# Tonewood Treatment Ideas for Musical Instruments Soundboards

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***Abstract.*** *A suitable piece of wood for a musical instrument soundboard must show the proper and within the acceptable ranges of acoustic radiation and damping capacity to form its acoustic conversion efficiency and must have a mechanical impedance match with those of the vibrating string. It has shown mathematically that each acoustic parameter is somehow related to elastic stiffness and density.*

*So, manipulating the density separately but beside the elastic stiffness, through a proper chemical or non-chemical treatment procedure would lead to either a positive or negative change into any of these parameters.*

*An idea for tonewood treatment was proposed to tune the density versus the elastic stiffness, simultaneously, to reach to a suitable set of the acoustic radiation, damping capacity and mechanical impedance.*

## 1 Introduction

Wood is a critical component for string musical instruments. For such a chordophone, the sound produced by the vibrating string, attacks the soundboard and regarding to frequency and mechanical impedance match between the wood and the string, the soundboard begins the resonance.

Human ears hear the musical sound through the soundboard acoustic radiation and its damping or sustain capacity.

There are some sets of the acoustic qualities of wood that must stand within the acceptable ranges, introduced earlier by Wegst (2006) and Roohnia (2019) [1, 2]. But if a piece of wood didn't match these criteria, a scheduling treatment would become necessary to tune the tonewood acoustic parameters, accurately as they are already precisely defined.

First we start to define the acoustic properties, and then the treatments ideas are shared.

## 2 Acoustic properties

Definitions:

A suitable piece of wood for a musical instrument soundboard must show the proper and within the acceptable ranges of acoustic radiation and damping capacity to form its acoustic conversion efficiency (Wegst 2006; Roohnia 2019) [1, 2].

$$ACE = \frac{K}{\tan\delta}$$

In which, K is acoustic radiation and tanδ is the damping capacity.

Acoustic radiation depends on Elastic Stiffness and apparent density of wood.

$$K = \sqrt{\frac{E}{\rho^3}}$$

E corresponds to the dynamic Elastic stiffness of the body, evaluated through one of the dynamic vibration methodologies and ρ is the apparent density of the specimen at servicing condition moisture content calculated directly from mass and the dimensions of the specimen.

Meanwhile, Sound wave resistance or the mechanical impedance of wood (z) in (N.s/m^3) is calculated through the elastic stiffness and density, too.

$$z = \sqrt{E.\rho}$$

Low impedance facilitates resonance.

Damping capacity is an indicator for internal friction of the material that causes the dissipation of vibration while guaranteeing enough sustains for each playing note. There are several methodologies to evaluate damping capacity of wood but a direct measurement of the sound wave attenuation is the most common one. Considering *n* times of full oscillations, damping capacity is calculated from the logarithmic decrement, as:

$$\tan\delta = \frac{1}{n\pi}\ln\frac{X_i}{X_{i+n}}$$

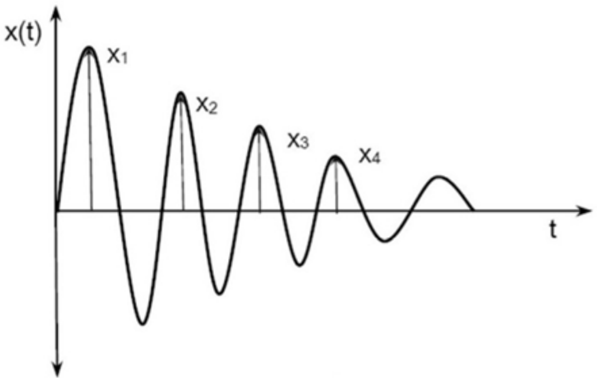


Figure 1. Logarithmic decrement of vibration to represent damping capacity

In 1983, Ono and Norimoto [3] showed that damping capacity is also affected by and depends on the elastic stiffness and density. This truth was revised again later by Bremaud et al. (2012) [4].

$$\tan\delta = 10^{-1.23} \times \left(\frac{E}{\rho}\right)^{-0.68}$$

Ono and Norimoto's proposed regression model is not as strong as the logarithmic decrement model, but is just enough to show that the vibration and acoustic behavior of a piece of wood, even its damping capacity is always under the effect of the ratio of elastic stiffness divided by apparent density. So, adjusting the vibration and acoustic properties of a piece of wood, indeed, means the tuning of its elastic stiffness beside its apparent density, through the possible chemical or physical treatments.

Acceptable ranges:
Wegst (2006), characterized the acoustic parameters of wood in different components of the various musical instruments in their experimental acceptable ranges. Table 1 summarizes these minimum and maximum borders in soundboards of the string instruments.

Table 1. Minimum and maximum acceptable values of each acoustic parameter for wooden soundboards

| Sound board | min | max |
|---|---|---|
| ρ (Kg/m^3) | 300 | 550 |
| E (GPa) | 6 | 20 |
| tanδ | 0.003 | 0.009 |
| K (m^4/Kg.s) | 9 | 16 |
| z (kN.s/m^3) | 1342 | 3300 |
| ACE | 1000 | 5000 |

## 3 Ideas for acoustic manipulating of wood

Density
First of all it is necessary to predict that, what would happen to the introduced acoustical parameters, as the density of wood decreases. Decreasing the density while keeping the elastic stiffness unchanged, will increase the acoustic radiation, decrease damping capacity, increase the acoustic efficiency and decrease the mechanical impedance.
In most of the engineering materials but the wood it is not possible to decrease the density without keeping the stiffness constant. Solvent extraction using distilled water or an ethanol acetone solution will decrease the wood mass without doing any important destruction to the cell walls and the elastic stiffness will be nominally remained unchanged.
This idea has already tested in several researches using several wood species. Some of them were successful to decrease damping capacities while increasing the acoustic radiation coefficient. Padauk, Maple and Spruce are taking into account in this group (Roohnia et al. 2014; Miao et al. 2017; Traore et al. 2010) [5, 6, 7]. In Some species the extractive content found strangely useful for acoustic vibration and decreasing the extractives content increased the damping

capacities and decreased the radiation coefficients. For an example, Pink silk wood and Pernambuco are the members from this group of the species (Farvardin 2015; Matsunaga 1999; Alves 2008) [8, 9, 10]. Previous experiences showed that the extractives from Pernambuco were also useful to improve the acoustic quality of spruce, if impregnated with.

Elastic stiffness

Manipulating the stiffness is not easily possible without doing the changes on density, but it is possible to increase the apparent stiffness, virtually. One of the oldest traditional treatments was bowing the structural material to produce arches and etc. But for wood, an orthotropic material, it has some important aspects that are not concerned in other isotropic ones. Wood has directional properties i.e. bowing by grinding would be highly different from bowing by elastic bending in longitudinal direction. While the elastic bending is done, the growth direction would not be destroyed (Figure 2).

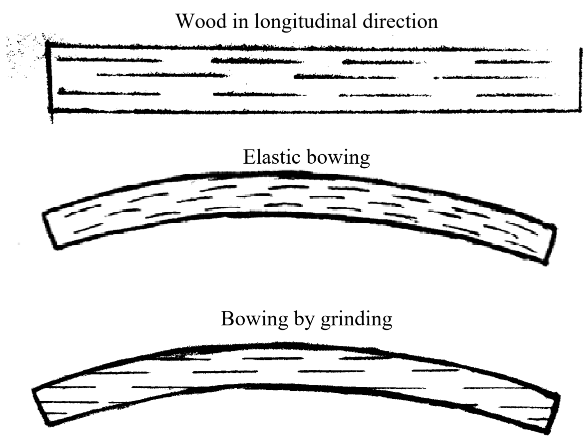


Figure 2. Elastic bending vs grinding the wood to reproduce bowing

So, the grinding would decrease the longitudinal elastic stiffness.

Though, this idea has not been published yet, but has been tested successfully by two Iranian skillful luthiers, i.e. Mr. Saeed Peymani and Mr. Naeem Khatooni in Persian Setar instrument.

Increasing the longitudinal stiffness of wood, even apparently, by elastic bowing the soundboard would increase the radiation coefficient dramatically. But it is important to note that this manipulation would increase the mechanical impedance as well. So, to keep the resonator soundboard, easy to vibrate, it is recommended to combine the two proposed ideas for increasing the stiffness and decreasing the density, together. We recommend doing these both together, unless making changes to the impedance is also of interest.

Noteworthy is that the elastic bowing of the soundboard is traditionally done by bridge's tensile or compression force in string instruments and also the Sound-post in the violin family instruments do an elastic bowing on the top plate, too. This additional elastic bending approach must be carefully tuned in terms of the radiation coefficients and the mechanical impedances of the wooden soundboards, unless the instrument would lose some notes in its frequency range.

## 4 Further comments

There are lots of cases that a selected wood specimen falls naturally within the acceptable ranges, same as table 1. So, such a wood would not need any treatment at all. If there would be any of the out of range acoustic parameters, it is recommended to be tuned in terms of the density and the elastic stiffness. One must be concerned about the simultaneous unwanted changes in some other parameters beside the scheduled program.

For example, in a hypothetical specimen, programming for increasing the acoustic radiation might be done by increasing elastic stiffness or by decreasing density of the wood. It must be noted that while increasing the elastic stiffness, the mechanical impedance will increase as well and causes an additional unwanted resistance against the resonance. On the other side, decreasing the density to hit the higher acoustic radiation would decrease the mechanical impedance, too. It could be good for facilitating the resonance but some times the impedance matching might be disturbed. So, a sufficiently good idea of tonewood treatment deals with an accurate tuning of elastic stiffness and density to keep all the acoustic parameters still remained within the finest acceptable ranges.

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