Introduction to the Piano for Piano Majors
The Mechanism/Action

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September, 2008

A piano action is extremely complex, and its condition has an enormous impact on the pianist's ability to learn and to perform. Hundreds of minute adjustments and procedures are necessary to make a piano into a fine musical instrument, capable of nuance and sophisticated expression. Understanding how the mechanism works will help you

- analyze and improve your technique
- communicate with piano technicians – to get the service you need, you must know what it is you want or need, and be able to explain
- oversee service of your own piano, possibly other pianos under your care, and advise others

Basics: A key goes down, a hammer goes up, sound is created

Keys are levers fixed on pins to keep them in place, and are allowed to pivot only a very small amount. When the front goes down, the back goes up.

Hammers are free-swinging in one plane, and are fixed in place so that each hits its own string(s).

There is an intermediate, complex lever called the wippen (or repetition), which conveys the movement of the key to the hammer along with other functions.

There is a "lever advantage" in the design: the key is depressed about 10 mm, and the hammer rises about 46 mm, for a nearly 1:5 ratio. Small movement at the keytop means large acceleration of the hammer. This design adapts the piano to the human hand and finger, and their possibilities of movement.

The back of the key also raises a damper, allowing the string to ring freely (the dampers comprise a separate "action").

Details:
<u>Key</u>

- A wooden lever, covered in ivory/plastic or ebony/plastic on the surface where the finger touches it.
- The key is located on a key frame, consisting of a front rail, a balance rail, and a back rail. The balance rail is slightly higher than the other two. At rest, the back of the key lies on the back rail. When the key is "played" (the front of the key is depressed by a finger), the front of the key contacts the front rail.

- The key rides on two pins: a balance pin (attached to the balance rail) holds the key upright, while a front pin (attached to the front rail) keeps it from swinging side to side.
- The key is bushed with a dense felt where it contacts the keypins.
- This bushing felt must be of very high quality. It is best for the felt to be lubricated, either with microfine powdered Teflon or a liquid solution of Teflon. This helps reduce friction, and thus wear of the felt, and also allows for smooth glissando playing, and for easier playing of passagework (which often presses the key against the pin, especially scale passages).
- The point of contact between the felt and the pin must be free but firm: there must be a very close tolerance, within .005". With high humidity, the felt may swell, causing additional friction and possible binding. With wear, the keys may become loose and sloppy feeling.
- Bushings may be eased (compressed by pressure with special pliers), ironed, or steamed and ironed to help size them to the pins. When necessary, they may be removed and replaced.
- At the base of each keypin (under the key) is a round piece of felt (key punching), to eliminate noise and to make for a cushioned feel.
- Under the felt key punchings are paper and/or cardboard punchings, to level the keys at rest, and to fine adjust how far a key may be depressed. These are adjusted to within .002" for height (balance pin) and .005" for dip (front pin).
- The felt punchings can pack, and the wood of the key can warp, so it may be necessary to adjust the key level and dip from time to time.
- Also attached to the key are the capstan, back check, and damper lift felt.
    - The capstan contacts the wippen, and is screw adjustable.
    - The backcheck stops the hammers movement and holds it in after it rebounds from hitting the string. It is on a wire that may be bent to adjust.
    - The damper lift felt contacts the damper lever.
- Most keys have lead weights inserted into holes drilled through the side of the key, to counterbalance the weight of the hammer and action assembly and reduce the effort needed to move the key.

<u>Hammer and Shank</u>

- The hammer head is very densely pressed wool felt, glued to a wooden core. This head is drilled and glued to a "handle" called the shank. The shank is hinged to a piece of wood called the flange, which is screwed to a rail.
- The "hinge" (action center) between the shank and flange is bushed with very dense felt. It is very important that this joint be very firm and also free. Tolerances for this joint are within .001". Too tight means sluggishness and possibly freezing up. Too loose means clicking sounds and loss of power and control.
- The screw holding the flange to the rail must be tight, or there will be clicking sounds and movement side to side. The screw is also used to allow fine adjustment of the alignment of the hammer to the strings.
- The glue joint between the hammer and shank must be solid (another source of clicking sounds).

- The hammer must be glued on the shank so that when it strikes the string, it is at precisely a right angle to the string. Fine adjustment can be made using heat, twisting the shank.
- The flange/shank must be tilted if necessary so that the shank travels precisely vertically. Small shims are used to make fine adjustments (called traveling).
- The hammers must be spaced precisely to their strings, and so that none of them rubs against a neighbor.
- Over time, from striking the strings repeatedly, the hammer felt will wear and compact. It must be filed and reshaped periodically, and replaced when worn too close to the wooden molding (true especially of the top few notes).
- On the bottom of the shank is the knuckle, a leather covered cylinder which is contacted by the wippen and used to propel the hammer to the string. The knuckle must be round and firm. It should be brushed periodically and lubricated with Teflon powder.

<u>Wippen/Repetition</u>

- This intermediate lever is screwed to its own rail, and has its own flange and "hinge" joint.
- There is a felt cushion on the bottom which contacts the capstan of the key. This is where the key propels the wippen.
- The jack (or fly) is hinged to the wippen lever.
- The top of the jack contacts the knuckle of the hammershank.
- The movement of the key is transferred to the wippen at the capstan/cushion, and then from the jack to the knuckle, thus propelling the hammer to the string.
- The jack has an escapement mechanism. Just before the hammer hits the string, the jack is tripped so that it no longer contacts the knuckle. (Otherwise, the hammer would jam against the string, and the string wouldn't be able to resonate).
- There is an additional part of the wippen called the repetition lever. Invented by Sebastian Erard, it is sometimes called the "double escapement." It is spring loaded, and also contacts the knuckle. Its upward movement is stopped shortly before the hammer contacts the string.
    - When the hammer rebounds, the knuckle contacts the repetition lever again and presses it downward, compressing the spring.
    - The hammer is caught after rebound by the back check. The tail of the hammer contacts the leather of the back check, and the friction between them holds the hammer in place until the key is released.
    - When the key is released, the spring tension of the repetition lever propels the key downward (through the capstan/cushion) and, at the same time, slows the descent of the hammer. This combination of actions allows the jack to re-engage under the knuckle before the key returns to rest position.

Regulation

This complex mechanism must be adjusted very precisely to give good results. All keys must function as nearly the same as possible so that their action will be predictable. Proper adjustment will allow for minute control of dynamics and tone production.

1. Let off – the escapement point of the jack. This should be as close to the string as possible, with a little distance as insurance against humidity change or other minor variance. When the key is depressed very slowly and with control, the hammer should come to about 1.5 mm (1/16") of the string or a little closer before the jack escapes.
2. Drop – the "escapement" of the repetition lever. The repetition lever should contact the drop screw at the same moment that the jack tail contacts the let off button. This gives a very precise and reliable feel to the action. You should be able to depress a key lightly until you feel this positive resistance, and then from that point, with a sudden rapid depression of the key, the hammer should very lightly hit the string for a ppp effect. This is a sign of a very well regulated action. When the key is depressed very slowly and with control, the hammer should come to about 3 mm (1/8") of the string or a little closer after the jack escapes.
3. Check – the point at which the hammer is caught when the key is held down after playing the note. The backcheck should be adjusted so that the hammer is caught about 10 – 15 mm from the string. The angle of the backcheck, and the condition of the hammer tail (it should be somewhat rough) are important to good function.
4. Repetition spring strength must be precisely regulated. If it is too strong, the hammer may double strike on a soft blow, and checking will not be reliable. If it is too weak, repetition will be slower, and there may be malfunctions.
5. Hammer height at rest (adjusted by turning the capstan screw on the key) should be about 45 mm from the string (the tops of the hammers should all be in a straight line with one another, with bass hammers at a higher level than treble). Packing of felt and leather makes this an unstable regulation that needs to be adjusted often. Failure to do so will affect aftertouch.
6. Key dip/aftertouch – the distance the key can travel from rest to the point when it hits its felt punching. This distance must be carefully calibrated so that the key continues to travel about 0.040" after let off occurs (this is the "after" touch). If aftertouch becomes too little, let off won't occur when the key is played lightly, and the hammer will bounce on the jack (and may double strike the string). Too much aftertouch means excess motion, requiring more overall effort to play the keys (the fingers move a greater distance). It also slows repetition, as the key must rise farther before the action resets.
7. Dampers – the damper levers should be adjusted so that at rest they are a specific distance above the back of the key. The key should contact and begin to lift the damper when it has been depressed about 3 – 4 mm (1/8" – 3/16"), and when the hammer is about half way to the string. When the key is played slowly, you should feel the resistance of the damper about halfway between rest and the point where let off and drop contact occurs. This means that the momentum of the key

helps lift the damper. If the damper is set to rise earlier, this can make the action feel heavy when played without the pedal, and it will accentuate the difference between playing with and without pedal.

8. Dampers must also be adjusted so that they lift (and return) at precisely the same time when the pedal is used.

Voicing

The sound and range of sounds a piano produces are affected to a great degree by the condition of the felt of the hammers. Altering the condition of the hammer felt is called voicing. Several techniques are used:

1. Needling. Needles are pressed into the wool felt to separate the fibers, making it less dense, softer, more resilient.
    a. A common treatment for relatively hard-pressed hammers, particularly in European factories, involves some 60-100 needle strokes per hammer, with a tool containing three needles. The needles are inserted in a very specific and controlled way, to create a pattern of felt density in the hammer. When this is done in a skilled manner, the hammers are capable of a wide range of tone colors.
    b. For any hammer, work with a single needle tool is done to refine the voicing, evening it out over the range of the piano.
    c. Very shallow needling is often done on the striking surface of the hammers to allow for a softer tone on a softer blow.
    d. Needling is often done "between the string grooves": in other words, in the area which will contact the strings when the action is in the una corda position, increasing the difference in tone color between tre corde and una corda positions. This may be further refined, making a gradation between full una corda pedal, half pedal and full pedal. This is found most commonly on concert instruments, and by no means all concert instruments.
2. Filing/shaping. The purpose of this is to create an even and rounded surface to strike the string. Wear creates "grooves" in the hammer which are flat relative to the strings. This creates a harsher and often less defined tone quality in general. Filing is necessary on a regular basis to maintain good tone quality.
    a. The sound created by a worn, grooved hammer, with its flat surface striking the strings, can be compared to "slapping" a table top with the palm of the hand. When the surface is re-shaped to a rounded profile, the sound becomes more like a "knock" with the knuckles of a fist.
    b. When hammers are too dull, due to over needling or other reasons, filing will make the tone brighter, as it will expose denser felt in the interior of the hammer.
3. Chemical hardening. Application of a thin solution of lacquer is standard procedure for New York Steinway hammers. The hammers are pressed less densely than many other hammers, and the application of the hardener makes the felt stiffer and produces a brighter tone. Following application of lacquer, filing

and needling is necessary to remove a thin “crust” of material that creates a very bright, objectionable tone.

   a. Application of a thin chemical solution, often acrylic plastic dissolved in acetone (which evaporates almost instantly) is a common procedure to brighten the tone of individual hammers as needed. This is particularly common in the top treble octave.

4. Many factors are very important to tone quality. The strings should be level (the three strings of a unison should be level to one another so that the hammer strikes all three strings simultaneously. This is a very fine adjustment). String terminations, at the bridge and at the agraffe or capo bar, must be clean and crisp. Hammershanks must be well traveled and the hammers square on the end of the shank so that they will hit the strings squarely. Regulation must be even. In sum, a number of factors must be in place before needles or hardeners are used.

The goal of fine voicing is to create the potential for a range of tone color in each hammer, and to make that even throughout the scale. The nature of the felt used for hammers is such that on a hard blow the felt becomes harder and rebounds faster. This means that more high partials are excited, or, more precisely, that less of them are damped during the shorter time the hammer is in contact with the string.

A tonal profile with more high partials makes the sound of a note stand out from among other notes played with slightly less force. The increase in loudness (decibel level) is far less than what is perceived by the human ear as a result of the additional high partials. Thus, this characteristic of a well-voiced hammer makes it possible to create a number of different tonal levels at the same time (“foreground,” “background,” “middle ground,” possibly more), to “voice” chords so that the top note (or another chosen note) stands out, to create a prominent melodic line above a harmonic background, and other aspects of pianistic nuance.

Unvoiced hammers are often fairly monochrome, either harsh and brittle, or soft and muddy. A characteristic of a well-voiced hammer is a range of partial mixes as the note is played successively harder. The actual tone color of the piano as a whole may vary considerably from instrument to instrument, but in any case, the hammers should be prepared so that they are capable of a range of color, and so that both piano and forte are possible without a great deal of effort.

Hammers are not the only factor in the tone quality of a piano. To a large extent, other factors will determine the tonal character the piano will produce. It is also necessary to take into account the use of a piano. A piano that is used for concerto with orchestra needs to be powerful and somewhat strident in character in order to penetrate the sound of the orchestra. For a chamber music situation, a more mellow character is appropriate, a sound that blends well with other instruments and is able to play softly and fit below other instruments when necessary. Unfortunately, concert instruments often have to fit both roles to some extent, so compromises are required.

Pedals

1. Una Corda – "shift pedal." This pedal shifts the keyboard and action toward the treble (there are rare pianos in which the shift is toward the bass), in order to change the color and volume of tone.
   - The entire key frame slides on the key bed. The key bed and key frame must be clean and lubricated, or there will be noises when the shift occurs.
   - The most common regulation has the hammers miss the left string of three string unisons and only strike the two right strings when the pedal is fully depressed.
     - This scenario requires very precise alignment of the hammers to the strings, so that each hammer misses at the same time when the pedal is depressed.
     - The amount of shift should be precisely adjusted so that when the pedal is fully depressed, the portion of the hammer felt hitting the string is softer felt, not the same felt that strikes the strings in rest position. (If the hammers are worn and have grooves, the felt between the grooves should be striking the strings).
     - Many, but by no means all, piano technicians voice the area that will be struck in the una corda position. Others simply rely on the fact that the "grooved" area of the hammer will be more compacted due to playing, and the rest of the hammer will naturally be softer.
   - The alternative regulation has the shift position include all three strings, and relies on less compacted (or more needled) felt to produce a different tone color.

2. Damper. This pedal lifts a "tray" (a pivoting strip of wood) that is suspended under the damper levers and behind the keys. The individual dampers must be regulated so that they are lifted by the key about 1/3 of the way through key travel. They are fine adjusted so that they lift with the damper tray and pedal absolutely simultaneously. This is very important for fine pedaling effects, such as half pedal, flutter pedaling, and lightly bouncing the dampers on the string to clear partially but not fully. It is also very important for times when the pedal is released very slowly.

3. Sostenuto. This pedal rotates a rod with a blade. Each damper lever has a "tab" that sticks out toward the sostenuto rod. The rod must be adjusted so that the blade misses all the tabs when the dampers are at rest, but catches all the tabs when the dampers are raised by the key. Thus, it will catch and hold up all the dampers that are in a raised position at the time when the sostenuto pedal is activated.
   - The tops of the tabs of the dampers that aren't being held up by the sostenuto pedal will press against the bottom of the sostenuto blade. On many but not all pianos, the tabs are hinged and spring loaded to allow for this. On other, usually older instruments, with fixed tabs, there may be a feeling of resistance in the key when contact is made. It is possible to make small adjustments to the regulation to alleviate this.
   - The sostenuto pedal is most commonly used in conjunction with the damper pedal, with a few notes held by the sostenuto for a period of time while the damper pedal is used in a normal fashion. The sostenuto pedal must be released

after or at the same time as the damper pedal. If the sostenuto pedal is released while the damper pedal is depressed, the blade of the sostenuto rod will rotate and press down on the tops of each of the tabs, creating a considerable noise. This is simply a fact of life, and cannot be avoided.

The feel of a well-regulated action in good condition:

- Lightly rest your fingers on a group of keys, and move your hand from side to side. The keys should feel firm, with a very little side play, and any "knock" from side to side should feel cushioned. Excess side play and a significant knocking feel mean bushings are worn or possibly have been over eased.
- Lightly depress the key. You should feel two points where there is additional resistance. The first is the key coming in contact with the damper lever, which should happen at about 1/8", or about halfway to the second point of resistance. This should be consistent throughout the keyboard (except the top two octaves or so, where there are no dampers).
- The second point of resistance is the most important. This is where escapement happens. The point should feel defined, not spongy. It is easier to feel this point if the damper pedal is depressed.
- Pressing through the second point of resistance, the feel should be of smooth, even friction over a short distance, followed by a short "free fall" where there is no resistance (aftertouch). This feel should be consistent from key to key. It is particularly common to find differences in aftertouch between naturals and sharps. This is a defect in regulation and should be corrected by the technician.
    - To feel this aspect of regulation, it is helpful to depress the damper pedal, so the weight of the dampers is removed from the picture. Rest the fingers of a hand on five adjacent keys (either naturals or sharps) and very lightly and sensitively depress them until the point of resistance is felt. Then, holding the hand and the other fingers in position, press each finger in turn through to the bottom of the keydip. With practice, this becomes a very good way to feel the evenness of the regulation, and to sensitize your fingers to the feel of the piano.
- Do a very soft, slow glissando up and down the keyboard, using the fleshy part of the fingers held at a very sharp angle, with very light pressure. There should be minimal and even resistance.