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IDENTIFICATION OF LIP-PARAMETERS ASSOCIATED TO DIFFERENT TRUMPETS USING CONSTRAINED CONTINUATION

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ABSTRACT

The relationship between the player's global perception and acoustical characteristics of a musical instrument is very complex but nevertheless an important topic of interest for musical instrument makers. One of our hypotheses is that some aspects of the biomechanical control required by the player to achieve a given task (embouchure adjustments for instance) can contribute to explain the player's perception of an instrument: for an exact same musical task, if two instruments require different lip adjustments, there are likely to be perceived as different in terms of "blowing feeling" by the player. In this study we follow this idea in order to compare numerically two trumpets. Our strategy is based on the application of constrained continuation where the physical model studied is enriched with target trajectories for some of the output variables, and where two lip parameters of the physical model are relaxed. These constraints are established from playing measurements on one player and two trumpets. The evolutions of the relaxed parameters along the solution branches are then compared between the two instruments, and confronted to the blowing feeling reported by the player.

Keywords: *musical acoustics, numerical continuation, brass instruments, physical modelling*

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1. PLAYING MEASUREMENTS AND PHYSICAL MODEL

Playing measurements are conducted on two trumpets. The mouthpiece is equipped with a pressure sensor (ENDEVO 8510B) that records the acoustic pressure in the mouthpiece cup p. A similar sensor is used to measure the quasi-static pressure in the oral cavity of the player p_0. The player is instructed to play a crescendo maneuver for a Bb4 (about 466 Hz) while trying to maintain the pitch as stable as possible.

The physical model considered is based on four equations: two coupled mechanical equations to represent the dynamics of a two d.o.f. lip model as presented in [1], a nonlinear flow equation and a modal representation of the air-column to represent the nonlinear characteristics and the linear air-column resonator respectively, as detailed in [2]. The choice of the two d.o.f lip model for the lips is motivated by some limitations observed in previous work with the simple one d.o.f. lip model, where constrained continuation could be successfully performed, but the exact value of the target fundamental frequency could not be reached [2]. Indeed a drawback of the one d.o.f. outward-striking lip model is a tendency to produce a sharp intonation. We try here to overcome this issue by considering a more sophisticated model that includes two mechanical modes.

In addition, two equations are considered in order to account for the constraints obtained from playing measurements. A first equation ("loudness equation") sets the relationship between the L2 norm of the mouthpiece pressure p, and the mouth pressure p_0, and a second equation ("intonation frequency") forces the fundamental frequency to a constant value f_{0c} (since small variations of intonation are observed in the player's performance along the crescendo maneuver):

$$||p||_{L2} = a\sqrt{p_0^2 - p_{0s}^2} \quad \text{and} \quad f_0 = f_{0c}, \qquad (1)$$

where a, p_{0s} and f_{0c} are set by an optimization routine in order to match the playing measurements.

Since two equations have been added to the original model without constraints, two parameters need to be relaxed to keep the system balanced. We choose here to relax two lips parameters: ζ, a dimensionless lip parameter that depends on the lip opening width b, and $f_x = \omega_x/2\pi$, the natural frequency of the outward striking (x-direction) mechanical mode of the lips.

2. NUMERICAL RESULTS

This system of equations can then be recast into a quadratic system, and the continuation of periodic solutions can be performed using the Asymptotic Numerical Method (ANM) [3] implemented in the software ManLab [1]. The constrained bifurcation diagram obtained for the first trumpet is given in Fig. 1, along with the evolution of ζ and f_x with respect to the continuation parameter p_0. Note that the natural frequency f_y of the second lip mechanical mode – that behaves as an inward-striking reed – was kept constant and set above 466 Hz.

It can be seen that a periodic solution which successfully follows the constraints established from playing measurements can be found over the p_0 range covered by the player. Furthermore significant variations in the lip parameters are observed along the solution branch. After running similar calculations with trumpet 2, the variation of lip parameters for the two trumpets are gathered in Table 1 for two scenarios: 1- the variations $\Delta\zeta$ and Δf_x along the solution branch up to a same reference amplitude of p, 2- the variations $\Delta\zeta'$ and $\Delta f_x'$ above 1.6 kPa up to a same reference amplitude of p. This second scenario consists in ignoring the *piano* range at the beginning of the maneuver.

These results illustrate the noticeable differences in lip parameter values between the two trumpets. Over the full p_0 range, larger variations of both ζ and f_x are observed for trumpet 1. However, if the *piano* range is ignored, larger variations of f_x are observed for trumpet 2.

[1] ManLab. http://manlab.lma.cnrs-mrs.fr/spip/. Accessed: 2023-04-17

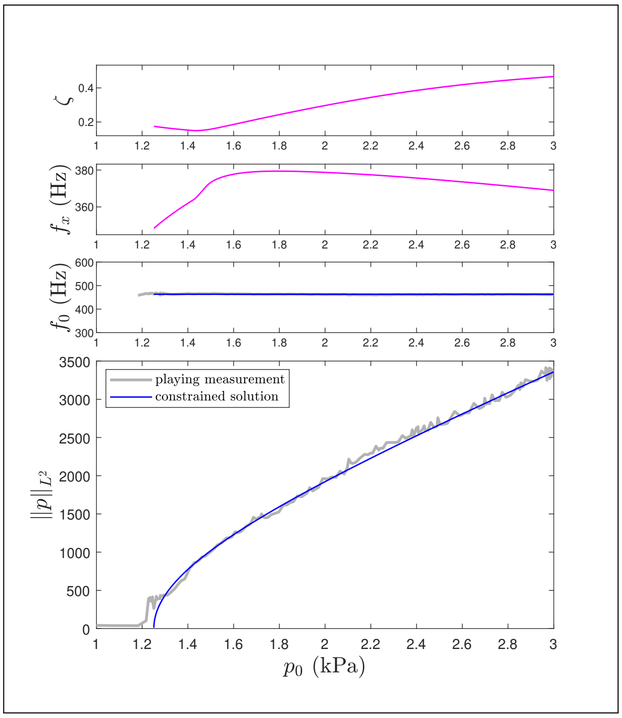

Figure 1. Results from constrained continuation applied to trumpet 1.

Table 1. Variations of ζ and f_x along the solution branch.

	$\Delta\zeta$	$\Delta\zeta'$	Δf_x	$\Delta f_x'$
Trumpet 1	0.267	0.23	31.03 Hz	5.7 Hz
Trumpet 2	0.094	0.07	25.63 Hz	14.9 Hz

3. CONCLUSIONS

We presented a "hybrid" numerical approach based on numerical continuation and constraints coming from playing measurements, that allows variation of lip parameters to be computed along the solution branch. Considering a two d.o.f lip model and a nonlinear constraint we could find a periodic solution that matches relatively well the performance of the player on two trumpets. In this first attempt of trumpet comparisons, the variations of the lip parameters along the branch suggest that the two trumpets have different requirements in terms of embouchure adjustment in order to perform a crescendo at constant frequency.

Furthermore, the player reported experiencing more difficulties in maintaining constant pitch with trumpet 2. In light of the numerical results, we may then make the hypothesis that $\Delta f'_x$ (variation of f_x above 1.6 kPa) may be associated to the feeling of embouchure adjustment reported by the player. This link between constrained continuation results and blowing perception should be studied in a more systematic manner in the future in order to make it a trustworthy prediction tool.

4. REFERENCES

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