

Rectangular test soundboard study

Hideo Suzuki*

A & D Co., Ltd., 1–243 Asahi, Kitamoto, 364–8585 Japan

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1. Introduction

A piano soundboard is one of the major components that have significant contributions to its sound quality. The “soundboard system” consists of a soundboard, ribs, and two bridges. Considering that the soundboard is a transducer that converts strings’ vibration energy to sound energy, the requirements for the soundboard are:

- (1) Strings’ energy components should be effectively and evenly transformed into sound energy from bass to treble.
- (2) When the strings’ energy does not change smoothly from bass to treble, the soundboard should be able to compensate the unevenness by implementing appropriate design features.

Four rectangular test soundboards were made with different parameters such as thickness of the board, rib width and height, and distance between adjacent ribs. The effects of these parameters on the vibration characteristics were investigated.

This letter is a summary of one of piano acoustics studies conducted at CBS Technology Center [1].

2. Specifications of rectangular test soundboards

General descriptions of the four test soundboards are shown in Fig. 1. The board is made of six spruce planks glued side-by-side and re-enforced by ribs (shown by thick dotted lines), which is fixed to beech beams at the four sides. During the measurements, edges of the soundboard are fixed to a 200 kg granite table by several heavy duty L-clamps.

Dimensional parameters of the four soundboards (TS1–TS4) are given in Table 1. TS2 differs from TS1 in the board thickness, TS3 has 8 ribs compared to the 5 ribs of TS1, TS2, and TS4. TS4 has a thinner but higher rib shape than TS1. Total weights of the ribs of the four soundboards are kept roughly the same.

3. Inertance functions and mode shapes

Inertance functions (acceleration/force) were measured at 12×17 points over the soundboard. The 204 Points were excited by an impact hammer and responses were measured by an accelerometer at a reference point near but off the center of the board.

Eighteen transfer functions measured at different points over the soundboards are shown in Fig. 2. The five major resonances in the low frequency range are numbered, those frequencies are shown in Table 2, and the corresponding

mode shapes are shown in Fig. 3. The following conclusions are drawn from analyzing these results:

- (1) The first resonance frequencies are not affected much by the design parameter changes given in Table 1.
- (2) The increase of the board thickness by 25% (from TS1 to TS2) contributes significantly to the increase of the several lowest resonance frequencies except for the first.
- (3) The corresponding resonance frequencies of TS1 and TS3 are almost the same, which indicate that the number of the ribs (i.e., distance between ribs) can be changed with minor effects on the lowest several modes as far as the weights of the ribs are kept the same.
- (4) Comparison of the resonance frequencies between TS1 and TS4 show that the height/width ratio has a significant effect on stiffening the soundboard.
- (5) Inertance level differences among the boards are observed, which indicate that design parameter changes may contribute to the changes of the soundboard’s responsiveness to the string excitation.

4. Driving-point inertance

In order to find out whether the stiffening effects of the ribs are global or local, driving-point inertances characteristics were measured at the four points indicated by ● and □ shown in Fig. 1. Results are shown in Fig. 4. The four curves are crossing with each other below the frequency marked by the dotted vertical line in each figure and then two curves take different paths from the other two above that frequency. Even though the determining of the frequencies is rather subjective, Fig. 4 clearly shows that each soundboard has a transition frequency at which its vibration characteristic changes from “global” to “local.”

TS1 (and TS4), TS2, and TS3 have transition frequencies roughly at 600, 800, and 1,300 Hz, respectively. The frequency at which the half wavelength of a transverse wave along the grain (perpendicular to the rib) equals the rib distance d is given by

$$f_{\lambda/2=d} = 2\pi[E_g/12(1 - \nu^2)\rho]^{1/2}h/(2d)^2 \quad (1)$$

where E_g is Young’s modulus in the grain direction, ρ is the density of the board, ν is the Poisson’s ratio, and h is the thickness of the board. If we assume that the transition frequency is given by

$$f_x = 0.65f_{\lambda/2=d} \quad (2)$$

we have 611, 755, and 1,378 Hz for TS1 (TS4), TS2, and TS3,

*e-mail: suzukihideo@nifty.com

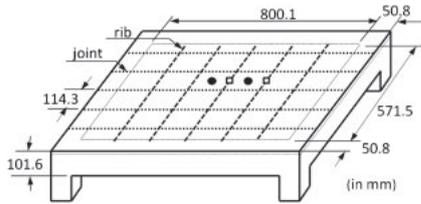


Fig. 1 Sketch of the test soundboards.

Table 1 Dimensions of the four test soundboards.

	TS 1	TS 2	TS 3	TS 4
board-thickness	6.4	7.9	6.4	6.4
rib-distance	133.4	133.4	88.9	133.4
rib-width	25.4	25.4	14.4	15.9
rib-height	22.2	22.2	22.2	33.3

(in mm)

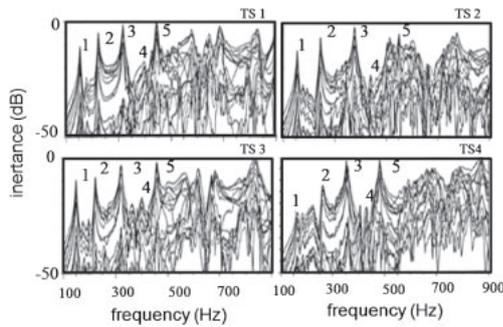


Fig. 2 Plots of 18 inertance functions among 204 measured on the soundboard.

Table 2 Resonance frequencies of the four soundboards at resonances shown in Fig. 2.

	1	2	3	4	5
TS1	156	225	319	401	445
TS2	157	246	377	439	552
TS3	151	224	322	380	458
TS4	160	261	355	420	482

respectively ($E_g = 1.2 \times 10^{10}$ Pa, $\rho = 400$ kg/m³, $\nu = 0.316$ were used). These frequencies are close to the observed frequencies, indicating that Eq. (2) may be used as a rough estimate of the transition frequency (beginning of the localization of the ribbing effect). For a more rigorous discussion, analyses by a finite element method should be used.

Chladni patterns of a real piano soundboard confirm the localization of the ribbing effect (see Fig. 5) [2]. Excitation

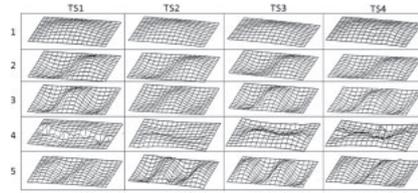


Fig. 3 Modal shapes of the four soundboards at resonances from 1 to 5 in Fig. 2.

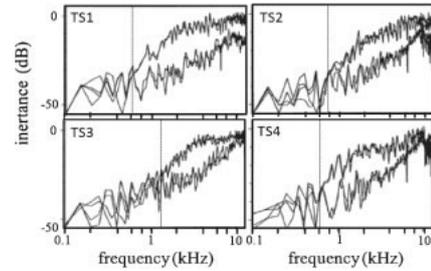


Fig. 4 Driving point inertance measured at four points indicated by ● and □ shown in Fig. 1.

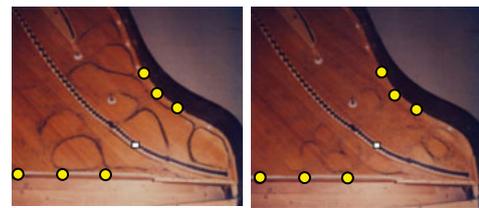


Fig. 5 Chladni patterns of a real soundboard, when excited from behind the soundboard at the positions indicated by the white dot, at 932 Hz (left) and 1,864 Hz (right).

frequencies are at 932 and 1,864 Hz (1st and 2nd partials of note A#5). The excitation point is indicated by the white dot. Three lines (not shown) connecting the corresponding yellow dots indicate positions of the three ribs. At 932 Hz (close to $f_{\lambda/2=d}$ for TS1 and TS4), the sizes of the “cells” are still slightly larger than the rib distance, but at 1,864 Hz, cells are mostly confined within two adjacent ribs and they are narrower in the cross-grain direction than in the grain direction. At this frequency, the ribbing effect is quite localized.

References

[1] H. Suzuki, “Rectangular test soundboard study,” *CBS Technol. Cent. Rep.* (1984).
 [2] H. Suzuki, “Vibration analysis of piano soundboard by Chladni method,” *CBS Technol. Cent. Rep.* (1983).