Tongue and reed motion producing initial transients in the clarinet

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Transients are perceptually salient. The ability to produce a range of elegant initial transients is part of the art of articulation and is highly valued by musicians. Players of wind instruments often start a note by tonguing. On the clarinet, this means releasing the tongue from the reed.

One recent study [1] from this lab used a sensor on the reed to measure tongue-reed contact and pressure transducers. It showed that players coordinated tongue release with a range of increasing rates of mouth pressure to produce different articulations, including accent, *sforzando*, *staccato etc*. However, tongue and reed motion were not studied. Another study [2] used a clarinet playing machine to produce transients under controlled conditions. Regeneration by the reed produces a brief (tens of ms) phase of exponential increase in the sound pressure amplitude with rates of tens to > 1000 dB.s^{-1}. Final transients show exponential decays. The exponential rates are related to the differences between energy losses and regeneration. This study extends [1,2] by using an endoscope to study motion of the tongue and reed directly in human players.

Materials and methods: Volunteer clarinettists with a minimum of nine years experience played notes at four pitches with normal, *staccato*, accent and double tonguing articulation on a clarinet mounted rigidly on an optical bench. A video camera (1200 frames.s^{-1}) was mounted on a rigid endoscope, whose objective was positioned next to the reed at the tip of the mouthpiece. A transducer on the mouthpiece measured the steady and sound pressure in the player's mouth; other microphones measured the sound pressure in the bore at 240 mm from the reed and outside the bell. These were amplified and recorded along with the camera images and a synchronising signal.

Results and Discussion: Fig 1 shows results for the lowest note studied (D3 concert, 147 Hz) tongued normally. Combining these measurements with those of [1,2] allows several observations about the transient.

Initially, the reed is pushed closed against the mouthpiece (separation = 0) but, over ~20 ms, the wet tongue draws it away, pulling beyond the point of mechanical equilibrium. After they separate (b), the reed slowly approaches mechanical equilibrium (c).

The reed-lip system is overdamped, so the elastic energy and kinetic energy associated with its initial displacement and release are lost: the reed rarely vibrates, even briefly, at its own natural frequency (close to that of the squeak feared by clarinettists). However, the sudden changes in aperture (a-c) produce a sudden increase then decrease in airflow. This pulse in airflow is reflected at the remote end of the bore and then again at the reed. Because of a negative slope in the operating *airflow*(*pressure*) curve for the reed, AC reed conductance ($\partial U/\partial P$) is negative. Hence the pulse is amplified by successive reflections, giving an exponential rise in reed motion and bore pressure, until they approach saturation. During this, the mouth pressure is gradually increased by the player. Its oscillatory component is small compared with that in the bore, because the frequency is close to a resonance or maximum in the impedance of the bore, while the impedance of the vocal tract is small. The radiated signal (different scale) shows higher harmonics growing more rapidly. This is because the bell radiates high harmonics more efficiently.

Variation between players, articulations and pitches are discussed in terms of the different control parameters: pressure rise rate, lip force, tongue action and tongue timing. Examples are at [3].

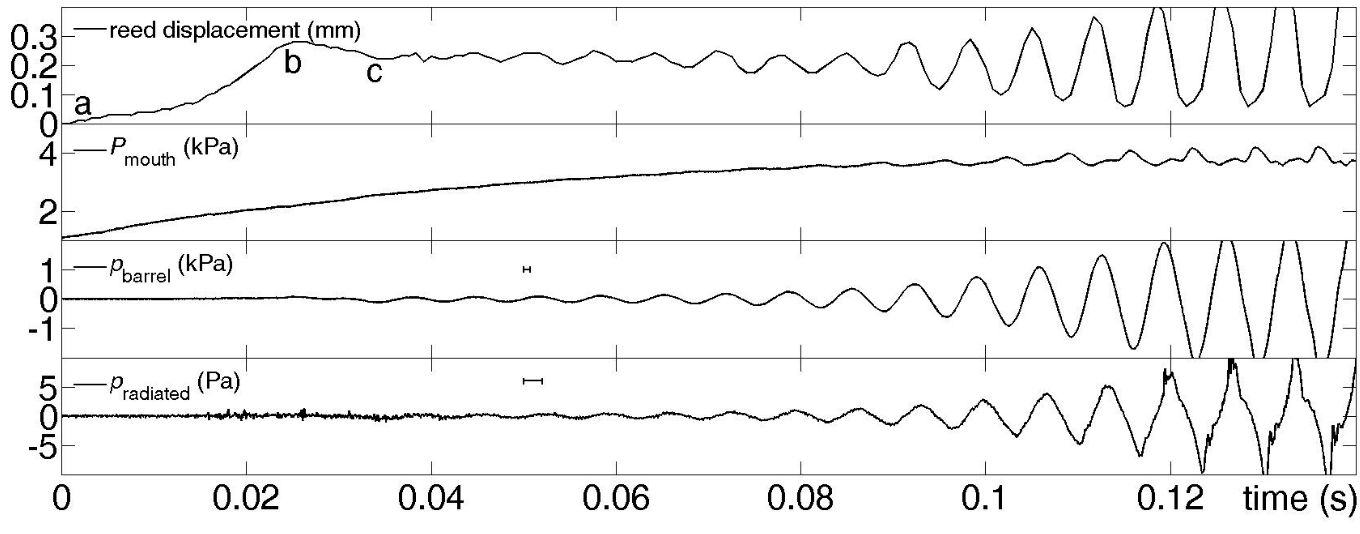

Figure 1: Reed displacement from the mouthpiece, sound pressure in the bore at 240 mm from the mouthpiece, mouth pressure and radiated sound outside the bell. Horizontal bars show the distance of each microphone from the reed, divided by the speed of sound.

References

[1] Li, W., Almeida, A., Smith J. and Wolfe, J. (2016) "How clarinettists articulate: The effect of blowing pressure and tonguing on initial and final transients" *J. Acoust. Soc. Am.*, **139**, 825-838.

[2] Li, W., Almeida, A., Smith J. and Wolfe, J. "The effect of blowing pressure, lip force and tonguing on transients: a study using a clarinet-playing machine" accepted for publication in *J. Acoust. Soc. Am.*

[3] www.phys.unsw.edu.au/jw/clarinet-articulations.html