The Acoustical Effect of a Metal Rose in a Harpsichord: Part I

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Abstract

The armature of an electro-mechanical vibrating system was mounted on the bridge of the harpsichord. The response curves with different weights of the lead plate fixed on the soundboard were taken. It was found that with reasonable weight the highest peak, at about 94 Hz, and the dip at the lower side of the peak were damped. Playing the strings, the same result was obtained. The better responses were with the weights of 100-140g. The ancient harpsichord makers' practice of using a metal rose has a scientific base.

1. Introduction

Early Flemish and French harpsichords very often include a metal rose mounted on the soundboard [1]. Contemporary organologists have usually seen such roses as either purely ornamental [2], [3]. The effect on tone of the small aperture of a soundboard rose has usually been thought to be insignificant by comparison with the much larger opening between the upper and lower belly rails.

In harpsichords with two 8ft registers, where the length of the two strings for any note is roughly the same, the front 8ft register which is closer to the keyboard, makes the sound more nasal. Typical difference of timbre between the front and back 8ft registers is a relative diminution of 1st harmonic. The composition of higher harmonics is practically the same between the two registers at lower side of keyboards. The deep tone means normal level of response of the 1st harmonic and nasal tone is attenuation of the 1st harmonic. Because of the difference in the plucking point, it is possible to distinguish between the sound of each one.

Using the back 8ft register on the French style instrument described below, F# (92,5 Hz) and G (98 Hz) gave a deep sound, while on, E (82,4 Hz) and F (87,3 Hz) were nasal sound. This unevenness of timbre could be corrected by placing lead weights on the soundboard, demonstrating that the weight of a rose could affect the tone of the instrument. This paper sets out experimental evidence for the changes brought about by variations in the weight and placement of the rose. So far as the author is aware, this kind of study has not been carried out by other workers in the field [4], [5], [6].

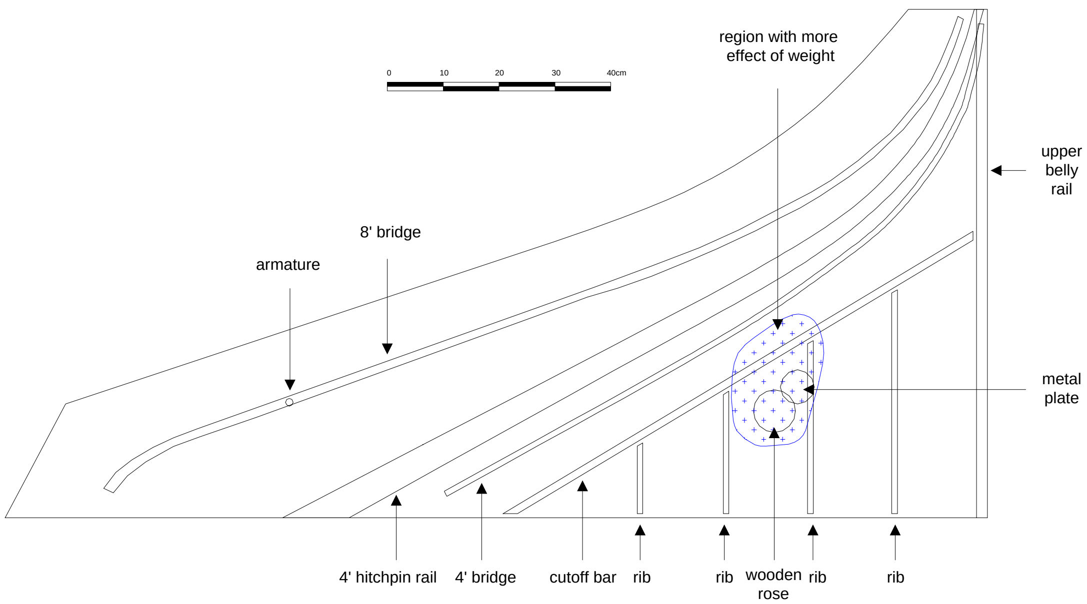

Figure 1: Form of soundboard

2. Method

The harpsichord used in this experiment was a French type mounted by the author from a Frank Hubbard kit. On the soundboard a light wooden rose, 8 cm in diameter and an orifice of about 18 cm² was fixed as shown in Fig. 1. All experiments were done on the instrument with playing condition (A= 440 Hz) with opened wooden rose, except fig. 2. An armature of electro-mechanical vibrator weighing 5,8 g, was mounted on the bridge pin of F (87,3 Hz) of the 8ft register. Before deciding the position of the armature at F (87,3 Hz), the response curves at various points from the low end to center of bridge were taken. The position of F was considered satisfactory for this work. A coil excited with 20 Vp-p of a sinusoidal wave from audio generator, was fix above the armature maintaining a minimal distance, only sufficient to avoid contact on maximum vibration. A block of lead of equal weight was provisionally put on the side of the armature and it was verified that the weight of the armature was no influence on the response curve. One meter above the soundboard a microphone was suspended and connected to the spectrum analyzer. All signals, except total (no filter) in the loudness curve, were treated through third octave filters.
A lead plate with a diameter of 6 cm, with different weights, 80, 100, 120, 140 and 160 g, was fixed to the soundboard with adhesive tape, beside the open wooden rose. With the same microphone set up, loudness curves of total (no filter) and first harmonic (with filter) were taken playing the back 8ft register with the keyboard.
The experiment was done in an acoustically live room. This has been taken into consideration in our analysis. The interference of standing waves was found to be small under 100 Hz.

3. Result and analysis

Due to a problem of the computer program, all response curves are dislocated about 1/3 Hz to the right side of the scales.
The curve in Fig. 2 was measured with the wooden rose closed with cardboard and adhesive tape. Fig. 3 is the result with an open wooden rose.
Comparing the two curves the following facts are observed.
A peak at 30 Hz for the case with the closed rose is 10 dB lower than for the open rose.
A peak at 73 Hz for the closed rose is shifted 2 Hz higher for the open rose.
A dip at 81 Hz for the closed rose shifted 4 Hz higher for the open rose.
Other parts of the curves show no significant differences.
Fig. 4, 5, 6, 7 and 8 are the response curves with weights of 80, 100, 120, 140 and 160 g respectively. The shape of the curves changes gradually with increasing weight.
From this series of figures it can be observed following things.
The most intense peak of the curve measured with no weight is at 94 Hz.
The most intense peak of the curve measured with 160 g is at 82 - 83 Hz.
A dip at 85 Hz of the no weight case is 29 dB lower than the peak of 94 Hz and 24 dB lower than the peak at 75 Hz. This dip disappears gradually across the series with the increase of weight.

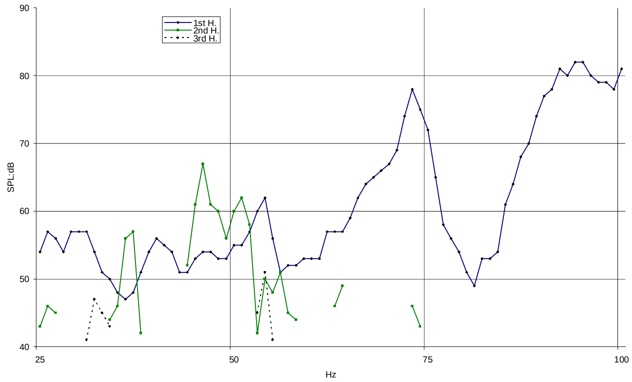

Figure 2: Responsecurve with closed wooden rose

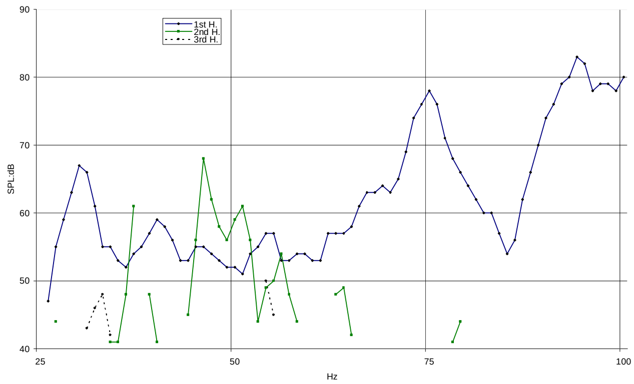

Figure 3: Responsecurve with opened wooden rose

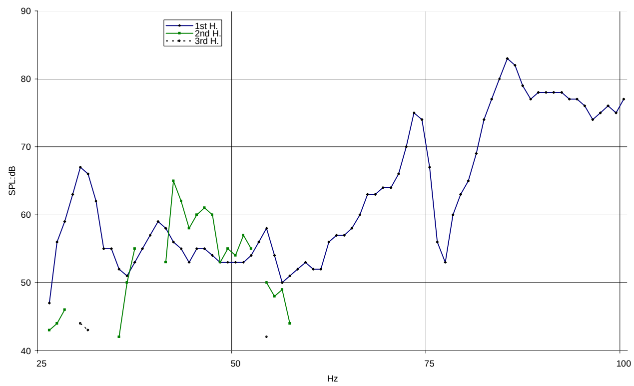

Figure 4: Responsecurve with weight of 80g

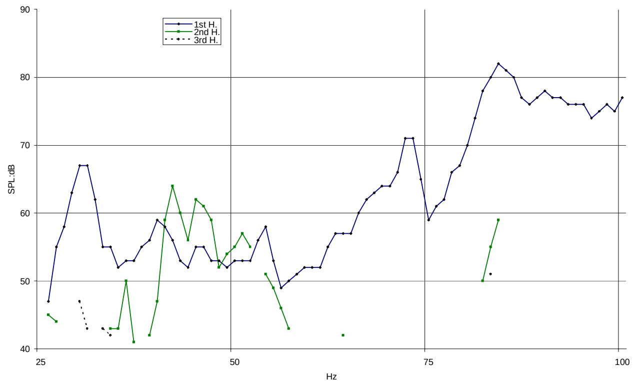

Figure 5: Responsecurve with weight of 100g

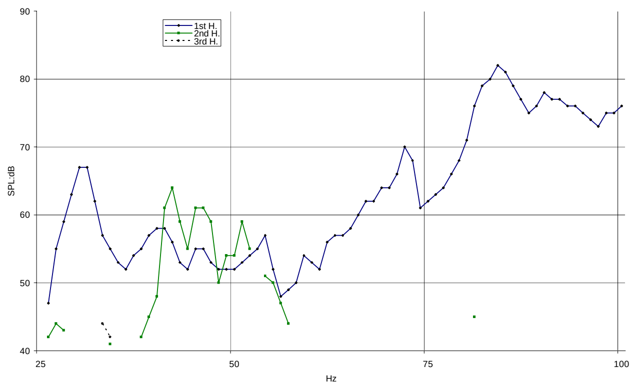

Figure 6: Responsecurve with weight of 120g

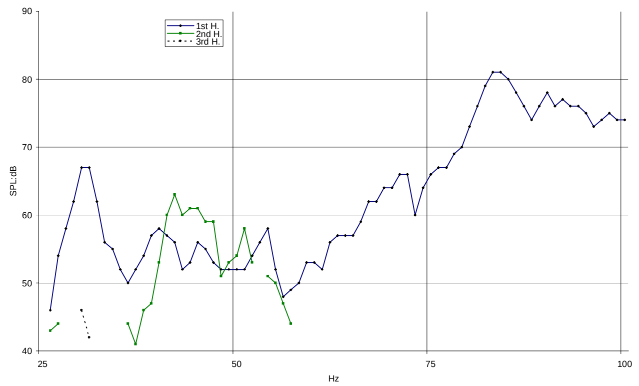

Figure 7: Responsecurve with weight of 140g

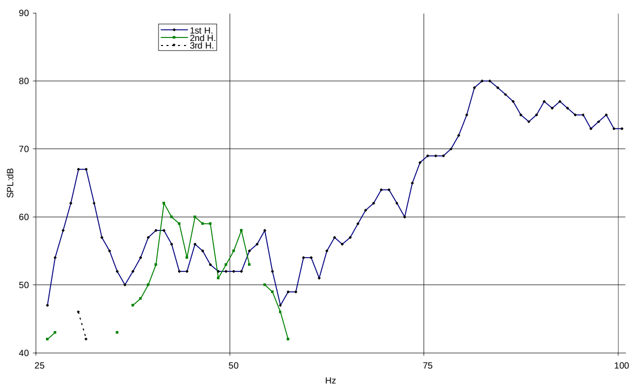

Figure 8: Responsecurve with weight of 160g

In all response curves there are some peaks and dips whose positions do not move with the closing of the rose or variations of the weights. The precise mechanism producing the features, for example, at 40 and 54 Hz has not been determined. Further study of these phenomena is necessary.

In every curve the existences of 2nd and 3rd harmonics were observed. These frequencies coincide with intense peaks. In some cases parts of 2nd harmonic were more intense than the 1st harmonic.

Loudness curves of Fig. 9 with no weight and Fig. 10 with a weight of 140 g were obtained playing the back 8ft register with the keyboard. In the response curve of Fig. 3 there is a pronounced dip at 85 Hz. Notes E and F are respectively at 82,4 and 87,3 Hz. As not only many notes do not coincide with peaks and dips but also irregularity of volume of the sound is corrected by voicing, the loudness curve become somewhat different from the response curve. But the loudness curves of 1st harmonic resemble the response curves. With an adequate weight on soundboard the variation of timbres of adjacent notes becomes less perceivable than with no weight.

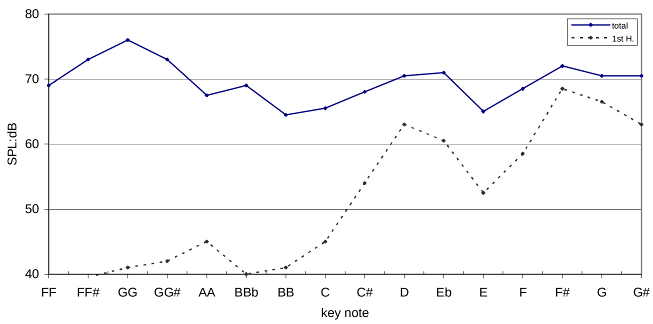

Figure 9: Loudness curve with no weight

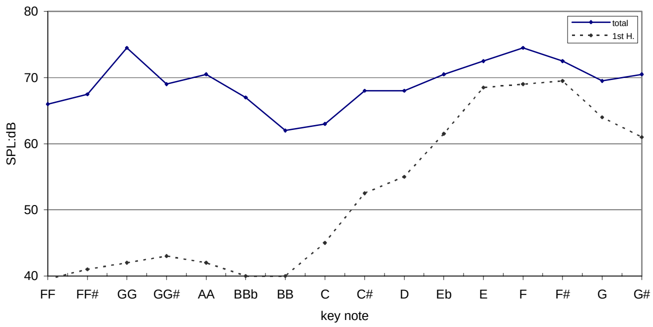

Figure 10: Loudness curve with weight of 140g

4. Conclusion

Response curves present not only first harmonic also higher harmonics where these frequencies coincide with peaks on the curves. With increment of the weight on the soundboard the frequencies of some resonance move to lower sides. Acoustical effect of rose is not depended on air passage but its weight. With weight of about 100 – 140 g at an adequate point on the soundboard, the response curve become more linear from 56 to 90 Hz and shows a minimum reduction of gain from 90 to 132 Hz. With weight of 160 g the response curve is more linear between 75 – 100 Hz but the level become lower at others parts than lighter weight.
It is admirable that some harpsichord makers empirically discovered the acoustical effect of rose. Examining antique instruments, to the trace origin of metal rose would be very interesting.

References

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[3] Halfpenny, E., "Soundholes", Grove´s Dictionary of Music and Musicians. 5th ed., St. Martins Press, New York, 1954.
[4] Weyer, R. -D., "Timevaring amplitude-frequency-structures in the Attack Transients of Piano and Harpsichord Sounds - I", Acustica, 35, 1976, 332.
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[6] Fletcher, N. H., "Analysis of the Design and Performance of Harpsichords", Acustica, 37, 1977, 139.

Notes

The author retired from the institution at end of October, 2003.
This data was first presented as oral contribution (in portuguese) at 3rd Latin America Congress on Acoustics in Curitiba, Brazil in February of 1979, but has never been published. Due to space limitations it has not been possible to include all tha data presented in Curitiba here. This work and Part II was done at the now extinct Musical Acoustics Laboratory of the institution.
As the room where the experiments were done was acoustically live, with rigid parallel walls, it was not possible to measure reliable response curves above 100 Hz. The presence of standing waves at high frequencies was easily detectable by changing the position of the microphone or in some cases just moving about in the room.
Due to similarities and differences of our data set to that presented by Kottick (see reference [1] in Part II) some comments would be useful. Kottick collected response curves covering frequencies of 1st harmonic of all notes from 39 instruments. Some doubt as to the reliability of the response curves presented from 38 of these instruments should be considered. Two phrases in Kottik's article should be noted, the first: "...a sound pressure level meter whose microphone was placed a little over one meter above the center of the soundboard. At this distance very little of the reflected sounds in the room were picked up, compared with the direct sound from the instrument.", seem to be inconsistent with second: "We found however, that because of the location of the sound pressure level meter the rooms affected the strength of the peaks, rather than their location on the response curve." These phrases indicate that he disconsidered the interference of standing wave in his experiments (and that they were present).
As compared to this work one notes the absence of some peaks the apperance of others. The response curves of the intruments belonging to the Yale Collection, the Taskin(large instrument) and the Marchionus(small instrument), have a strange intense peak at exactly the same frequency (139 Hz). The different types of instruments tested in Zuckermann´s shop; French, Hyman and Italian, all showed an intense peak at the same frequency, 185 Hz. In some response curves, Ruckers of the Yale Collection and Zuckermann Fortepiano, there are intense peaks at 233 Hz, this intense peak is not familiar to the author. It may be mere coincidence.
Curiously he considers the response curves of Ruckers and Taskin of the Yale Collection as representavives of Flemish and French instruments. The peak at the same frequency may be a mere coincidence and a peculiar characteristic of the instruments of the Yale Collection.
The author could not access the intruments of the Yale Collection but had oppotunity to test two Taskin instruments of Russell Collection by ear. For these two instruments no such peak was detected.
It should be noted that in Kottick´s experiments the lids were fixed in vertical position near the microphone, possibly acting as a reflector for standing wave.
The structures and acoustical characters of the Flemish and the French instruments are similar except for the size of the bodies. As the Flemish instrument is smaller than the French the peaks and dips in the response curves shift to higher frequencies.
Kottick´s experiments with his acoustcal harpsichord (Flemish) seem to have been done in better acoustical conditions. Notwithstanding the use of voltage units instead of dB there are similarities between his response curve of his acoustics harpsichord and Fig. 2 and 3. His intense peak at 103,8 Hz corresponds to the peak at 94 Hz in Fig. 3, his dip at 92,5 Hz to the dip at 85 Hz in Fig. 3. Similarly the peak between 82,4 and 87,3 Hz in his curve corresponds to the peak at 75 Hz in Fig. 3.
It is regretable that, having sited our Curitiba contribution, Kottik did not notice the similarities between our response curves and his and consequently the possible acoustical effects of metal rose in the response of his instrument.
The author is very thankful to Prof. Richard Landers for the revision of the author´s two papers.

The Acoustical Effect of a Metal Rose in a Harpsichord: Part II

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Abstract

The experiment is concerned with vibration modes at low frequency where large variation of the response curve happens.
The armature of an electro-mechanical vibrating system was mounted on the bridge of the harpsichord. Using small accelerometer vibration modes of the soundboard with no weight and with a lead plate (metal rose) of 140 g on it were taken.
It is found that the position of traditional rose coincides with one of the peaks of the vibration mode at 94 Hz with no weight and that a reasonable weight on this point dampens the vibration.
With no weight the phases of vibrations of major parts of the soundboard shift to opposite phase between resonances at 75 Hz and 94 Hz. This is possibly the cause of the dip of the response curve at 85 Hz. With a rose of reasonable weight this phenomena cease and the dip disappears.

1. Introduction

This study is the continuation of part I. In the previous work relations between various weights of the lead plates on the soundboard and the response curves were discussed. The vibrations of the cords are transmitted to the soundboard. The soundboard then forces the surrounding air to vibrate. In the earlier work the vibration of the air was studied. This article is concerned with the vibration of the soundboard. With Part I it is natural to imagine that the vibration mode changes with additions of the weight. The acoustical effect of a metal rose was analyzed with the vibration modes. Here we will be concerned with vibration modes at low frequency where large variation of response curve happens.
There are various methods of the measuring vibration mode of the musical instrument. Chladni patterns and other similar methods are commonly used method for measuring the vibration of the soundboard [1], [2]. The author opted for the use of a small accelerometer that could be mounted directly on the soundboard with wax. Its small weight did not affect the vibration mode. Although collecting data with an accelerometer is extremely time-consuming, the advantage over other methods is the precision of the measurement for both intensity and phase of the vibration, and additionally the possibility of measurements over every point of the response curve. Chladni patterns on the other hand need strong and well-defined vibration mode to be formed and thus can only be applied at the resonance point of the response curve. One limitation of the use of accelerometers is that for the historical instruments it is not desirable to use wax or other types of adhesives for fixation of the accelerometer on the soundboard.

2. Method

The Harpsichord and the instruments used in this experiment are the same as in Part I except for the microphone, Fig. 1 of Part I. A small accelerometer, weight 0,4 g and diameter of 5 mm, was connected in the place of the microphone. The accelerometer was fixed with wax on to the soundboard. An armature of electro-mechanical vibration, weighing 5,8 g, was mounted on bridge pin of F (87,3 Hz) of 8ft, Fig.1 of Part I. It was verified that there was no modification on the vibration mode with the weight of 5,8 g. A coil excited with 20 Vp-p sinusoidal wave from an audio generator was fixed above the armature. The acceleration of 1 G was calibrated as 100 dB. At each degree of 5 dB a contour line was traced. All signals were passed through third octave filters. The phases of vibrations were measured with an oscilloscope. The exciting point was fixed at zero degrees and positive numbers were delay degrees in all measurements. The vibration modes of the soundboard with no weight and with a lead plate of 140 g on it were taken and phases of vibrations were measured. The frequencies of vibrations analyzed were selected according the response curves of Fig. 3 and Fig. 7 of Part I.

3. Result and analysis

Each pattern of vibration mode at a resonance point has definite phase except at an air resonance. Other parts of the resonance curves are forced vibrations. At these the vibration spread from one point to others and phases change gradually in the patterns. Because of the resolution used, the patterns are apparently not separated with nodal lines in some figures.
Fig. 1 and Fig. 2 are respectively the vibration modes at 30 and 40 Hz with no weight added. The vibration mode at 30 Hz is caused by air resonance in the cavity. The patterns of the vibration modes at 30 and 40 Hz are very similar for both cases, without weight and with a 140 g weight. Above 54 Hz the differences of patterns between without weight and with a weight of 140 g, become apparent, Fig 3 and Fig. 4. With no weight there is strong

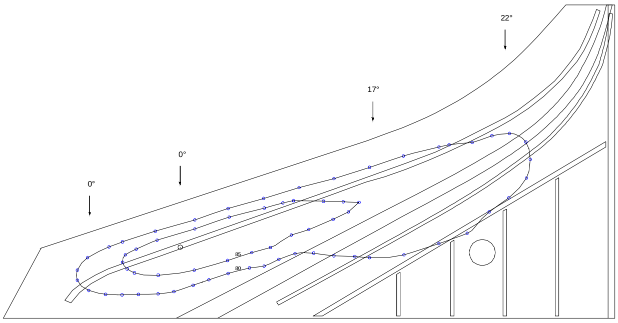

Figure 1: No weight. vibration mode at 30 Hz

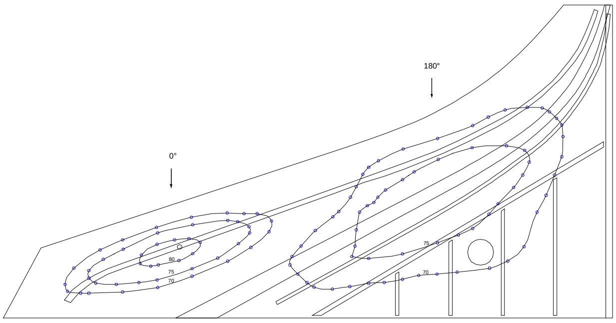

Figure 2: No weight. vibration mode at 40 Hz

resonance at 75 Hz with one nodal line, Fig. 9. One of the vibrations is along the 8ft bridge and another at the ribs with a phase difference of 180°. Additionally the strongest resonance is at 94 Hz with two nodal lines, Fig. 13. The part of vibration along 8ft bridge at 75 Hz is divided into two parts of opposite phases at 94 Hz. The phases of the parts at the ribs at 75 Hz move to opposite side at 94 Hz. The phases of vibrations of major parts of soundboard shift to opposite phase between resonances at 75 Hz and 94 Hz. Fig. 11 shows the vibration mode with no weight at near the dip.

With the weight of 140 g the strongest resonance changes to 83 Hz with one nodal line. One part is along 8ft bridge and another part is along the cutoff bar and the ribs. The two parts are separated by the 4ft bridge and vibrate at same phase.

Fig. 14 is a vibration mode at 94 Hz with weight. The position of lead plate is exactly on one of the peaks of the soundboard with no weight at 94 Hz and the vibration of this part and the vibration along 4ft hitch pin rail are heavily dampened.

The vibration mode at 75 Hz with no weight and the vibration mode at 83 Hz with weight are practically same patterns but the phases of patterns are different. The vibration mode with no weight is in the form of a seesaw and the vibration mode with weight is the form of a butterfly.

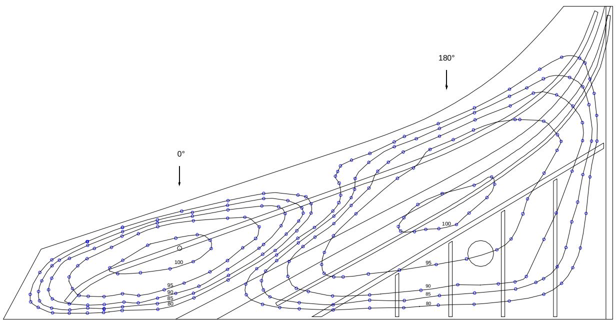

Figure 3: No weight. vibration mode at 54 Hz

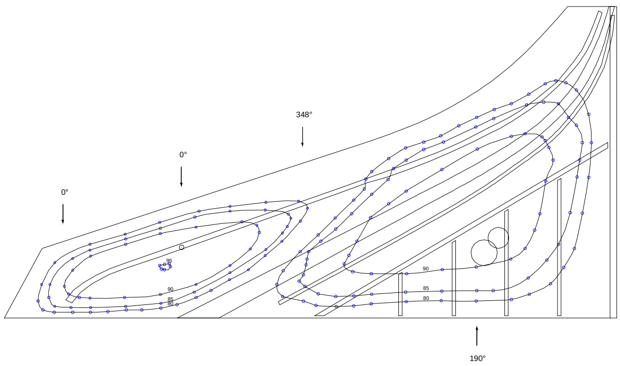

Figure 4: With weight. vibration mode at 54 Hz

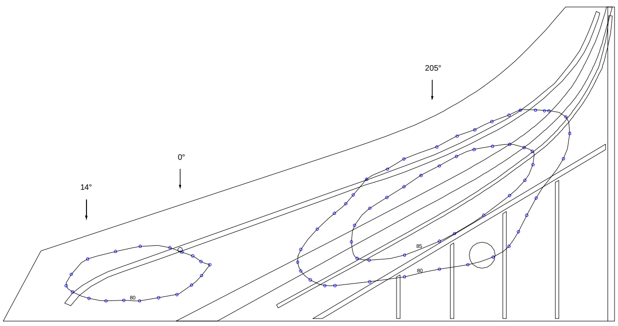

Figure 5: No weight. vibration mode at 61 Hz

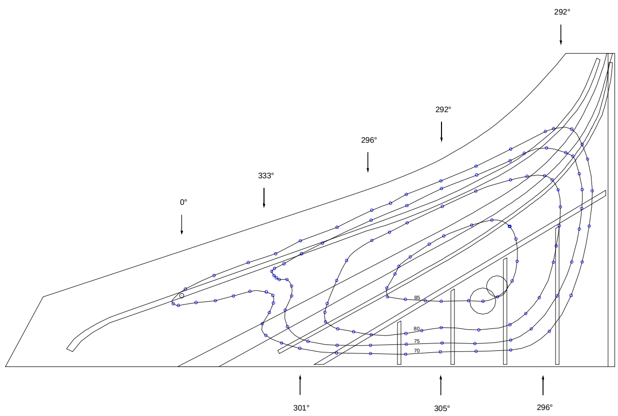

Figure 6: With weight. vibration mode at 61 Hz

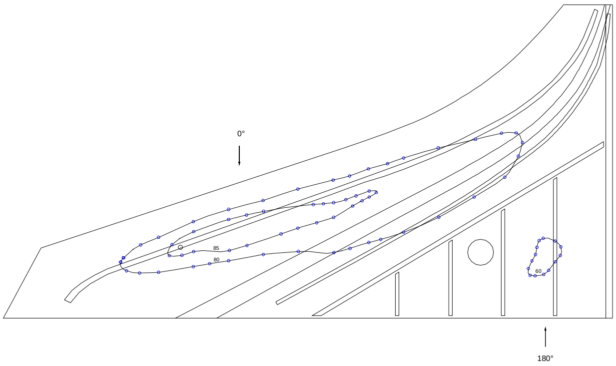

Figure 7: No weight. vibration mode at 70 Hz

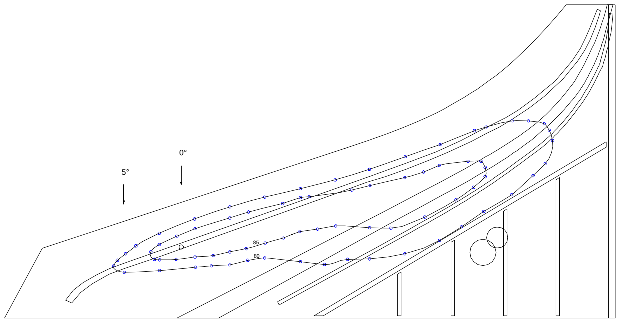

Figure 8: With weight. vibration mode at 68 Hz

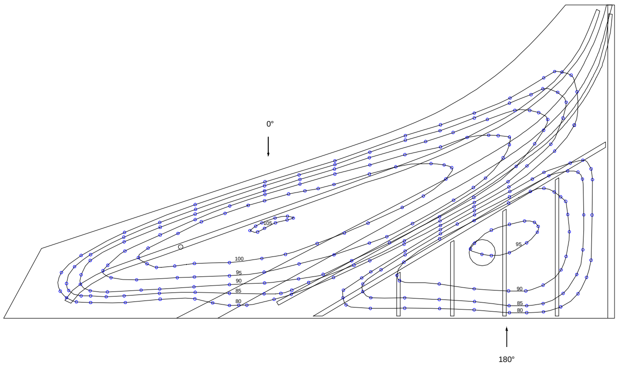

Figure 9: No weight. vibration mode at 75 Hz

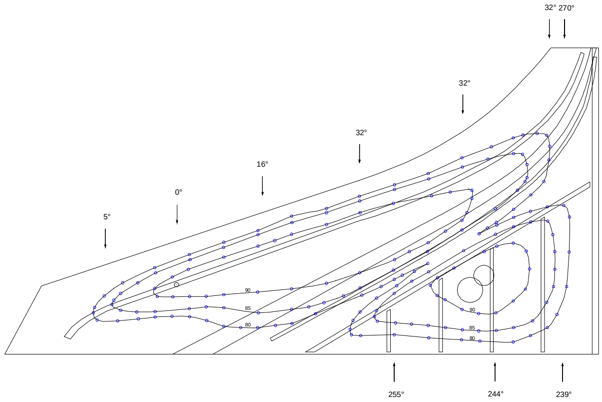

Figure 10: With weight. vibration mode at 72 Hz

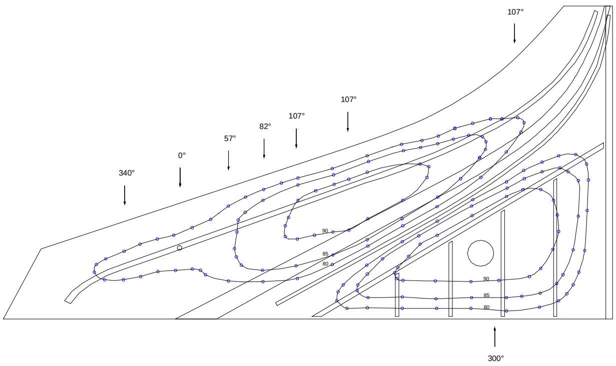

Figure 11: No weight. vibration mode at 85 Hz

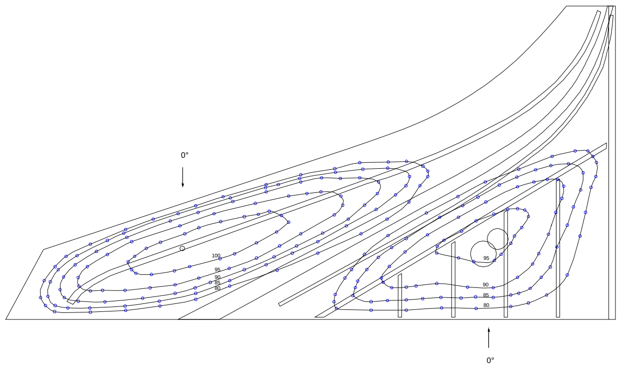

Figure 12: With weight. vibration mode at 83 Hz

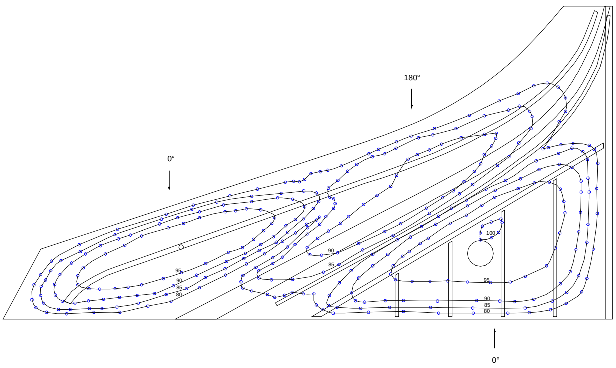

Figure 13: No weight. vibration mode at 94 Hz

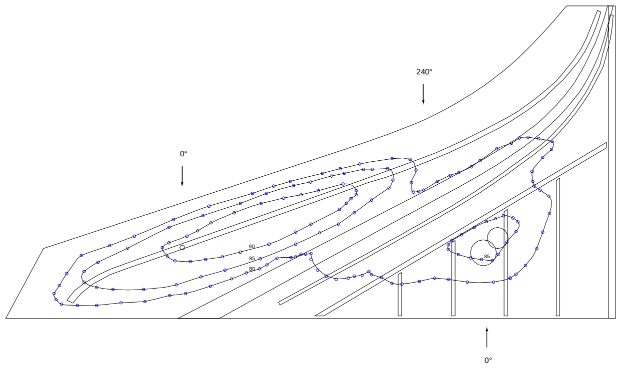

Figure 14: With weight. vibration mode at 94 Hz

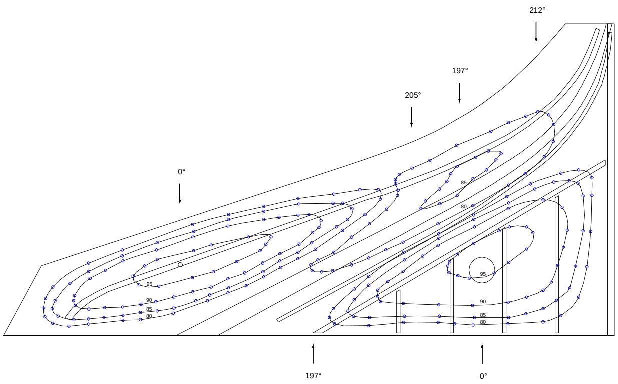

Figure 15: No weight. vibration mode at 101 Hz

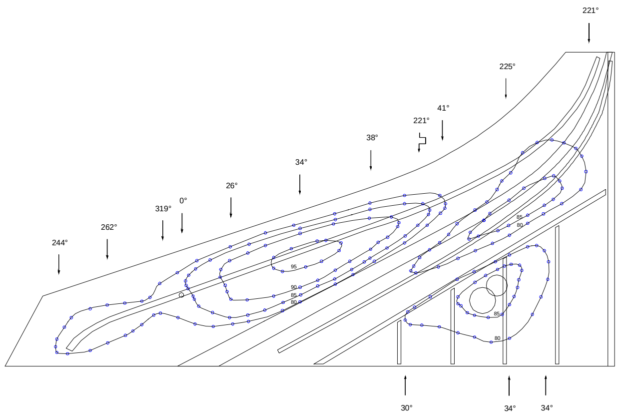

Figure 16: With weight. vibration mode at 101Hz

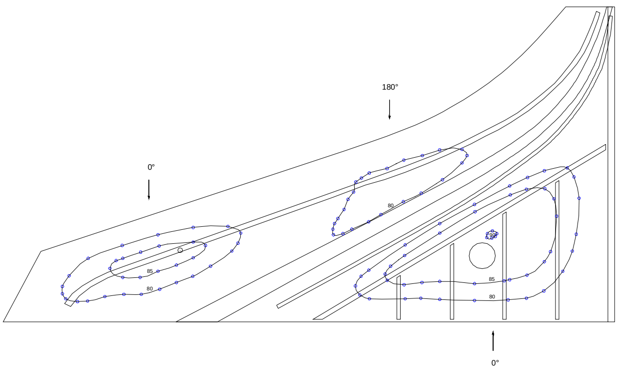

Figure 17: No weight. vibration mode of 2nd Harmonic at 46 Hz

Where resonance frequencies coincide with those at one or two octave above, vibration of second or third harmonics were observed. Fig. 17 is a vibration mode at 46 Hz of the 2nd harmonic with no weight and has the same pattern and phase of the vibration mode at 94 Hz, Fig. 13. From 100 to 140 Hz no definite resonance vibration mode was found.

4. Conclusion

The high peaks in the resonance curves are resonance points. In the vibration mode cause by air resonance, phase in the pattern is variable. In other resonance peaks each pattern of resonance vibration modes has a definite phase. In the forced vibrations, vibrations spread one point to others in the pattern and its phase change gradually.
The two vibration modes at 94 Hz demonstrate the damping effect of a metal rose. The most effective place of a metal rose is exactly on one of the peak of the vibration patterns at 94 Hz with no weight. This point coincides with metal rose of the historical Flemish and French harpsichord.
With no weight the phases of vibrations of major parts of the soundboard shift to opposite phase between resonances at 75 Hz and 94 Hz. This is possibly the cause of the dip of the response curve at 85 Hz. With a rose of reasonable weight this phenomena cease and the dip disappears.

The higher harmonics noted in the response curves whose frequencies coincide with intense peaks form the vibration modes of the definite phases. These vibration modes superimpose on the vibration modes of the first harmonics.

5. Discussion

Although Kottick´s vibration modes are rudimental, some similaritys may be found with the vibration modes of the author [1]. His vibration mode at 104 Hz may be same to Fig. 13, vibration mode at 94 Hz with no weitght. His vibration mode at 88 Hz may be same to Fig. 9, vibration mode at 75 Hz with no weight. His vibration mode at 74 Hz may be same to Fig. 4, vibration mode at 54 Hz with no weight.
Savage and others collected vibration modes with sofisticated method in Kottick´s instrument [2]. Because their experiment was done with no wiring and the results are somewhat rudimental it is dificult to discuss their work. Kottick traced the two nodal line in the vibration mode at 104 Hz, same as Fig. 13, [1]. The nodal line of vibration mode at 102,4 Hz of Svage is different from nodals lines of Kottick although they are the vibration modes of the same instrument.
Savage and others demostrated the vibration at 27,1 Hz as mode 1, vibration mode of one pattern. The author failed to find the vibration mode 1. All aparent resonance vibration modes with one pattern at low frequency were out of phase as demonstrated in Fig. 1. They were caused with air resonance and acompanied the change of the air resonance frequency.

References

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