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THE INFLUENCE OF TONGUING ON TONE PRODUCTION WITH SINGLE-REED WOODWIND INSTRUMENTS

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Abstract: *Physical modelling based sound-synthesis requires physically meaningful parameters for controlling the model. Previous studies on modelling single-reed woodwind instruments have concentrated mostly on the influence of the pressure difference across the reed on the behavior of the reed oscillation. The interaction with the player's lips and the mouthpiece lay has also been taken into account. However, studies on the effect of the player's tongue are limited. Articulation on real saxophones is produced by tongue impulses to the reed. In portato playing the air pressure is held approximately constant by the player, while there are articular interactions of the tongue with the reed.*
In this study we aim to explain the influence of tonguing for tone production with single-reed woodwind instruments using experimental measurements in an attempt to model articulation in sound synthesis. During the experiments an alto-saxophone mouthpiece was attached to the saxophone neck and tones with different articulation were recorded. The mouthpiece pressure was measured using a microphone inserted into the mouthpiece and a strain gauge glued on a synthetic reed was used to track the reed bending.
A damping effect of the tongue on the oscillating reed can be observed between two articulated tones and the release of the tongue affects the transient behavior of the instrument. An attempt is carried out to include the effect of the tongue control on articulation during a physical modelling application.

Key words: articulation, tongue, woodwind instruments, single-reed, physical modelling

1 INTRODUCTION

Dynamics and articulation are two important parameters in expressive music performance. In playing woodwind instruments, dynamics are controlled by the air stream towards the mouthpiece. The influence of mouth-pressure on the reed oscillation has been studied intensively by musical acousticians for saxophone and clarinet (see historical overview given by Nederveen, 1998). Based on these findings physical models for steady-state sounds were built.
Human classification of musical instruments depends highly on the attack phase of the sound, especially when instruments are played in high register (Reuter, 1995).
In single-reed instruments tonguing is used to give tone-onsets a clean start (Bate, 1984; Liebman, 1989; Koch, 1989). Articulation thereby describes the different intensities and combinations which can be used to combine two consecutive tones (Krautgartner, 1982; Abeles, 1973). Goolsby (1997) measured that expert teachers spend 21% of band rehearsal time on instructions of articulation. Concepts of how to teach woodwind articulation are intensively discussed in music education (Sullivan, 2006).
Liebman describes the technique of tonguing for saxophone players as follows: "it is the front portion of the tongue containing muscle tissue which flaps upward stroking the reed" (p. 28). Furthermore he explains the resulting effect as "the reed's motion and sound are

momentarily stopped. The actual sounding of the articulation comes with the release of the reed". One common form of articulation is portato playing. It is produced by soft tongue movements while the player's air-stream is held constant (Koch, 1989). For fast sequences sometimes the technique of double tonguing is used. Hereby instead of a second tongue impulse to the reed, "the hump portion abruptly rises up striking the roof of the oral cavity which in turn stops the air flow from the larynx" (Liebman, 1989, p. 31). Liebman describes the sounding effect as less effective on saxophone than on the flute, but useful. We see that tonguing is an important part of musical training and conclude that tonguing-based articulation is essential to expressive music performance on woodwind instruments.

Studies on the effects of tonguing on sound production with single-reed instruments are limited. In a previous study we measured the time duration of tongue-reed contact with a mean of 34.5 ms for portato playing (Hofmann *et al*., 2012). Now we want to focus on the effects of tongue impulses to the vibrating reed.

Ducasse (2003) mentioned the importance of tonguing to build physical models which are capable to simulate phrasing for single-reed mouthpiece systems. He describes the damping effect of the tongue to the reed and its force to change the equilibrium position of the reed.

Sterling & Bocko (2009) modell tongue actions by a sudden change of mouth pressure, they describe the tongue as a gate which prevents the air-stream to enter the mouthpiece. We will investigate tongued and air-stream interrupted tone sequences.

2 METHOD

We measured reed bending and inner mouthpiece pressure for two different types of tone repetitions on an alto-saxophone.

2.1 Experimental setup

1) Reed

Reed bending was measured on a synthetic saxophone reed. A strain gauge (2 mm, 120 Ohm) was glued on the upper side of the reed to avoid lip contact. The sensor was placed in the center of the reed with a distance of 4 mm to the tip (Fig. 1).

2) Inner mouthpiece pressure

Inner mouthpiece pressure was measured by a small condenser microphone (G.R.A.S. - 40DP, 26AS) inserted through a hole in the side of a Vandoren AL3 mouthpiece (Fig. 1).

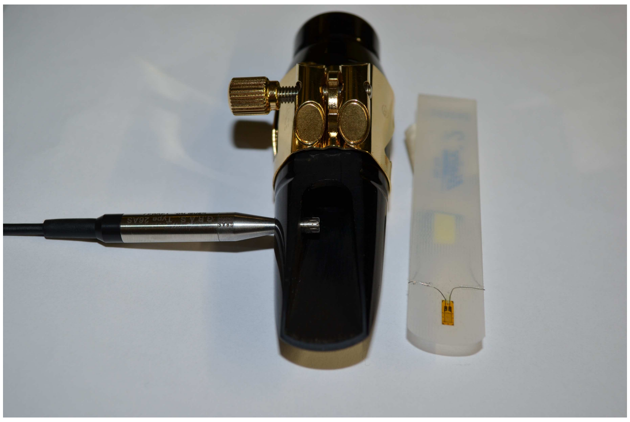

Figure 1. Vandoren AL3 mouthpiece with microphone attached (left); Synthetic saxophone reed with 2mm strain gauge sensor (right)

3) Inner mouth pressure

Blowing pressure was measured (Technoterm 5402) to verify that it is constant for the tongued sequence and varying for the air-stream interruption.

4) Recording

The three-channel recording was made with National Instruments (LabView 2011) hardware and software using a sampling frequency of 11025 Hz (16 Bits).

2.2 Procedure

An experienced saxophone player played 14 consecutive tone repetitions in mezzo piano dynamics to avoid beating of the reed to the mouthpiece lay. For the entire experiment the mouthpiece was connected to the alto-saxophone neck only. Seven tones were separated by tonguing and seven by stopping the air flow.

3 RESULTS

3.1 Recorded data

Our measurements show reed bending and inner mouthpiece pressure under human performance condition.

Observed signals during sound production

In steady-state sound production the player's mouth-pressure bends the reed towards the mouthpiece, this motion is additionally reinforced by the Bernoulli-force from the flow of air into the mouthpiece.

The bent reed reduces the tip opening, this lowers the air pressure in the mouthpiece. At a certain point the pressure which is build up in the mouthpiece turns the reed motion into the other direction and opens the mouthpiece tip. Constant air pressure from the player keeps this system oscillating.

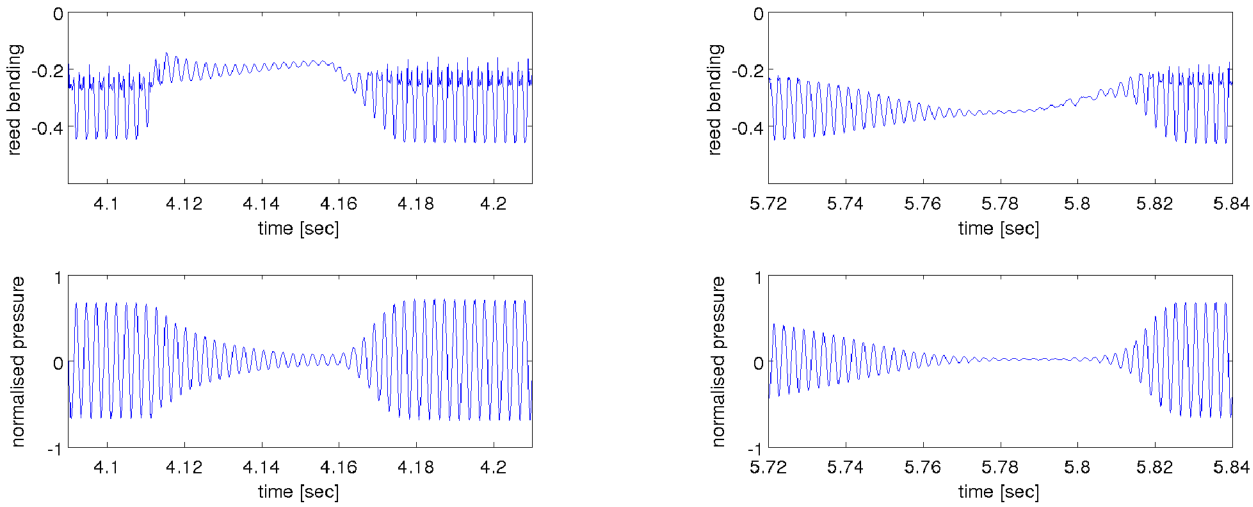

Figure 2. Measured reed bending for tongued tones (top left) and air separated tones (top right); Inner mouthpiece pressure for tongued tones (bottom left) and air separated tones (bottom right);

Extracted parameters: Tongued portato tones

Now we'd like to investigate the transition from one tone to the next, when tones are separated by tonguing.

When the tongue touches the reed (tongue-reed contact, TRC) it abruptly bends the reed towards the mouthpiece, the reeds oscillation is being damped (Fig. 2 top left). This reduces the amount of air-pressure in the mouthpiece, which causes a sudden reduction of sound level but no complete silence (Fig. 2 bottom left). When the tongue releases the reed (TRR), the reed bounces back to the equilibrium and immediately starts to oscillate.

A detailed investigation of the reed bending shows a 180° phase inversion at TRC (Fig. 3). We'd like to give the following explanation: The oscillating reed has one non-free boundary condition at the point were it is fixed by the ligature. On the other side it remains flexible and can be bent towards the mouthpiece tip.

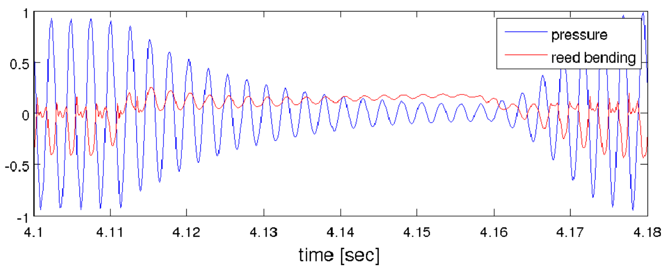

Figure 3. Observed phase-shift at TRC; Inner mouthpiece pressure and reed bending high-pass filtered and normalized

We assume that when the tongue presses the reed towards the mouthpiece tip, this changes the boundary condition and causes the phase shift. When the reed is "fixed" on both sides, the returning pressure deforms the reed, so that the air can escape at the sides between mouthpiece lay and reed (Fig. 4). In that case an increasing mouthpiece pressure appears to close the reed, resulting in the observed shift.

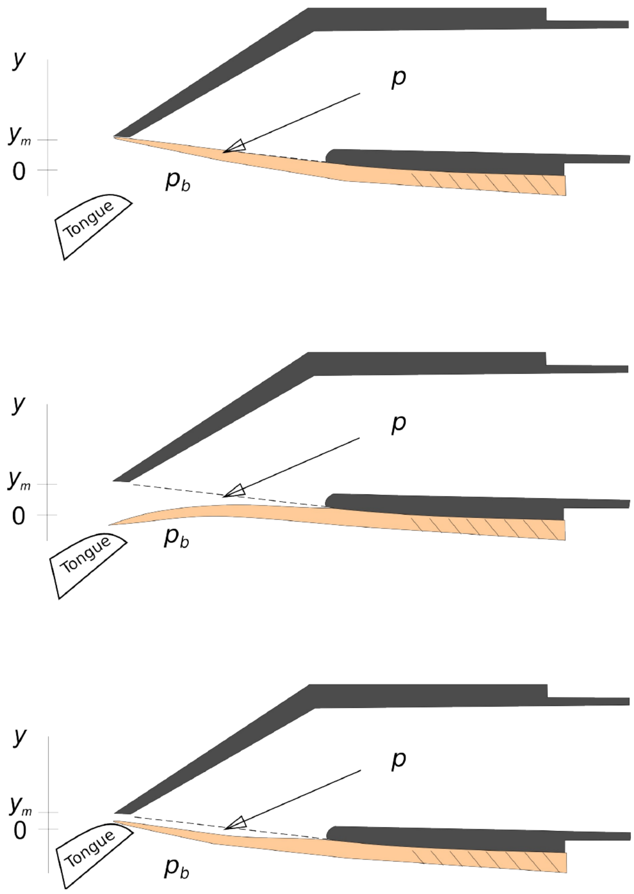

Figure 4. Blowing pressure closes the reed during sound production (top). Without tonguing, the inner mouthpiece pressure bends the reed away from the mouthpiece (middle). With tonguing the inner mouthpiece pressure deforms the reed (bottom). p_b represents the blowing pressure and p the pressure in the mouthpiece.

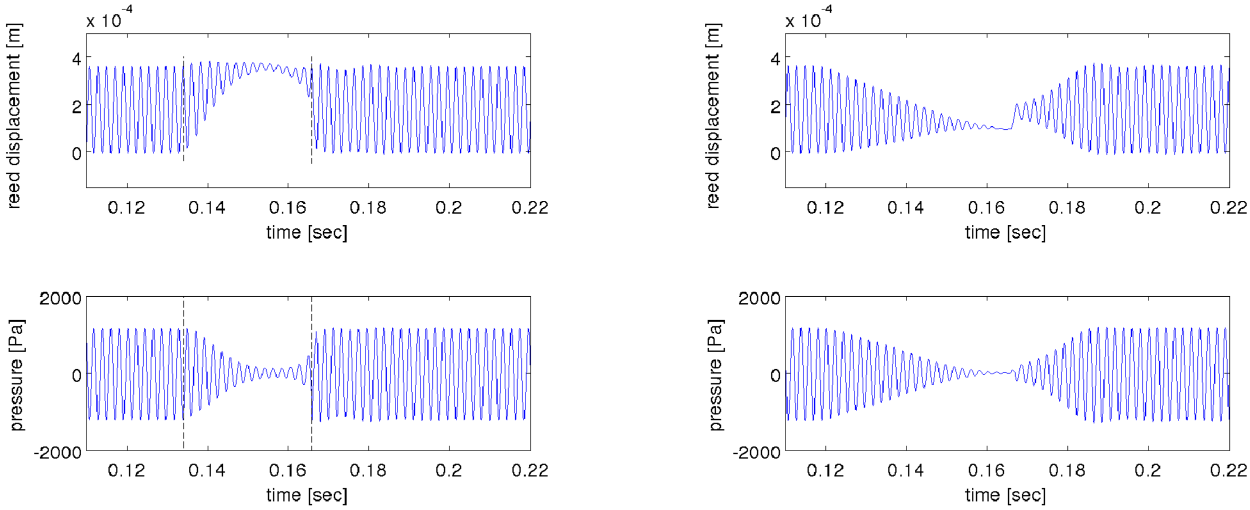

Figure 5. Modelled reed displacement for tongued tones (top left) and air separated tones (top right); Modelled inner mouthpiece pressure for tongued tones (bottom left) and air separated tones (bottom right);

Extracted parameters: Air separated tones

When the player momentarily stops the air flow, this interrupts the oscillating system because of the sudden energy loss. The reed bending signal shows a smooth fade-out (Fig. 2 top right). This results in a linear decrease of inner mouthpiece pressure (Fig. 2 bottom right). For the non-tongued attacks the reed oscillations start from the equilibrium position of the reed.

3.2 Application to physical model

A single mass-spring model is used to represent the excitation mechanism and it is coupled with the tube by convolution with its impulse response (Chatziioannou & van Walstijn, 2012). In this case, since there is an attempt to avoid beating conditions during the experiments, no contact forces are modelled between the reed and the mouthpiece lay.

To model TRC we adjusted the following parameters for 30 ms:

- sudden displacement of the equilibrium of the oscillating spring towards the mouthpiece
- increase of the internal damping of the exciter

To model TRR we adjusted the following parameters:

- revert spring to original equilibrium
- revert damping parameter
- give extra amount of blowing pressure, because of barrier effect caused by the tongue closing the tip of the mouthpiece

To model air intermission we adjusted the following parameter:

- reduction of blowing pressure

The variation of the parameters in both articulation methods has been chosen, such that the resulting pressure waveforms are similar to those measured in the experiments (Fig. 5). However, in the case of the model, the reed displacement is calculated, whereas during the experiments the bending of the reed is measured. These two signals are not directly comparable and the latter can only be used in a qualitative prediction of the motion of the reed.

DISCUSSION

Tonguing is an important technique for correct articulation which supports expressive performance on single-reed woodwind instruments. We showed that two different tonguing techniques result in different variation of the embouchure related parameters. We were able to model some of the observed effects. With the current single mass-spring model we were not able to simulate the reed deformation under the boundary condition of the tongue.

This was a first study where we transferred measured effects of articulation to a physical model. In future we plan to work with a more detailed representation of the reed to optimise simulations of tongue-reed interaction.

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