

## AN ACOUSTICAL STUDY OF FLAT- AND ROUND-BACKED DOUBLE BASSES

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### ABSTRACT

The form of the violin has prevailed as the standard for the violin, viola and violoncello, but not for the double bass. Surveys reveal that while some tendencies exist among instrument makers and musicians, opinions about the sound of the two main types of basses, flat- and round-backed, often conflict. Several new double basses of nearly identical form and extremely similar materials were created especially for this study, presenting a unique opportunity to define acoustical characteristics of flat-backed and round-backed basses. The pairs of instruments differ, in theory, only in the form of the back. Laser vibrometry, analysis of audio recordings made in an anechoic chamber, and listening test surveys were used to delineate differences between the types concerning radiation characteristics and timbre. A special flat back for an existing violoncello was also made, tested and compared to a similar instrument of the standard form. Room acoustics and psychoacoustical considerations are discussed along with experimental results to offer an explanation about why the double bass is the only modern bowed instrument in use that has a flat back.

### 1. INTRODUCTION

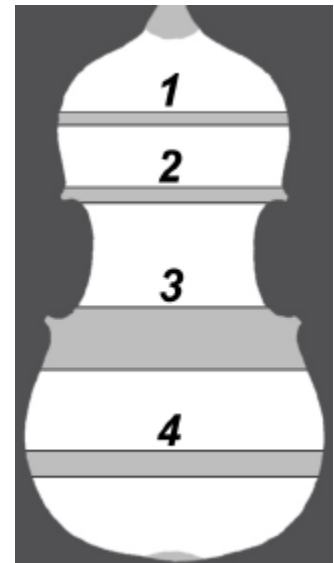
Though many aspects of the modern double bass have yet to be standardized, currently used instruments may be divided into two main categories: those with a flat back, and those with a rounded (“carved”) back. The flat backed double bass has its roots in the design of the viol. An important feature of this type is not only the flat back plate, which is most often uniformly thick, but the size and configuration of internal bracings (Figure 1) which support the soundpost and add stiffness to the plate. Rounded backs have no such supports and are graduated like violins.

A survey of instrument makers and musicians shows no overwhelming preference for one type at this time, though many have opinions about the instruments’ static and acoustical properties. According to the surveys, the flat back plate is prone to shrinkage problems because the perpendicular spruce braces do not allow the plate to expand and contract freely with atmospheric changes. On the other hand, flat backs require less material to make, and are less labor intensive if the bass is made by hand. Of the few makers and players who had an opinion, the majority described flat backed basses as sounding “more direct”, “boomier”, and rounded backs as “rounder (!)” and “warmer”.

Papers on the acoustics of the flat double bass back were written by Wall [1] and Traeger [2], but do not present a

comparison to the round back design. The standard literature on instrumental acoustics has not up till now made a distinction between these two types of basses.

*Figure 1: A bracing pattern often seen in flat backed basses, including the test basses, which are arbitrarily numbered here. The braces are made generally of spruce and glued onto the interior side of the back with the grain perpendicular to the years of the plate. Any number of variations on this pattern have been reported: one, two or three braces, an “x” formed support under the soundpost, or even this standard pattern carved out of a round back!*



#### 1.1. Experimental setup

Ten instruments were measured during this study. Five are basses made especially for this test by a Bavarian luthier that have nearly identical design features and accessories, such as strings, tailpiece and fingerboards, except for the backs. Two were made in poplar and spruce and two in maple and spruce. The fifth has a plywood back with maple ribs. The poplar basses, which were cut from the same tree, are the focus of this paper. The components were manufactured by a large CCD milling machine, thinned by hand partially at the edges of the top plate and assembled. The bridges and soundposts are of similar materials and were fitted to the same positions. The instruments are not varnished.

Examination with a magnetic gauge revealed that thicknesses among the basses were generally within a  $\pm 0.5$  mm tolerance, with two important exceptions: the thickness of the top plate at the upper and lower widths inside the purfling was found to vary in the range between 3.0 and 4.7 mm, and braces 1, 2 and 4 (Figure 1) of the maple flat back were double the thickness of the poplar flat back (20 mm as opposed to 10 mm).

For measurements, each instrument was mounted on an artificial endpin affixed to a stone plate, allowing the instrument to stand firmly without any other contact. A B&K shaker 4810 on a heavy mounting sat on the stone plate, driving the bridge on the bass side. For audio recordings of sine sweeps, the

instrument was placed in a quasi-anechoic room with the strings dampened with foam. Five AKG CK92 spherical characteristic microphones were arranged in a half circle at a distance of 100 cm to the vibrating surface at the height of the bridge. A B&K accelerometer 4374 (0.65g) was placed on the bridge next to the shaker contact point as a reference. A sine sweep from 40–3500 Hz over sixty seconds was recorded onto six channels (five audio + one reference) and repeated, then the instrument and shaker were rotated 180° and the process repeated. The resulting audio files for 000°, 045°, 090°, 135°, 180°, 225°, 270°, and 315° and two reference channels (front and back measurements) were RMS analyzed, yielding response curves.

For measurements using the Polytec laser vibrometer, the instrument and shaker were mounted as above, in a relatively small room with smooth concrete walls. 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.

## 1.2. Audio Analysis

Attempting measurement of low frequencies in an anechoic environment is problematic. The repeated microphone channels at angles 090° and 270° show that audio signals below 100 Hz may vary by +/- 15 dB and by +/- 5 dB above 100 Hz. Since the soundpost and bridge set-up and other conditions were controlled as closely as possible, the measured differences between both instrument types should still have their origins in the design or materials. Consideration of the near- and far-field is also an important aspect of double bass acoustics, but the acquisition of sufficient signal levels at greater distances in larger rooms is difficult.

At the time of writing, many casual but no methodical listening tests have been performed. Playing a few bowed notes on both basses in the anechoic chamber yielded material for a few informal listening tests. When various recorded excerpts were played for “blind” colleagues, the result was quite entertaining: one said the first bass sounded “rounder”, while the second sounded “flatter” (“*flächig*”). Since then, any number of informal tests have shown that there is some sound difference, but no one has been able to recognize or consistently identify one or the other in blind tests, whether or not the research topic is known to them. The general response to the flat-backed ‘cello was that it “had a nice sound” but that the modulation of the tone color was difficult or impossible.

## 1.3 Radiation and Mobility Analysis

All flat-backed stringed instruments measured, including four basses, the special ‘cello, and a ‘cello-sized viola da gamba, are characterized by narrow band peaks and valleys in the response curve showing extreme amplitude differences within the range of middle body modes. The poplar flat-back bass shows troughs in forward-radiated energy occurring at 175, 205, and 260 Hz which do not occur in its round-backed twin (Fig. 2). The four

round-backed instruments recorded have a smoother response curve in this range.

The signal of the accelerometer waxed onto the bridge near the shaker’s needle yields a kind of input admittance curve, assuming that the input force remains constant. This curve, referred to here perhaps imprecisely as “mobility”, was used to help identify some air mode differences between the two models: the A0 mode at 67 Hz appears as expected in the radiation curve stronger than in the mobility curve. The T1/A1 mode appears at 115 Hz in both instruments, as its frequency is dependent on the body dimensions. The next appearance of an apparent air mode is the suspected A2 at 150 Hz in the flat-back and 158 Hz in the round-back. High mobility and low radiation is found in both basses at ca. 100 Hz, indicating blind power. Such values are also found in the flat-back at 175 Hz and 250 Hz and in the round-back at 230 Hz.

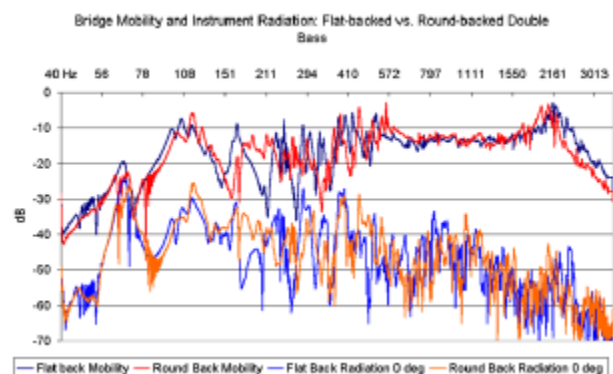


Figure 2: comparison of curves between the two poplar test instruments: Mobility above, radiation below.

Fig. 3 shows the response curves of the two flat-backed instruments (left) and the two round-back basses averaged over all eight audio channels. Several peaks are significantly different between the two flat-backed models, probably due to the thickness differences in braces 1, 2 and 4. The round-back models conform to one another more closely. This seems to indicate that the choice of poplar or maple for the back and ribs has little influence on the response curve.

## 1.4 Laser Vibrometry Analysis

Given the large amount of literature on the modal behavior of the violin, it was entertaining to discover many of the same patterns in the round-backed double bass and sometimes in the flat model. Due to technical difficulties, the first useful laser measurements occur above 80 Hz, so the first corpus bending modes and A0 mode are not well visible. The T1/A1 mode is very clear at 115 Hz in both basses, corresponding to the response curves of this study and illustrations from related literature. It is however remarkable that the top plate in both models vibrates as the violin

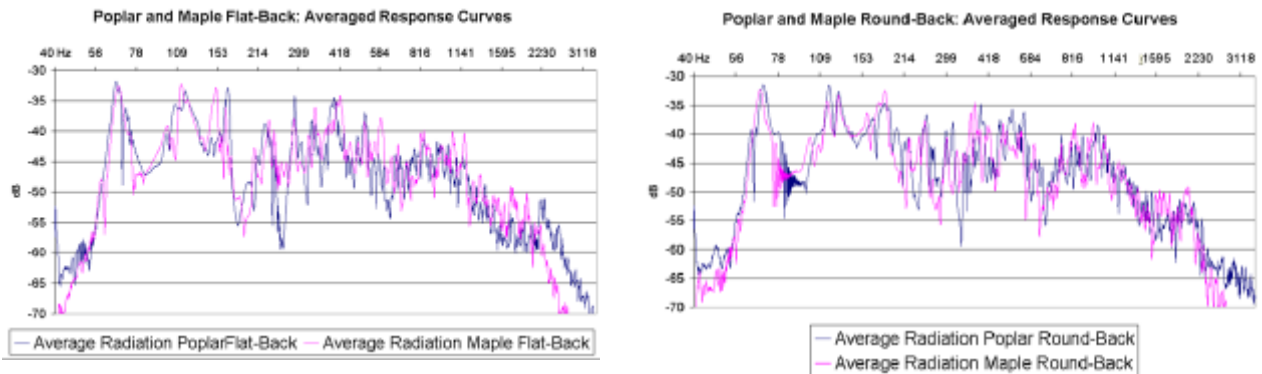


Figure 3: Averaged response curves of two flat-backed basses (left) and two round-backed basses, in poplar and maple.

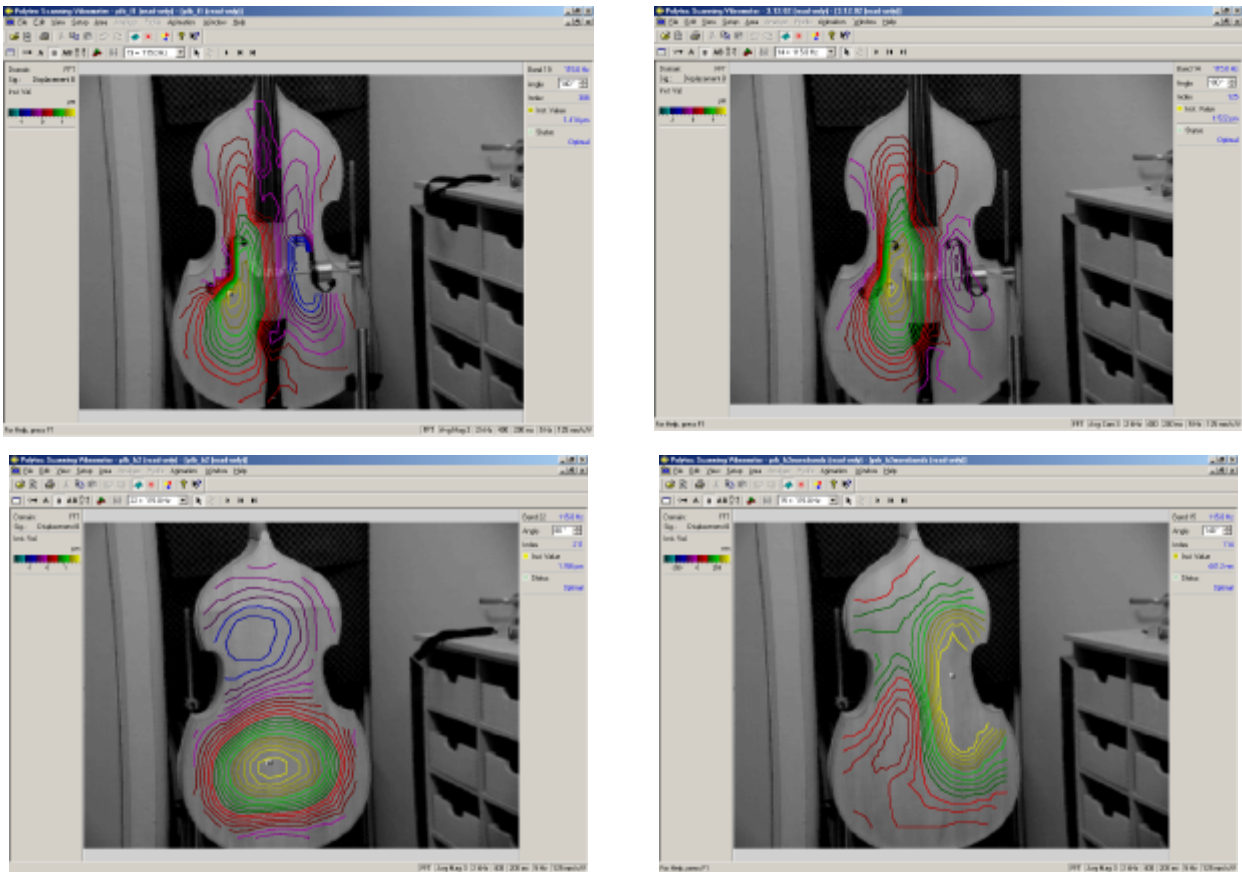


Figure 4: The T1/A1 mode at 115 Hz, flat back at left. Which pattern doesn't fit?

does [3], but that the back plates vibrate completely differently: the rounded back seems to behave as a large violin while the flat back with braces behaves presumably like a gamba (Fig. 4). Patterns of the backs remain different to varying degrees throughout the measured range. A ring pattern in the rounded back 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. The flat back, in contrast, goes through a rapid transition between deflection patterns within

narrow bandwidths. This appears to be the cause of the smoother response curve in the case of the rounded back: in the range of about 90-300 Hz the braces of the flat back sharply dampen narrow frequency bands and resonate in others. It is also characteristic of the flat back to vibrate symmetrically along the vertical axis, divided into sections by the braces, while the rounded back shows asymmetrical patterns along the length of the back, apparently due to the influence of the soundpost. An FFT of the vibration in both backs over the entire bandwidth reveals this tendency (Fig. 5).

In progressively higher frequency ranges, the modal patterns for both models get predictably more intricate. A more detailed list of deflection patterns and frequencies for both bass types will soon be available from the IWK.

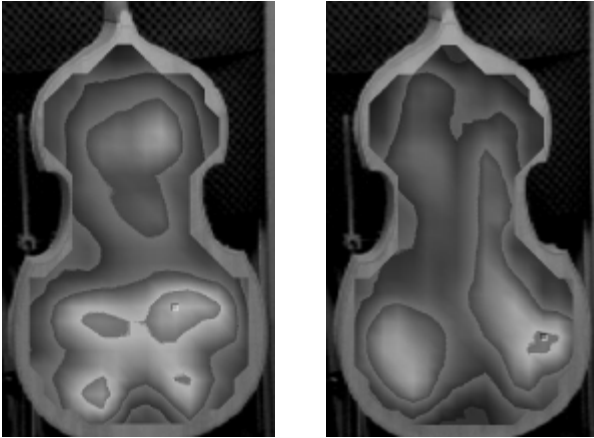


Figure 5: Laser vibrometry FFT of velocity over the entire bandwidth of 5-2000 Hz, flat back left, round back right. The maximum value (marked) for the flat back is 1.49 mm/s and for the round back 1.37 mm/s.

## 2. CONCLUSIONS

Analysis of radiated sound and laser vibrometer data has shown that there are remarkable differences in the resonance characteristics of two types of bowed instrument backs. The measured flat-backed instruments are characterized by narrow-band resonance peaks and troughs in the low and middle range of response curves. The flat backs demonstrate completely different operational deflection patterns than their rounded counterparts, which share many similarities with the violin. It is therefore remarkable that on the whole, both types are used equally often by bassists today. It is suggested that in spite of the large measurable differences observed between the two types, these differences are less significant in practice on account of psycho-acoustical and room-acoustical factors, but this must be confirmed with pending systematic listening tests.

## 3. REFERENCES

- [1] Wall, E., "Preliminary Studies of Flat-Backed Bases", *JCAS* Nr. 44, 1985, pp. 28-33.
- [2] Trager, C., "Tuning flat backs", *CASJ*, Vol. 3, Nr. 2 (Series 2), 1988, pp. 40-44, 198.
- [3] Moral, J.A. und E.V. Jansson (1982). *Eigenmodes, Input Admittance, and the Function of the Violin*, in *Acustica*, S. Hirzel Verlag, Stuttgart, Jahrgang 50, Nr. 5, S. 329-337.