Soundboard Maladies

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Piano history

- Originally pianos were made by individual craftsmen
- In the early days, applying hot animal glue to a cold surface would cool the glue quickly and the glue would gel. To cope with this transformation, they would heat the wood up in a box to 115-125 degrees, then apply the glue, and then take the wood into the regular wood. If this wood were in the hot box for a short time, it would not warp much. If it stayed in the box overnight, it would definitely warp. Soon it was discovered that soundboards with warped boards sounded better than those that were straight, and so crowning was accepted.
- A lot of early pianos were not designed well. For example, some had string tensions that were too high.

The Problem: Lost Crown

- Age
- Crown system
  - Compression-crown
  - Rib-crown
- Loss of crown is permanent
  - No method of "restoring" crown is effective
  - Crack shimming is cosmetic repair only

Why is soundboard crown important?

- Crown
  - Crown is roughly the radius of 60'
  - Where did the concept of crown come from? Late 1700's?
- The idea of opposing springs
  - Strings press down – down-bearing
  - Soundboard assembly presses up
  - System is at equilibrium when down-force and up-force are equal.
    - The upward force of the soundboard spring balances the downward force of the string spring.
    - When we lose this equilibrium, there will be a decrease in impact and an increase in sustain.
    - If crown is lost, stiffness overwhelms the soundboard and the sound becomes more percussive and decreases more quickly.
    - Lousy grain, cracks and splits in the soundboard do not really matter. What matters is the sound.
  - The more deflection, the more force it will take to deflect it further.
- Soundboard assembly with crown forms a non-linear "disc-spring."

- Assuming that the piano was well-built at the time and everything else in good shape, the only remaining change would be to replace the soundboard.

Creating Crown: Two primary methods for creating crown

- Compression crown
  - Crown formed by a stress interface between the soundboard panel and the ribs
- Rib crown
  - Crown formed by machining (or otherwise forming) a curve into the surface of the ribs
- Combinations
  - Many, if not most, soundboards are crowned using a combination of these two systems.
  - 4%, in the winter, 3.8% in the summer
- The bridge pushes the soundboard down, while the ribs are forcing the crown up. This creates a double arch.

A system under stress

- A crowned soundboard assembly under deflection stress is stiffer than a flat soundboard assembly that is not under deflection stress, under the same construction.
- Soundboard crown is a method of increasing soundboard assembly stiffness without increasing soundboard mass.
- When you measure the height and width of the ribs under a compression soundboard, they will be a little square and wider than they are tall. The ribs do not support crown. Only the compression in the soundboard panel creates crown.

Lost Crown

When **crown is lost**, what changes?

- Mass stays the same
- Stiffness is reduced
- Soundboard impedance is affected
  - At high frequencies the soundboard is primarily mass controlled
  - At low frequencies the soundboard is primarily stiffness controlled
- Lost crown is characteristic of compression-crowned soundboards.
  - Drying (shrinking the soundboard panel to 4% moisture content)
  - Gluing ribs across-grain to dry panel
  - Exposing soundboard assembly to normal atmospheric conditions
  - Wood fibers in soundboard panel try to expand and return to normal
  - Expansion restricted by ribs across-grain to the panel
  - Resulting stress interface forces crown into system
- Traditionally ribs were glued into the soundboard with animal hide glue and the bond would be indefinitely tight. However, in factories, this does not happen because the glue gets older and the precision is lost. Consequently they started

notching the soundboard to accommodate the ribs; this actually is detrimental to the tone quality.

- The mass of the soundboard has more effect on the higher frequencies than the stiffness.
    - On the low bass, add stiffness and there will be a change in the fundamental lower frequencies.
    - Add mass to the bass there will be relatively little effect on the fundamental frequencies.
    - The soundboard is feathered around the bass to allow more movement at lower frequencies.
- Bass bridge cantilevers or suspense levers are unnecessary. Designing them out of the system will always improve the performance in the low bass.
    - The cantilever adds mass, but dramatically decreases stiffness.
    - What little energy there was is dissipated into the cantilever in the form of heat.
- When stiffness is reduced the soundboard more readily accepts low frequency energy
    - Fundamental energy transfers quickly
        - Percussive attack
        - Short sustain (Sustain depends on low frequency energy content.)
- Problem first noticeable in upper tenor and lower treble region.
- When trouble-shooting, confirm or rule out everything. When it is not any other problem, then it must be a soundboard problem.

Where does crown go?

- Wood has structural limits
    - Typical compression-crowned soundboard panel can develop as much as 2% internal compression
    - Spruce can only tolerate 1% internal compression without sustaining permanent damage
    - Even without compression damage wood fibers under continuous compression stress deform over time – *i.e. compression-set*
    - There is no way to restore crown by rebuilding the soundboard. Crown is not restored. It is simply reconfigured.
- When restrained, the amount panel would have expanded turns into internal compression
- Wood fibers under long-term compression undergo compression set
- Wood fibers compress and permanently change form
- Internal compression dissipates
- Damaged wood fibers do not revive or restore themselves
- Lost internal compression = lost stress-interface between the rib and the soundboard panel
- Lost stress-interface = lost crown (permanently)
- It is the internal build-up in the panel, with the ribs, that, over time, destroys the panel. Pianos in the NW live longer. In a normal house it would be rare to have serious soundboard damage in the NW. This happens more in the Midwest.

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Wood as an engineering material

- **Strength**
    - Strength is a way to define if anything will withstand applied stress.
    - To understand the soundboard and its problems we must understand some basic characteristics of wood
    - In terms of sheer compressive force, wood is very strong.
    - Apply this stress to a soundboard panel perpendicular to the grain, it is much less strong
- Strength as a function of time
    - The strength characteristics listed in reference books are based on a time under load of 5 to 10 minutes
    - Various strength characteristics must be de-rated if the TUL (time under load of 5-10 minutes) is substantially longer than this.
        - If this load is only a few seconds, it is over-rated.
        - If this load extends over a decade, the load capacity must be de-rated considerably.
- **Compression** strength
    - The measure of a material's ability to resist compressive loads
    - In wood, this varies with the direction of applied load, i.e. parallel to/perpendicular to grain
- Compression recovery
    - The amount, in percentage, of return to the original dimension is a given time
    - Recovery ability decreases under a prolonged load
- Compression Set
    - The amount that a material fails to return to the original dimension when an applied compression load is removed
    - Compression set occurs whenever wood fiber is compressed beyond its FSPL
- The 1% compression limit" rule
    - On average, with stress applied perpendicular to the grain, the FSPL is reached when strain approaches 1%compression.
    - Beyond this point further increases in stress simply crush the wood fiber – primarily the softer early-wood fibers
    - Even within the 1% compression limitation, long-term compression-set will reduce the strain within the compressed panel.
- Diagram of wood swelling under restrain

- In response to normal humidity fluctuations, wood can swell as much as 3% perpendicular to the grain. In typical homes, 2% is fairly common.
- If the fiber stress exceeds the proportional limit, it will never go back to its original size because the permanent shape of the wood fiber has been changed. It is no longer neutral: it is now under tension.
- Although 3% swelling is extreme, variations of 1% to 2% are fairly common in homes located in areas of high temperature and humidity swings.
- The effect on wood fibers of restrained swelling is similar to that of compression and may cause wood to load itself beyond its FSPL causing permanent shrinkage, or compression set.
- **Tensile strength**
    - The measure of a material's ability to resist tensile load
    - Tensile recovery and tensile set are similar to compression recovery and set
- **Tension** perpendicular-to-grain (less leeway)
    - Things pull apart and crack
        - This is a typical stress/strain graph of tension perpendicular to grain
        - FSPL is reached well under 1% strain
    - Failure – i.e., cracks through earlywood – occurs at less than 2% strain.
- Samples were place in fixture at 7% MC
    - All samples were attached to lower frame with a wood screw
    - The sample on the left was attached to the top frame with a wood screw.
    - The MC of the wood was raised to 18%, at which point there was no discernable damage to anything.
    - The sample on the right was unconstrained, the other two were constrained by the top frame
    - The two constrained samples develop internal compression that exceeded their fspl
    - No damage was apparent at that time
    - The MC was taken back to 7%
    - The right sample returned to its original height
    - The middle sample shows the result of compression shrinkage
    - The left sample, also subjected to compression shrinkage but constrained, develop internal tension sufficient to break it apart.
- Wood failure always starts in the larges area in the new big growth cells. These cells are the weakest. Late wood growth in the fall creates smaller, tighter, thicker, tougher fibers.
- All adhesives designed for wood use water as a solvent. When a water-based adhesive is spread on the wood, certain amounts of water will go into the wood. The machining process slightly damages the wood into compression. As the water soaks in and carries a little glue resin with it, it
- Stress relaxation: a reduction in stress in material held at constant deformation over time
    - Creep

        - Permanent deformation resulting from load (stress) applied over time
        - Long-term failure can result from high loads
    - Creep rate
        - The rate at which deformation occurs in a material under load
    - Creep strength
        - The maximum tensile or compressive stress that can be sustained by a material for a specified time and temperature without rupturing
    - Creep recovery
        - A measure in percent of the decrease in strain, or deformation, when a load is removed (see FSPL)
- Tree Growth
    - Annual ring
    - The structure of wood
- **Traditional soundboard problems**
    - Audible
        - Percussive attack
        - Loss of sustain
    - Invisible
        - Cell damage due to compression
        - Loss of stiffness
    - Visible
        - Compression ridges
        - Cracks – seen & unseen
        - Loss of crown
- **Traditional soundboard repairs**
    - Shimming and/or filling cracks
    - Stripping/scraping soundboard surface and applying new finish
    - Corrects only visible problems
    - Structural
        - Re-glue loose ribs
        - Re-glue soundboard panel to rim/bellyrail assembly
    - Restore crown?
        - Soundboard system crown cannot be restored.
            - All crown restoration techniques give only temporary results at best
            - Typically yield no results at all in critical upper tenor and lower treble region
        - Real problem is not loss of crown but loss of stiffness

Solutions

- The Illusion
    - When I restore crown in the soundboard the piano sounds better!
        - New strings
        - Reset string bearing
        - New hammers

        - Regulated action
    - It is the whole rebuild that sounds better
        - Results are still limited by loss of soundboard stiffness
- The Ideal Solution
    - Replace the soundboard assembly – but…
        - Expensive
            - And the piano may not be worth it
        - Customer may not be able to afford it
        - Customer may be unwilling to afford it
        - Customers requirements may not justify expense
- The Less Ideal Solution
    - The problem is not with longitudinal-to-grain stiffness, but with cross-grain stiffness
    - Wood cells are damaged – permanently
        - Nothing we can do will change that
        - But we can restore at least some stiffness to the system without restoring crown

Changing rolls
Boat
Applying principle to the soundboard
The process
Etc.
Epoxy, silica & sawdust slurry to fill soundboard cracks. Use an actual coating epoxy, not a standard epoxy. Coating epoxy is very thin. Another epoxy www.masepoxy which cures very slowly.
After cleaning off all the old finish, wash it down with sanding
Mix epoxy in a shallow container rather than a deep one.Keep brushing on until nothing more will saturate or soak in. You will see little cracks open up from the epoxy. By the next day it will be dry to the touch, but it won't be cured for another sevento ten days.
Sand it down but don't go into the wood.
Coat it with an exterior coating with ultra-violet blockage to protect the epoxy.
This process gives the system a lot of stiffness.
Set bearing on the light side.
While you're doing this,