The string ’after length’ of the cello tailppiece : History, acoustics and performance techniques

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In a long term study of cello tailpieces, we have first identified the vibrating modes of a cello tailpiece mounted on a dead rig [1], and have worked on the possible influence of the wood on theses modes [2]. The influence of the position of the tailpiece on the modes and on the sound has also been explored, by varying the "after-length", i.e. the distance of the tailpiece to the bridge which leaves a small length of vibrating string. Here, our study takes a more historical path to identify the trends and theories on this "after-length", and the changes in the history of the cello. Then the few texts of the 19th century mentioning its role on the sound of the cello will be studied. A synthesis will be tempted on the effect of setting-up the tailpiece: modal analysis results on the acoustics of the tailpiece and historical research lead us to understand a change in production in the violin trade.

1 Introduction

Like in any bowed instrument, each string of a cello is tuned by the peg in the peg box under the head of the instrument. At the other end, the string has a knot or blobbed end arranged by the string maker that stops it into a hole drilled in the top end of the tailpiece. The bottom end of the tailpiece is in its turn attached with a loop of some kind of string around the button or the endpin of the instrument.

We explore in a first part the history of the cello tailpiece, from iconography, remaining artifacts and texts. Then, we'll see the links in the set up between length of tail piece, length of tail cord and the different *after length*s. We'll explore the different theories as well as the so called "theory of the 1/6th". We attempt to make connections between the synthesis of our acoustic experiments whith that of the opinions on the tuning of the "*after length*", its acoustics and the perception of sound when varying the position and length of the cello tailpiece.

2 History of the "cello" tailpiece

The tailpiece, like in all instruments of the violin family, is a fixture that has changed in time with the stringing and set up of these instruments. The lack of technical texts on violin making before the 19th c. leads us to study the iconography of violoncellos, which is quite rich and diversified. Dutch, Italian and German 17th and 18th century paintings can be relatively credible in terms of proportion, as well as some "*Natures mortes*" by French painters, quite reliable as far as technical details are concerned. We still have to stay circumspect about measurement taken on paintings [3], but these representations often show a great interest in the instruments themselves, which were considered at the time as technically innovative.

2.1 Iconography

When studying the iconography of the *cello*, we can divide the corpus into two main historical stages of the history of the instrument, keeping in mind that these stages overlap depending on places and musicians : the time of the *Basso di violino* in the 16th and 17th centuries, and the time of the *violoncello* after the invention of the wound string. Effectively, as Stephen Bonta has shown [4], the development of the wound string during the second half of the 17th century, gave the possibility of shortening the string length of the *Basso di violino*, thus permitting the beginning of a new instrument of the same tuning, more suited to virtuoso playing techniques: the *violoncello*. Brenda Neece has shown the change of bridge placing in Britain as below the ff holes in the late 17th century, then at the bottom of the f-holes, and later, from 1775, a position of the bridge at the nicks of the f-holes [5], but this cannot be generalized as a strict chronology.

In the Pieter Claez painting figuring a *Basso di violino* painted in 1623 (**Fig.1)** nevertheless, the bridge is placed at the nicks of f-holes, from which we conclude that there was no standard in this matter. Here, the distance between bridge and tail-piece is proportionally very small, with a particularly long and flat tailpiece, whose shape has an intricate outline, showing remains in the baroque era of Renaissance fixtures, but much simpler (see below the large Renaissance tailpiece Musée de la musique E.999.9.1).

Figure 1. *Basso di violino*, Pieter Claesz (c.1597–1660), Still-Life with Musical Instruments, Harlem, 1623, Musée du Louvre RF 1939-11.

This distance between bridge and tailpiece depends on the length of the tailpiece in relation of the position of the bridge, and determines a small vibrating string length behind the bridge that is the point of this article. In the Claez representation of the *Basso*, this distance is featured as less than a sixth, of the played vibrating string.

On Dirk Hals' self-portrait as a *Laag van viool* player in Fig.2 painted in the first half of the 17th century, the tailpiece is also quite flat, but made with straight edges, as a dove tail, the distance between the tail piece and the bridge seems to be about a third of the vibrating length.

Figure 2. Dirk Hals' self-portrait as a cello player, (1591 – 1656) Akademie der Bildenden Kuenste Oil Inv. 734, Vienna.

A representation of a *basse de violon* can be seen in the *Grande chapelle royale* of the *Chateau de Versailles*, built by Hardouin-Mansart between 1698 and his death in 1708, and was then finished in 1710.

Figure 3. Basso di violino, Chapelle royale du Chateau de Versailles. Photo A.H.

The tailpiece still seems quite flat, it has no stopping nut for the strings, and it appears quite long. The tail piece is of a tail shape, and the distance to the bridge looks also smaller than a sixth of the string length. Notice the large diameter of the bare gut strings not allowing having the smaller string length of the violoncello.

After 1720 however, the French court will progressively adopt the new violoncello, which the Bolognese virtuoso and composer Domenico Gabrielli had adopted in the 1680's. Still be used for accompaniment with *Basso continuo*, but gaining in virtuosity, with a thinner neck and thinner bass strings, the cello becomes progressively more of a solo instrument.

The founder of the French school of cello playing, Martin Berteau (1700-1771) had many students, including the eldest of the two brilliant cellists Jean-Pierre (1741-1818), and Jean-Louis (1749-1819) Duport. Here we can see a tail piece that is more rounded in section, distant from the bottom saddle, and seems of similar proportion of after length as in Fig 5.

Figure 4. Nicolas Lépicié (1735-1784), sanguine. Localization unknown.

The painting by Henri-Horace Roland de la Porte shows a cello may be dating from the classical era around the 1770's.

Figure 5. Henri-Horace Roland de la Porte (1725 - 1793), La table du musicien, 18th c. Musee Municipal of Cambrai no. 152767.

The tailpiece is now plated with ebony and also of a tail shape. The distance from the string hole of the tailpiece to the bridge seems again more like around less than 1/6 of the string length. Here, the attachment at the bottom of the tail is relatively long compared with the preceding representations.

By the 1770's, concerto and chamber music players use transitional bows and bridges, as well as thin cello necks with higher angles, ebony plated fingerboard and tail-pieces, and long and thin double-curved bows having hair further away from the sticks. Here, the musician applies much more strength and weight on the stick of the bow and attacks the string much nearer to the bridge. The tailpiece seems again more rounded like in Fig. 5, and near the bottom saddle at the lower part of the cello. The neck seems proportionally longer (represented too long?), and the space between the relatively smaller tailpiece and bridge looks like it is about an eighth of the string length.

Figure 6. The Remy Family in Bendorf near Koblenz, 1776 (oil on canvas), Zick, Januarius (1730-97), Germanisches Nationalmuseum, Nuremberg, 330191.

The modern cello was then born, but changes in playing techniques, musical taste, sound expectations and the technology of string making drove more changes in the 19th and 20th century, that remaining tailpieces and texts can enlight.

3 Remaining tailpieces artefacts

The set-up of instruments of violin family is only maintained in position with the tension of the strings: as soon as you take the tension off all the strings, the bridge and the tailpiece fall. This happens when the instrument is not played or when all the strings are changed at the same time. The innovations in string making have led to changes in the tailpiece [7]. Detached tailpieces of the 17th and 18th c. have been given by Jean-Baptiste Vuillaume to the Museum in Paris, and some other belong to that collection which are not associated to instruments. They can be related to the iconography.

One can see that the more intricate shapes of the Renaissance and of the first baroque period have been replaced by the simpler shape of a bird tail, and undecorated tailpieces around 1700 got hard ebony facings to lessen the ware by wound strings. Innovation can be seen in n°5 with the holes with slots, which we will find in the late 18th c. The solo technique developed by musicians during the 18th c. led to more pressure on bridge and strings (see Fig.5) and we can see then new innovations on the tailpiece first applied to violins, then on cellos: Slots that facilitate the change of strings with ready-made knots (Fig.7 n°6); a metallic wire replacing the gut (Fig 7. n°6); good quality tailpieces made in solid ebony, the first conserved in Paris being on the 1766 violin by Richard Duke (Fig.7 n°7); a stronger curvature (Fig.7 n°7); a nut that stops the strings above the holes, and holes with, the first tailpiece of that kind in the collection in Paris is that on a violin by François Lupot (Fig 7 n°8).

Figure 7. Tail pieces kept in Musée de la musique :
1. 6-strings tailpiece, MM E.999.9.1, Rotschild's sale.
2. 4-stings tailpiece, MM E.487 C.161 Given by Vuillaume, ascribed by him to Stradivari.
3. 4-strings tailpiece ascribed to Amati Brothers 1695 given by Vuillaume E.903. 1.
4. Cello tailpiece with inscription « Stradivarius », 17th c. E.619 C.193 given by Eugène Gand 1874.
5. Cello tailpiece ascr. to Stradivarius, E.486.2 C. 192, given by Vuillaume 1873.
6. Cello tailpiece ascr. to Stradivarius, c.1720, E.486.1 C. 192, given by Vuillaume 1873.
7. Child's cello tailpiece, Léopold Renaudin c.1780. E.981.4.1. 8.
8. Modern 19th c. cello tailpiece, mounted on the cello made in the 19th century from a re-cut 17th c. bass violin M.M. E.974.10.1.

A very few 18th c. cellos remain with original fittings. In this study, we can only mention a rare cello by Lambert in Paris (Private collection) with settings from the second half of the 18th century has a tailpiece painted black and measures around a third of the string length. The *after length* measures 0,19 times the string length of the instrument, so about a fifth of the vibrating string, tuned near the fifth harmonic.

Sauveur had discovered that harmonics and partials can be different, thus separating in 1702 the science of acoustics from the theory of music. But the use of proportional tools for designing musical instrument from the divisions of the monochord stayed a constant in instrument making, thus linking visual proportions to the production of sounds.

4 19th and 20th century writings

Technical writings on musical instrument making started at the end of the 18th century, but we didn't find any written detail on tailpieces before 1840 in Louis Spohr's violin method [8] were he mentions the importance of tuning the "after-chord" and develops a special tail piece permitting the musician himself to do so. German violinist, conductor and compose, Spohr belonged to that interdisciplinary melting pot of musicians, physicist and instrument makers that met regularly in Germany at the time, and sang together at meetings [10]. In the 1830's, he was in contact with Johann Heinrich Scheibler, issued from a silk manufacturer dynasty, who, as an amateur musician, became interested in the tuning of piano with tuning forks. He experimented and designed apparatus, like the "*tonometer"*. He submitted his invention to the Science Academies in Berlin, London and Paris, in the hope to have enough recognition to market his inventions in the musical world, where Spohr was his strongest support [10]. As Jackson suggests, mechanical precision was becoming a strong economic pulse in the acceleration of mechanization, and the trend of the time was to get finer measurements, which Scheibler tried to apply in the tuning of musical strings. Combination tones, the over tones heard by musicians that Tartini advised his students to listen to while playing, had been in question during the 18th century and were still not clearly understood. But a violinist is inclined to listen to what we call the harmonics produced by his playing, including those produced by the *after length*.

The Spohr *after length* adjusting tailpiece is described by Otto in 1848 [9] and later in 1885 by Heron-Allen [11] and consists of a metallic tailpiece with sliding nuts that press the strings in order to stop their length at the location desired.

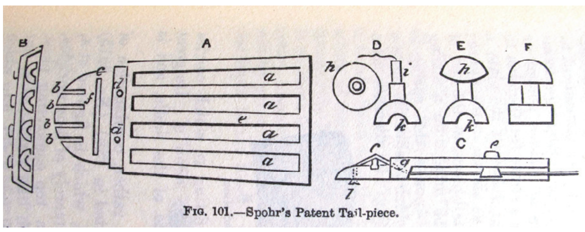

Figure 8. Spohr's patent tail-piece, Heron Allen p.193.

Heron Allen's comment is "By moving them to and fro in their respective openings, those portions of the strings between them and the bridge are lengthened or shortened, and thus the different intervals are obtained." This "might tend, perhaps, to modify little inequalities of tone in some instruments, or prove advantageous in other respects." "This contrivance is very scientific and ingenious, but has been but little used."

In 1895, in his book devoted to the violin, August Riechers says nothing on the cello tailpiece, but many details on the violin's tailpiece: *"This part of the instrument exercises a great influence on the tone, although the fact is doubted by a great many performers."* He is the first to mention the "saddle of the tailpiece" (see Fig. 7.8) and its size: "*The semi-circular ridge at the upper end is called the saddle and must project about 1 m/m."* He insists on the importance of the after-length left by the tail piece in relation to its length: ***The length of the strings below the bridge from the upper edge of the same to the saddle on the tail-piece should be 55 mm. and then the A-string behind the bridge will give the high E.***

The standardization in the violin set up is apparent since the beginning of the 19th c., but while Heron Allen presented the tuning of the *after length* as an unused adjusting method, Riechers is then presenting it as a fixed "scientific" rule: he gives the position of the saddle that stops the strings on the tailpiece, the length of the tailpiece and the distance to the bridge, which for a standardized string length "should be of 55 mm in order to get an *after length* tuned an octave and a fifth above the tuning of its vibrating string. However, his justification for this is not credible: changing it would modifies the tension of the four whole strings : "*If the proportion of the tail-piece to the bridge be changed, that is to say, lengthened or shortened by the use of a larger or smaller tail-piece with the same length of the tailpiece fastener, the tension of the strings also becomes altered, and the tone and vibrations are thereby affected.*

If, for instance, the tail-piece is so constructed that the portion of the A-string behind the bridge gives F, the other strings must also be correspondingly slackened, for ***the tension of a string reaches not only from the bridge to the nut as many suppose, but from the tail-piece to the peg****.*

In consequence of this, the pressure of the strings on the instrument can be increased or lessened by means of a longer or shorter tail-piece, whereby the tone is correspondingly modified. *"*

On can see here a presentation of a "scientific" approach wanting to estimate separately two aspects of the adjustment that luthiers would otherwise treat as a whole: the will to distinguish an independent effect of the *after length* on the tension of strings justifies for him the standardization of all dimensions, instead of judging the effect produced onto the sound the violinist can produce, which is the purpose of the violin makers' craft.

This promotes and justifies an industrially made tailpiece, like the violin fittings made in the manufactures in Markneukirchen and exported at the time all over the world. In fact, Riechers assumptions may have something to do with the US Würlitzer firm [12]: **Rudolph Wurlitzer,** an instrument maker born in Schöneck in 1831, had settled in Cincinnati, and his music business became the most successful ever in the USA. He sent his second son **Rudolph Henry Wurlitzer** to Berlin in 1891 to study violin, music history, acoustics and violin making with Emanuel Wirth, Oskar Fleischer, Hermann von Helmholtz and August Riechers. As we have seen with the relation between Louis Spohr and Scheibler, the link between Riechers and Würlitzer, between acousticians, musicians and the violin trade was very strong in Germany in the 19th century [10].

In 1924, Greilsamer recognizes also a big influence of the tailpiece on the sound quality. Its role, for him, is to stop the end of the strings after the bridge to vibrate in sympathy and to produce a bad effect on the general sound of the instrument. It should muffle and shorten the useless *after length* of the string. He is not interested in the after-length, only for its muting effect.

André Roussel's treaty was published in Germany in 1956. As an engineer, he has a mechanical view of the role of the tailpiece rather than an acoustician's, but he also has the experience of a practicing violin adjuster, and has worked with the luthier Charles Enel. He doesn't mention any tuning of the *after length*. He considers the all "chain" from the top nut to the bottom saddle at the lower end of the instrument: string length, and the distance between bridge and the lower part of the instrument including the *after length* and the tailpiece. For him, the all chain vibrates, and the principal influence and the mechanical role of the tail piece is its weight: if too heavy, its inertia will handicap the vibration of the whole, and the chain will tend to be stopped at the tailpiece's saddle, instead of vibrating to the bottom of the instrument thus wasting part of the energy that is not communicated to the bridge. If the tailpiece is too light, it will move so much as to be pulled too far by the bowing action, and then it counteracts the vibration of the bridge by moving out of phase. This softens the tone of the instrument. In consequence, he considers that the length of the tailpiece, should not be too near the bridge (the tailpiece is then heavy and not movable enough) nor too far (the tailpiece is then light and too movable).

5 The acoustics of the tailpiece

Recently, some patent on new tailpieces designs have again enhanced the necessity to tune the *afterlength* to certain musical intervals in relation to the tuning of the vibrating string, and sometimes with different lengths for the different strings. The studies on string *in-harmonicity* and the large diversity of string materials that may give different results in the tuning of four strings *after lengths* of the instrument may add new questions to a complex one and to an old debate

In our article presented at SMAC 2013 [16] we have applied modal analysis to study the effect of lengthening or shortening the gut attaching the cello tailpiece, as well as the changing the *afterlength* as well as the length of the tailpiece. The effects of the lengths in the "chain" = *afterlength* + tailpiece length + after cord has been described with modal analysis and related to tonal adjustment: We found that variations in the *after-length* from standard to smaller *after-length* do not significantly affect the tailpiece modes frequencies measured on a Dead Rig, nor the Bridge Admittance of the cello on which the set-ups were tried, except on the B1+ whose frequency was raised 2,5% with a -15, 8% *after-length* change. The *after-length* has been found to be more sensitive to diminution than to increase around the standard length.

Changes in the standard tailpiece lengths of 116 mm ± 5 mm did not affect sensibly the frequencies of the Cello Body Modes nor the perception of the tone, except where the flexibility of the tailpiece itself is involved. It is more in the variations of the tail cord that differences were measured. Frequency rises of + 25 % for a diminution of 54% of tail cord have been noted. The increase in frequency is significant with the diminution of the tail cord, and these changes were related to perception changes. It has been found that the air mode of the cello A0 is important for the quality of lower tones. The higher in frequency and the steeper is the A0 peak, the quicker there is saturation when pushing the string hard with the bow. On the opposite, when the A0 peak is moved and widened towards lower frequencies, the general tone of the instrument is lower, and the bow can be pressed harder. Thus, tailpiece adjustments can be used to move A0 in order to enhance these effects when desirable. Other factors are to be associated like weight and wood variations [12], and have as much importance in the tonal adjustments of the cello.

6 Conclusion

Our investigation led us to read how, after a debate on the influence of the tailpiece length, *afterlength* and gut attachment that started at the beginning of the nineteenth century, the violin's dimensions became much standardized. In 1895, Riechers presents the position of the tailpiece as a fixed "scientific" rule: he gives the position of the saddle that stops the strings on the tailpiece, the length of the tailpiece and the distance to the bridge, for a standardized string length. In consequence, all tailpieces of that time are heavier than before, stiffer with a tighter cuvature, with an ability to flexibility revealed only in higher frequencies.

The "scientific" approach described in technical documents of the time was aiming to persuade violin makers and musicians that fixed rules were necessary for the set-up of violins, and this helped the Markneukirchen industry to sell normalized part pieces for violins in Europe and in United States.

Separating two aspects of the adjustment that luthiers would otherwise treat as a whole, gave weight to a scientist view, and helped the industry: the will to distinguish an independent effect of the *after length* on the tension of strings justifies the standardization of all dimensions. This replaced the sensitive work of instrument makers: instead of listening and judging the effect produced by the violinist on the sound, and trying to enhance it by small adjustments, by trial and error, which is the purpose of the craft, the worker is applying fixed rules and measurements to adjust the sound. Thus, the industrial world has, here also, reduced the actions of the craftsmen and musicians on the musicality of the instrument.

When Tartini was using his gut strings and listening to the harmonics of his instrument to discriminate them, he was developing listening skills that may have permitted him even to hear the differences in tailpieces.

In seeing the tool marks on a 17th century tailpiece (Fig. 9), we can see how the maker can act on the flexibility of the piece. It could very well be that in earlier times, before the standardizations of the 19th century, some violin makers (probably the most skilled and informed ones) could tune not only the *after length but* also the tailpieces of the instrument itself, and harmonize the all "chain" from nut to saddle.

It is now tempting to conclude that once the making of tailpieces got in the hand of specialized manufacturers, violin makers could only standardize the string lengths in order to get good enough sound adjustments.

Figure 9. 17th century 4-stings tailpiece MM E.487 compared to a 19th century thick industrial cello tailpiece.

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