FALSE BEATS

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Ed's Notes

Definition of false beat; In pianos, most commonly it is a regular pulsing sound that interferes with the aural resolution of beats between unison strings to an essentially zero beat state. It can also occur between octave intervals involving wound strings.

Piano strings carry two types of waves when struck by the piano hammer. The Transverse wave, (T-mode), which is elastic energy imparted to the string at a nominal right angle to the body of the string. And a Longitudinal wave, (L-mode), that is excited by stretching effects at the hammer strike point, and at the termination points if they allow movement in line with the string. The L-mode is carried internally in the wire and does not usually result in string displacement out of the string plane. We describe T-modes with possessing two possible directions of vibration; the vertical motion imparted by the hammer strike, and a horizontal motion produced by stiffness effects and degrees of freedom found at the termination points.

Movement of the string terminations allows for the angular momentums of the T and L-modes to mix. Movement at the string terminations is the source of many false beats in my experience. This can be movements of string termination pieces like bridge pins, agraffes, V-bars, or the structures holding them that interfere with precise and stable T-mode frequency definition and/or mode mixing between both vertical and horizontal T-mode movement, and L-modes.

The type of materials used at the termination points also affects production of false beats.

The stiffness of piano wire also allows the T and L-modes to be influenced by conditions beyond the termination points of the T-mode.

Transverse string movement horizontal to the hammer strike will usually be a slightly different frequency from the one shown by vertical Transverse movement.

The tuners allies in resolving some false beating effects are:

Spacing strings so there is no lateral offset to the line of the string as it passes under the V-bar or agraffe

Having the V-bar and agraffe string holes shaped to a true V-shape to allow the pivot termination to have maximum effect which strengthens unison string coupling.

Having the bridge pins tight in the hole.

Stringing practices that do not twist the plain wire.

Unison string coupling. Tone regulating the action so the hammer strike is as vertical as possible and most importantly, the hammer strikes all unison strings in the same phase, (at the same time). This phasing of the unison strings allows the coupling of the unison strings to be quickly established, and thus each string will “bend” the pitch of each other to allow for a purer unison.

Wound strings with unevenly applied wrappings can produce some beating effects.

Plain piano wire with two differing diameters in the speaking length can make some really false tones. (I have only seen this once).

Mixed wire diameters in the unison also make beatless unisons impossible.

Deeper levels of false beat remedies involve reducing the ability of the string terminations to allow “rocking” motion.

Dean's Notes

We need to think of what type of wave in the string there is. The transferous wave is a displacement perpendicular to the string; Ed calls it the T-wave. The longitudinal mode is affected by stretching in the wire. Think of hitting a metal rod on the end, causing a wave through the rod. Ed calls this the L-wave. These two types of waves are intrinsically coupled but have two distinct ways of moving. This vector can cause a lot to happen. These movements can affect the terminations, like the bridges or agraffes. The stiffness of the wire plus the termination points combine with both directions of waves. You can hear the pulsing at the rate of the T-mode, most noticeably in the treble. The L-mode is a function of the elasticity of the wire. As the T-modes decay, the side motion will oval out in the string motion, so they gradually equal out, with the longitudinal and vertical becoming the same. Movement of the string terminations allows for the T and L motions to mix, couple, and mutually affect themselves.

The most common problem with false beats is loose bridge pins. Longitudinal waves can create false beats even with tight pins. Loose agraffes and loose V-bars exist but are not common. Baldwin's terminator bars are screwed in to reduce this motion. Ed checks each string and makes notes whether the beats are weak or strong. Some pianos will still carry false beats even after replacing strings or changing bridges.

Whistling sounds come from longitudinal beats because none of the lengths of strings are the same. These beats slip under the V-bar. There are 6 fundamental beats on each note. Mild steel has a little springiness in it, so a bridge pin can slightly move when vibrated. Install hard drill rod as bridge pins and the sound will be awful because the T waves are cancelled but the L waves continue.

Off-set and spacing makes a difference. The angle of the string where it passes over the bridge is critical. At the V-bar there is an off-set angle, and there is a slight beating in the tenor because the wave transfers across the V-bar and follows across the termination points.

Ed added wood on the side of a bridge and capped it on a Chickering and the beats vanished. Roger heard a different kind of false beat that was high and fast rather than low and pulsing. Different wire types can make a difference as well; there are newer, softer wires available.

When tuning a unison, there is a certain point when all three strings pulse together and the frequencies grab each other and match. Leveling strings at the strike point help the strings start beating in phase. Listen to each string individually – especially in the long strings – and you will notice that no two sound the same. The coupling in the unisons is most noticeable in the lower notes, creating a sense of fundamental in the note. Soundboards themselves are in the mode around 30-50 Hz. The bottom note is 27 Hz. If the soundboard cannot handle 27 Hz, the tone will not be good. Hammers act like dampers.

A Fender Rhodes is primarily a tuning fork struck by a hammer, producing a fundamental. Ed made the tones very dark to listen to the parameters of the tines. Roger's MoonDog stabilizing tool puts a little bend in the wire around the bridge pin. Aggressive seating of the string doesn't last because the wood gets crushed, and the string eventually moves back up. Soft vs. hard bridge pins can make a difference; plating is soft enough that it doesn't seem to make an effect. Copper is soft enough that it gives a little extra grip. Stainless steel is too slippery and the string will slide up then move back down on it. Steinway has case-hardened V-bars; they use carbon black on top to heat it up to a certain color and then let it cool, thinking this process will stop strings from cutting grooves. However, the strings stick and are hard to tune. The carbon has been changed. When carbon is cooled faster, the graphite becomes harder and does not have a perfect cubic shape. Piano wire is made through diamond steel hardened dies. Bend a hardened steel at a sharp point and it will break. The strength of piano wire is in the skin. Look at a micro-photo of wire and you can see scrape marks on the string from rubbing on the friction points. Frequent tunings will fatigue hard wires quickly. Softer metal V-bars can be filed down. Hard V-bars take the edge off your file; filing soft V-bars sounds like filing wood.

Wire is heated, and then cooled, annealing, and then is drawn on a big drum. Wire is not straight – it always has a curve, so when laying a wire in the piano, don't twist it: follow the curve. Bass string wires have been straightened out and have no curve. Roger got a wire straightener but didn't notice much difference. You can't do it once: you have to do it several times.

Steinway talks about the pivot termination. By having a stronger fundamental in the note, it is easier to get out the beats. There is some flex at the termination point. A hard V-bar leads to fatigue, especially in the treble. Because the speaking length is longer than the duplex section, the speaking length controls how the energy transfers. Fine wire trichords are difficult to make, but accurately made strings sound clean. As you get higher in the scale, the little noises disappear, and you can hear clean sounds when the interference is gone.

String makers generally do not tell their secrets how they make good strings. There needs to be about 100 pounds of tension on the core wire when winding the copper on. Wearing gloves, apply pressure consistently all the way down the wire. This takes patience and a steady hand. Once Ed found a false beat caused by two wires that had slightly different diameters on the same note. Subtle inconsistencies can be heard. Yamaha uses Suzuki wire.

A rocking motion will cause L-modes to start acting up. String grooves appear deeper on soft bridges. Roger believes that over time wear occurs from the upswing and downswing of the string, and it is this worn gap between the bridge pin and the bridge that causes beats. The rocking motion is different from the strike. Multiple reflections become chaotic; small perturbations create larger effects.

Solutions for eliminating false beats:

- CA glue
- Roger's tool that tightens the bend around the bridge pin
- Seat the strings
- Level the strings
- Roll the strings
- Move strings at the V-bar with a screwdriver to get them straight
- Remove bridge pins, sand down the bridge cap, and install new pins (shop work)
- Prevent the bridge from rocking by making it stiffer so it can't move in the direction of the string line (shop work)

Ed treats the surface for new caps like a drafting table and makes a pattern where the pinholes are on a piece of thick masking tape. Whenever you make a copy of anything, you introduce error. With anything, make a pattern, make a fixture, then make the item, and there are several margins of error during this process. To achieve a high degree of uniformity, he sets his back row of bridge pins closer to the front and increases the distance as he goes down. Bridges fail and have unclean sounds when the pins are too close and angled wrong. It is important to keep them away from each other. The same force over a shorter area creates a nice clean sound. Almost all pianos have false beats in the high treble. Ed also uses smaller bridge pins farther down -- 6's -- because they are lighter. The shorter ones do not hold well, so he uses 1" pins. Bridge caps are critical. Beats can be false up high at the V-bar or top agraffes. Agraffe string holes are too broad, and the termination points are more critical with the shorter strings. There must be a bit of counter-bearing so there is a free link near the duplex.

Think of the vocal compass of sound. On a piano there is the vocal range in the middle, at the top is the bird sound treble, and the bass is like a gong. All these frequency ranges must blend and be in proper proportion, making piano engineering a complex task. The killer octave is 1000 Hz, which is the top of the vocal range. In linguistics, all languages have the same tones and sounds. Music is an emotional language. All musical engineering must relate somehow to the human voice.