The characteristic sound of the oboe: Can it be played with a single reed and still maintain its tone colour?

Sandra Carral
carral@mdw.ac.at
Institute of Musical Acoustics
University of Music and performing Arts
Vienna, Austria

Christophe Vergez
vergez@lma.cnrs-mrs.fr
Laboratoire de Mécanique et d' Acoustique
LMA-CNRS
Marseille, France

Kees Nederveen
cjnederv@xs4all.nl
Pijnacker, The Netherlands

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
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!

Double reed functioning

Figure 1: Typical oboe reed

Does the oboe reed behave like [Hirschberg, 1995] and [Fletcher and Rossing, 1998] suggested?

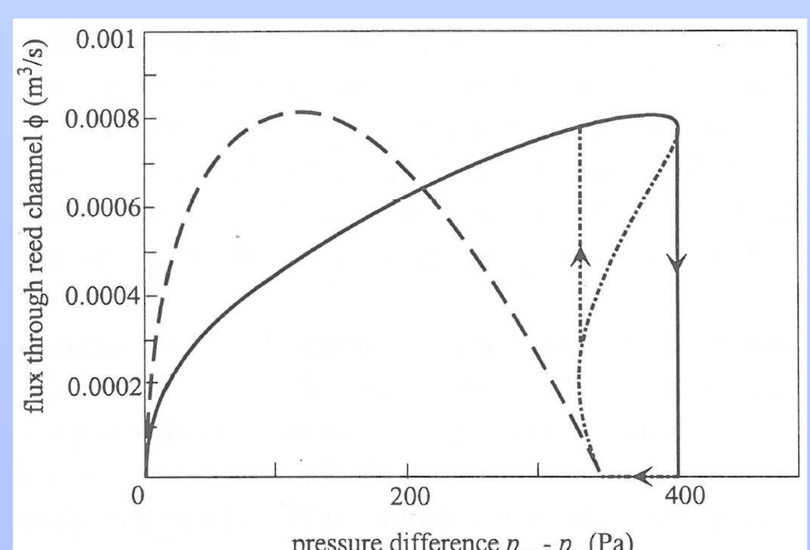

Figure 2: Pressure vs Flow characteristic curve for a reed with flow separation in the reed channel with (solid) and without (dotted) a downstream neck (taken from [Hirschberg, 1995], page 352, with author's permission).

Equations

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

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

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

where u is the particle velocity and U is the volume flow. Equation 2 is represented as the Pressure vs Flow curve in Figure 2 by the dotted curve.

[Hirschberg, 1995] presented a model for a double reed with a downstream neck or constriction, which presents a flow resistance, adding a 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. Does the oboe reed behave like that?

Measurements

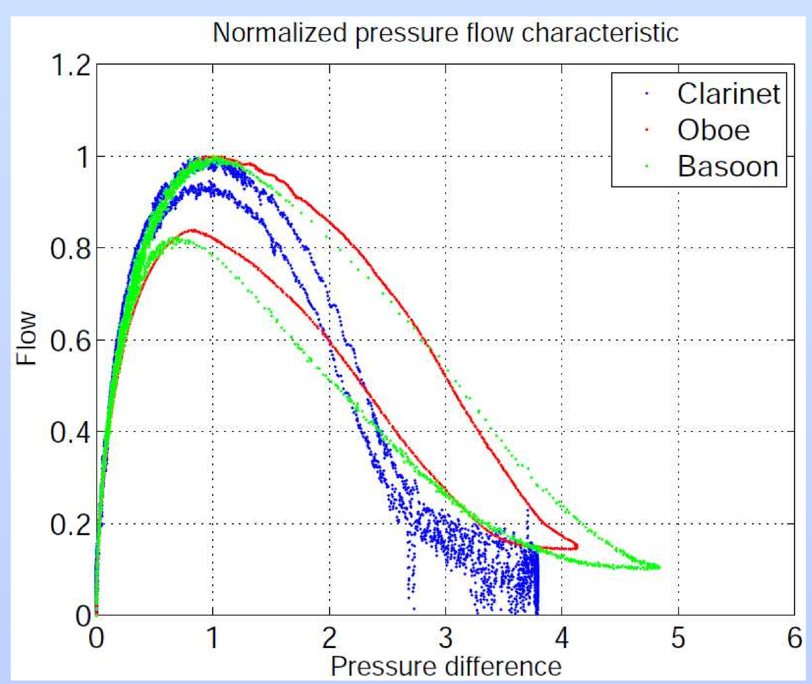

Figure 3: Comparison between pressure and flow characteristics of clarinet, oboe and bassoon reeds. The measurement corresponding to the clarinet reed was obtained by [Dalmont et al., 2003]. For the purpose of comparison, all three measurements have been normalised according to the maximum flow and closing pressure (taken from [Almeida, 2006], page 65, with author's permission).

As can be seen in Figure 3 the characteristic curve of the oboe reed is not as described by [Hirschberg, 1995]. In fact, the oboe reed geometry does not present a downstream neck (for a detailed diagram of the internal geometry of the reed, see [Almeida, 2006], page 33), so Hirschberg's model does not apply in this case.

Furthermore, by comparing the curves of clarinet and oboe, 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 clarinet reeds this is typically at $\frac{1}{3}$ of the closing pressure p_M, by the measurements done by [Almeida et al., 2007] 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. It may be also partly due to (possible non-linear) reed properties.

Mouthpiece Requirements

Mouthpiece cavity volume

According to [Nederveen, 1998], the volume inside the cavity of the mouthpiece has to match the volume of the missing part of the cone, which should correspond to the volume inside the double reed without the staple plus the virtual volume due to reed motion. A typical bore profile of an oboe can be found in [Campbell et al., 2004], and is shown in Figure 4.

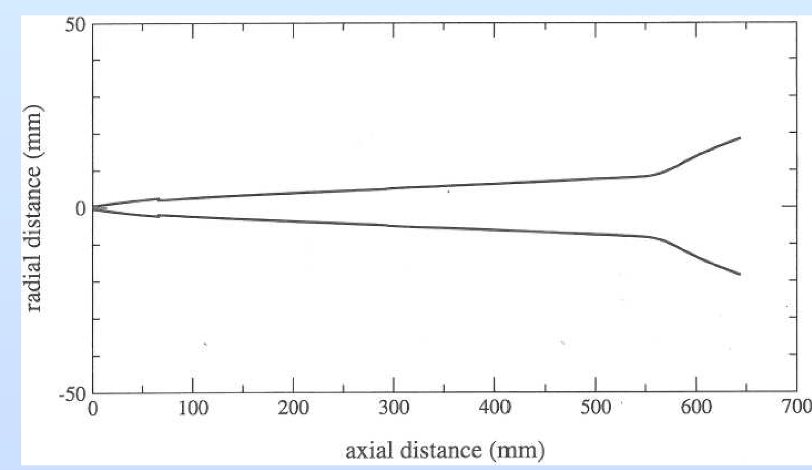

Figure 4: Internal bore profile of an oboe (taken from [Campbell et al., 2004], page 77, with author's permission).

Careful measurements of the bore profile shown in Figure 4 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

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 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.

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: Staple and reed lengths by different reed makers

Mouthpiece staple

The mouthpiece should allow the insertion of a standard oboe reed staple, since it is hypothesised [Almeida et al., 2007] that it is its geometry that is responsible for the small difference in behaviour between clarinet reed and oboe 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.

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.

Mouthpiece Prototype

A prototype has been built according to the previous requirements, and is shown in Figure 5.

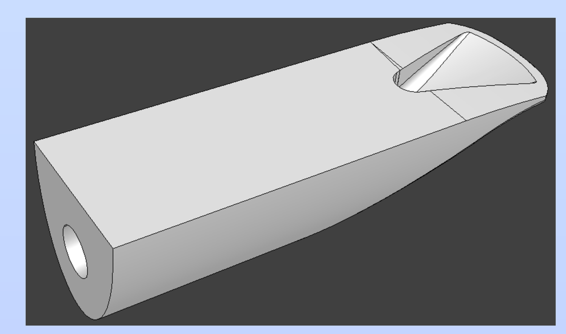

Figure 5: Mouthpiece prototype.

Conclusion

The prototype shown in Figure 5 is already playable. The sound is still about 50 cents flat, and the timbre is somehow brighter than that of the double reed. Some minor modifications are planned to try to improve sound and intonation.

References

Almeida, A. (2006). *The physics of double-reed wind instruments and its application to sound synthesis.* PhD thesis, Université Paris VI.

Almeida, A., Vergez, C., and Caussé, R. (2007). Quasistatic nonlinear characteristics of double-reed instruments. *Journal of the Acoustical Society of America*, 121(1):536–546.

Campbell, M., Greated, C., and Myers, A. (2004). *Musical Instruments - History, Technology, and Performance of Instruments of Western Music.* Oxford University Press.

Dalmont, J.-P., Gilbert, J., and Ollivier, S. (2003). Nonlinear characteristics of single-reed instruments: Quasistatic volume flow and reed opening measurements. *Journal of the Acoustical Society of America*, 114(4):2253–2262.

Fletcher, N. H. and Rossing, T. D. (1998). *The physics of musical instruments.* Springer, second edition.

Hirschberg, A. (1995). Aero-acoustics of wind instruments. In for Mechanical Sciences, I. C., editor, *Mechanics of musical instruments*, pages 291–369. Springer-Verlag.

Nederveen, C. J. (1998). *Acoustical aspects of woodwind instruments.* Northern Illinois University Press.