PLAYING ABOVE AND BELOW THE RESONANCE: THE CHANGING RELATIVE PHASES OF PRESSURE, FLOW AND TROMBONISTS' LIP MOTION

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ABSTRACT

We report the lip motion, upstream and downstream pressures, and flow components as trombonists play the compliant and inertive loads produced by lipping up and down from B♭2. The bore impedance is measured immediately after playing. The amplitudes of its impedance peaks monotonically decrease with playing an initially dry instrument; we attribute this to losses involving water phases. For playing durations less than 10 seconds, the resonance frequencies decrease, attributed to a dominant effect of CO2. Over longer times, increasing humidity and slowly increasing temperature overcome the CO2 effect and raise the resonance frequencies. Notwithstanding these effects, the bore impedance is usually compliant at normal playing frequencies, and its magnitude is more than 10 times larger than the upstream impedance measured in the mouth. Consequently, the mouthpiece acoustic pressure lags behind the flow and is much larger than that in the mouth. At these frequencies, a significant and early component of flow is due to the longitudinal sweeping motion of the lips. Lipping up and down from B♭2, players could readily play over more than three semitones, a range centred approximately on the bore resonance, with their lips auto-oscillating with a compliant or inertive load downstream. The vertical (z) component of the upper lip oscillation, in phase with the inter-lip aperture, lags behind the forwards (x) component by less than 90° and its amplitude is at least 50% larger. This phase difference is reduced while lipping up. The phase of the mouthpiece pressure is closer to z while lipping up and to x while lipping down, but always lies between them. The measured phase relations are consistent with a simple lip model with a bending or swinging x mode whose resonant frequency is always below the playing frequency f0, and a compressive z mode whose resonance lies always above f0.