Why *f*-holes?

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This year is dedicated to a big project which is building a violin. During this year's BachoT_EX there was a presentation on the actual building of such an instrument. Just before the ConT_EXt meeting Hans Hagen came up with the question, why the sound holes in the violin has the shape of an f, and whether it would be possible to use another (glyph) shape. The article reveals new knowledge about these holes and discusses restrictions. Although sound holes had different shapes in the past it appears, that the wellknown f-shape has definitely technical advantages and fits the design of the instrument perfectly.

1. Introduction

Begin 2015 I got the opportunity to follow classes in violin building in Poznań, Poland. After my first stay I presented the development of my first instrument during the BachoT_EX. During the preparation of the ConT_EXt meeting Hans Hagen came up with an interesting question. Is the *f*-hole always identical and could it be another shape, another glyph as a sans-serif f? – This is indeed an intriguing issue. So I decided to do some investigation on the development of the *f*-holes.

During the tour through information related to the *f*-holes in string instruments I stumbled over an article published in February 2015 by the MIT (Massachusetts Institute of Technology). This article is the base for this article.

2. History

The MIT researchers present an overview of the development of sound holes in the past. They cover a period of about 800 years starting at the 10th century.

The sound holes started as circle round holes in different instruments. During time the shape changed into a semicircle, half-moon and later into a C-shape. To this shape more elements were added like circle round holes at the end of the shape and carving a kerf in the middle. Only in the golden time of the violin in the Cremona aera these holes were given the shape of an f. Different violinmakers experimented with this shape. In some cases they were shorter or longer, had a narrower or wider stem and the curves at the top and the bottom differ. – In general it can be said, that each violinmaker develops his own details, keeping the general appearance of the f in the style developed during 16th to 18th century.

There is also a discussion, whether it is an f or a long S as it was used in medieval scripts. Of course there is something to be said that it is an f due to the two small kerfs in the middle of the shape. With these kerfs which indicate a line it is indeed resembling an f.

10th century:	:	circle round sound holes: fiddle, which is the ancestor of the violin
12-13th century:	:	semicircle shaped sound holes (lyra)
13-16th century:	:	C-shaped with holes at the ends (Medieval and Renais- sance rebec)
15-17th century	:	C-shaped sound holes with circular end nobs, central cusps (vihuela de arcos,
16-18th century	:	violJ Classical Cremonese <i>f</i> - shaped sound holes



Development of sound holes through centuries

3. Article MIT

During the 8 centuries the development of the sound hole shape can be seen as a development of selecting more efficient sound holes, by increasing perimeter length for better air volume and mass flow rates and higher radiated power for the same sound hole area at the air resonance frequency (low frequencies) and reducing the acoustically inactive space inside the sound hole

Overall sound radiation of a violin however depends also on changes to the thickness of the backplate, which increased during the Cremonese aera.

Investigation of the airflow through the different sound holes revealed, that the power of radiation depends largely on the perimeter of the sound hole. Furthermore the main effects happen along the perimeter. Inside areas of the hole do not add significantly to the efficiency of the sound hole. Investigations of sound holes with complex carved rosettes on circular sound holes as seen in lutes and harpsichords have hardly any influence on the overall efficiency of the hole as a total.

Chanot and Savart built experimental violins with resonance bodies in the shape of a quitar and a 'trapezoidal' violin. The sound holes were simple longitudinal forms with significantly shorter perimeter lengths as compared to the *f*-holes of the Cremonese type violin. Power radiation of these sound holes is comparable to sound holes of the 14th-15th century.





Open sound holes

Lute sound hole with carved rosette

Airflow in different sound hole shapes

4. Reaction from "Strad" magazine

The Strad magazine published an article on 20 March 2015, shortly after the publication of the MIT article. The publication of the MIT researchers started a big debate. According to the Strad magazine it is not true, that the evolution of the violin's power is a sum of "accidental" changes. Especially the shape and placement of the *f*-hole is a matter of rigid rules, developed early in the 16th century in Cremona. Furthermore the sound holes in the experimental violins built by Chanot and Savart, did not fail because of their simple shape but because they were simply unaesthetic.

The researchers left out important facts when investigating Cremona-type violins. They did not take into consideration the differences in arching of the plates, which changed during the Cremona-aera considerably when comparing Guarneri 'del Gesiù' instruments to those of his predecessors. – During time many of the instruments from this golden aera were re-worked and changes where made to them in order to increase overall power of the violins. So were top and backplates re-graduated, were bass bars replaced, neck angles and length increased and not to forget were gut-strings replaced by steel, other metals and synthetic materials.

5. *f*-holes by famous luthiers

Andy Fein, luthier and violin shop owner in the USA, has an article on *f*-holes on his website. From there the examples given below are taken.



Andrea Amati ca. 1560



Antonio & Girolamo

Amati ca 1595

Gasparo da Salo

viola ca 1609



Girolamo Amati 1604



Nicolo Amati ca 1628

Figure 1:



Antonio Stradivari, "Harrison" 1693



Andrea Guarneri ca 1664

Maggini, Brescia, 1615

6. Considerations about *f*-holes

Andy Fein describes the effects of placement of *f*-holes on his web-site.

- *f*-holes too wide apart, the sound tends to become rough.
- *f*-holes too close together and the vibrating part of the top becomes too narrow with a resulting "pinched" sound.
- *f*-hole too wide (more than 8mm at the notches for violins) and the violin loses projection.
- *f*-hole too narrow (6mm or less for violins) and a luthier might have trouble getting the soundpost in to the instrument.

7. What the Polish violinmakers school tells about *f*-hole placement

The mensur for the Stradivari type violin is 195 mm. This line is drawn perpendicular to the center line of the top plate. A parallel line is drawn 21 mm distant form the center line of the plate. The template of the f-hole is placed such, that the inner kerf of the *f*-hole is placed on the mensur line. The head of the *f*-hole template is placed against the parallel line to the center line and the lower circular nob is placed 12 mm from the edge of the C-outline.



8. What happens if you want to get fresh air into string-instrument development

At Warsaw's instrument fair in 2015 there was also a luthier who builts bowed string instruments with the mensur of a cello. However the form of the resonance body is based on a harmonic form, involving concave and convex

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plates and twisted side walls. The sound holes worked into the plates are simple, longitudinal openings of even width carrying a thong-like piece of wood at each end. - There was a musician taking such an instrument outside the hall and played it beautifully in the open air. Asking him about the touch and feel of this "cello" he answered: "This is an absolutely fine instrument. easy responding, offering all the possibilities of intonation. It is a joy to play this instrument". Asking mr. Król, the luthier, who built this instrument, about the acceptance of such modern approach in the music world, explained, that this instrument is very well accepted by the singular musician, but it is absolutely not done to come with it into an orchestra. - With a sigh he said: "If you do not want to hassle with conventions, then you should build other instruments than string instruments from the violin familu".



Król's approach to the Cello

9. Conclusions

Sound holes can have a different shape indeed. If it comes to efficiency of the sound hole in terms of power radiation at air-resonance, then the f-shaped design as on the Cremonese-type of instruments is superior, because it has a long perimeter and only little acoustically inactive space. When discussing overall power radiation of an instrument the sound holes play an important role but more aspects are of influence, like

the graduation of the plates, the type of strings used, the bass bar and more. The placement of the *f*-holes does not allow much variation, because of the influence on the freedom of movement of the top plate and restrictions from other elements of the instrument like the bass bar and the width of the bridge. Apart from this, one needs to know that the shape of the string instrument's body, the design of the neck and the *f*-holes is somehow petrified sinds the golden time of the Cremona instruments. Gross alterations to them is not welcome in orchestra environments and therefore limits the possibilities of luthiers to come up with modifications. Although there exist modern bowed string instruments with complete different design approach, the use of them is restricted to personal use and probably in experimental music scenes.

10. Note of the author

While I am just at the beginning of learning how to build string instruments the question of the *why* about the *f*-holes triggered me to find out what it is all about. The article of MIT is very interesting, but needs a lot of mathematical background in order to really understand what it tells. So what I present here is just what I filtered from it with my understanding of the complex investigations done. My article is therefore only meant as an illustration to people interested in typesetting and not for scientists...

11. Sources

http://blog.feinviolins.com/2013/04/why-f-holes.html https://www.sciencenews.org/article/how-violin\%E2\%80 \%99s-f-holes-influence-its-sound

http://www.thestrad.com/cpt-latests/new-research-into -the-development-of-violin-f-holes-is-simplistic-at-best/