THE CHARACTERISTIC SOUND OF THE OBOE: CAN IT BE PLAYED WITH A SINGLE REED AND STILL MAINTAIN ITS TONE COLOUR?

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ABSTRACT

In the reed woodwind family instruments differ between them in both their geometry (mainly cylindrical or mainly conical) and their excitation mechanism (single or double reed). How much of the produced sound is due to the single/double reed, and how much to the geometry of the instrument? Measurements done by Almeida et al. [1] show that the flow vs pressure characteristic curve of a double reed is not that different from that of a single reed, the only difference being probably due to pressure recovery inside the conical staple. Is it possible to make a single reed mouthpiece for an oboe, keeping the conical staple, that would still give the oboe its characteristic sound? To find out, a mouthpiece with the following characteristics is being made: A standard clarinet $B^\flat$ reed can be attached to it, its volume is approximately that of the missing part of the instrument cone, and a standard french oboe staple can be inserted to it, so that it can be inserted in the usual way in any french oboe. Examples of the first prototypes, as well as sound samples will be presented.

1. INTRODUCTION

Would an oboe with a single reed sound like a saxophone? What difference exactly does a single reed make compared to a double reed? Is the sound of the oboe due to the double reed, or to the conical bore? Measurements done recently in double reeds point to the fact that the behaviour of double reeds is not fundamentally different from that of a single reed, as had been thought before. In the light of this, it is hypothesised that, given the right parameters, it is indeed possible to build a single reed mouthpiece for an oboe without modifying its characteristic sound or tuning. Some advantages of having such a mouthpiece could be:

1. Playing oboe would be more accessible to other woodwind players such as clarinetists and saxophonists
2. It would be easier to learn for beginners, since blowing a single reed requires less pressure and support
3. The single reed excitation is less vulnerable, since the mouthpiece forms a natural protection for the reed

Figure 1: Typical oboe reed.

4. It would not require the oboist to make his/her own reeds: Buy one from the counter, attach it to the mouthpiece, and play!

2. DOUBLE REED FUNCTIONING

Hirschberg [2] presented a model of a double reed with a downstream neck or constriction, like the one shown in Figure 3. This constriction presents a flow resistance, making the pressure vs flow characteristic curve highly nonlinear and hysteretic. Since then researchers like Fletcher and Rossing [3] and Vergez et al. [4] have extrapolated Hirschberg's model to double reeds like those of oboes and bassoons (see [3], page 405):

> "An important modification of this behaviour occurs in the case of double reeds such as those of the oboe and bassoon, in which there is a long narrow passage through the reed. Such a passage can introduce appreciable flow resistance, which can have a significant effect on reed behaviour"

How does the oboe reed really behave?

2.1. Equations

The relationship between pressure difference across the mouthpiece ΔP and the volume flow inside the instrument U is described by the Bernoulli equation:

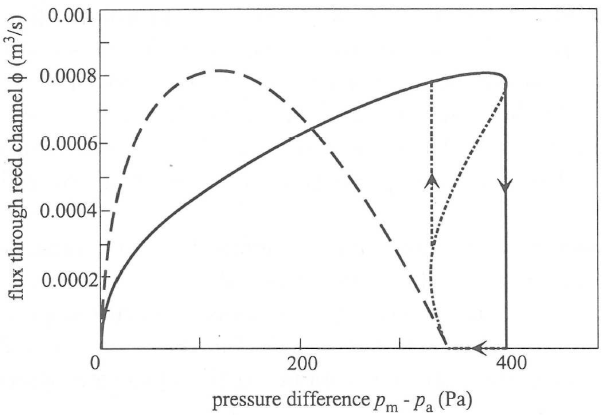

Figure 2: Pressure vs Flow characteristic curve for a reed with flow separation in the reed channel with (solid) and without (dotted) a downstream neck (taken from [2], page 352, with author's permission).

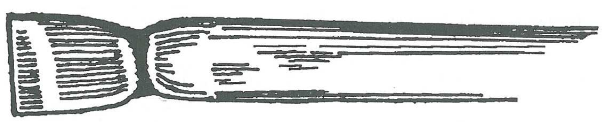

Figure 3: Sketch of an ancient Egyptian double reed with a neck (taken from [2], page 350).

$$\Delta P = \frac{1}{2}\rho u^2 = \frac{1}{2}\rho\left(\frac{U}{S}\right)^2 \quad (1)$$

$$U = S\sqrt{\frac{2\Delta P}{\rho}} \quad (2)$$

where u is the particle velocity, S is the opening area of the reed (which depends on ΔP), and U is the volume flow. Equation 2 is represented as the Pressure vs Flow curve in Figure 2 by the broken curve.

Hirschberg [2] presented a model for a double reed with a downstream neck or constriction like the one shown in Figure 3, which presents a flow resistance, adding an RU^2 term to the Bernoulli equation, giving:

$$\Delta P = \frac{\rho}{2}\left(\frac{U}{S}\right)^2 + RU^2 \quad (3)$$

$$U = S\sqrt{\frac{2\Delta P}{\rho + 2S^2 R}} \quad (4)$$

The curve resulting from equation 4 is plotted in Figure 2 as solid curve. The extra flow resistance shifts the characteristic curve to the right, resulting in a strong hysteretic behaviour.

2.2. Measurements

Figure 4 shows the pressure vs flow characteristic measured by Almeida et al. [1] on oboe and bassoon reeds, as well as the clarinet reed measured by Dalmont et al. [5]. It shows that the characteristic curve of the oboe reed is shifted to the left compared to that of the clarinet reed, and not to the right, as predicted by Hirschberg's model.

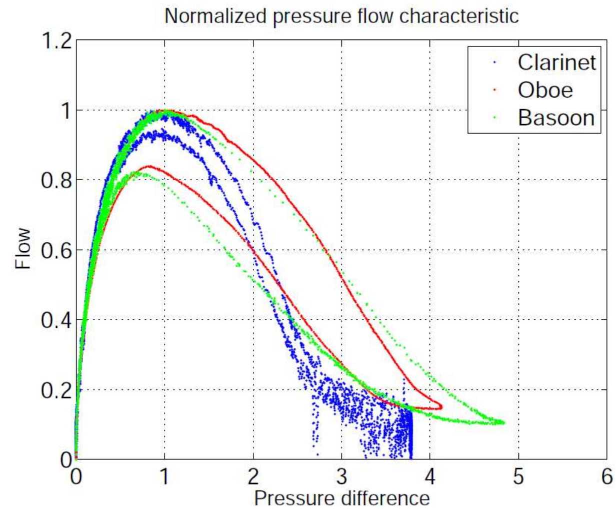

Figure 4: Comparison between pressure and flow characteristics of clarinet, oboe and bassoon reeds. The measurement corresponding to the clarinet reed was obtained by Dalmont et al. [5]. For the purpose of comparison, all three measurements have been normalised according to the maximum flow and closing pressure (taken from [6], page 65, with author's permission).

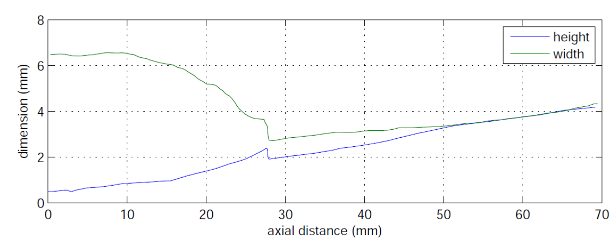

Figure 5: Internal profile of an oboe reed (taken from [6], page 33, with author's permission).

Almeida [6] presented measurements of the internal profile of an oboe reed (including the staple). They are shown in Figure 5. According to the measurements presented in Figure 4 it seems that the reed passage is not narrow enough to add a significant extra flow resistance.

Furthermore, by comparing the curves of clarinet and oboe in Figure 4, it can be seen that the behaviour of a double reed is of the same kind as that of a single reed. The only difference lies on the pressure difference at which the flow is maximum: In single reeds this is typically at $\frac{1}{3}$ of the closing pressure p_M, by the measurements done by Almeida et al. [1] it is at $\frac{1}{4}$ for oboes and $\frac{1}{5}$ for bassoons. He concludes that this effect can be due to the geometry of the staple, which can be assimilated to a conical diffuser.

According to Almeida et al. [1], adding the conical diffuser after the reed results in an extra term:

$$\Delta P = \frac{\rho}{2}\left(\frac{U}{S}\right)^2 - \alpha U^2 \quad (5)$$

where

$$\alpha = \frac{\rho}{2}\frac{C_P}{S_{in}^2} \quad (6)$$

$C_P \approx 0.8$ is the pressure recovery coefficient, and S_{in} is the opening area at the top of the conical diffuser. It follows then that the volume flow is:

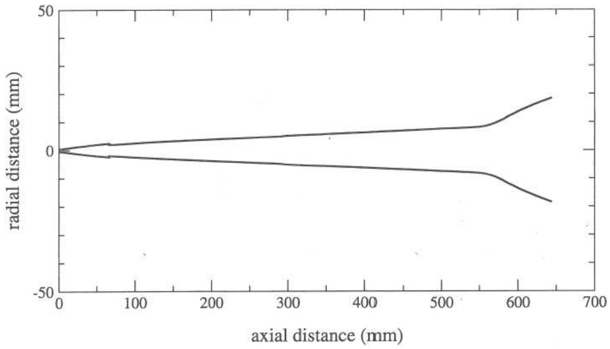

Figure 6: Internal bore profile of an oboe (taken from [7], page 77, with author's permission).

$$U = S\sqrt{\frac{2\Delta P}{\rho - 2S^2\alpha}} \tag{7}$$

3. MOUTHPIECE REQUIREMENTS

- *Mouthpiece Cavity Volume:* According to Nederveen [8], in order for at least the first two modes to be tuned properly, the volume inside the cavity of the mouthpiece has to match the volume of the missing part of the cone, which in turn corresponds to the volume inside the oboe reed without the staple plus the virtual volume due to reed motion. Deviations from the preferred value of this volume strongly influence the high register and the upper part of the low register [8]. A typical bore profile of an oboe can be found in [7], and is shown in Figure 6. Careful measurements of the bore profile shown in Figure 6 reveal that:
  - the (half) angle of the main cone is $0.82°$
  - the length of the missing part of the cone is 82.4 mm
  - therefore the volume of the missing part of the cone is approximately 0.12 cm^3
  - the volume inside the reed is just under 0.02 cm^3, leaving approximately 0.1 cm^3 for the reed motion
- *Mouthpiece Total Length*: Given the fact that the proposed mouthpiece will have a very different geometry than that of a double reed, it is possible that a different length will be required in order to achieve the desired pitch. However, making the total length of the mouthpiece plus staple of approximately the same length of a standard double reed seems to be a good starting point.

  A quick survey on reeds and reed makers (see Table 1) revealed that the considered standard total length of the oboe reed is 72 mm, and that of the staple is 47 mm. This is if the player wishes to play at $A_4 = 440$ Hz. Reeds get shorter, down to 69 mm (usually on shorter staples as well), for people who wish to play at a higher pitch.
- *Mouthpiece Staple:* The mouthpiece should allow the insertion of a standard oboe reed staple, since it is hypothesised [1] that it is its geometry that is responsible for the difference in behaviour between single reed and double reed.
- *Mouthpiece Width:* It is intended to use a standard clarinet $B^\flat$ reed that can be bought in any music store and used immediately. The maximum width at the top of a traditional Vandoren reed is 13 mm.

Reed maker	**Staple length [mm]**	**Total reed length [mm]**
www.britanniareeds.com	45 - 47	69 - 72.5
www.girardreeds.com	47	72
www.chaseoboereeds.co.uk	??	72
www.reedmaker.co.uk	45 - 47	70 - 72

Table 1: Length of reed plus staple and of staple alone by different oboe reed makers

- *Mouthpiece tip shape:* The tip of the mouthpiece should match the shape of a standard clarinet reed.
- *Mouthpiece tip thickness:* The thickness at the top of the mouthpiece should be as thin as possible, so that an oboe player can still use his/her accustomed embouchure.
- *Distance between reed and mouthpiece lay:* It has been found by trial and error that a distance of 0.8 mm between mouthpiece lay and reed presents a good compromise between a loud and full tone and ease of play.
- *Other geometrical considerations:* Sharp edges inside the mouthpiece should be avoided, in order to avoid turbulence and noise that would result from it.

4. MOUTHPIECE PROTOTYPE

A prototype has been built according to the previous requirements, and is shown in Figure 7. Does it sound like an oboe played with a double reed?

4.1. Sound comparison between the prototype and a standard double reed

A professional oboe player was asked to play a melody of her choice 5 times with a standard double reed and 5 times with the single reed mouthpiece and a standard Vandoren reed strength 5. The melody she played is "Blues for oboe" written by Christopher Norton, and is shown in Figure 8.

After having played her own oboe with the two mouthpieces (the prototype shown in Figure 7 and a standard double reed of her choosing), her opinion was that the instrument with the single reed mouthpiece sounds as if it were being played with a standard plastic double reed. She also commented on the intonation being flatter.

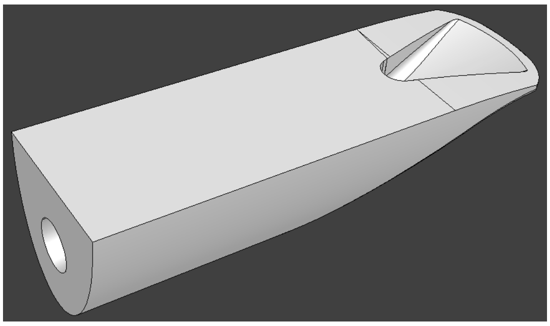

Figure 7: Mouthpiece prototype.

Figure 8: Melody played by a professional oboe player on the mouthpiece prototype and a standard double reed of her choice.

With the aid of the program SNDAN [9], the playing frequency and normalised spectral centroid vs time were calculated for each played instance. The average and standard deviation over the 5 instances played for each mouthpiece are shown in Figures 9 and 10. Close inspection of Figure 9 reveals that the playing frequency of the oboe was approximately 50 cents flatter when played with the single reed mouthpiece than with the standard double reed. This is an indication that the volume inside the mouthpiece is too big.

Figure 10 shows that the spectral centroid of the oboe played with the single reed mouthpiece is in most notes higher than with the standard double reed. The only exception was the highest note played, which was a G_5, where the situation was reversed.

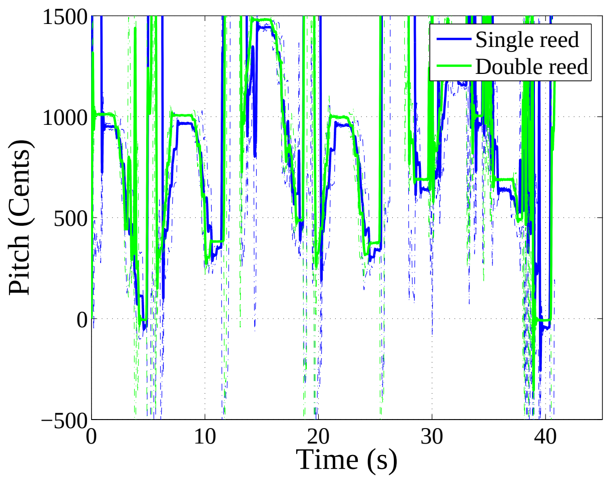

Figure 9: Playing frequency vs time averaged over the 5 played instances. 0 cents corresponds to the nominal frequency of note E_4 (329.63 Hz)

5. CONCLUSIONS AND FUTURE WORK

The prototype shown in Figure 7 is already playable. The sound is about 50 cents flat, and the timbre is somehow brighter than that of the double reed. Some minor modifications that are planned to try to improve sound and intonation include:

- Reduce the volume inside the mouthpiece cavity
- Make the shape of the mouthpiece cavity rounder

Once these modifications are done, more sound tests will be performed. A measurement of the pressure vs flow characteristic curve is also planned, in order to confirm experimentally Almeida's hypothesis.

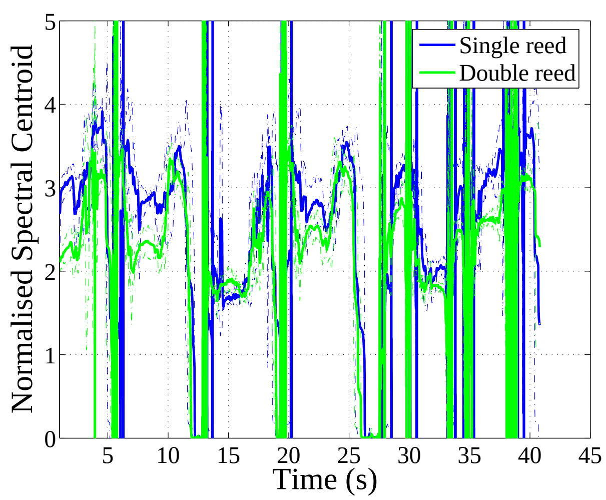

Figure 10: Normalised spectral centroid vs time averaged over the 5 played instances.

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