VIBRATIONS OF THE CONCERT HARP SOUNDBOARD AND SOUNDBOX

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The soundboard of the concert harp under investigation - the Salvi "Orchestra"- is a plate of length 136 cm with a width of 44 cm at the bass end, narrowing to 12 cm at the treble end, and a tapering thickness which varies from 12 mm at the bass to 2 mm at the treble. The soundboard is of European Spruce, quarter sawn with the grain running across the board. On the front of the board there is a thin veneer of spruce with the grain running along the board.

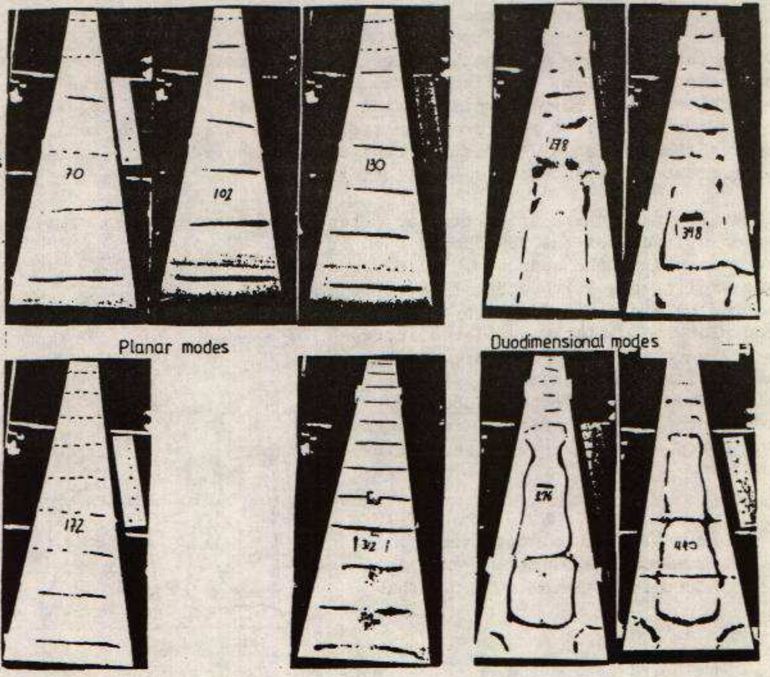
There are two central bars on the board; these are of beechwood. On the front is the cover bar, while on the back is the larger reinforcing bar. There are two other bars on the back of the board; these are the harmonic bars. They are small, light and positioned on either side of the reinforcing bar. They bear little of the tension from the strings.

We would begin by considering the vibrational characteristics of the free soundboard. Fig 1 shows some Chladni patterns for the board without any bars. At the lowest frequencies the board bends only along one direction, and the

Fig.1

Chladni Patterns of free harp soundboard with bars

the figures indicate the frequency of resonance



nodal lines are across the board this group of resonances are referred to as the planar modes. At higher frequencies the vibrations are along and across the board and the effect of this are round nodal patterns; this group of resonances are referred to as the duo dimensional modes.

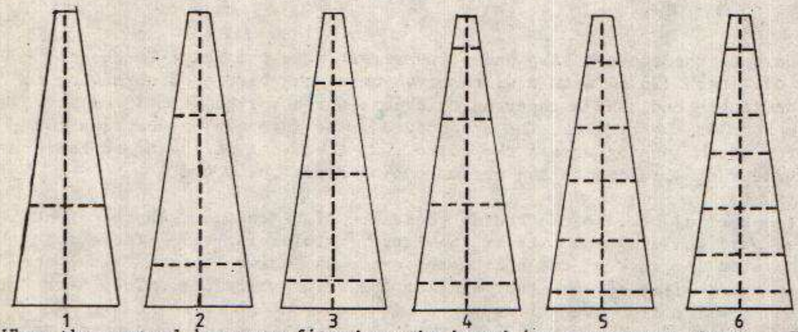


Fig. 2 Vibrational patterns of free harp soundboard with central bars: Torsional modes

When the central bars are fitted to the board its resonances change. Fig 2 shows the first six members of one group of resonances which are called the tortional nodes. These have in common a node running along the central bars, and an increasing number of transverse nodal lines. An interesting feature of this group is that the resonances are harmonic; in one case up to the twelth mode.

Using the technique of speckle interferometry another important resonant family has been identified, the first three members of which are drawn in fig 3. These are called the duodimensional or ring modes. Although the edges of the soundboard are quite free they are almost modal; the actual node running a few centimetres from the edge. It is the centre of the board, despite the presence of the stiff central bars, that is oscillating.

These resonances are of particular interest as they are very similar to the resonant modes of the soundboard when it is attached to the soundbox. Just as, on the violin, the fifth mode of the free plates have a similar motion to the first top plate mode of the completed instrument, we wish to propose that the characteristics of these ring modes will significantly affect the soundboard resonances on the completed instrument and thereby contribute to the quality of the harp.

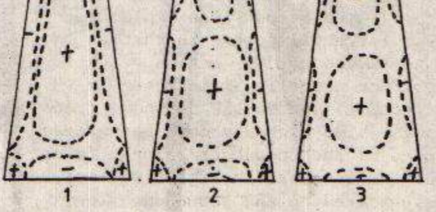


Fig 3 Vibrational patterns of free harp soundboard with central bars: ring modes. Plus and minus signs indicate relative phase.

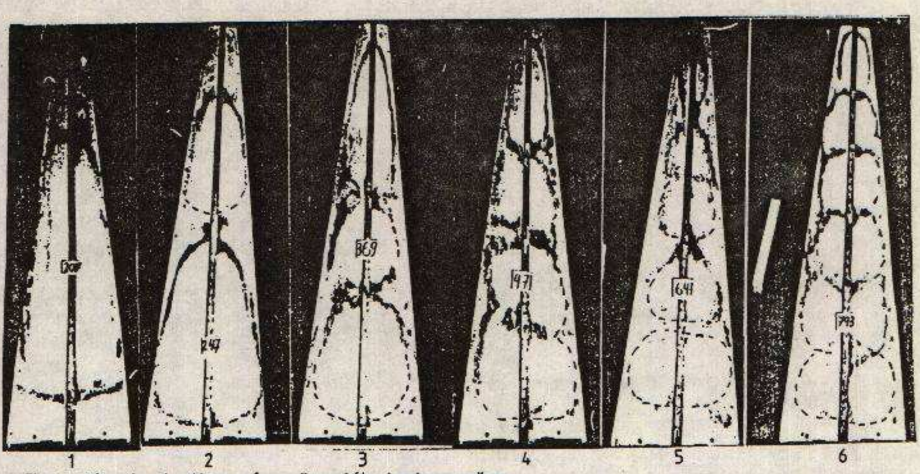


Fig 4 Vibrational patterns of soundboard fixed onto soundbox

The concert harp soundbox is a truncated semicone of rigid wood laminate. When the soundboard is fixed to the soundbox; the resonances are similar to the ring modes of the free board (fig 4). Under these boundary conditions, as one would expect, the edges of the board are nodal and there is a series of resonant modes like the modes of a diaphragm. It should be noted that the first and second resonances of this group are not eigenmodes of the soundboard alone (unlike the subsequent modes). At these resonant frequencies the treble end of the whole soundbox oscillates in response to the motion of the soundboard.

What then is the relationship between the ring modes of the free soundboard and the eigenmodes of the soundbox?

Fig 5 shows a logarithmic-linear plot of resonant frequency against mode number for these two cases. It is possible to draw straight lines connecting the experimental results. For the fourth, fifth and sixth modes, the two lines are almost parallel and the resonant frequencies only 10% different. However, for the lower modes there is a much larger frequency drop between the resonances of the free board and those of the clamped board. One explanation of this large difference is that as the lower modes involve motion of whole soundbox there is an increase in effective mass so the resonant frequency falls. The higher modes, being eigenmodes of the soundboard alone, do not have an increase in effective mass on being fixed to the soundbox. The vibrations of the back of the soundbox

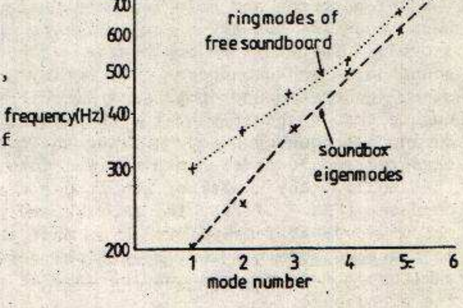


Fig 5

have also been studied. The results which are not illustrated here, show that the box not only bends in response to the oscillations of the soundboard, but that it is also, at least to a small extent, a radiator of sound in its own right.

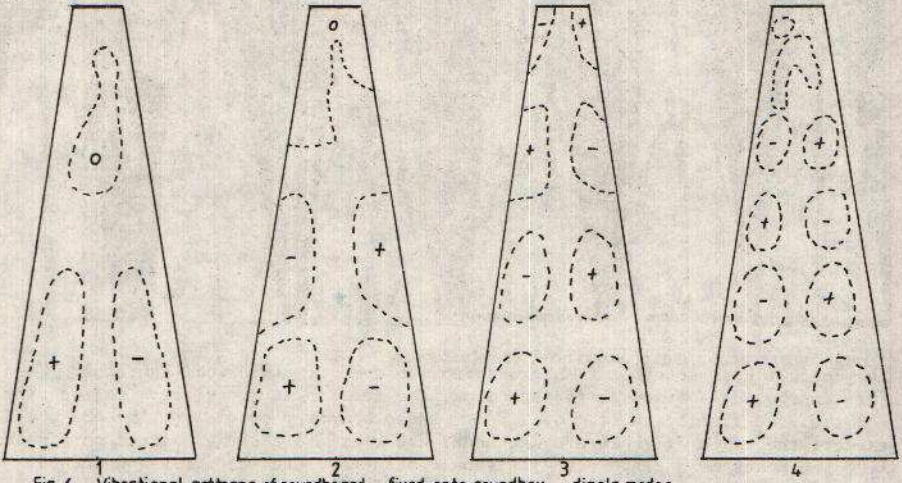
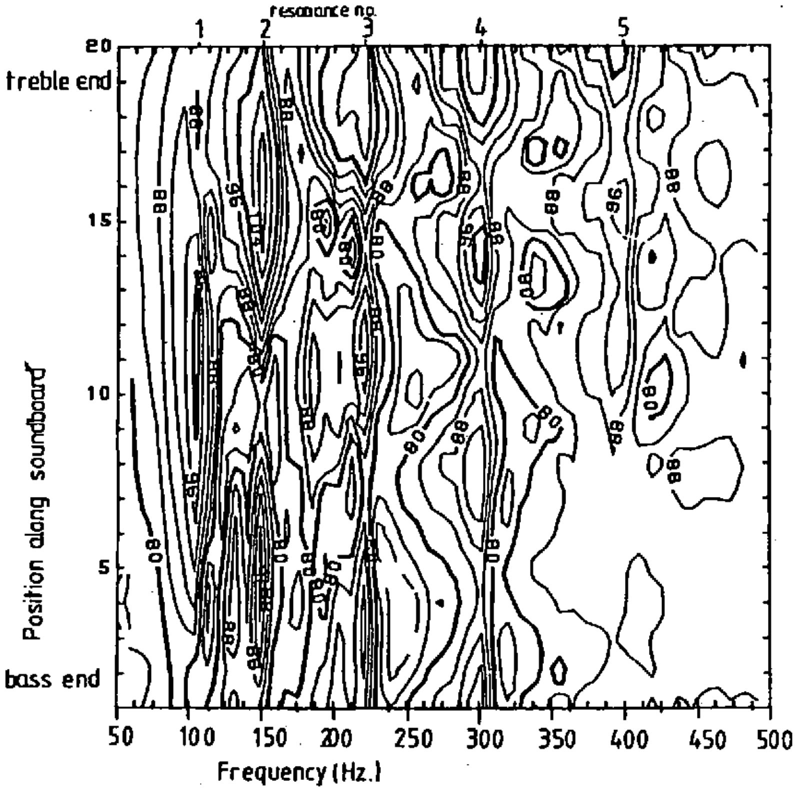


Fig 6 Vibrational patterns of soundboard fixed onto soundbox. dipole modes

Returning our attention to the clamped soundboard, there is another group of modes, called the dipole resonances, and the first four members of this group are shown in fig 6. They are characterised by twin antinodal regions, one on either side of the central bars which, in these cases, are nodal. As the harp strings oscillate into a nodal line, one would not expect them to be the primary method of soundproduction. As well as the dipole modes, fig 6 also shows a tripolar mode. This has the characteristic of three antinodal regions situated side-by-side across the soundboard.

Chladni patterns and holographic interferometry serve as a useful introduction to harp acoustics but there are limits to the information these techniques can provide. Therefore we employ the method of measuring the input admittance of soundboards and soundboxes. We employ a standard experimental method, using the signal generator and compressor circuits of a heterodyne analyser (B+K 2010) to ensure that a shaker vibrates the soundboards with a constant excitation force during a frequency sweep. During the sweep, the velocity of the soundboard is measured and recorded, in a digital form, on a high resolution frequency analyser (B+K 2033). Any number of admittance measurements can then be transferred to a computer (VAX - 11/780) for storage and processing. With research on the guitar, measurements at four points on or near the bridge are considered sufficient [1]. In order to obtain a full acoustical description of the harp, some twenty admittance measurements must be made at positions all along the central bar of the soundboard.

Fig7 Soundboard Admittance contourmap



To present all this data in a simple comprehensible fashion we construct a contour map from the results (fig 7). This is by no means a new method, one of us, IMF, having drawn such maps for the clarsach (the small harp native to Scotland) back in 1977 [2].

On such maps, the Y-component represents the position of excitation on the central bar from the base at the lower end of the plot to the treble end at the top; the numbers indicating the number of admittance sweep. The X-component represents the excitation frequency, in this case from 50 Hz to 500 Hz, while the contours of the map link points with equal admittance value (dB). Peaks on the admittance map indicate soundboard resonances. In this case, that of a soundboard with its edges held, the first peak is at 100 Hz and being single, represents the fundamental soundboard resonance. There then follows a valley of admittance before the second harmonic is reached at 150 Hz. The third, fourth and part of the fifth resonance can also be seen on the map; their respective positions bieng indicated by the numbers at the top of the plot.

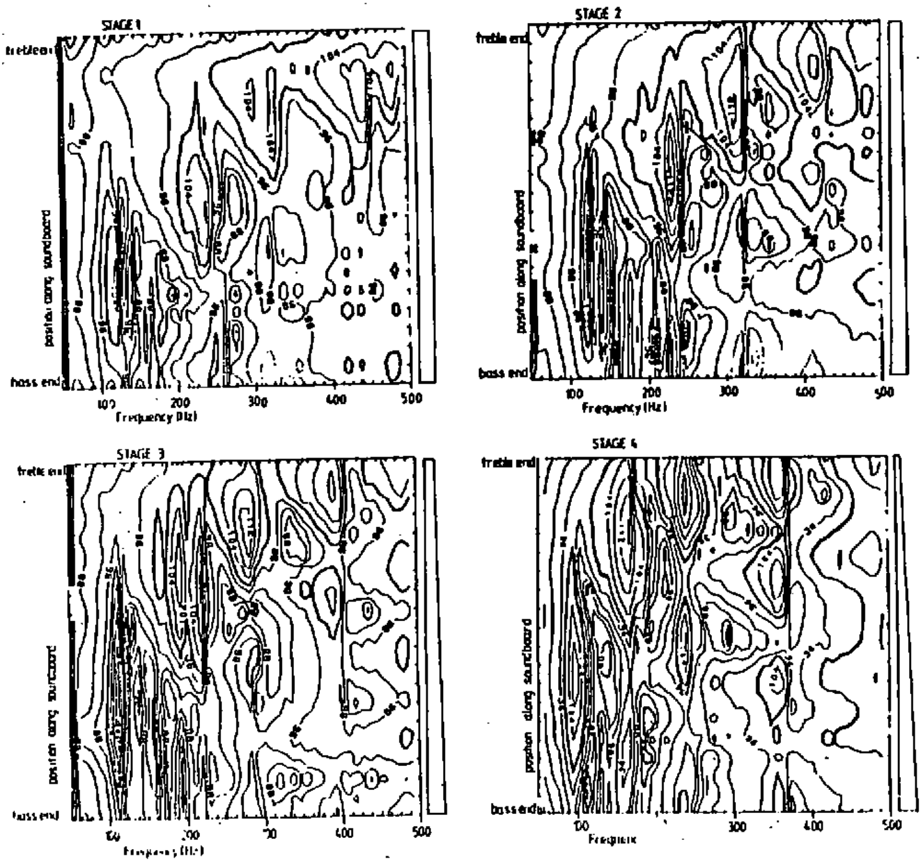


Fig 8 Change in soundboard admittance with taper

Our experiment using this technique of drawing input admittance maps have dealt with the effect the dimensions of the soundboard have on the resonant format of the harp.

It was mentioned in the introductory paragraph that the harp soundboard thins from the bass end to the treble. We wanted to determine how the resonant vibration of the soundboard changed as its thickness was increasingly tapered. Beginning with an uniformly thick soundboard admittance measurements were made at different stages as the board was gradually tapered; the results being shown in fig 8. By considering the last contour map first, one can see the characteristic resonant patterns of a normal soundboard with its edges clamped. But in the first admittance map the pattern is quite different. Resonances do occur but each occurs at only one particular region in position and frequency.

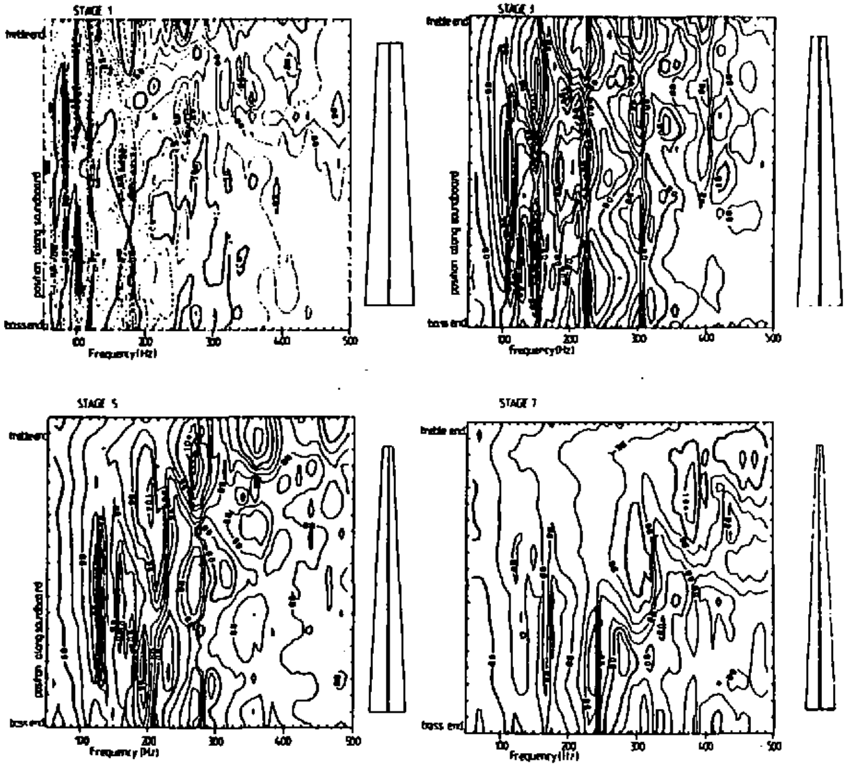


Fig 9: Change in soundboard admittance with width

In a similar experiment to this, we wanted to determine how the soundboard's resonances were dependent on the width of the board. We began with a very wide soundboard - its thickness had the usual taper - and we measured the admittance as it was narrowed. Fig 9 shows some of the admittance plots. With the very wide soundboard the major resonances are situated at the low frequency end of the map. Narrowing the board increases its stiffness and the resonant frequencies increase and we gain a soundboard with a wide frequency distribution of resonances. But there is a limit as to how far one can narrow such a board as it becomes too rigid. With dimensions just two centimetres thinner than a normal soundboard (stage 7) the normal resonant pattern has collapsed.

In this paper we have presented an introduction to the harp and some of our research on the vibrations of the soundboard. Work is continuing on this topic and also on the coupled topics of harp strings and air resonances in the soundbox.

We wish to thank Mr Victor Salvi of Salvi Harps Italia for his continued interest and and support in our work and for his grant which enabled us to present this paper.

References

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