USING PULSE REFLECTOMETRY TO COMPARE THE EVOLUTION OF THE CORNET AND THE TRUMPET IN THE 19TH AND 20TH CENTURIES

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ABSTRACT

Pulse reflectometry with improved accuracy has been used to study the acoustically-significant features of the bore profiles of brass instruments. The refinements in the technique which have permitted measurements sufficiently accurate to allow subtle discrimination between apparently similar instruments are outlined.

The commonly-held view that the cornet and the valved trumpet have evolved to become less easily distinguished is shown to be over-simplified, although broadly correct. It is also demonstrated that the modern trumpet has many resemblances to some models of early cornet.

1. INTRODUCTION

The characteristics of brass musical instruments as experienced by players and as heard by audiences depend on the bore profile. A variety of instruments of approximately 1.25 metre tube length (4ft C and $4\frac{1}{2}$ft B♭) have been regularly used: bugles, cornets, flugelhorns, trumpets and others. Of the common types, bugles and flugelhorns are readily distinguished by their bell flare shapes, but trumpets and cornets are not [1]. Mouthpiece cup shapes for cornet and trumpet were distinct in the 19th century, but present-day mouthpieces are made with exactly the same cup shapes for cornet and trumpet. It is therefore useful to examine the bore profiles of these instruments considering the overall topography of the tube. This can have practical application in the performance of original cornet parts by Berlioz, Elgar and others. To approach the originally intended sound, should they be performed on modern cornets or trumpets, or are antique cornets necessary?

Pulse reflectometry has been used for some time in the measurement of musical wind instrument bore profiles [2,3], and the technique has recently been improved to give significantly more accurate results [4,5]. The technique can readily be applied to musical instruments where direct internal measurement is difficult, such as coiled posthorns. The accuracy of the bore profile measurements allows discrimination between different models of similar instruments.

For the purposes of comparison between instruments, we treat a coiled instrument as being equivalent to a perfectly straight instrument with the same cross-sectional area at each point along a line drawn through the geometric centre of the bore, the ‘mid-line’. The bends encountered in the great majority of actual instruments give rise only to second-order discrepancies. Pulse reflectometry gives the reconstruction of the bore profile in this straightened form.

PULSE REFLECTOMETRY

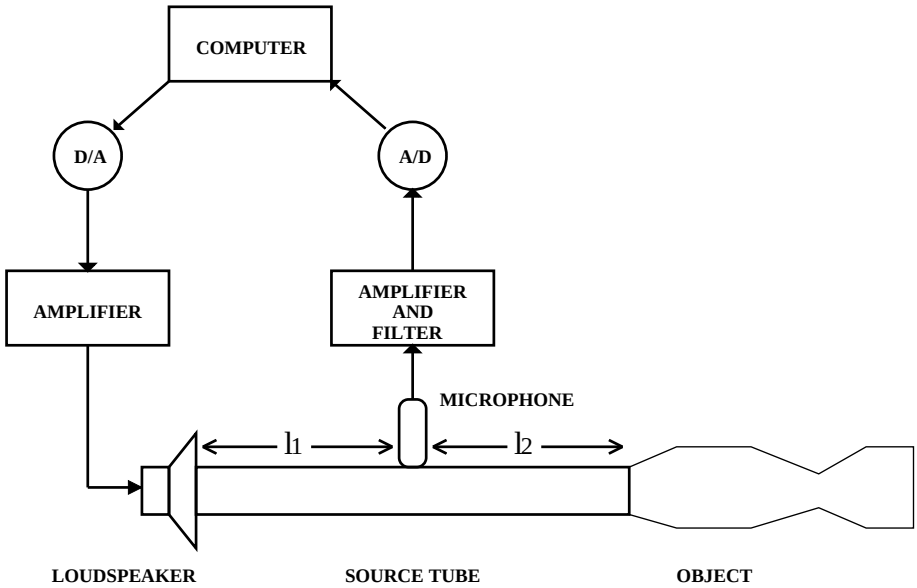

Figure 1: Schematic diagram of pulse reflectometer

2. EXPERIMENTAL METHOD

Figure 1 shows a schematic diagram of the pulse reflectometer used in the present study. An electrical pulse is produced, amplified and used to drive a loudspeaker. The resultant sound pressure pulse travels along a 6.19m long copper source tube (of internal radius 4.8mm and wall thickness 1.2mm) into the instrument under test. The instrument is coupled to the far end of the source tube using a tapering adaptor. A microphone embedded part of the way along the source tube records the reflections returning from the instrument. The microphone signal is low-pass filtered (to prevent aliasing), amplified and sampled. This procedure is repeated 1000 times and the samples are averaged to improve the signal-to-noise ratio.

For an ideal delta function sound pressure pulse, the reflections measured by the microphone would be the input impulse response of the instrument. However, the sound pressure pulse is not ideal; to obtain the input impulse response, the reflections are deconvolved with the input pulse shape, which is measured by terminating the source tube with a flat plate and recording the reflected pulse. This ensures that both the instrument reflections and the input pulse have travelled the same path in the source tube and have therefore experienced the same source tube losses.

The reflections returning from the instrument occur at changes in impedance, such as expansions or contractions along the object's bore. A suitable algorithm (such as the algorithm developed by Amir, Rosenhouse and Shimony [6], which compensates for attenuation due to losses) allows the reflection coefficients arising from these impedance changes to be evaluated from the input impulse response. Assuming cylindrical symmetry, the changes in radius along the bore can then be calculated. However, DC offsets in the input pulse and instrument reflection measurements

generally cause a small DC offset in the input impulse response. This offset manifests itself by causing the reconstruction to expand or contract too rapidly. For accurate reconstruction, the DC offset must be removed from the input impulse response prior to application of the reconstruction algorithm. This is done by introducing a precisely-profiled section of cylindrical tube between the source tube and the instrument. There should be no signal reflected back from this cylindrical tube and the input impulse response should be zero. The average value of the input impulse response over this range thus gives the DC offset value.

The bore reconstructions break down at the final bell flare, but direct measurement here is not difficult: by using gauges of a size where the bore radius determination by pulse reflectometry is still valid (10mm to 20mm bore radius) and measuring the depth of insertion of the gauges from the bell end, the overall tube length can be ascertained.

3. RESULTS

The instruments examined have all been drawn from the Edinburgh University Collection of Historic Musical Instruments (EUCHMI), and the profiles are shown without mouthpiece and without any valves operated. In the figures, the bore radius (y axis) is exaggerated relative to the longitudinal distance (z axis) for purposes of comparison, and the final flare of the bell (bore radius greater than 16mm) has been omitted.

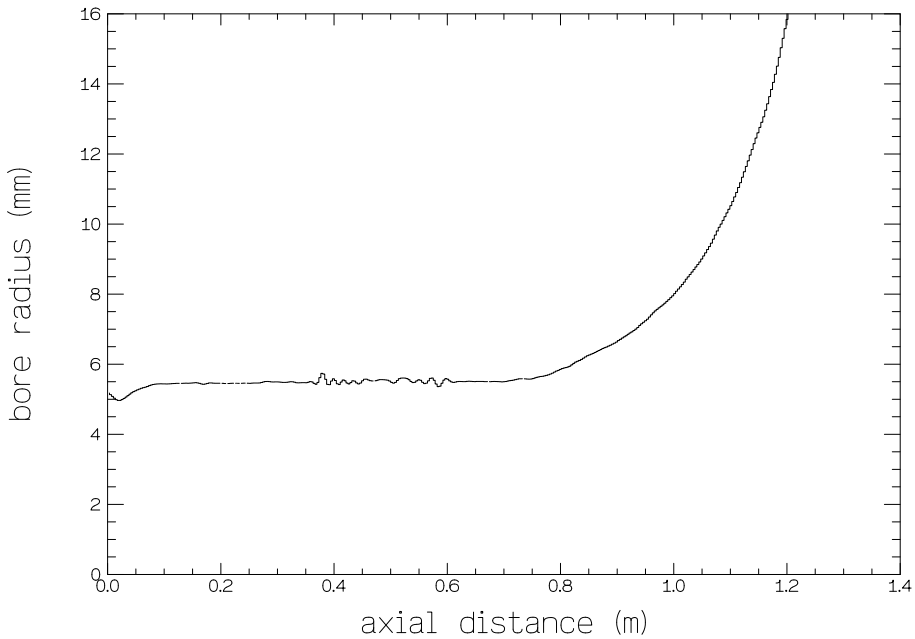

Figure 2: Trumpet in B♭ (Boosey and Hawkes, c 1931)

Figure 2 shows the bore profile of a trumpet in B♭ by Boosey and Hawkes (EUCHMI 3212), not significantly different from the standard modern B♭ trumpet. The undulations between 380mm and

600mm from the mouthpipe end are the irregularities in the windway at the water-key and through the tuning-slide and valves. There is a dip in the bore near the beginning: the minimum bore radius occurs after the taper of the mouthpiece receiver (which does not represent part of the sounding bore when a mouthpiece is inserted) and is followed by a short expanding portion, known as the leadpipe.

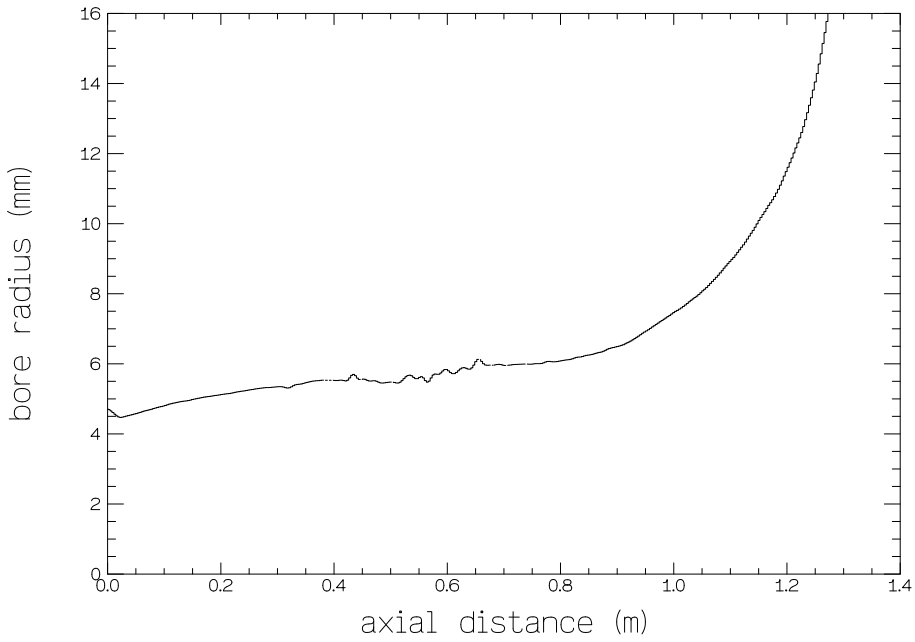

Figure 3: Cornet in B♭ (Couturier, c 1920)

Figure 3 shows a 20th-century cornet in B♭ by Couturier (EUCHMI 3694). There is a long tapered leadpipe between the point of minimum bore and the valves which is a feature of the modern cornet with fixed mouthpipe.

To underline the similarity between a trumpet and a cornet, we show in Figure 4 the bore profile of a flugelhorn (EUCHMI 3959) to the same scale.

The cornet widely used over a long period was the French model, developed by Paris makers such as Besson and Courtois circa 1850 and still in use quite recently. This model had detachable shanks or crooks of different length which were inserted between the mouthpiece and the body of the instrument to put the instrument into different keys. Figure 5 shows a cornet by Courtois (EUCHMI 3710) with a shank for B♭. The shank is not significantly tapered and there is a rather abrupt increase in bore where the shank is inserted into the body of the instrument, in turn followed by a tapering section.

Finally, in figure 6 we show the bore profile of an early British cornet of the model sometimes known as a “cornopean”. This employed an earlier form of valve (the Stölzel valve) which has noticeably

PULSE REFLECTOMETRY

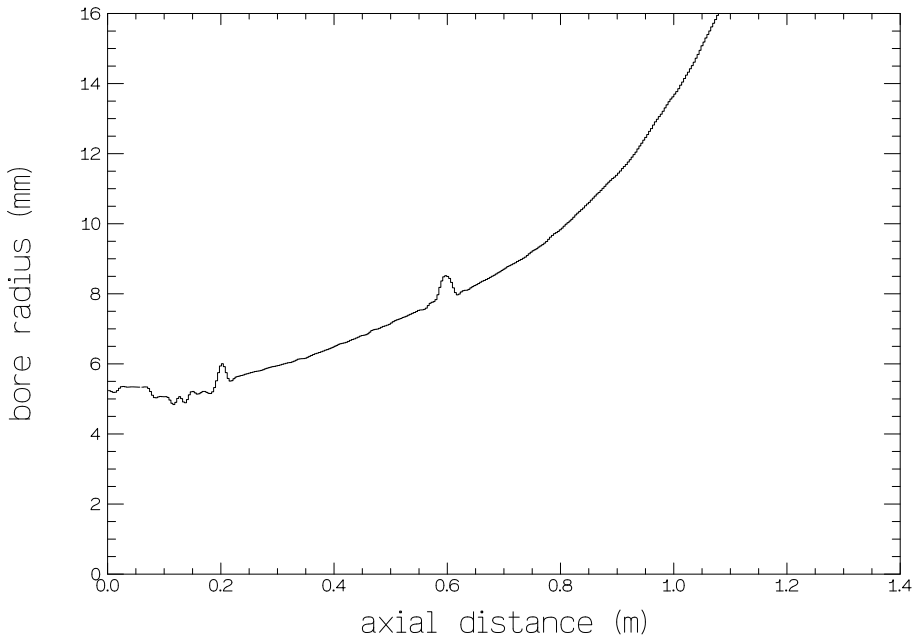

Figure 4: Flugelhorn in B♭ (Besson, c 1900)

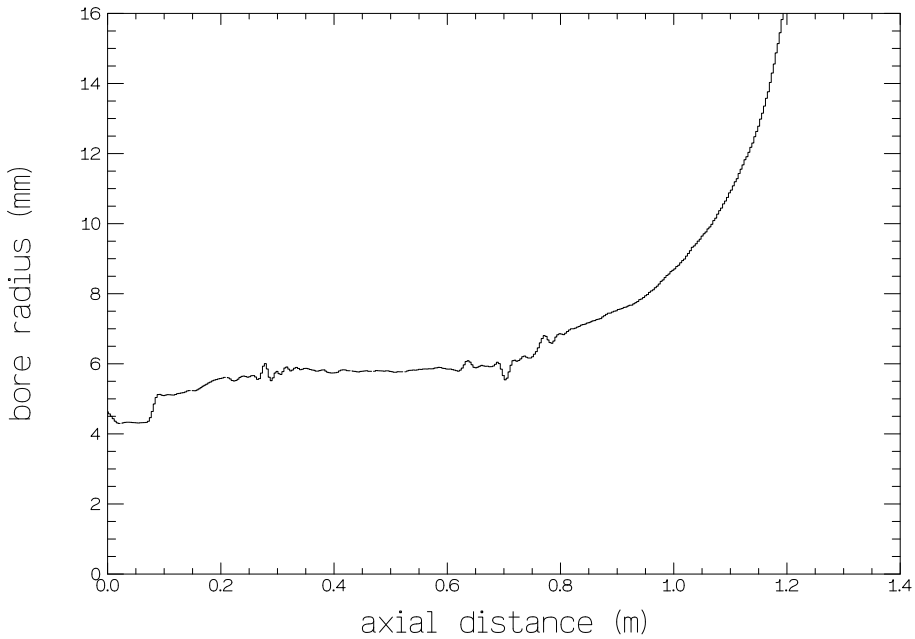

Figure 5: Cornet in B♭ (Courtois, 1862-71)

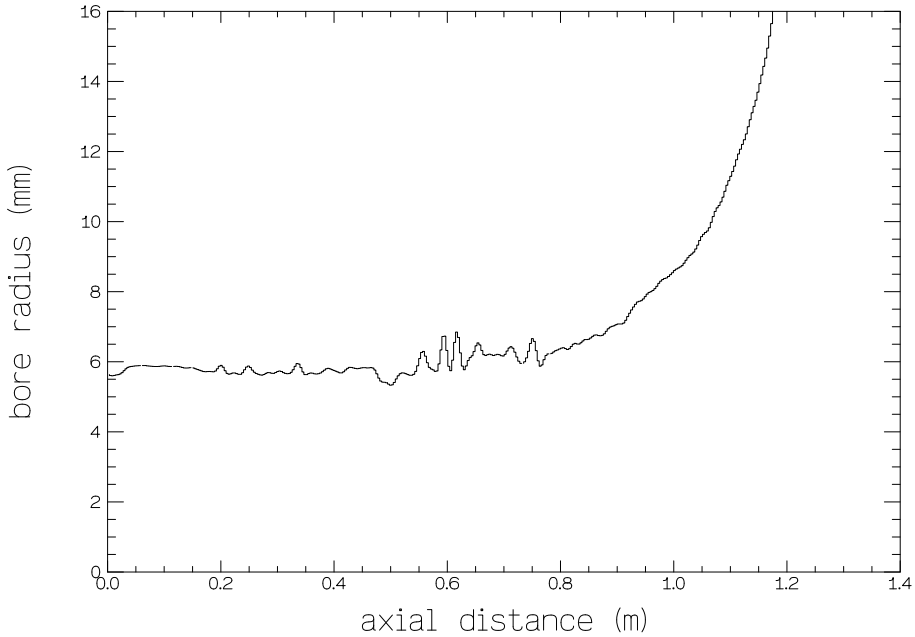

Figure 6: Cornopean in B♭ (Glen, c 1840)

more irregularities in the windway due to the abrupt bends in the valve passages. The significant feature is the lack of any tapered leadpipe. The tubing of the crooks is of approximately the same radius as the tubing of the body of the instrument. The overall topography is thus very similar to that of the modern trumpet.

It should be pointed out that in the mid-nineteenth century the trumpet was of a longer basic tube length, and is thus not comparable with the instruments we have been discussing. Also, the mouthpieces for cornet and trumpet were of markedly different designs, so the similarity between trumpet and cornet that we now observe would not have been apparent at that time.

4. INTERPRETATION OF RESULTS

The variation of the cross-sectional area of the tube $S(z)$ with axial distance z is of critical importance to the acoustical behaviour of a brass instrument. Clearly for a full consideration of an instrument design, a detailed description of the whole bore profile is needed; however, to facilitate quantitative comparisons corresponding to the qualitative comparisons of the instruments in the previous section, it is useful to define the simple parameter

$$K = \frac{S_{mid}}{S_{min}} \tag{1}$$

where S_{min} is the cross-sectional area of the bore at its minimum (which occurs at or near the

mouthpiece receiver) and S_{mid} is the cross-sectional area of the bore at the point mid-way between the two ends (ignoring local irregularities).

In cornets and trumpets, the mid-point of the air column occurs towards the end of the approximately cylindrical part of the tube, before the marked expansion of the bell flare. The extent to which K differs from unity can be regarded as a measure of the extent to which the bore of the instrument departs from a pure cylinder over the first half of its length. We propose this parameter as a simple, widely applicable and readily determinable measure which can be useful in the classification of instrument models.

For the five instruments discussed above, which further measurements have shown to be typical of their models, the values of K are as follows:

(215)	Cornopean in B♭ (Glen, c 1840)	1.13
(3212)	Trumpet in B♭ (Boosey & Hawkes, c 1931)	1.22
(3694)	Cornet in B♭ (Couturier, c 1920)	1.75
(3710)	Cornet in B♭ (Courtois, 1862-71)	1.98
(3592)	Flugelhorn in B♭ (Besson, c 1900)	2.70

It is certainly true that in terms of the initial bore profile the twentieth century cornet ($K = 1.75$) bears a closer resemblance to the twentieth century trumpet ($K = 1.22$) than does the cornet from the second half of the nineteenth century ($K = 1.98$). The instrument with the smallest initial taper, however, is the cornopean ($K = 1.13$), which is generally taken to be an early member of the cornet family. The commonly-held view that the first members of the cornet family had a much more strongly tapering conical bore than did the trumpets, and that this distinction diminished as the instruments evolved, is thus evidently an oversimplification.

5. CONCLUSION

Pulse reflectometry can quickly and accurately provide ‘inside information’ about brass instruments and reveal the hidden differences and similarities. It is a non-invasive technique and hence is very useful in the measurement of instruments with a degree of inaccessibility, and can be safely used on museum instruments.

A parameter K has been defined which is useful in comparing instrument designs, and which allows a quantitative approach to discussions of the evolution of instruments.

6. REFERENCES

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