Hammer-String Interactions in Piano Sound Production

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Introduction

As he stands up after rehearsing for a recital the Brazilian pianist Nelson Freire looks sideways at the piano and says to the camera crew recording his documentary "This piano doesn't like me. I don't know why, I haven't done anything."[1] For pianists one of the big issues to be dealt with in any performance is the instrument they are playing on. If asked, any pianist can tell of an experience involving a performance on an instrument that sounded too mellow or too bright. While a proficient performer has to know how to work around such issues, it is still interesting to know why such situations occur. What makes the sound of a piano brighter of darker?

According to McFerrin, the timbre of a piano is related to how the string is divided into its vibrating parts as well as how it is activated.[2] He mentions other factors such as pedal use and unavoidable noise which can affect timbre as well. It is also common knowledge among instrument-owning performers that a cracked sound board can have a negative influence on the quality of the sound produced.

Since the main source of sound for a piano is the hammer-struck string, this research paper will focus on how the hammers and strings interact during performance and the sound resulting from such interactions. To this end, this paper is divided into an analysis of the structure and movement of the hammers and strings as well as how they interact for sound production. This will be followed by a short conclusion section in which practical applications will be described, based on the information provided in the main body of the paper. It is important to point out that, as the piano action system has not changed much over the past century, it was not necessary to search for extremely recent bibliography.

1. *Nelson Freire*, directed by João Moreira Salles (2003; Rio de Janeiro, RJ: VideoFilmes, 2003), DVD.
2. W.V. McFerrin, *The Piano – Its Acoustics* (Wakefield: Wakefield Item Press, 1972), 45-53.

The Piano Hammer

The piano hammer is described by Fletcher and Rossing as being part of a complex action system which makes it possible for energy to be transferred from the performer to the string.[3] According to them, this transfer process is started when the player presses down a key. This causes the far side of the key to be raised, raising also the capstan and rotating the whippen. In this way the jack is pushed against the hammer knuckle and the hammer is projected towards the string. Once the hammer has struck the string, it rebounds and the backcheck keeps it from bouncing back towards the string again. Figure 1 shows a sideview of the action system described above.

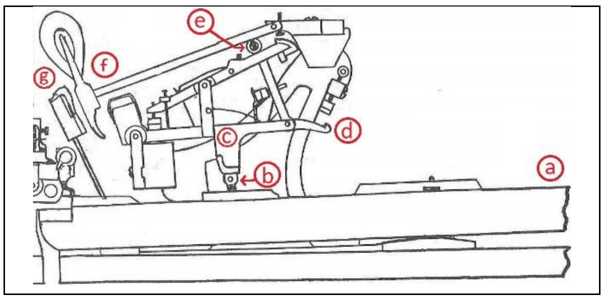

Figure 1. Grand piano action system. Labels have been added to highlight the parts of the mechanism active in the stages described in the text. (a) Key. (b) Capstan. (c) Whippen. (d) Jack. (e) Hammer knuckle. (f) Hammer. (g) Backcheck (Figure adapted from Comparetto, 2017).

The hammer itself is constructed under specific guidelines to guarantee optimum timbre quality. According to Fletcher and Rossing, grand piano hammers are made of hardwood covered with felt.[4] Their masses (and sizes) vary depending on the range of the piano they will be used for – 10 g for the bass hammers and 3.8 g for the treble hammers. Density of the felt also

3. Neville Fletcher and Thomas Rossing, *The Pysics of Musical Instruments* (New York: Springer-Verlag, 1998), 354

4. Fletcher and Rossing, 366.

varies. Fletcher and Rossing stress that harder hammers are better suited for activating higher pitches, so that the felt used for the treble hammers is harder than that of the bass hammers.

McFerrin sheds some light on the topic of hammer felt density.[5] He explains that hard felt will allow upper partials to be developed when the string is struck and that soft felt will keep this from happening. The presence or absence of upper partial is what makes the piano sound bright or mellow, respectively. By way of example McFerrin describes two scenarios in which the state of the felt can negatively affect the timbre of the piano sound as well as how to remedy the faults. The first is if groves have been worn into the felt due to use. These will wrap around the string as it is struck, cancelling the upper partials, and causing the tone produced to have less brilliance. In this case, a piano technician can remove the groves with sandpaper and restore the hammer to its proper shape. McFerrin states that the opposite can also happen. The felt can become so hardened from use that it produces too many upper partials. The excess brilliance that results can be lessened by sticking needles into the hammer. This technique is called voicing. In Figure 2 Fletcher and Rossing have diagramed the proper piercing spot for achieving soft, medium and loud playing.[6]

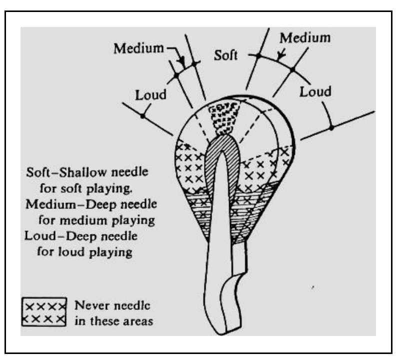

Figure 2. Areas of the hammer to be pierced, depending on the desired amount of voicing (Fletcher and Rossing, 1998, 372).

5. McFerrin, 45-50.
6. Fletcher and Rossing, 372.

The Piano Strings

As the size and mass of the hammers vary across the range of the piano, so do the strings. Fletcher and Rossing inform us that the treble strings are made of solid steel wire while for the lower strings, a solid core is wrapped with wire, usually made of copper.[7] According to them, the vibration of the string, caused by the hammer strike, is the main means of transmitting energy to the sound board.

McFerrin goes into great detail as he explains the dynamics behind the differences between the lengths, diameters and structures of the piano strings.[8] He starts by explaining three basic laws under which strings as vibrating bodies fall.

The first law governs the length of the string as it relates to its frequency. It states that if a length of vibrating string is shortened by half, the resulting tone will be an octave above. Subsequently, and an octave and a fifth above the original tone will be the result if the same string is reduced to one third, and so forth up the harmonic series.

The second law governs the tension of a vibrating string as it relates to the frequency produced. It states that its frequency is proportional to the square root of its tension, represented by the ratio $f/\sqrt{T}$. As McFerrin explains, this means that in order to reach an octave above the original frequency (double), the tension (T) will have to be multiplied by four (2^2). To reach an Octave and a fifth above the original (three times), "T" must be multiplied by nine (3^2). This relationship goes on to multiply "T" by sixteen (4^2) to reach a pith that is two octaves above the original one.

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7. Fletcher and Rossing, 362-65.
8. McFerrin, 19-30.

Finally, McFerrin explains the third law, which governs the diameter of a vibrating string as it relates to its frequency. It states that if the mass per unit length of a string is increased, its total length can be shortened keeping the same frequency. McFerrin explains that this is the reason why the bass strings are wound with copper. A core wire wrapped in copper makes it possible to keep the tension, length, and mass of the bass strings within a proportion that is feasible. If this method were not used the wires would have to be either thin and extremely long or short and extremely thick (and rigid) in order to reach the correct frequencies.

Hammer-String Interaction

Now that the basic dynamics of the hammers and strings have been established, it is possible to move on to greater depths of how they interact with each other. McFerrin says that how the string divides into its parts is a determining factor in the timbre of the resulting sound.[9] This division is affected by the point at which the hammer strikes the string, the characteristics of the hammer, and the characteristics of the striking movement, among other factors such as pedal use and unavoidable noise. How the quality of the hammer affects the string has already been discussed. Therefore, the focus of this portion of the paper will be primarily the striking point and the striking movement.

According to Fletcher and Rossing, when the hammer strikes, it divides the string in two and generates pulses that travel down both the lengths of the string.[10] The hammer is then slowed down by the string and, as the pulses return from both ends, it interacts with them (affecting and being affected) and is launched back away from the string. McFerrin describes this interaction

9. McFerrin, 45.
10. Fletcher and Rossing, 44,45.

when he discusses how tone quality varies depending on whether the attack is fast (percussive) or slow (non-percussive).[11] According to him, the speed of the key attack will determine how long the hammer will be in contact with the string. If the attack is slow, the hammer will stay in contact with the string for a longer time. As the string brushes against the felt of the hammer multiple times before launching it back to its original position, the upper partials are cancelled. This reduces the brightness of the tone produced. Conversely, it the attack is fast, the hammer will be immediately repelled, having little cancelling effect upon the string. This will allow more upper partials to be heard, creating a brighter timbre.

The relationship between hammer speed and tone quality is confirmed by the pianist Claudio Richerme in his research comparing the percussive and the non-percussive attack.[12] By way of a spectral comparison of both attacks (Figure 3), he was able to show that a percussive attack activates secondary overtones, in between the overtones normally produced by the piano. With a non-percussive attack, on the other hand, these disruptive harmonics are more subdued, which in turn makes the sound more pleasing.

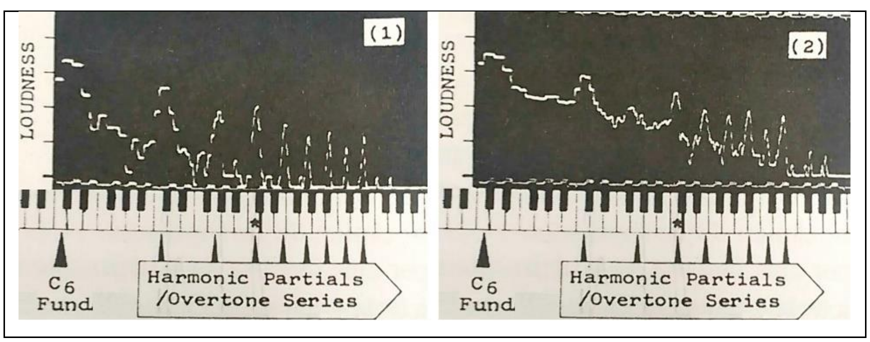

Figure 3. Spectrum analysis of non-percussive attack (1) and percussive attack (2) (Figure adapted from Richerme, 1997).

11. McFerrin, 50-57.

12. Claudio Richerme, *A Técnica Pianística: uma Abordagem Científica* (São João da Boa Vista: AIR Musical Editora, 1997), 28-29.

One final important aspect to point out regarding the hammer-string interaction is the point on the string that is struck by the hammer. According to Bernard Richardson, the hammers are positioned on most pianos so that they strike the string roughly at 1/8 or 1/9 of the length of the string.[13] The reason he gives for this is that at such a point there is a compromise between the strengths of the low and high partials created. Fletcher and Rossing explain this further by saying that, if the string is struck closer to the tip, the fundamental will be too weak (in comparison with the upper partials), creating a shrill sound. On the other hand, striking the sting too far towards its middle portion will cause the hammer to remain in contact with the string for too long, reducing the clarity of the sound produced.

Conclusion

Although it is not necessary to know how a piano works in order to play it, understanding how an instrument works is important for several reasons. The first is that such knowledge can better equip a performer/instrument owner to perceive when maintenance is necessary. As has been shown, excessive tone brightness or lack thereof can be dealt with quite simply by a technician. Having a well-maintained instrument to practice on is fundamental in preparing for the performance of a piece, for it will result in less estrangement when playing on a concert-level instrument.

Secondly, understanding the dynamics behind the hammer-string interaction can aid in comprehending and explaining the difference between a percussive and a non-percussive touch

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13. Bernard Richardson, "The Acoustics of the Piano," in *The Cambridge Companion to the Piano*, ed. David Rowland (Cambridge: Cambridge University Press, 1998), 96-113.

and the sounds resulting from each. In practice, making this distinction is often intuitive and quite some time is usually needed before students can achieve a well-rounded, non-percussive tone. The knowledge attained during the writing of this paper will be invaluable in helping the student understand the non-percussive attack.

Finally, this information has practical applications for performing New Music. Some composers are very specific when they notate extended techniques and distinguish, for instance, between plucking the strings with the finger tip versus the finger nail. Others, however simply write “pluck the strings,” leaving the decision of “how” or “where” to the discretion of the performer. Understanding how the activation of a string will affect the timbre of the sound produced can greatly aid the performer in exploring different methods of producing sound on the instrument.

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