

Acoustics of Baltic Psaltery; Another Outstanding Latvian Kokle

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We have studied the acoustics of a Latvian Baltic psaltery (kokle) which was judged by performing and recording musicians to be outstanding. Previous work by the authors pointed out the importance of a high population of body-resonances within the tuning range of the instrument, with good string-to-resonance coupling also playing an important role. Results on this kokle are compared with data on the other instruments. This particular kokle shows outstanding coupling of strings to body-resonances, with all strings evidencing some degree of coupling. In some cases, the strings couple to a superposition of more than one body-resonance.

1 Introduction

We are dealing with the archaic form, in which usually the bottom, sides and frame are carved from a single block of wood, with an added soundboard. Because of its mode of construction, the archaic form is called the *carved* Baltic psaltery.

Why study this kind of instrument at all? One answer is that it has had a revival in recent years. A second is that it is a relatively simple instrument, thus more amenable to research. But perhaps the most compelling reason stems from the fact that no two genuine antique instruments were exactly alike. This individualized tradition leaves the field wide open for experimentation.

Previous work by the authors on carved Baltic psalteries [1] pointed out the importance of (1) a high population of body-resonances within the tuning range of the instrument, (2) optimal location of the lowest body-resonances with respect to tuning of the instruments, and (3) good string-to-soundbox coupling. The importance of good string-to-soundbox coupling was brought out by the data on the outstanding Latvian kokle KD9. That instrument is a 13-string kokle made by the late Konstantins Dravnieks, last residing in Thiensville, WI, USA. Keeping with the notation used in the previous work, to avoid ambiguity we denote each instrument by the maker's initials followed by the sequence number.

Three carved Baltic psalteries from our previous study [1] are shown in Figure 1.

The kokle on which we report here was made by the Latvian-American woman Ieva Sijats Johnson, Zionsville, IN, USA, with advice and guidance from Ain Haas, Indiana University and Purdue University in Indianapolis, IN, USA, an experienced maker. Accordingly, we denote it as IJ1. This is shown in Figure 2. This kokle is of the Kurzeme type, western

Latvia. It has 12 strings and a soundhole rosette symbolizing a sun-wheel with six rays at the center, surrounded by an array of 18 small circular holes, plus two other rosettes, each with six small circular holes. The tuning is diatonic, in the key of C, from G3 through D5.



Figure 1. Three carved Baltic psalteries included in a previous study, from left: AP1, AH19 and KD9.

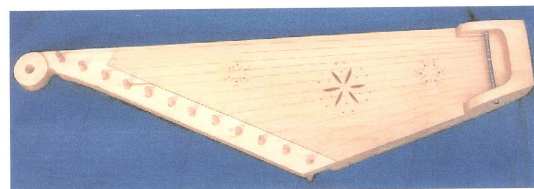


Figure 2. The kokle IJ1

Because of its lower tuning, the instrument IJ1 is a bit larger than the carved Baltic psalteries we studied previously. Overall length is 80.0 cm and overall width is 22.0 cm. For comparison, the kokle KD9, which is tuned to E, has overall length 63 cm and

overall width 20.6 cm. KD9 also has relatively light weight (788 gm compared with the outstanding 6 string kannel AP1 at not much less, 726 gm; [1]).

The instrument IJ1 is also of lightweight construction. On this kokle, the thickness of its Sitka spruce soundboard is nominally 3 mm, though spot-checks at the edges showed a low of 2.5 mm and a high of 3.3 mm. Because of the relatively thin unbraced soundboard on such a larger instrument, the soundboard has buckled downward by 9 mm at its center. The thickness of the bottom of its soundbox, made of American basswood, is 4 mm, compared with most previous carved Baltic psalteries studied at approximately 7 mm or more, and KD9 at 6 mm. Total weight is 1400 gm. Even allowing for the increase in lateral dimensions compared to KD9, it still comes out heavier by that measure, by roughly 30%. On this instrument, there was not as much emphasis in eliminating excess mass from the tailstock end nor from the peg-frame and pegs, as was done on KD9. Nevertheless, the weight of the 12-string kokle IJ1 at 1400 gm is about the same as that of the 10-string kannel AH19, which was also judged to be an outstanding instrument, at 1389 gm.

This instrument IJ1 was judged by performing and recording amateur musicians in two folk instrumental ensembles (“Tuuletargad” and “Siilikesed”; each has a CD out), including the first author of this paper, to be the most outstanding carved Baltic psalteries currently available in the area encompassing Illinois, Indiana and Wisconsin, USA. This includes the other carved Baltic psalteries available for our previous work [1].

We would also like to mention in passing that a consensus among musicians is also emerging according to which carved Baltic psalteries with traditional distributed sound holes tend to sound better than modernized versions with a single sound hole. In our previous work, experiments in covering different sound holes on AP1 gave laboratory support [1]. To make the story short, distributed sound holes beneficially affect the higher modes of the air cavity, which in turn couple to the soundboard resonances.

2 Results on the Body-Resonances for IJ1

Operational deflection shapes of the soundboard vibrations at their peaks are shown in Figure 3. As in our previous work [1], the measurement method was electronic TV holography. In taking the data in Figure 3, a strip of masking tape was spread across the strings (to disable the strings). This strip is visible in Figure 3. The body was driven by coil and magnet, at a position optimized for least distortion by a contact microphone

on a very similar instrument (specifically AP2; [1]). Basically, 6 body-resonances within the tuning range are available to support the 12 strings. Note that the second of the lowest resonances is between the keynote and the tone above, as suggested by the optimum in our previous work [1], though closer to the tone above.

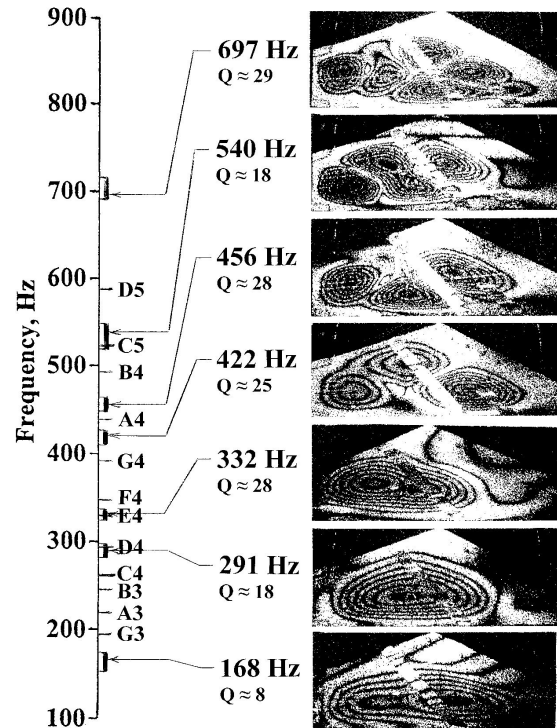


Figure 3. The 12 string kokle IJ1. Body-resonances

3 Coupling Between Strings and Body-Resonances

The method developed in our previous work consists of scanning for narrow peaks within the nominal tuning tolerance (a few Hz) of a string left free to vibrate, using electronic TV holography while driving the body by coil and magnet. Such scans have to be done at intervals as fine as 0.1 Hz, as the peaks at the string frequencies are very narrow. With Baltic psalteries, two narrow peaks separated by only a few (2-5) Hz are often seen. This is probably due to the influence of the knot in the end of the string opposite the tuning pegs, which creates a slightly higher string frequency for motion perpendicular to the soundboard than for motion parallel to the soundboard. The influence of the knot was studied by researchers mostly in Finland [1].

The amplitude of a narrow peak at a string relative to its neighboring (much broader) body-resonance can be

Table 1. Amplitude ratios of narrow peaks at strings to neighboring body resonances at their peaks

Kannel AP1													
String tuning				G4	A4	B4	C5	D5	E5				
Amplitude ratios, higher string freq.				1.2	1.5	1.2	--	0.75	0.3				
Amplitude ratios, lower string freq.				1	0.7	1.1							

Kannel AH19													
String tuning	D4	E4	F#4	G4	A4	B4	C5	D5	E5		G5		
Amplitude ratios, higher string freq.	0.95	0.45	0.1	0.45	0.6	0.9	0.5	--	--		1.2		
Amplitude ratios, lower string freq.	0.5			0.4	0.7	0.95							

Kokle KD9													
String tuning	B3	C#4	D#4	E4	F#4	G#4	A4	B4	C#5	D#5	E5	F#5	G#5
Amplitude ratios, higher string freq.	0.4	0.3	0.4	0.8	0.9	0.2	--	0.85	1.3	0.45	1.1	--	0.8
Amplitude ratios, lower string freq.			0.35	1				0.8	0.55	0.4	0.9		
Amplitude ratio, third string freq.				0.7									

Kokle IJ1													
String tuning	G3	A3	B3	C4	D4	E4	F4	G4	A4	B4	C5	D5	
Amplitude ratios, higher string freq.	See text	≈0.6 (168)	0.45 (291)	0.55 (291)	1.8 (291)	1.5 (332)	0.6 (332)	0.6 (422)	1.0 (456)	0.75 (540)	1.5 (540)	0.6 (540)	
Amplitude ratios, lower string freq.		0.1 (332)	0.27 (332)		1.3 (291)					0.75 (540)		See text	

determined by counting fringes while keeping all test conditions except driving frequency the same. This means using the same excitation current, and no changes in the setup, for each amplitude ratio comparison. It was suggested that this amplitude ratio can serve as an approximate measure of coupling the string vibrations to the body resonances [1]. In case different excitation currents are used, the fringe counts can be corrected assuming proportionality between number of fringes and excitation current when the frequency is constant.

The resulting amplitude ratio data are shown in Table 1. Similar previous data, on the kannels AP1, AH19 and kokle KD9 are also included for comparison. In taking the data on the higher strings, a strip of masking tape was applied across strings which were an octave lower so as to rule out confusion between the

fundamental of a high string with the second harmonic of a string tuned an octave lower.

With the instruments AP1, AH19 and KD9, the neighboring body-resonances were self-evident. With the kokle IJ1, things are more complicated. Therefore, with the kokle IJ1, the frequencies of the body-resonances which most closely resemble holographic interferograms taken at the narrow peaks at the strings are also included in Table 1, in parentheses.

The holographic interferogram of the narrow peak at the lowest, G3 string, is shown in Figure 4. The contour-map of the soundboard vibration resembles the body-resonance at 422 Hz, with possible admixture of the body-resonance at 332 Hz (compare with Figure 3). It is tempting to conclude that the modes observed on

the soundboard in Figure 4 relate to second harmonics of the G3 string.



Figure 4. Narrow peak at the G3 string, observed at 195.9 Hz

As the instrument was excited at the fundamental of this string, how can this be? Explanation is provided by Erkut et. al. [2], who pointed out that the knot at the “varras” end also helps generate a significant second harmonic even if the string is plucked at its middle. Thus, it should not be surprising to see a 2nd harmonic come forth under these conditions.

The other “See text” note in Table 1, at the lower-frequency narrow peak at the highest string, relates to the fact that the shape of the holographic interferogram observed there does not resemble either the 540 Hz nor the 697 Hz body-resonances, nor is it clearly explainable by their superposition. Possibly, a higher body-resonance may also have been involved.

4 Conclusions

As mentioned earlier, there is a consensus between performing and recording amateur musicians in Indianapolis, Chicago and Wisconsin that this is the best carved Baltic psaltery currently available in that area. Also, good string-to soundbox coupling has been found to be an important indicator of a successful carved Baltic psaltery [1]. *This particular kokle is the first Baltic psaltery we have investigated which shows some degree of coupling between ALL its strings to its body-resonances.*

This instrument’s relatively thin soundboard (3 mm for such a larger instrument) and also its relatively thin bottom (4 mm) probably help. The fact that its overall mass is not as low as KD9 suggests that it may be more important to minimize mass around the soundbox itself rather than at its ends.

We thank Ieva Sijats Johnson for graciously lending her instrument for this study.

5 References

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