THE SOUNDPOST IN THE VIOLIN

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SUMMARY

The soundpost is important to boost sound output at the lower end of the range. The position of the soundpost has an effect on the sound quality. The first, subjective impressions on this by players and makers are at variance with a later subjective study that was combined with objective measurements. Objective studies have used linear circuit analysis, acoustic spectrum analysis and mode shapes. The difficulty in understanding subjective assessments makes objective studies more attractive for future progress.

INTRODUCTION

An argument can be put forward for a fine violin to be sensitive to the position of the soundpost and a lesser instrument not show this sensitivity. Similarly an argument for the reverse could also be made. Attempts to understand the function of the soundpost have continued for nearly 200 years. That its presence is essential` for enhancing the sound output of the violin has never been disputed. The effect of changes in position have always been regarded as critical and in recent times, as more has been learned about the violin, the importance of the soundpost has been better evaluated. Therefore there is still more to learn. A review of some past studies and the results of some recent work on the soundpost are outlined in this paper.

REVIEW OF PUBLISHED WORK

The literature on the soundpost can be reviewed in two parts, what might be called the "folk lore" or subjective aspects because they originated at an earlier date and the more objective or measurement based attempts to understand its purpose.

"SUBJECTIVE" METHODS OF ADJUSTMENT.

The soundpost and the effect of its position has fascinated violinists ever since the violin existed. The soundpost was in place before the bassbar which evolved from a thickening of the top to the separate entity we are now familiar with. A reference to the early interest in the soundpost appears in Sol Babitz [1] where he says that when the bridge was moved below the soundholes, the sound was worse if the soundpost was moved away from the centre of the violin to a new position below the bridge similar to that it would have had before the bridge was moved. The sound quality was only restored by moving the soundpost back to its original position.

Much has been written on the subjective reactions of players to the sound quality change obtained on moving the soundpost. That it should fit well without creating stresses has always been emphasised when first making a violin. It is not clear whether this fit was to be maintained on subsequently moving the soundpost for tonal adjustment. Most of what had been written related to remedying faults in the quality or balance of the sound produced. Fine grained spruce was usually specified but the use of "softer" spruce has appeared. Position has been the main means of adjustment. In the past, makers have advised moving the soundpost toward the bassbar to strengthen the G string and moving it away from the bassbar to strengthen the E string.

Henry Saint-George [2] puts the standard position of the soundpost 1/4 inch behind the treble foot of the bridge. If it is more than this "the tone will be soft, lacking grip, flabby and colourless; - the remedy - bring up to the standard position. If no better or only slightly, move it closer to the bridge. This will probably make the sound more focussed". Moved closer to the bridge the sound will become "thin and meagre". The "edge" will be too unpleasant. If the tone is too "hard" the soundpost is probably too close to the bridge - move it away for a more pleasing result - too far will give a "fuzzy" sound.

Again: To "harden" the tone move the soundpost nearer to the bridge. To "soften" move it further away.

And finally: A soundpost "tightly jammed in" gives a "hard" tone, too loose that it falls down when the strings are slackened , a "soft" tone. Gluing the soundpost in "mutes" the sound.

He goes on; if the lower strings are "harsh" and the upper strings "weak" move the soundpost toward the ribs. This "brightens" the A and E strings and takes the "edge" off the G and D strings. If the upper strings are "shrill" and the lower strings "softer" move the soundpost toward the centre. This advice may have been taken from Heron Allen [3] where it first appeared.

Rodgers [4] quotes other early writers since Heron Allen, who give similar advice, one of which was Broadhouse who stated that moving the end (presumably the top) of the soundpost toward the centre favoured the lower strings and that if the upper strings were "dull and heavy" it should be moved a little inside and further back, whatever that meant. Alton [5] said that if the soundpost was too tight, the tone was "tense and hard", if too forward "the tone was loud and shrill, without quality", if too far to the right, "the E tone was loud and coarse, the G dull", if too far to the centre, "the E tone will suffer and the G will be loud and strong".

Modern makers' advice appears to be no more informative. Rubbio [6] says that a tight soundpost makes the sound "nazal and sharp". Moving the soundpost back from the bridge makes the sound "gentle in the treble"; closer to the bridge "sharper and more authoritative". Gerald Betteley [7] says "a harsh tone can be mellowed by fitting a softer soundpost and bridge, and a weak tone can be strengthened by fitting a bridge and soundpost of greater density". He goes on "if the E string is brilliant but the G string lacks power, fit a new but fractionally longer soundpost, using the same wood density. To make the upper register less strident and improve the resonance of the G string, move the soundpost toward the G string (and vice versa)".

Because the words used to describe the quality of the sound from the violin are vague and imprecise, more recent investigators have looked for objective ways to characterise sound quality. These have included dividing the response of the violin (and other sounds) into zones based on the vowels in human speech, Winckel [8]. Lottermoser and Meyer [9] have used these vowel formants, Meinel [10] has used intervals of a fifth, Lottermoser [11] used third octave bands, and Yankovskii [12] compared all three attempting an objective appraisal of violin tone quality. These have largely gone out of favour and frequency response curves (from which the others were derived) are in more widespread use.

More recent workers, Jansson et.al. [13] have described player reaction, in subjective terms, to alteration in the position of the soundpost across the violin and lengthwise behind the bridge foot. The low frequencies were suppressed by moving the soundpost toward the centre of the violin and the tone was "looser"; moved away from the centre the tone was "rumbling and harder". The tone quality with the soundpost moved toward the centre line was similar to that with no soundpost. They also considered the effect of these moves which were "± a soundpost width" but the starting position was not indicated, on the shape of the response curve.

This last study is at variance with the earlier advice given above which may be summarised as follows:

1. If the soundpost is too tight, the sound will be tense and hard; if too loose, the sound will be soft.
2. If the soundpost is too forward (near the bridge?) the tone is loud and shrill without quality.
3. If it is moved toward the centre, the lower strings will be loud and strong.
4. If it is moved toward the f-hole the upper strings will be

strengthened.

"OBJECTIVE" STUDIES

The last reference dealt with above attempts to combine aspects of the two kinds of approach to studying the effect of the soundpost on sound quality. Objective studies include theoretical work as well as experimental studies. Much of the early work, mainly that of Savart and Huggins is reviewed by J.W.Giltay [14].

The first effect of installing a soundpost in the violin is to stiffen the body. Evidence for this was very well demonstrated by Carleen Hutchins in 1974 [15] at the time the findings of Felix Savart who had explored the importance of the soundpost in 1824, were published in JCAS. It was pointed out that cutting the ff-holes to provide a Helmholtz resonance weakened the top plate even though their shape which the violin exploits for sound production, made the top more compliant. The soundpost, together with help from the bassbar, gives support to the central area of the top. The stiffening effect of the soundpost is shown by the increase in frequency of the lower (Helmholtz) air resonance by about 4 semitones when it is installed compared with its absence. Fang and Rodgers [16] found that over the frequency range of the violin the soundpost was rigid to a first approximation and implied that a smaller sampling interval in their computer study, might have revealed interesting detail. This leads to the second major effect of the soundpost. The nodal patterns of the vibrations of the violin are altered by its presence; a nodal point may be introduced or the position of a nodal line in its vicinity may be changed. Its presence may also eliminate a mode.

Erik Jansson et al. [17] demonstrated, with the use of holography, how the nodal pattern is changed when a soundpost is introduced. Their figures 9 and 10 for the top plate (see Figure 1), and their figures 11 and 12 for the back plate (see Figure 2) show these effects. As Schelleng [18] points out, modes a and b without the soundpost in Figure 1 are replaced by a single mode with a soundpost. The remaining mode shapes match up, one to one, but there has been a shift down in frequency for the higher modes. Another way to look at this effect is that the soundpost eliminates the first top plate mode and makes the second one asymmetric. The two lower modes in the back are not combined, but the soundpost modifies the shape and raises the mode frequencies. The plates in this instance were glued to rigid sides. In the complete instrument the authors obtain similar mode shapes on the top plate to those for the separate plate. Cremer [19] reproduces these figures and discusses the general function of the soundpost but not in detail. He draws attention to a paper by Moral and Jansson [20] in his figure 12.9 (their figure 8) where he shows that the input admittance at the top of the bridge revealed the effect of the bridge resonance at 3000 Hz (the bridge hill) but the input admittance measured at the bass foot of the bridge did not show this peak. Figure 10 of Moral and Jansson showed a lower input admittance, below 600 Hz, when driven over the soundpost than when driven over the bassbar. This implied that the soundpost was offering a higher local impedance to the input than the bassbar by a factor of about 10 (10 dB).

George Bissinger [21] has carried out an extensive study comparing the vibrational behaviour of a violin with and without a soundpost. Removal of the soundpost lowers the output in the range below 1 kHz. The strength of the main air resonance, A0, is markedly lowered. Of the B1 modes (with the baseball seam pattern) B1- below 500 Hz and B1+ above 500 Hz [22], the strength of B1- is all but removed. The mode shapes are generally similar between the two conditions.

When Meinel [23] took the soundpost out, in addition to the major effects already noted, two pronounced resonances were obtained that led to "wolf" notes.

Few mathematical treatments of the action of the soundpost have been published in recent times perhaps because of the absence of experimental results for comparison. After Jansson et al. [17] showed the influence of the soundpost on the mode shape, Stetson and Agren [24] outlined an approach for the calculation of modal parameters in the presence of a soundpost but did not refer to Jansson's work. A following paper by Agren [25] failed to extend this aspect of the subject. More recently Knott et al. [26] has included the soundpost in a finite element study of the violin vibration modes.

John Schelleng [18] described how the soundpost brought the two lowest modes of the vibrating top plate together to produce a breathing mode and thus enhance sound radiation at the lower frequencies. The soundpost made the rocking motion of the bridge asymmetrical. This breathing action is very important in the frequency range below 600 Hz where the body is small compared with the wavelength of the fundamentals of notes played. Savart [27] early last century, and later in the century, Huggins [28] showed that a nodal point could be set up by external pressure on the top at the position of the soundpost to give a similar effect on the sound output as when a soundpost was present. This was clearly due to immobilizing the treble foot of the bridge. The soundpost does more than immobilise the top, it permits an energy transfer to the back. A more recent attempt to provide the nodal point in the top and remove the coupling with the back [29] by supporting the soundpost on a stirrup glued to the sides, showed a reduction in peaks below 2 kHz and a loss in output from the back.

Schelleng described the resulting mode in the top as a mode combining features of two low frequency plate modes, with no soundpost. He gave an analysis of the admittances (A) at each end of the soundpost position and expressed their relationship in the equation: $A_{11} + A_{22} - 2A_{12} = 0$; where the subscript 1 refers to the top plate and 2 refers to the back plate. The first subscript refers to force (F) and the second to velocity (V). The admittance is related to the force (F) acting, and the resultant velocity (V) through $A = V/F$, and the relation above is based on the assumption that the soundpost has no mass for F_1 to equal F_2 and infinite stiffness for V_1 to equal V_2. The transfer admittance must include a contribution from the sides as well as the soundpost. The principle of reciprocity results in $A_{12} = A_{21}$ yielding the third term. The equation applies in the absence of the soundpost and indicates the condition at resonance with a soundpost in place. Two practical studies followed, one by Ian Firth [30] and the other by W. James Trott [31]. Both studies confirmed the reciprocity relation.

The study by Firth does not give phase data so antiresonances cannot be identified. When excited at the bridge, the velocities at each end of the soundpost were similar but showed anomalies at frequencies near 300 Hz and 600 Hz. The forces on the other hand, measured at each end of the soundpost for the same excitation were similar except for an anomaly at 400 Hz. The input admittance measured at each end of the soundpost had a similar level but there was much less activity at the back than the top. The transfer admittance when the soundpost was absent, measured at each plate showed similar curves but at a level one tenth the input admittances at the same locations. Transfer of motion from one plate to the other in this case would be through the sides.

Trott studied the input admittance and transfer admittance at the soundpost positions on the top and back plates in the absence of the soundpost. He studied a well documented violin by Carleen Hutchins, SUS 181, and provided the plot of sound response as well as the input admittance of the instrument complete with soundpost. This violin had also been studied by Beldie [32] who published sound pressure level, (SPL), and admittance plots which can be compared with those of Trott. The phase plot is also included by Trott. It can be seen that there is a peak at the position of the lower air resonance in all admittance plots in Trott's paper but at a lower frequency when the soundpost is missing. The Helmholtz resonance appears as the next minimum with the phase change indicating a parallel resonance. The resonance at 430 Hz probably drives the lower air resonance by exciting the Helmholtz resonance. However it cannot be identified easily on the sound level plot as there are two possibles, at 388 Hz and 417 Hz. Marshall [33] shows a mode shape at 435 Hz that is identical with that at the lower air resonance which lends support to this idea as the driver. This mode does not appear as a maximum when the soundpost is absent as its existence depends on one being present. In Trott's figures 1 and 2, without the soundpost there are features in this region where the back and sides are active but they cannot be connected with this mode at 430 Hz. They may possibly be linked to the antiresonance at 475 Hz in his figure 4. Marshall has a prominent mode at this frequency associated with the top plate and he links it with the first higher air mode, A1. The main body resonance at 550 Hz does not appear on the sound level plot of figure 3 (Trott), yet appears on the admittance plot, figure 4. Beldie [32] showed similar data for this violin and recorded a minimum at 550 Hz. In Trott's paper, at 650 Hz a peak in the sound level plot appears as an antiresonance on the admittance plot in figure 4. For the top and back plate admittance with the soundpost absent there are minima at this frequency but maxima in the transfer admittance (Trott's figure 1 and 2) indicating rib action. Marshall found a "ring" mode in the back at this frequency, with the top and back plates at the position of the soundpost moving out of phase. This means the plates are decoupled and force transfer is through the ribs. Marshall's figure 4 suggests a minimum at 650 Hz while Hutchins [34] in figure 2 (courtesy G. Weinreich and O.E.Rodgers) shows no monopole radiation peak while Marshall's figure 10 suggests there should be one. The confusion existing with these results suggests there is a need for further work to correlate admittance measurements with sound level plots.

Cremer [19] discusses the work of Beldie on the "breathing" modes below 600 Hz at length and summarized the admittance and phase relations of the main resonances A0, B1- and B1+. Since the violin is not grounded in the strict engineering sense, the question of the relative phase of the various parts such as the plates and sides, has not received a consistent treatment. Cremer has regarded the holding of the violin at the shoulder as a "lossy" spring support. The relative phase of the motion of the different parts of the violin is of main concern below 1 kHz where the breathing action operates. Meinel [23] and others have related the phase to the centre of gravity of the violin. Motion to or from the centre of gravity is taken as in phase. Beldie's 4 mass (4 spring) model of the violin at low frequencies has been reviewed by Cremer [19]. The four masses are the top, sides, the back (including the soundpost and a small section of the top in contact with it) and the air enclosed. The four corresponding springs are placed between the top and the "island" at the soundpost, at the margins of the top and back plates and the stiffness of the air. Cremer's fgures 10.2 and 10.9 summarising this model and its application to the low frequency behaviour has been reproduced here as Figure 3. The sides are in phase with the plates i.e. all moving in and out together, at A0 and from approximately 400 to 600 Hz. There are antiresonances at about 300, 500 and 700 Hz. The soundpost is assumed to have infinite stiffness and to move as one with the back. Firth's [30] finding that the velocities are different at each end of the soundpost (his figure 4) while the forces remain equal (ignoring the anomaly at 400 Hz, his figures 6 and 13), suggest that the mass may be ignored (it is less than 0.6% of the back) but not the stiffness. It may be more realistic to replace the spring, S_{12}, in the Beldie model with the stiffness of the soundpost and ignore the "island" in the top which is only typical of one top plate mode. The soundpost is more generally situated near a nodal line in the top at low frequencies where this model applies.

Following Cremer [19] the Helmholtz resonance using equation 10.13 with typical values for the violin and the stiffness of the air enclosed only, gives a frequency of 295 Hz. His equation 10.17 including with the air the stiffness of the body without that of the soundpost gives a value of 246 Hz. If the additional stiffness due to the soundpost is allowed for in his equation 10.32b a frequency for the air resonance, A0, of 286 Hz is obtained. A measured stiffness of 5×10^6 N/m for the soundpost has been used in equation 10.32b and an estimated stiffness for body of 1.5×10^5 N/m in equation 10.17. (The effective stiffness for B1 was measured at about 10^6 N/m). These frequencies are like those found without and with the soundpost respectively.

The sides and the soundpost are active members in the vibration of the violin. The difficulty lies in defining their respective roles. Figure 2 in Trott's paper shows that the admittance of the sides decreases with frequency, the trend line is about -6 dB/octave, while that of the soundpost increases, about 6 dB/octave. For the traditional soundpost the two curves cross at about 1kHz. For the soundpost, the slope indicates stiffness control. For the sides, a negative slope suggests mass control but this is too simplistic in a complex system. No doubt there are regions of mass control which become more important at higher frequencies. If the sides and soundpost can be taken as having a combined action there would be an antiresonance where their lines cross. Trott in another paper [35] points out that the violin on the whole, is essentially stiffness controlled up to 1 kHz. This perhaps indicates the controlling effect of the soundpost.

While the sides may act largely as a mass element, holographic studies have shown that some bending does take place. The extent of rib flexing is not expected to be large and would be restricted by the need to maintain the glue joint between the ribs and the plates. Studies have shown bending either along or across the ribs. Hutchins [36] shows a series of holograms for SUS 182 taken prior to 1971 that include the ribs with indication of bending though difficult to interpret. More recently Molin et. al. [37] have published holograms for five prominent body modes that show the rib bending more clearly (reproduced in Figure 4). The three lower modes show bending along the rib edges in the centre bout while the two higher modes suggest bending across the ribs near the corners. While the trendline may be mass like, at body resonances rib bending stiffness will combine with soundpost stiffness in determining the frequency.

Cremer [38] took up consideration of the soundpost and the "ring" mode in the back at 650 Hz. He likened the soundpost to a spring coupling two masses and compared the inverse admittance of the violin body with the stiffness impedance of the soundpost, i.e. ignoring its mass. The comparison did not lead to the result he expected. Trott's work suggests a crossing would occur at a frequency above 800 Hz, the limit of Cremer's figure. Is the comparison valid in this case, since the soundpost is decoupled?

If the curve for transfer admittance is characteristic of the general trend, figure 2 of Trott's paper allows the thoughts of Cremer, and Condax [39] to be rationalised and offers a suggestion with reference to the paper by Rodgers [40]. Figure 5 of this paper (Trott's figure 2) showed that, for SUS 181, the normal soundpost is stiffer than the sides, below 1 kHz. Cremer in his figure 6, showed that the body, hence the ribs, are more compliant than the soundpost, in agreement with this, up to the limit of his figure, i.e. 800 Hz. Following Cremer, if the "mass-spring-mass" mode at 650 Hz is present in SUS 181, with a mode shape similar to Marshall's 650 Hz mode, the compliance of the sides and soundpost must not be too different. Trott points out that the resonant frequency of the soundpost with the mass of the top and back occurred at 1760 Hz. If the mass of the body is taken, at 0.26 kg, an unrealistically high stiffness is calculated leading to an unrealistic admittance. If this calculation is done for the 650 Hz resonance, assuming the soundpost is the spring element, a higher than reasonable stiffness is found with a mass three times that of the body. If this is repeated allowing the sides to contribute to the spring element (and being able to measure the stiffness of the soundpost independently for comparison), for a body mass of 0.2 kg, the stiffness of the sides turn out to be half that of the soundpost at 650 Hz. Calculations similar to these need to be done more carefully.

Trott [41] extended the approach begun by Schelleng [18] and himself in experiments with the violin [31], to the soundpost in the cello where he points out some of the practical difficulties in this kind of study.

Turning to the paper by Condax, where he described an improvement in output of the violin by putting two waists at rightangles in the soundpost; the purpose of this, essentially, was to increase the lateral flexibility so that a better fit could be maintained with the plates in changing ambient conditions. In effect, he was really lowering the stiffness of the soundpost. Hutchins and Rodgers [42] confirmed this effect and found thinning the soundpost in the middle from 5 mm to 3 mm lowered B1+ by 8 Hz. A better way to achieve a lowering in stiffness and ensure a continuing accommodation at the ends of the soundpost, might be to cut the post in the radial direction of the grain. A stiffness value of about one fifth that in the longitudinal grain direction for a diameter of 6.5 mm can be obtained. Further lowering in stiffness can be gained by reducing the diameter. Baroque soundposts were about half the diameter of the present day posts, with the consequent lowering in stiffness. An even further lowering in stiffness can be found by a change in wood species. A balsa post cut radially will give a stiffness of 0.034×10^6 N/m ($E_R = 0.057 \times 10^9$ N/m^2). A longitudinal cut gives a similar stiffness to the spruce radial cut.

Finally, the suggestion by Oliver Rodgers that mode C4 of Moral and Jansson [20] which has a "ring" mode on the back plate, might be added to those present in the violin spectrum by an enterprising maker could possibly be met in an otherwise responsive instrument by varying the relative stiffness of the sides and soundpost. A diagram similar to Trott's figure 2 (see Figure 3) could be used to illustrate the relative effect of the sides and the soundpost. The stiffness of the soundpost can be easily calculated using; $S = Ea/l$, where "E" is the elastic modulus along the length "l" of the post, and "a" is the area of cross section. The admittance of the soundpost need only be calculated at one frequency from the relation, $A = 2iif/S$ where "f" is the chosen frequency. The elastic modulus can be easily found for each post using the Lucchi Elasticity Tester [43]. The admittance of the ribs cannot be so easily determined. What is needed is a repeat of Trott's determination of the transfer admittance, "A_{12}", for the same violin with different rib assemblies, essentially ribs of different thickness. Ribs made to a similar pattern, (as violins generally may be assumed to have) only have the thickness as a variable. Once measured, the transfer admittance could be taken as a reference against which the values for individual soundposts could be placed to assess the relative contribution of each. The rib assembly typically weighs about 60 g; a 10 g change in mass shifts the admittance line about 2 dB.

Saldner H.O., Molin N-E. and Jansson E.V. [44] confirmed Schelleng's description of the asymmetry produced by the soundpost. They also confirmed the equivalence of their T1 mode with B1- and C3 with B1+.

Jansson and Moral [45] explored the effect of soundpost position on the main top plate resonance frequency. Changes in position along the nodal line, even in front of the bridge, had no effect; displacement at rightangles, which involved a possible change in the position of the nodal line had a large effect. Repositioning the soundpost nearer the f-hole lowered the frequency of the first top plate resonance T1 (B1-), (5 mm gave a 5% lowering), moved toward the centre raised it (5 mm gave a 1% increase).

In a later paper discussed earlier, Jansson et.al. [14] extended their consideration of the position of the soundpost. Repositioning closer to or further from the bridge made little difference to the overall position and height of the resonance peaks. With the soundpost closer to the bridge, a peak at 700 Hz was absent and one at about 2200 Hz was lowered more than when the soundpost was further away. Lateral repositioning had a greater effect. Moving the soundpost toward the centre raised the level of the response curve but changed the balance in the 500 Hz region. If the assumed labelling of peaks is correct and the 500 Hz antiresonance remains fixed in position as appears the case, moving the soundpost closer to the centre enhances B1+ (about 15 dB) while not affecting the height of B1- significantly. With the soundpost nearer the f-hole, B1- was strengthened and the antiresonance was deeper.

Itokawa and Kumagai [46] determined response curves for different soundpost positions and found reduced response when it was placed away from the optimal position, either under the treble foot of the bridge or further below the normal position.

WAVE TRANSFER VIA THE SOUNDPOST

The rate of progress of a wave induced by an edge impact on the E-string side of the bridge is illustrated in a paper by Molin N-E, et.al.[47]. From the delay times quoted in the paper for an impulse to reach the top and the back, of 25 and 40 us resp. it can reasonably be deduced that the velocity along the soundpost was about 5000 m/s, a value for spruce along the grain. However reasonable results for the progress of the disturbance across the plates can only be obtained using typical values for the shear modulus. Scaling up the measurements to the outermost visible rings in figure 6 (their figure 3), assuming a body length of 355 mm, and G_{LT} (spruce) of 0.90 x 10^9 Pa and density 400 kg/m^3; and G_{LT} (maple) of 1.6 x 10^9 Pa and density 650 kg/m^3, the calculated velocity is about 1500 m/s and the measured velocity about 1680 m/s which is reasonable agreement. At 250 us the impulse in both the top and the back would have gone far beyond the edge of the two plates (about 0.2 m from the bridge).

OTHER MATERIALS FOR SOUNDPOSTS

Spruce combines a high elastic modulus with a low density so that the weight of the soundpost can be neglected. This has not stopped earlier workers trying other materials. Glass has been suggested and composites of spruce and lead have been tried and in more recent times carbon fibre and glass reinforced epoxy have been tried. These all fail probably because they are too dense and therefore weigh about four times a spruce soundpost.

The remaining aspect under this heading to be considered is wood treatment. Yano et.al.[48] have studied a range of low molecular weight resin/formaldehyde impregnation treatments for soundboards of musical instruments and found with little change in density, a gain in crossgrain modulus, a drop in damping and a resistance to changes in humidity. Yano and Kajita [49] studied the effect of formaldehyde treatment of violin parts on the behaviour of violins. They found a significant drop in damping and an increase in modulus which were more evident at low frequencies. These effects were greater with higher formaldehyde levels up to 2.5%. They found a slight improvement in sonority and brightness when the bridge was treated. They claimed a greater improvement when a violin was treated. However it does not seem that the gains are large enough to hazard the risks attached to using these chemical treatments which require special equipment as well as special precautions in handling. They did not deal with the soundpost specifically.

CONCLUSIONS

This review of the soundpost is a small part of the wider study of violin acoustics. It suggests that the sides may need to be taken into account with the soundpost. It shows that traditional thinking about adjusting the soundpost is not correct. It also suggests that the Beldie model may be modified for use in explaining the behaviour at low frequencies.

As a result of this brief survey it was decided to investigate two aspects: 1. soundpost stiffness and 2. soundpost position on the tap response employing microphone recording and spectrum analysis, and sound output using the Saunders Loudness Test by hand bowing an octave of semitones on each string and displaying the result as a graph of Sound Pressure Level versus frequency. Although it is not strictly correct to plot versus frequency since the strength of all the overtones excited are included in the SPL value at the position of the bowed fundamental, a semitone scale which would be linear, can easily be added. The result of these investigations appear as Part I and Part II which will appear in subsequent issues of JAAMIM.

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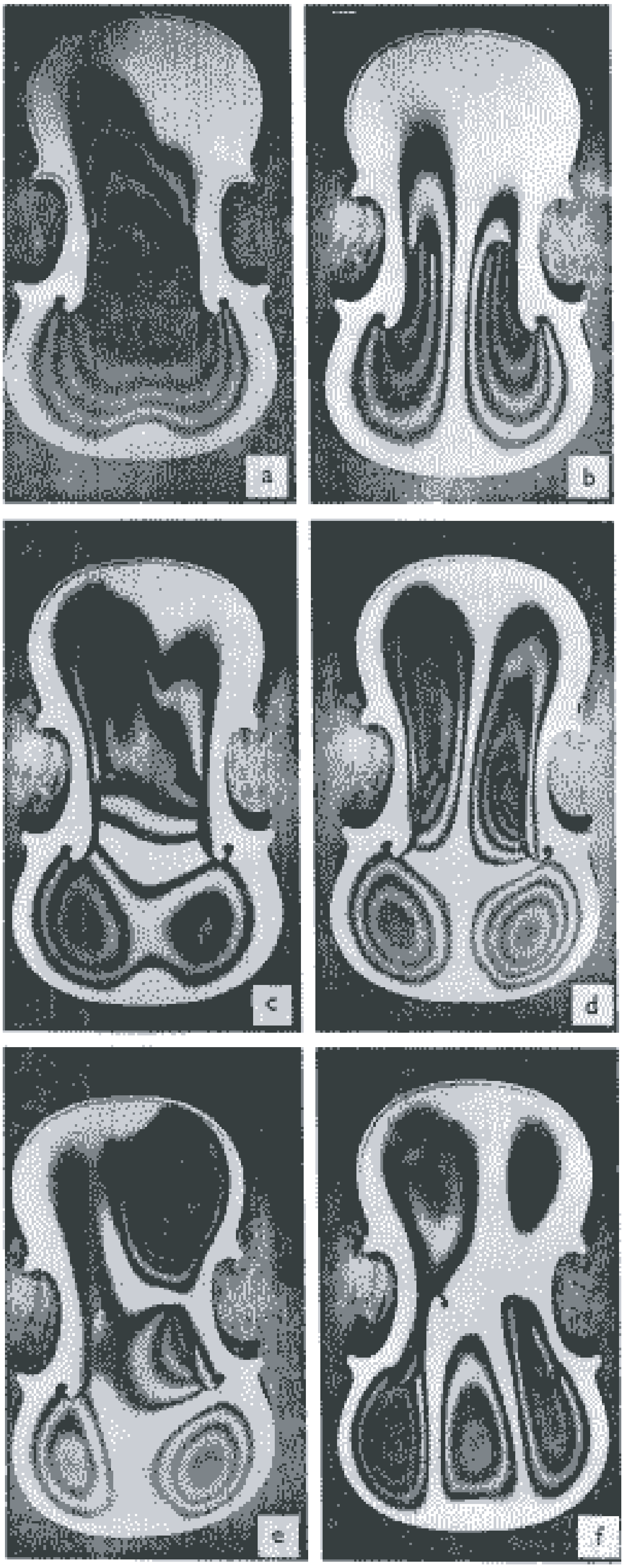


Fig. 9. Interferograms of series *(c)*, the top plate with f-holes and bass bar. *(a)* 465 Hz, *(b)* 600 Hz, *(c)* 820 Hz, *(d)* 910 Hz, *(e)* 1040 Hz, *(f)* 1090 Hz.

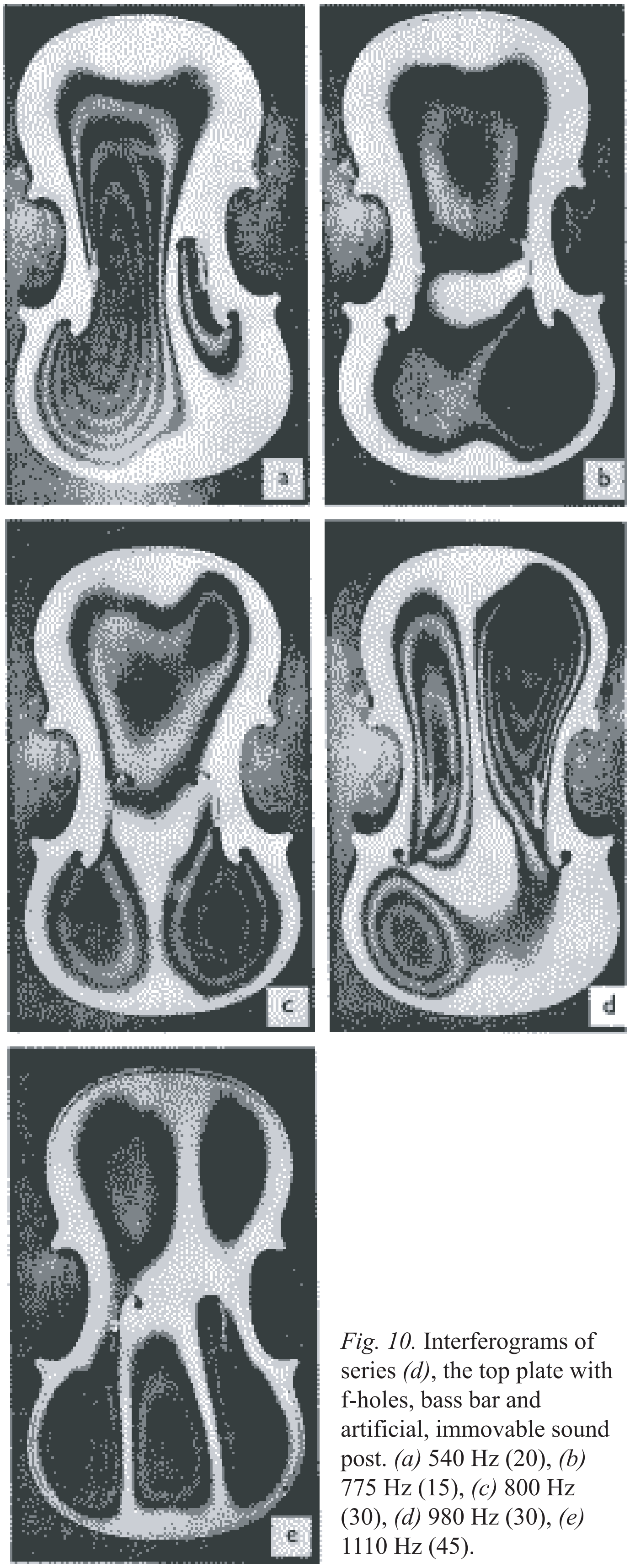


Fig. 10. Interferograms of series *(d)*, the top plate with f-holes, bass bar and artificial, immovable sound post. *(a)* 540 Hz (20), *(b)* 775 Hz (15), *(c)* 800 Hz (30), *(d)* 980 Hz (30), *(e)* 1110 Hz (45).

Figure 1. Figure 9 and 10 of Jansson et. al. [16] showing the effect of the soundpost on the top plate modes.

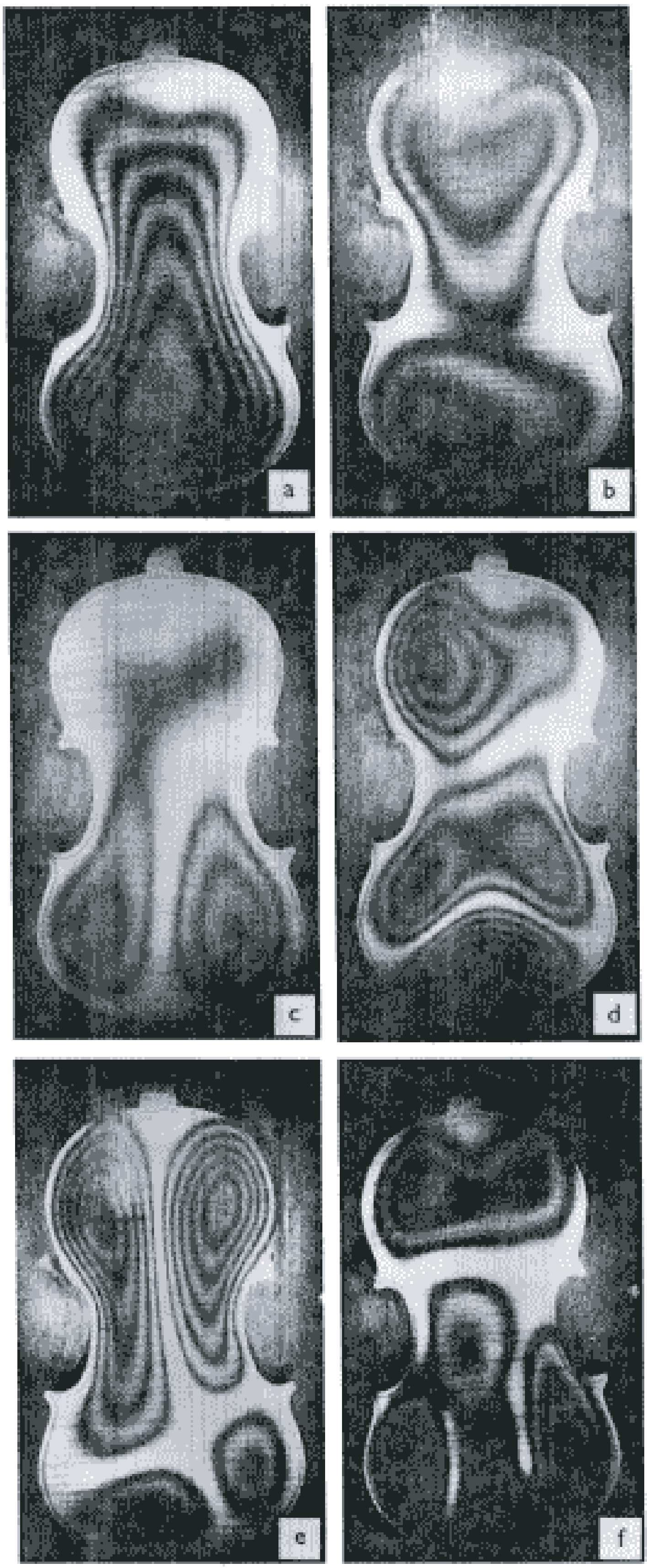


Fig. 11. Interferograms of series *(e)*, the back plate. *(a)* 490 Hz (10), *(b)* 660 Hz (10), *(c)* 840 Hz (35), *(d)* 910 Hz (30), *(e)* 1030 Hz (20), *(f)* 1120 Hz (20).

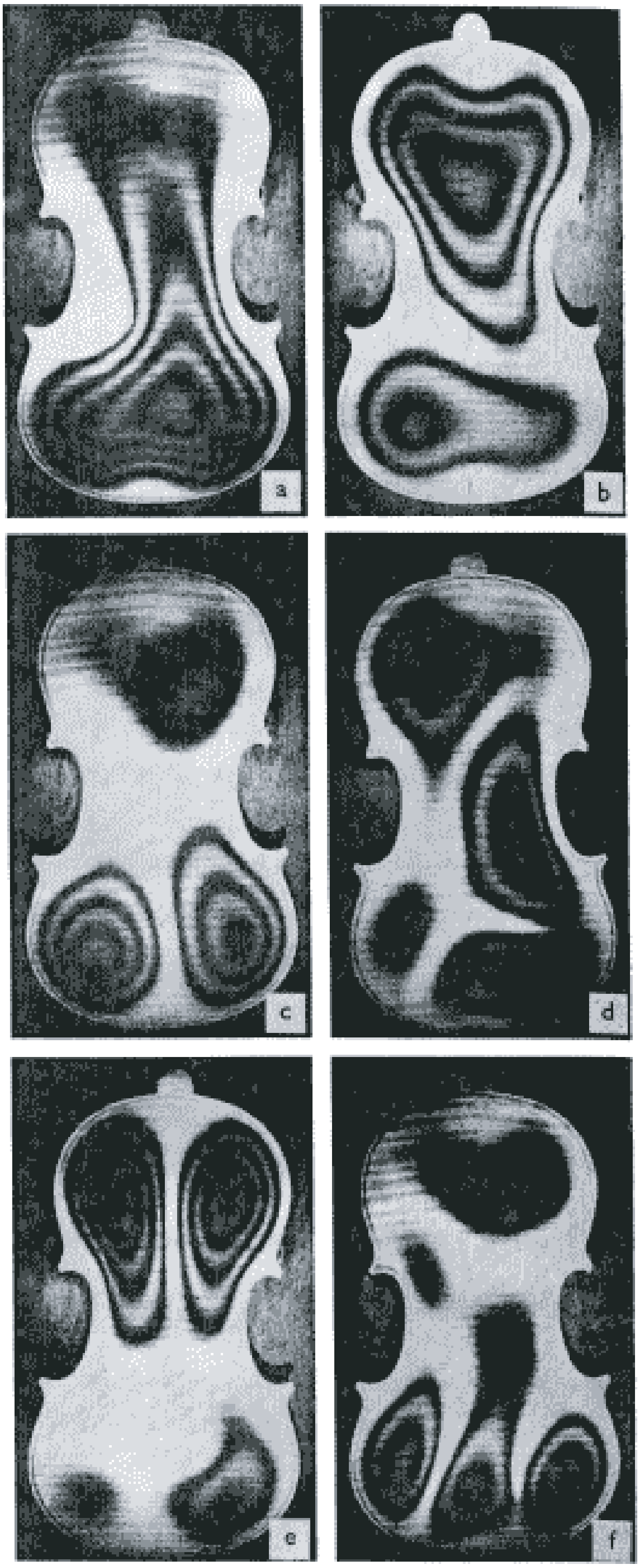
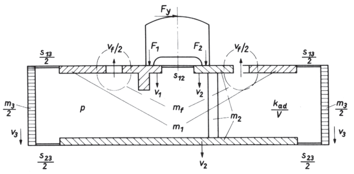
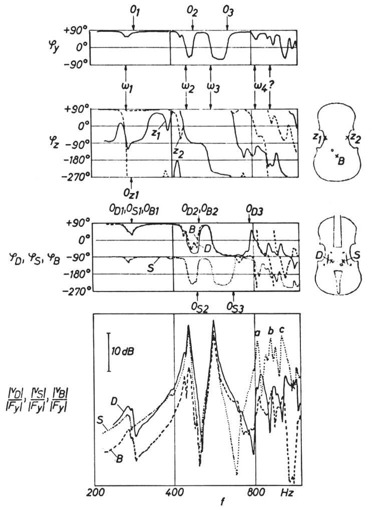


Fig. 12. Interferograms of series *(f)*, the back plate with artificial immovable sound post. *(a)* 740 Hz (15), *(b)* 820 Hz (15), *(c)* 960 Hz (30), *(d)* 1110 Hz, *(e)* 1200 Hz (20), *(f)* 1300 Hz.

Figure 2. Figure 11 and 12 of Jansson et. al. [16] showing the effect of the soundpost on the back plate modes.



Model of the body of the instrument as four independent partial masses (simplified, *after a model by Beldie*).



Measured velocity phases vs. frequency (three upper diagrams) and velocity-levels (bottom) normalized to the driving force, at the input of the bridge v_y; the ribs at two points Z_1 and Z_2, v_z; the top plate at D, v_D; the top plate at *S* (island region), v_S; and the back plate at *B*, v_B (after Beldie).

Figure 3. Figures 10.2 and 10.9 of Cremer [18] showing Beldie's 4 mass model and phase and admittance from 200 to 900 Hz (in violin SUS 181 studied by Beldie) for top, back and sides.

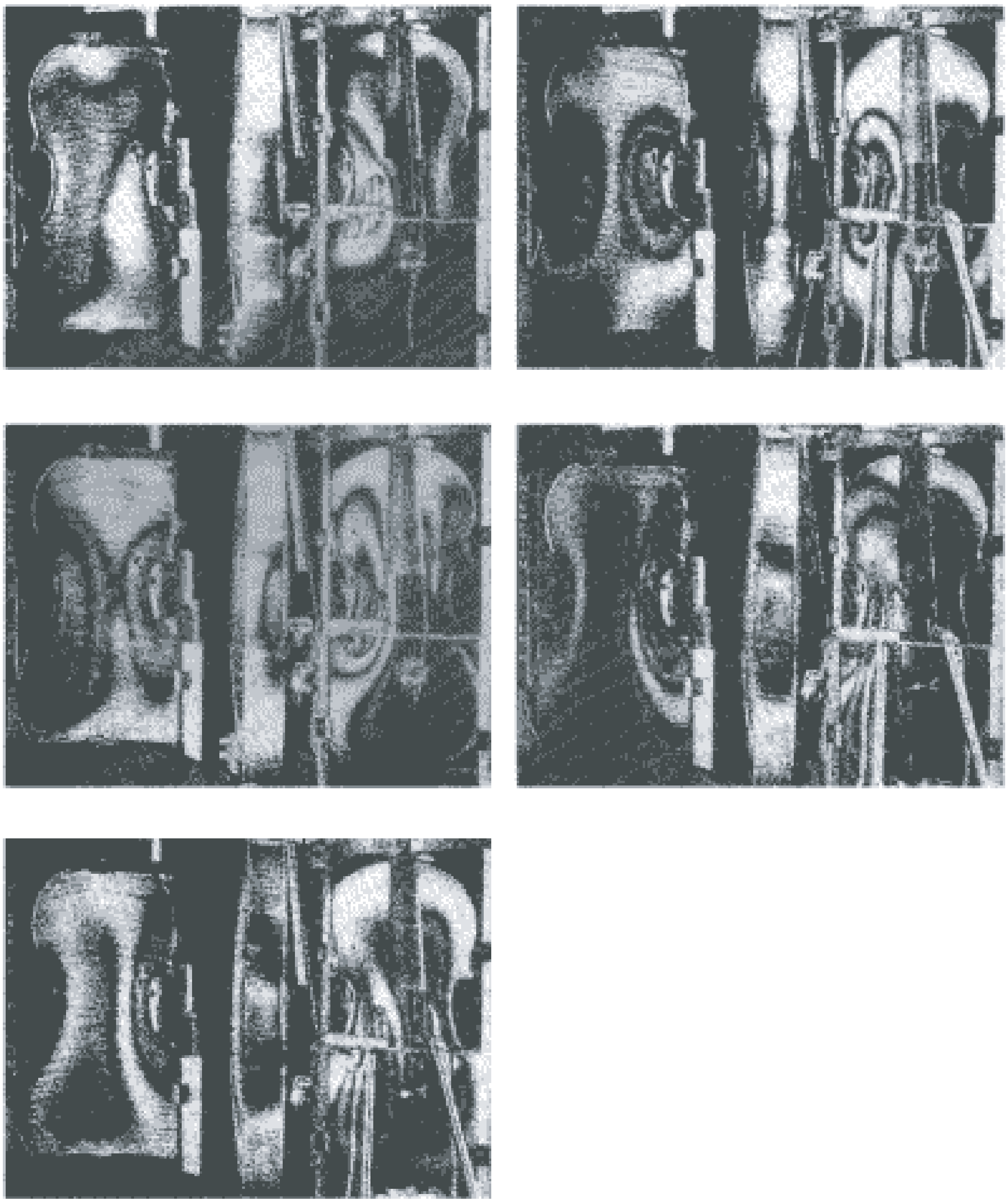


Fig. 5. Vibration modes obtained by electronic holography at resonance of violin HS71 at (a) 290 Hz, (b) 414 Hz, (c) 460 Hz, (d) 520 Hz, and (e) 570 Hz.

Figure 4. Figure 5 of Molin N-E. [36] et. al. SMAC 93, 397-410, 1994.

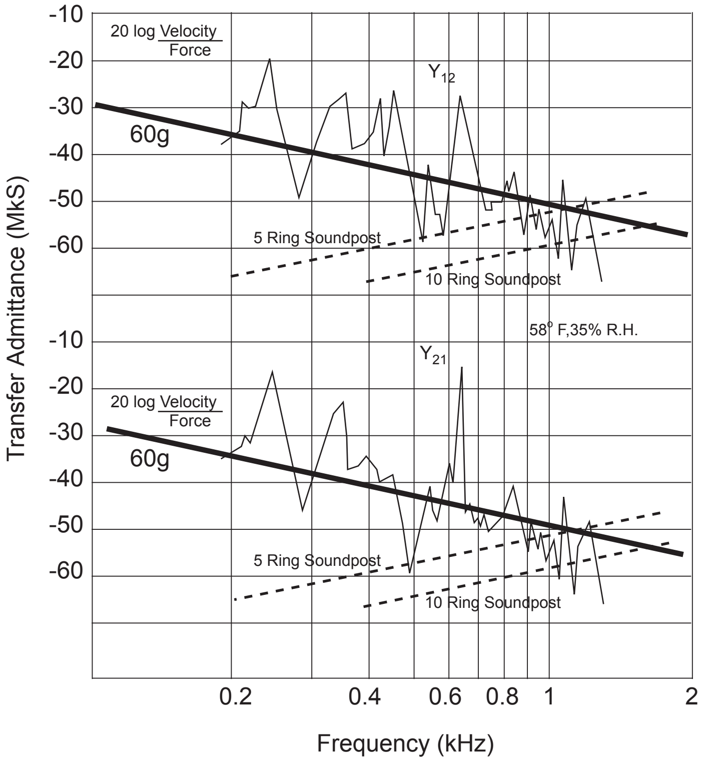


Figure 5. Trott's figure 2 [31] with the addition of a mass influence line for a 60g rib assembly with slope -6 dB/Octave.

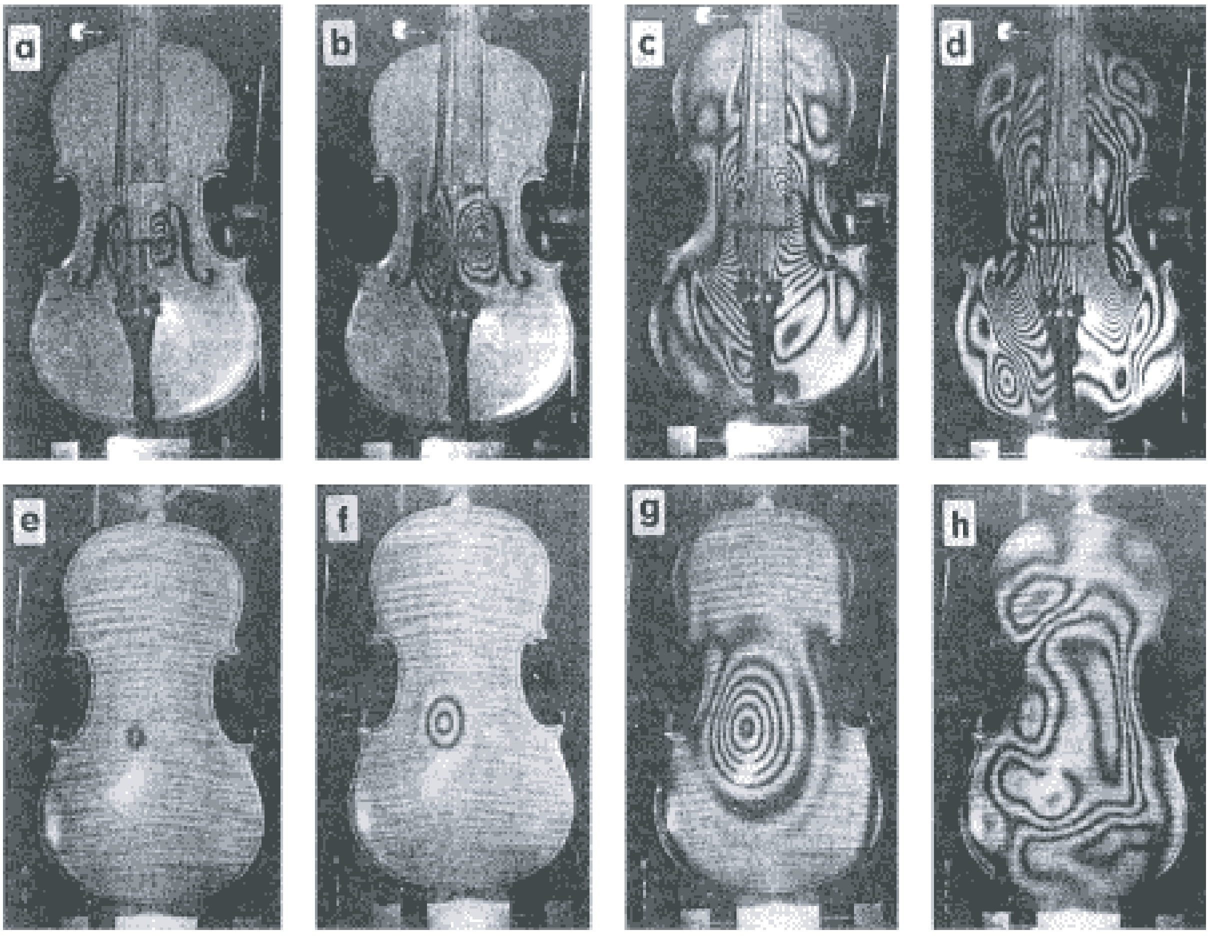


Fig. 3. Interferograms of the top plate at (a) 100 μs, (b) 125 μs, (c) 250 μs, and (d) 450 μs, and of the back plate at (e) 100 μs, (f) 125 μs, (g) 250 μs, and (h) 450 μs after impact start.

Figure 6. Figure 3 of Molin et. al. [46] showing the progress of elastic waves from the soundpost after impulsive loading at the bridge.