

Factors affecting transients in rapid articulation on a bass crumhorn

Alan WOOLLEY; Murray CAMPBELL; Simon CARLYLE.

⁽¹⁾University of Edinburgh, United Kingdom, awoolley@staffmail.ed.ac.uk

⁽²⁾University of Edinburgh, United Kingdom

⁽³⁾University of Edinburgh, United Kingdom

Abstract

The generation of a pitched note on a reed instrument involves a nonlinear acoustic coupling between the mechanical reed and the air column of the instrument. Once a stable regime of oscillation has been achieved the reed vibrates at the playing frequency, which is much lower than the reed natural frequency. On windcapped instruments like the crumhorn a change in the playing frequency is initiated by opening or closing toneholes. This modifies the acoustic resonances frequencies of the air column, and the pressure feedback to the reed causes its vibration frequency to change. Factors affecting the transients during rapid pitch changes on a bass crumhorn have been investigated using high speed video recording of reed motion, laser-based position tracking of the reed tip vibration, and measurements of pressure upstream and downstream of the reed.

Keywords: Woodwind, Double-reed, Transients.

1 INTRODUCTION

The crumhorn is a double reed windcap instrument dating back to the renaissance. Although the acoustics of single reed woodwind instruments has been very intensively studied there has been relatively little work on double reed instruments. The thesis of André Almeida [1] was a major step in filling this gap, and a paper by Almedia et al. [2] reported an investigation of modern double reeds using an artificial blowing machine and high speed photography. The work described here is part of a study taking a similar approach to the behaviour of renaissance and baroque double reed woodwinds. We chose to start with the bass crumhorn for a number of reasons. The windcap completely encloses the reed, so that unlike on the modern oboe or bassoon the player's lips are not in contact with the reed. The crumhorn has the further advantage that the bore is cylindrical along the majority of its length, apart from a very short flare at the end, thus eliminating the complications of tapered bores and bells. A final reason for choosing the bass crumhorn was that this unusual instrument has already been studied in experiments on period doubling [3].

This project seeks to examine the transient behaviour of the reed during rapid pitch changes. The normal windcap was replaced by a cylindrical Perspex cap, pressurised by an air pump and fitted with a window through which the reed opening could be videoed. Three different playing regimes were examined. First the reed motion was studied for continuous stable playing over a range of different blowing pressures and fingering patterns. Then the effect of a rapid change in the air column resonances caused by the opening or closing of one of the two metal keys on the instrument was investigated. Finally the action of the player in starting or stopping the note by 'tonguing' at the entrance to the windcap slot was simulated by constricting the air supply tube.

2 EQUIPMENT

The equipment used in this project included a multistage centrifugal air pump which supplied pressure to the transparent windcap. Pressure sensors in the windcap and the reed staple, and sensors measuring displacement of the reed tip and the instrument keys, supplied signals to an Iotech Wavebook 516E data acquisition system. The maximum data collection rate was 10^6 samples per second with 16 bit resolution. All recordings were taken at 10k samples per second per channel. The software used was Waveview v. 7.15.19.

The movement of the reed was recorded with a Baumer OADM 12U6430/S35A laser sensor. This has an operating range of 16-26mm with a distance resolution of 0.005mm and a response time of <math><0.9\text{ms}</math>. Tests confirmed that worked through the Perspex tube used for the windcap and also in close proximity to the bright lights necessary for the high speed camera. A similar sensor was used to record the movement of the keys.

A Sontortech HCCXM050D6V pressure sensor was used to measure the windcap pressure. This has a calibrated pressure limit of 5kpa although experiments confirmed that it remains linear slightly outside this limit. A G.R.A.S. 46BG high pressure microphone was used to measure the acoustic pressure downstream of the reed, through a short side tube on the reed staple. This microphone has a calibrated output of 0.27 V/Pa. Sound recordings used an AKG CE391B microphone. This was sampled at 10 kHz by the data acquisition system and was also fed to a Tascam DR100 mk2 digital recorder, allowing for recording sound files at higher sample rates.

High speed video recordings were made with a Photron SA1.1 camera operating at 4000 frames per second. The lens was a Nikon Macro Nikkor 24-85mm f2.8-4 with 2.2 times teleconverter and 4cm extension tube. Software: Photron Fastcam Viewer v. 3670. The camera was triggered in synchronism with the data acquisition system. The lighting of the reed was provided by small led spotlights that were selected for being flicker free. They are also cool running, and using multiple lights gives the even and adjustable field crucial for clear imaging of reed motion. High speed video recordings will be shown during the presentation, but have not yet been quantitatively analysed.

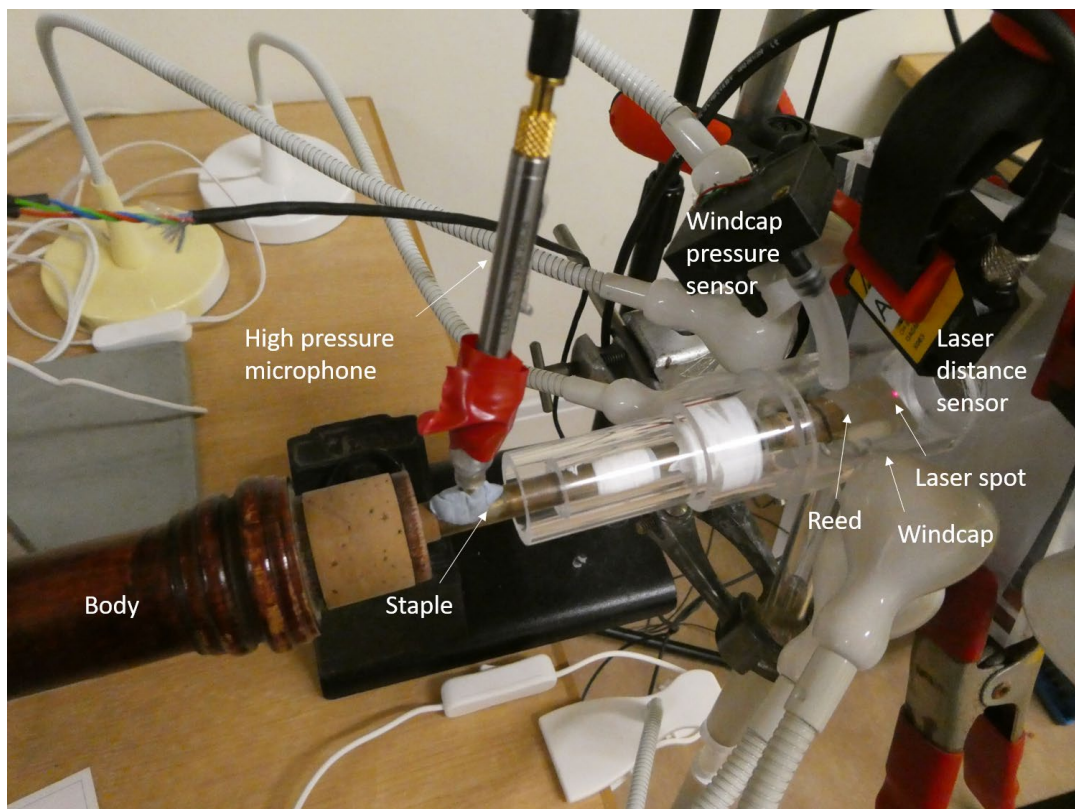


Figure 1. Instrumented transparent windcap.



Figure 2. The mounting arrangement of the bass crumhorn, with six tone holes closed by BluTak. The laser displacement sensor is positioned above the upper key

3 EXPERIMENTAL WORK

3.1 Constant sounding

The first set of readings were taken with the crumhorn playing a stable note, first at the nominal pitch and then at reduced pressure. The instrument has six open tone holes, which can be covered by the fingers. It also has two holes, one above the open set and one below, which are covered by pads and opened by depressing keys. For the measurement shown in Fig. 3, the lowest three finger holes were closed with BluTak. Fig. 3 shows the results of the crumhorn with the pressure adjusted to play at c^3 130.8Hz.

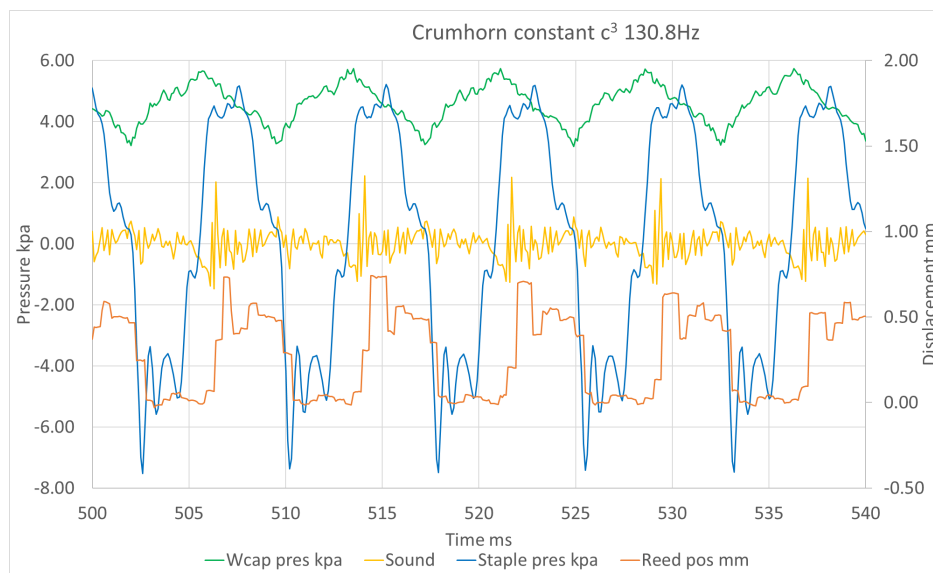


Figure 3. Steady note. Green: windcap pressure. Blue: pressure in reed staple. Yellow: radiated pressure. Red: displacement of reed tip.

The green line shows the pressure in the windcap measured in kPa; it is always positive and with a mean of 4.62kPa. The blue line is the pressure in the staple, alternating between positive and negative relative to atmospheric pressure with a mean of zero kPa. The red line is the position of the reed with zero representing fully closed. It was necessary to position the laser beam approximately 0.3mm from the edge of the reed. This shows the reed giving a distinct bounce on opening and also shows that when fully closed, the section of the reed between the front edge and the staple also bounces. The microphone was placed approximately 10 cm from the open end of the crumhorn and approximately 50 cm from the reed. There is therefore a delay of approximately 1.6 ms between a pressure change at the reed and the resultant change at the microphone.

3.2 Key opening

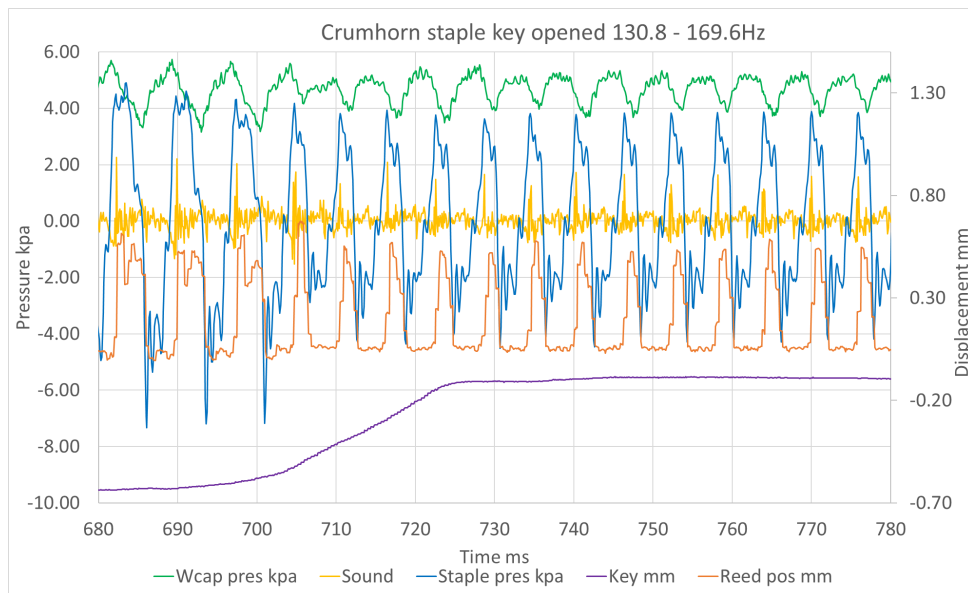


Figure 4. Opening of a key. Green: windcap pressure. Blue: pressure in reed staple. Yellow: radiated pressure. Red: displacement of reed tip. Magenta: displacement of key.

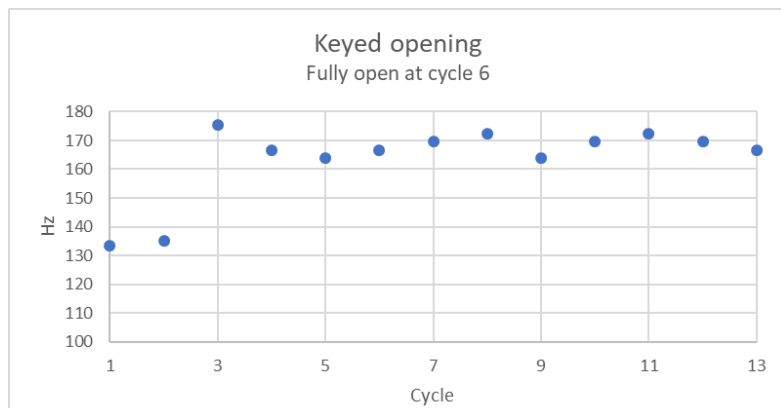


Figure 5. Frequency change during 13 cycles of vibration in Figure 4.

The downward staple pressure spike in Fig. 4 coincides with the closing of the reed. Cycles in Fig. 5 are measured from this point, starting at 686.1 ms; ‘frequency’ is the inverse of the cycle period.

The key starts to open at 690 ms and is completely open at 725 ms. The peak pressure in the staple starts reducing within one cycle and is stabilised at the higher frequency within two cycles. At 130.8 Hz the reed is open for approximately half of the cycle. At 169.6 Hz the reed is open for a significantly smaller proportion of the cycle and does not exhibit the characteristic bounce observed at the initial lower frequency.

3.3 Key closing

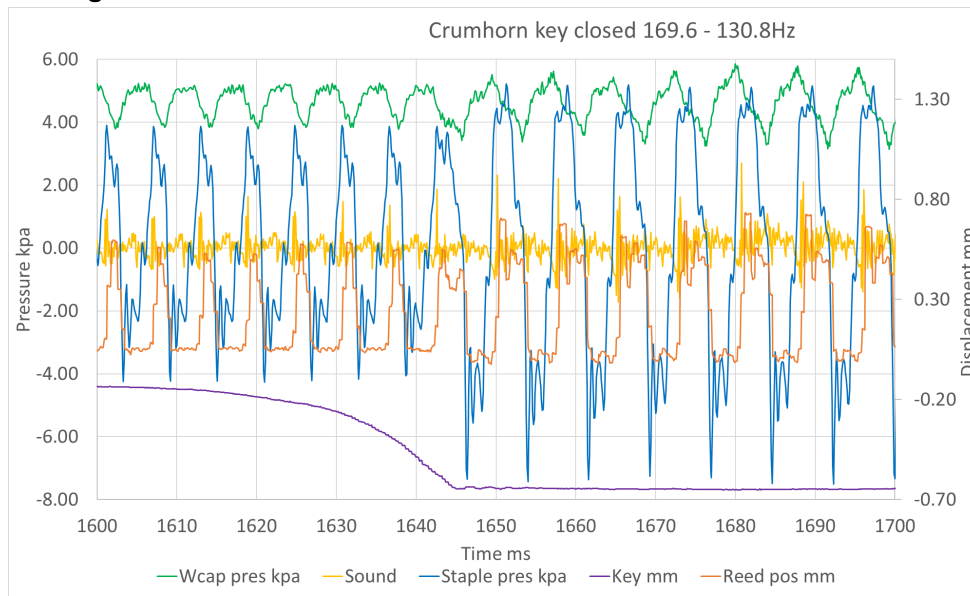


Figure 6. Closing of a key. Green: windcap pressure. Blue: pressure in reed staple. Yellow: radiated pressure. Red: displacement of reed tip. Magenta: displacement of key.

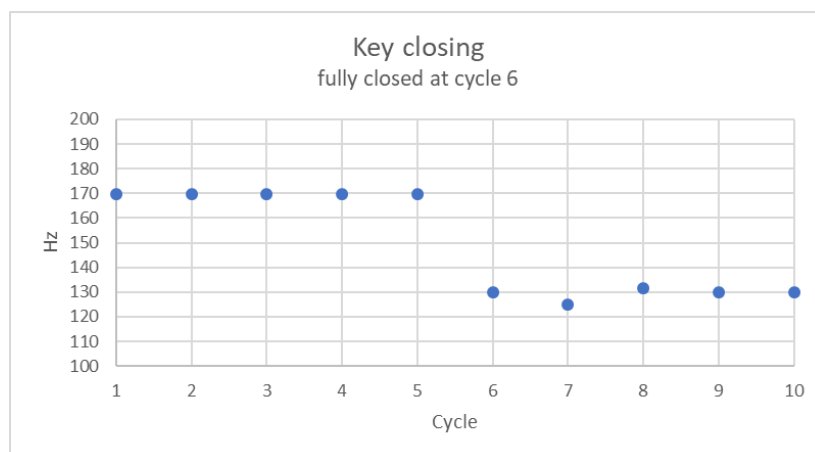


Figure 7. Frequency change during 13 cycles of vibration in Figure 6.

Cycle 1 is defined as 1609.2 ms to 1615.1 ms. The valve is fully closed at the end of cycle 6. As in the key opening case, the transition occurs almost completely within one cycle.

3.4 Simulated tongued start

In order to simulate the effect of tonguing, that is blocking the air inlet into the windcap with the tongue in order to cut off the wind supply quickly, a short length of flexible tube was incorporated into the supply tube from the air supply. This could be manually squeezed in order to cut off the air supply as quickly as possible.

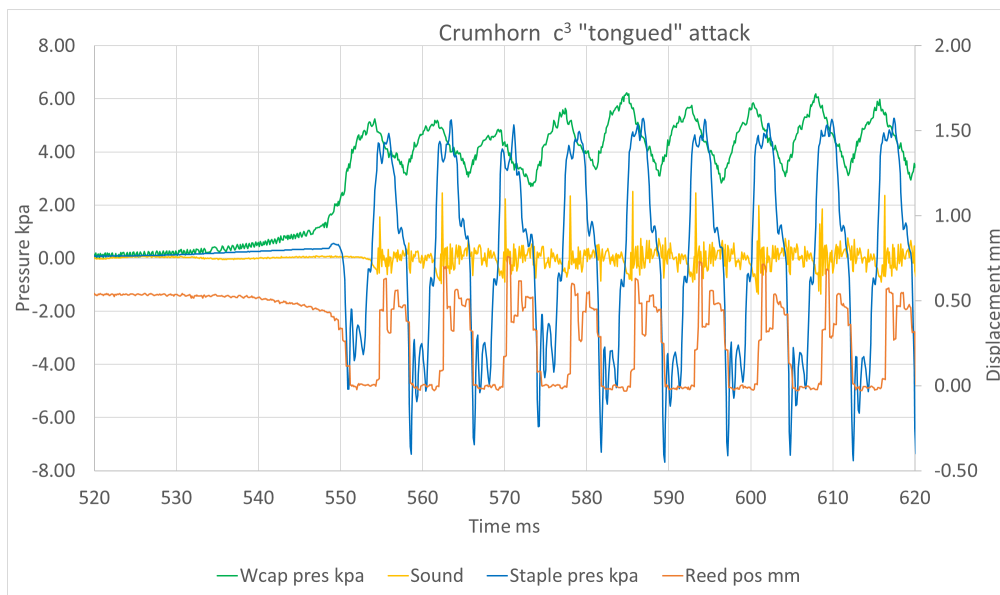


Figure 8. Simulated tongued start. Green: windcap pressure. Blue: pressure in reed staple. Yellow: radiated pressure. Red: displacement of reed tip. Magenta: displacement of key.

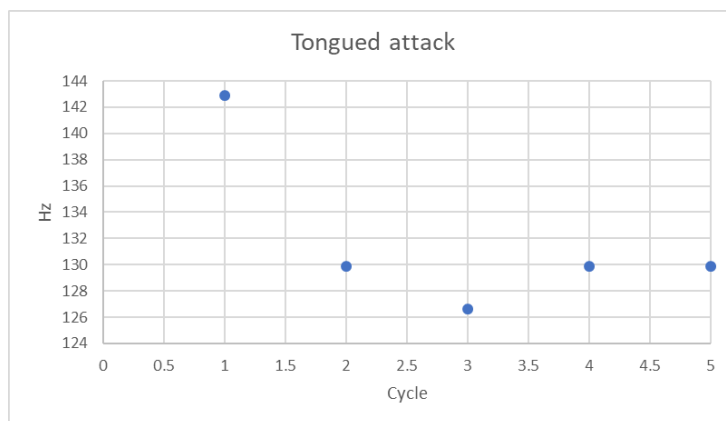


Figure 9. Frequency change during 4 cycles of vibration in Figure 6.

The pressure starts to rise at 530 ms, and the first downward spike in staple pressure occurs at 551.6 ms. The steady oscillation is almost completely established after one cycle.

3.5 Simulated tongued stop

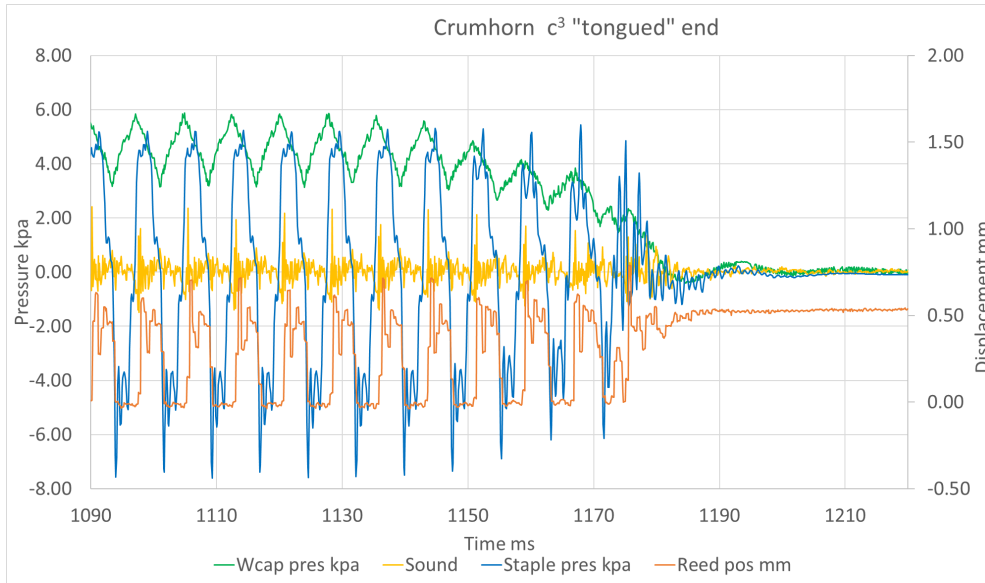


Figure 10. Simulated tongued stop. Green: windcap pressure. Blue: pressure in reed staple. Yellow: radiated pressure. Red: displacement of reed tip. Magenta: displacement of key.

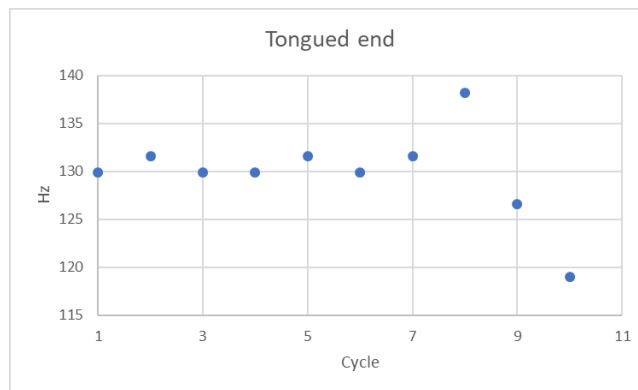


Figure 11. Frequency change during 10 cycles in Fig. 10.

Cycle 1 is defined as 1101.7ms to 1109.3ms. The inlet is closed at 1140 ms, but the air in the wind cap has to exhaust through the reed. The windcap pressure falls to zero at 1180 ms, the main part of the closing transient lasting around four cycles of the steady vibration. There is a small amplitude sinusoidal fluctuation in the tail of the windcap pressure with a period of approximately 20 ms.

4 CONCLUSIONS

The experiments described above have examined the transients during normal playing behaviour of the bass crumhorn. When a key is pressed or released, the reed responds to the change in air column geometry by changing its vibration state, and the new state is almost completely stabilised after one cycle of the new vibration. When a note is initiated by rapidly raising the blowing pressure above its threshold value, the starting transient lasts approximately one cycle, although small fluctuations are observed over the following few cycles. When the note is ended by rapidly closing the entry of the air flow, the fluctuations in pressure in the windcap die away over several cycles as the air is exhausted through the reed aperture. The final transient is therefore considerably longer than the starting transient.

Experiments have also been carried out for values of windcap pressure above the playing threshold but well below the values used in normal playing. Considerably longer transients are then encountered, including temporary excitation of period multiplying states. These phenomena require further investigation, and comparison with physical modelling of the instrument.

5 REFERENCES

- [1] Almeida, A. The Physics of Double-reed Wind Instruments and its Application to Sound Synthesis. PhD Thesis, Univ. Pierre et Marie Curie, Paris, 2006.
- [2] Almeida, A; Vergez, C; Caussé, R. Experimental investigation of reed instrument functioning through image analysis of reed opening. *Acta Acustica united with Acustica*, 93(4), 2007, pp 645-658.
- [3] Gibiat, V; Castellengo, M. Period doubling occurrences in wind instrument musical performance. *Acta Acustica united with Acustica*, 86, 2000, pp 746-754.