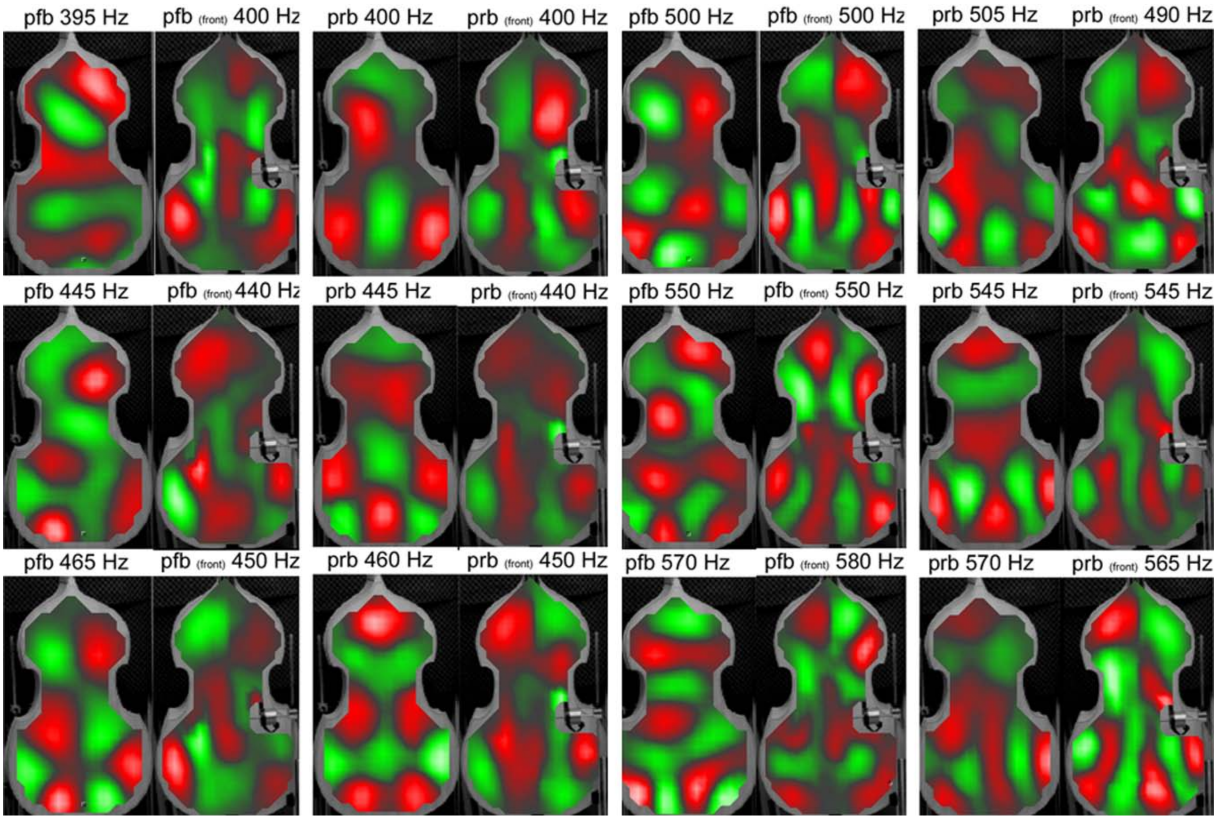

Fig. 3: flatback back, flatback front, roundback back, roundback front by frequency, in two columns.

5. Conclusions

The main result of laser tests shows that basses with a rounded backs show modal shapes like large violins, while the braces in flatbacks cause modal shapes that are like a viol. The radiated response of roundbacked basses is characteristically smoother in the lower and middle frequency range of 130 Hz to about 200 Hz due to the modal patterns and quality of the back plate, and the placement of the soundpost directly on it. The flatback is dominated by narrow-band resonances of the braces, which cause an uneven response in this range. The influence of the eigenfrequencies of the individual braces makes it possible, and indeed necessary, for the instrument maker to vary the form and quality of the braces in a flat back plate to achieve a desired configuration of resonances. Higher, stiffer braces will yield a greater Q-factor, which will isolate narrow bands and bring out the "flatback" character in the response curve. Lower, flatter braces will have a lower Q-factor, spreading the brace eigenresonances over broader bands and bringing a more "violin-like", smoother response curve. The input admittance of the back plate at the position of the soundpost is probably a most significant factor in the radiation of the top plate and the entire instrument and is therefore deserving of special attention from instrument makers while shaping and tuning the soundboard of a flatback.

6. Acknowledgments

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