Re-leathering your square piano hammers and action parts

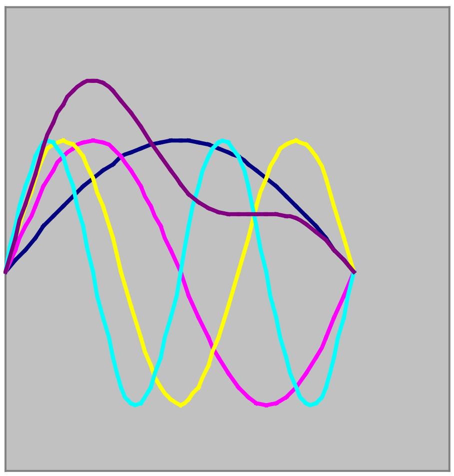
Not even the choice of historically appropriate wire rivals the disputes and concerns surrounding the subject of re-leathering piano hammers. Much has been discussed in on-line forums and workshops on the subject, and the intensity of feelings seems unnaturally high at times, as the nature of the hammer covering is, in fact, a major factor in the resulting sound. Fortunately for us, square pianos remain somewhat in the backwater, so an essay on recovering their hammers as they may require should not bring down too much wrath, and perhaps a little charity could be extended in any case!

First we should establish what the problem is before we begin to describe the potential fix. Many square pianos will be found with their hammers seemingly intact and neat, possibly slightly grooved, but able to produce a serviceable tone. I leave these alone myself, preferring not to fix something that is not obviously in need of replacement. Clearly, two hundred years have left the leather coverings (a natural product that has seen much dynamic use) in a different and probably harder condition than when new. The 'sound' is not authentic anymore, to the extent of the hardening from reaction with ozone, oxygen, water, etc. which has further complexed the proteins and altered the leather's response during a strike. But other alterations might have also occurred, so if a hammer is still resilient to the touch (more in a second) I am content to play it as an antique and go on.

If the square has seen more serious degradation, such as much water, insect or rodent action, or just harsh storage, such that the leather is in a crumbling state or missing, then we need to recover. The question is "with what, and how"? Our objective is clear; we want a pleasing tone and good response to the key stroke, that will last for quite awhile longer, and that remains true to the nature of the original sound. We are pretty sure there is no place for modern materials like felt, and given the size of the hammer, this turns out to be a poor choice no matter how much or little we want to remain true to the historical approach, just due to the nature of wool felt and how much we would need to achieve a comparable sound.

I am resolved never to practice mathematics in public, but we should make our foundation on the realities of the physics behind the sound produced by a piano. We know that as the key is depressed, the hammer, which is so arranged as to have more or less mechanical advantage, is accelerated towards the string 5 to 20 times faster than the key travel and so strikes the string at several meters/second. Visually, it seems to pop away at once, but in reality, it has to decelerate to a complete stop, then accelerate in the opposite direction, during which the hammer shank and hinge flexes ever so slightly, and the covering compresses and decompresses, part of which time it remains in full or partial contact with the string. This time frame is upwards of 4-6 milliseconds (thousandths of a second) for a note struck at ppp (very soft), and about 2 ms for fff (full forte). The energy transferred to the string causes it to begin to deflect and vibrate immediately, even while our hammer covering remains in contact with the string itself.

The string does not simply vibrate at the frequency we would calculate for its tension, density, diameter, and length, which is the fundamental tone and would sound incredibly dull all by itself. It can also vibrate at ½ its length, 1/3, ¼, and so on.



Plot shows fundamental and next three harmonics. The purple line gives the cumulative grand average.

These higher partials are critical to a rich final sound we want, but there is also a further complication. Because the string is obviously constrained at either end and has a finite diameter, an in-harmonicity is introduced that results in sharpening the partials, with each higher partial incrementally more sharp, which further enriches the sound if introduced in the right amount.

The bottom line is we need those partials, and they are the easiest to distort or lose with the wrong choice of hammer covering. The reason for this potential loss brings us back to the point about how long the hammer covering remains in contact with the string. At impact, the strike produces two pulses in the cord (string) which propagate towards the nut and the bridge. The one traveling toward the nut reaches its destination and flips its direction while the one traveling toward the bridge has only traveled the equivalent distance of the hammer point to the nut. This returning wave can interact with the hammer over the 2-5 ms the hammer remains in contact, during which time the hammer cover is dampening some of the higher frequency energy from the partials which each pulse contains. Additionally, the hammer hardens as it compresses into the string, and the harder you hit the key the more it will try to compress and the harder it will become, and this non-linear behavior is critical to achieving the right sound.

This is by no means a bad thing! Stick a tack in an old felt hammer and strike the note and you will hear a very sharp attack and a very metallic and brash sound emerge. In this case, no significant damping has occurred, the tack acts to reflect the energy back down the string, and all the partials are so pronounced as to create a cacophony of noise. Now put a blob of bubble gum or putty on the tack and listen. A dull and faint sound emerges, consisting of the remnants of the fundamental without any partials to speak of. Here we see the two extremes of what we can get from a hammer. We want a fundamental rich with the partials but at desirable amplitudes so that they convey 'color' but without harshness. This is the spice in the pudding, wanting neither too little or too much.

How we get this sound out of our piano is the critical basis for choosing the right material. Unlike our friends with more modern pianos, we will have less control over the final voicing by needling or sanding. Needling leather has no effect, as the material is very much more integrated internally than felt, and sanding the sides is only marginally likely to result in a harder final impact surface, and can actually soften the effect, as the leather integrity is reduced!

For us, the voicing will come from choice of leather, technique and tension of applying, and number and thickness of layers. Regarding the leather choice, we are really choosing several things, namely:

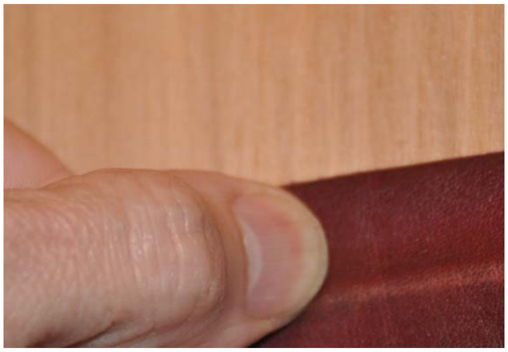
Animal from which it was obtained

Tanning method

Degree of post 'work' and post treating

Which side is presented outwards to the string

Before we can address all these, we return to the original question of what gives the best sound. We want something firm enough to impart sufficient energy to the string for a full effect, leaving that right recipe for partials to sing. This implies a need for a resilient surface, but not too hard or too soft. Empirically (which is really the only true way to find the 'best' sound) we see that if you press your finger nail into leather that springs back with no more than the slightest trace remaining, it is considered very resilient. If the impression persists, it really is not. You can try this both with a quick impression and a long term (perhaps 15 minutes) impression to reveal differences in closely resilient leather species. Try this on both the smooth and nappy surface.



You can see the indentation clearly in this chrome tanned leather above, not at all in the vegetable tanned deer shown below.

The resiliency of leather is largely a function of the way it was treated and tanned to get it from the animal to you. The process of removing it from the animal, and removing the hair/fat/tissue/etc. is all largely the same, involving washing, scraping, and lime treatments to clean the surfaces. We can then choose one of three basic tanning approaches:

Vegetable tanning

Brain/oil tanning

Chemical tanning

Vegetable tanning is the oldest method, dating back to prehistory. It involves treating in tannic acid from plant/tree material, often with several tree species combined for the best results. It is generally slow (6-12 weeks), involves numerous manual bath changes and stirring, and results in leather that will need to be physically worked and oiled to become flexible again. Leather from vegetable tanning is among the most resilient in general, but wide variation can be found, so sorting among the best is still required.

Brain tanning involves wetting the leather to soften it, then drying by blotting only and liberally coating with lightly cooked brain material. It is an old proverb that, except for the buffalo, every animal possesses just enough brains to preserve its own hide, dead or alive! So about a skulls' worth of brains are needed for a whole hide. Cow and pig brains are readily available cheaply. This is a fast process taking a few hours to a day to complete, thus it was desirable. It can also produce very resilient leather, but usually very soft as well, so the attack is diminished with brain tanned leather on small late 18th and early 19th C squares. Excellent for later squares and grands with larger hammers, and those dampers in Viennese Fortepianos though!

The oil tanning method is another exclusive and dedicated process, and today it seems to be in use solely to render chamois-type leather for good water absorbency. Typically the hides are from lamb or sheep, where Cod Liver Oil or other animal oils is used in an unoxidized form. This leaves tanned hides made for garments, gloves and filtration products. Brain tanning is a form of oil tanning. **A noted early piano restorer** has advised us that an "analysis he conducted on the skins found on a 1769 Zumpe and a 1793 Stodart Grand were both found to be identical (skin side out) veg-tanned sheep. The leather used on English squares from c1800 onwards was oil-tanned Chamois (the alpine goat-like animal Rupicapra-rupicapra). However beware, an c18th sheep bears no resemblance to today's animal which has such a relatively massive coat, the skin structure is compromised (for our purposes)." We will add that there are some restorers using the skin of the 'hair sheep' (haarschaf in German, breeds like the German Landschaf, the Lincoln, and the English Lonk and similar) but these are not the same creature as found in the 18th century shops. Ultimately, we must choose what sounds best, as will be discussed later.

Chemical tanning generally means chromium sulfate tanning, which rapidly complexes proteins and tans the leather in hours. This leather has excellent durability, water resistance can be made high, and flexibility is preserved, so great for coats and apparel in general. But the resilience is usually quite poor, and it generally fails our finger nail test. At its worst it can seem gummy and will give a sound similar to our putty experiment. It is therefore not so good for hammers, so you will hear the experts extolling the virtues of vegetable tanned leather, for the reasons we have now laid out.

Surprisingly, the animal from which the leather was obtained is rather a secondary consideration. Deer, goat, sheep, and calf can make good covering material, though it seems that goat and deer are more likely to be found appropriate in English square pianos. A full grown cow or horse has a hide so thick you would need to do some significant skiving or thinning to use it, thus altering the response. Very thin leathers from small animals are likely to be too thin without adding layers, which again impact the result. But good quality goat and deer are excellent, resilient without being too stretchy, and tough. Stretch is how the leather gives as you pull it. In general, the leather has a fair amount of stretch in the direction of the animals' girth, not so much from front to back. Sources of fine leather include Herzog in Germany, Peter Kendlbacher in Austria, Heckscher in the UK (look under 'B' for butt leather), and numerous cottage industries around the world. It is often stated that no vegetable tanned leather is available in the US, but through on-line auction houses such as EBay one can frequently find small industry or family made leather that has excellent properties.

Post treating can be grouped with the tanning process, and speaks to how much working or skiving the leather sees, or pouncing with alum, lanolin, etc. We can accept the final product as the tanned and treated leather and evaluate it from there.

The side you present to the strings can be the smooth side from where the hair was removed, or the flesh side which is rougher and nappy. After about 1785 the square piano manufacturers began turning the leather nappy side out; before that it was all smooth side out. Both wear about the same, but the nappy side makes superior magic with the partials and produces a generally more pleasing sound. So we'll put the rough side out for all those later squares.

Once we have selected our choice leather samples, we need to think about thickness and how to apply them. The thickness of goat and deer generally falls into the 0.8-1.2 mm thick range. Thinner leather for the treble, thicker for the bass, is a great rule, but how thick to use is largely a matter of taste. In general, thicker leather will leave a softer overall hammer cover, so for a brighter sound choose the thinner material. Most squares I have seen use leather about 1.0 to 1.2 mm in thickness, at least as they appear today. They may have seen a little shrinkage by the time we could measure them though!

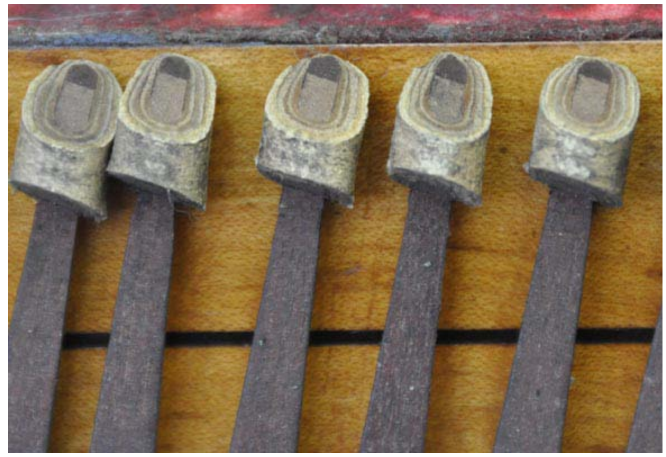
As far as the number of layers, on English instruments there were always at least two, usually three, and sometimes four layers applied. In the case of four layers, the core layer is usually a plug of buff leather just on the top of the wooden hammer core, with the three layers covering that, and found on late 18th to 19th C squares. Earlier, we usually find two or three layers wrapping the core.

Leather is always glued to the bottom and sides only, never over the top surface, even for under layers. It can consist of a continuous wrap like a jelly roll or a set of flaps, but glue remains out of the string contact area all the way to the core. The layers must be in good physical contact, but not stretched so tightly they become hard. This was, and is, a technique that is acquired with practice. The optimum sound will come from a hammer that has the right resiliency and the right tension of the leathers. That said, a little practice and listening to the result can have you arriving at a very acceptable sound with a day or two of experimentation. Anecdotal stories of shops that had but one man capable of this task are likely overly interpreted. This was a business, and was run as such, and while division of labor may have specialized the workforce, this was true for many operations not so critical to the final sound. Sitting down all day in a warm room gluing on hammers was superior work to standing in the pit sawing wood, so it is likely that helped nudge this one into legend.

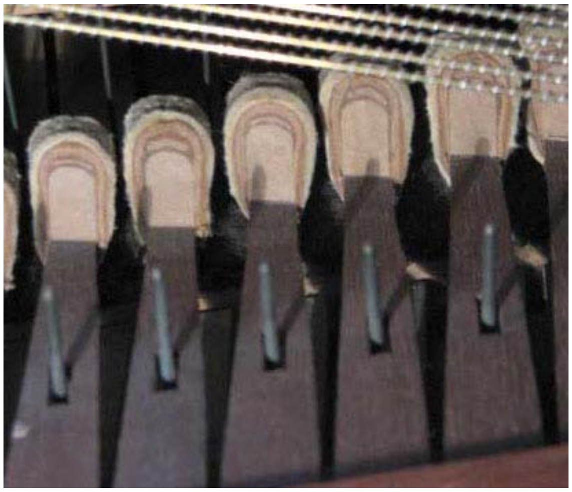
Trial and error will help you arrive at a great final sound. The size of your instrument, the scaling of the strings, and the method of snapping the hammer to the string will all contribute to the final sound as well. The hammer covering that works on lightly strung instruments may not service one from 20 or 30 years later. It seems a good way to decide is to re-leather enough notes for a chord or two, and try these out. You can pick out a dead sound quickly and adjust from a single note, but gradations of ‘great’ are trickier, and the comparison will benefit you. Appearance of a re-leathered hammer should be neat, but a nice look may not always have a nice sound. Leather is not very expensive, even the cottage industry vegetable type, compared to other items we may need, and once you find a good performing skin there is likely to be several pianos worth of material there.

Frederick Beck 1777, small rounded button core of lime wood with jelly roll winding, thinned on the bottom.

Broadwood, 1784, various orientations, showing triangular blade core and jelly roll winding.



Longman and Broderip 1787, with blade core and layered covers.



Longman and Clementi, 1799, with large core and jelly roll winding.