TRANSIENTS OF TRUMPET TONE: BASIC LINKS BETWEEN PERCEPTION AND MEASUREMENTS OF LIPS OPENING SURFACE AND PRESSURE IN PLAYER'S MOUTH

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ABSTRACT

Selected transients of trumpet tone are documented using high-speed imaging and measuring of pressure in player's mouth. Key features are described including phenomena that couldn't be described without high sampling rate ("initial blow off" on soft tones, parameters of triple staccato, legato transients).

1. INTRODUCTION

The transient of a tone is known to be one of the key features in recognition of tone source and major characteristics of instrument's timbre. However, its observation is complicated due to the natural instability of the process.

Measurements of lips motion is a classical topic in acoustics of brass instruments [1, 2]. Although some methods based on optical means became available only few years ago thanks to the development in the field of a high-speed imaging.

Methods based on stroboscopy are well-suited for describing the stationary or quasi-stationary motion but the transient is unapproachable by these means.

We described the lips motion during the selected transients using a high-speed camera. As the information about lips opening area would be just "kinematic", we added the mouth pressure monitoring to describe a part of the dynamics as well.

The selection of transients was made according to the typical situations common in instrumentation of brasses. Presented results are product of pilot measurement only, they should not be overinterpreted, but they are valid as well-founded hypotheses for future research.

2. MEASURING PROCEDURES

Experimental procedures are close to Logie et al. [4]. In order to make the conditions for the mouth pressure as natural as possible, glass mouthpiece was used. Mentioned mouthpiece has a realistic rim, throat and direction of the main flow, a bigger cup and not perfectly conical backbore (Fig. 1).

Measuring experiment schematics is shown in Fig. 3. The high-speed camera (1)(Phantom SpeedSense v611) shoots player´s lips through special glass mouthpiece inserted to the trumpet. If the player is an experimenter concurrently, he can activate the camera via a footswitch (6) which triggers a differential pressure meter (2)(of our own construction). Camera synchronization signal is recorded together with microphone (5) signal using an external sound card. Player's lips were lit by a DC powered light source (Olympus Visera CLV-S45).

Camera sampling frequency was 12 000 frames per second (FPS), pressure meter sampling frequency was 2000 FPS. Common Bb trumpet (Joseph Monke, older model) was used playing F4 or Bb4 (349 and 466 Hz respectively), so the signals were enough sampled, though in the text we focus mainly on the shapes of envelopes.

The cooling of the devices was not turned off during these pilot experiments and an anechoic room was not used, so a noise occured in recorded sound and a weak reverberation should be counted in. Microphone was placed 0.5 m in front of the instrument.

A simple threshold filter is applied on the captured grayscale images to pick out just the pixels corresponding to the mouth opening. Then the count of these pixels is used. A "DC part" (always black pixels) is subtracted and the data are smoothed using Golay-Savitzki filter.

A conversion between black pixels and mm^2 was not made. However, the geometry of the experiment, lighting, data processing etc. was kept the same, so the data in units of black pixels can be used as relative.

Fig. 1 – Common trumpet mouthpiece and glass model used for measurement.

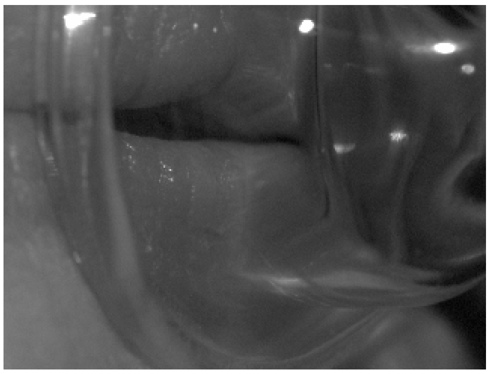
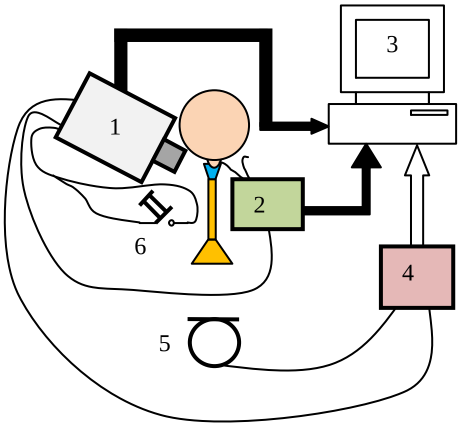


Fig. 2 – Example of captured image.



1 – High-speed camera
2 – Differential pressure meter
3 – Controlling PC
4 – External sound card
5 – Microphone
6 - Footswitch

Fig. 3 – Schematics of measuring system.

3. EXPERIMENTAL RESULTS

Description of selected transient follows. Triplets of plots are presented always in order *lips opening area* (black), *pressure in player's mouth* (blue), *recorded sound* (red).

a) *F4, mezzoforte, sharp beginning, loose ending*

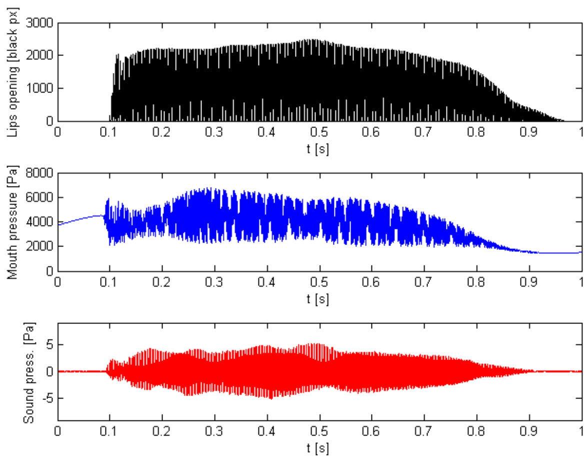


Fig. 4

Sharp beginning, typical for trumpet as a signal instrument. Initial leap of mouth pressure is almost 2 kPa (see Fig. 4), then a small attenuation and regular attack transient after brassy crack at the beginning comes.
Lips are opening and fully closing from the very beginning of the sound production. Amplitude of this opening almost does not vary except for "explosive opening" which could be seen at 0.1 s. Last but not least, the inertia of the lips is remarkable. At ca. 0.9 s, as the tone production is ended, the lips are still opening and closing.

b) *F4, piano, soft beginning, loose ending*

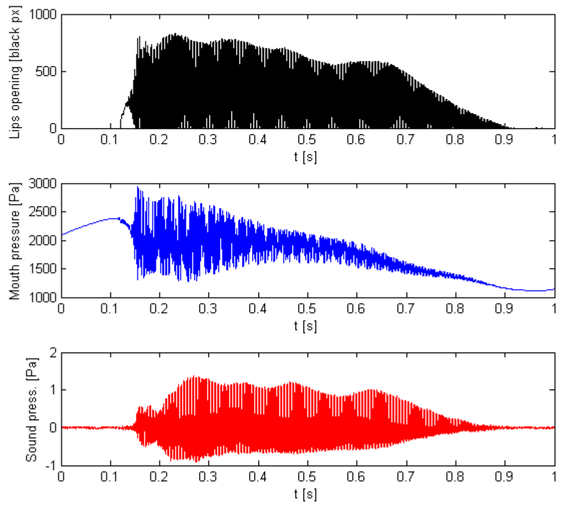


Fig. 5

Very soft, piano beginning, still clear and without noise or rustle.
Initial "blow off" of ca. 250 Pa is observed at 0.1s (see Fig. 5).
Initial leap of mouth pressure is less than 1 kPa (so more or less a half of previous situation).
Soft beginning is easy to spot on the recorded sound, but the mouth pressure is a bit more monotonic.
The build up of the lips opening is remarkable:

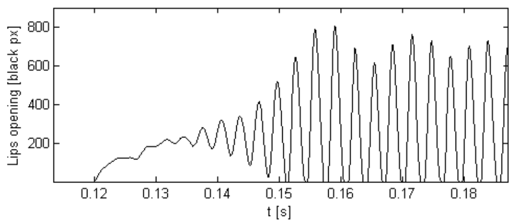


Fig. 6 – Detail of the first plot of Fig. 5 showing initial lips opening.

The oscillation actually started at the state of the opened mouth - hence the mentioned "initial blow off" removing the brassy crack.

c) *F4 to Bb4, legato, mezzoforte*

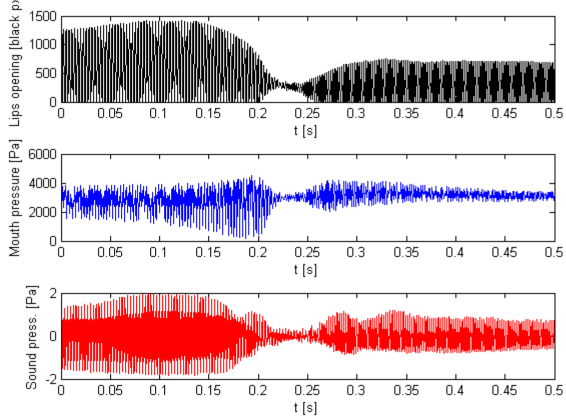


Fig. 7

As Logie et al. [4] showed, downward and upward legato (slur) is quite different in player's technique, therefore both cases are presented here.
An example of slow, sort of weary legato (with a bit more player's effort than is considered to be elegant) between two tones without action of valves (i.e. just change of the instrument's oscillation mode).
For a short time (0.2-0.25 s, see fig. 7) the player's lips are not fully closing. On a higher tone a lesser variation of the mouth opening is observed.
Small maximum (kind of "springing before the leap") in recorded sound at 0.2 s is created mainly by lower harmonics (see Fig. 8). The higher ones are attenuated before the mode change, which causes faulty but common tone without typical trumpet timbre.

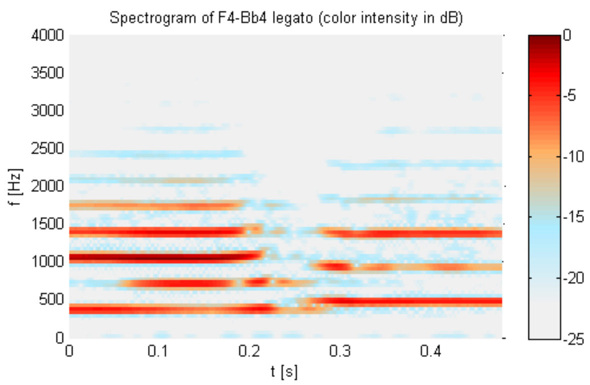


Fig. 8 – Spectrogram of sound in Fig. 7 (upward legato).

Simultaneously, mouth pressure is increasing its amplitude showing the player's preparation before the leap between the modes.
The same slur downwards (Bb4 to F4, see Fig. 9) exhibits less demands on player's embouchure. Less experienced players tend to loose their muscles too much causing audible attack on legato transient. Figure 9 depicting the downwards legato inclines to have signs of that at 0.15 s.

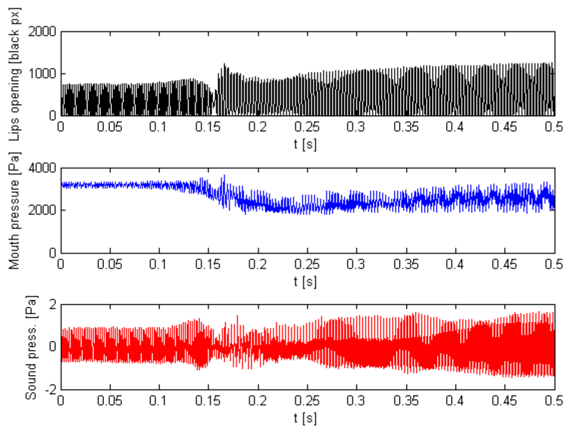


Fig. 9 – Legato downwards

d) ***F4, triple staccato, mezzoforte***

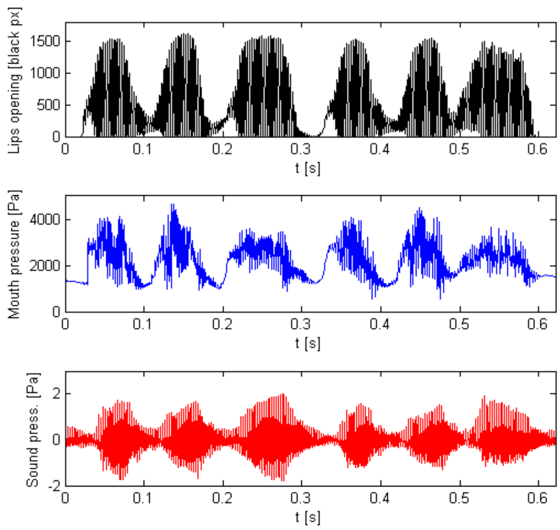


Fig. 10 – Triple staccato, depicted syllables in order ta-ta-ka-ta-ta-ka.

Soft triple staccato. The differences between toungue action ("ta" – 1st, 2nd, 4th, 5th wavelet) and throat action ("ka" – 3rd and 6th wavelet) are easily observable (see Fig. 10). Without tongue action there is no clear peak in the mouth pressure – it is a master technique to build the peak properly. "Ka-wavelets" are generally more flat, which could cause well-known loss on sharpness of the staccato while misusing this technique. Certainly, discussed quality strongly depends on player's mastery in double and triple staccato (see the discussion below).

4. DISCUSSION

The key features presented in the text are so far observed as systematic and repeatable, but only in a case of one particular player (semi-professional).
The main problem in applying this method to a wider group of players lies in a personal habit in inclining the direction of the blow relative to the plane of the mouthpiece rim. There are angles of inclination, in which the lips opening surface is not visible from the direction of instrument's leading pipe (and therefore not visible for the camera as well), but such a behavior is not to be generally condemned as a player's mistake.
Glass mouthpieces are comparable with real models only in a certain range of frequencies. The cup's acoustic compliance is much higher for a glass mouthpiece than for common ones. Hence, the input impedance looses on its maximal values so the higher tones demand more player's effort and are generally less accurate in pitch and less „brassy" in sound. To avoid this kind of data spoiling the measurements were made only in the middle (or lower) registers of the instruments.
Dynamics of tones (*p*, *mf*) was set subjectively in view of the player, so the connection between it and measured acoustic pressure might not be perfect. We have chosen this point of view for its link to the player's "self-adjustment".

5. CONCLUSIONS AND FUTURE GOALS

Some of the key features connected with the transients in trumpet sound were shown and commented. Especially the phenomena of "initial blow off" (see 3. b)), transients in legato or the "ka-wavelets" flattening couldn't be described without using the high-speed imaging.

The player's lips turned out to be a system with high inertia in the dynamics of the transient (see 3. a)). In correspondence with this statement no modulation or influence of subtle effects on them were observed so far.

Measured mouth pressures are corresponding to theoretical values proposed by Fletcher [3].

On the other hand, modulation on lower frequencies probably not connected with any simple geometrical proportions of the system were observed in player's mouth pressure. This topic as well as properties of the spectra of presented signals will be discussed in a future paper.

Without wider group of tested player's there cannot be any discussion of parallels between measured quantities and playability percieved by player [5]. This is one of the future goals as well.

6. ACKNOWLEDGMENTS

Supported by the Ministry of Education, Youth and Sports of the Czech Republic in the Long Term Conceptual Development of Research Institutes grant of the Academy of Performing Arts in Prague: The "Sound quality" project.

We would like to thank the technical glassworks of University of Chemistry and Technology in Prague, especially Mr. Josef Rotport, for accepting a peculiar challenge to make a glass mouthpiece.

7. REFERENCES

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