Detecting sound modes in a vocal tract model using Particle Image Velocimetry and Proper Orthogonal Decomposition

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Introduction

Prior work used near-field acoustic holography [1] to identify sound modes produced by an electrolarynx in a mechanical model of a vocal tract. The same method was applied to a live human in order to map the sound modes during voicing of different sounds. Increasing the near- and far- fields occlusions in the vocal tract affected the sound mode near the source. It showed that in the case of "nasal" sounds the main mode was more shifted toward the nostrils of the subject. The current experiment used particle image velocimetry (PIV) to measure the velocity fields in a mechanical vocal tract placed above an excised canine larynx. The goal is to show the correlation between the results obtained from NAH and POD applied to the velocity fields, in order to predict the sound modes in a vocal tract model using PIV.

Methods

One canine larynx was excised after the animal was euthanized. PIV measurements were obtained in three regions above the glottis, namely in the supraglottal region up to the false vocal folds occlusion (FVF), between the FVF and the far-field occlusion, representing the mouth occlusion (MC), and above the MC. Measurements were obtained at low and high subglottal pressures, relatively to the phonation threshold pressure. The occlusion at the FVF level was varied (no FVF, 7mm gap, and 3mm gap), and the occlusion at the MC was varied from existing to none (open). Proper orthogonal decomposition was applied to the measured fields and the energy of each mode was compared to the other configurations, in order to evaluate the mode location.

Results

Figure 1 shows the energy for the modes 1 and 2 at the three locations for the 6 considered configurations. Energy levels decrease at the FVF level when reducing the FVF gap. Adding the occlusion at the mouth level increases the first mode near the source. These effects are more visible at low subglottal pressure (a few cmH2O above PTP). At high subglottal pressure, an occlusion at the mouth increase the energy level at the mouth in the presence of FVF occlusion.

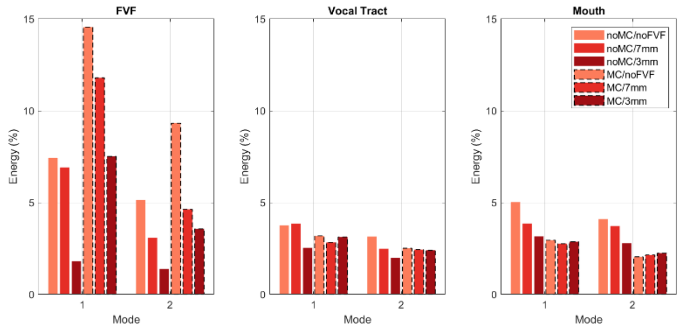

Figure 1: Energy for modes 1 and 2 at low subglottal pressure.

Figure 2 compares the strength of mode 1 obtained from NAH (left side of vignettes) and POD (right side). With an open vocal tract, POD shows a strong mode 1 through it and above, while adding MC pushes most of the energy closer to the FVF.

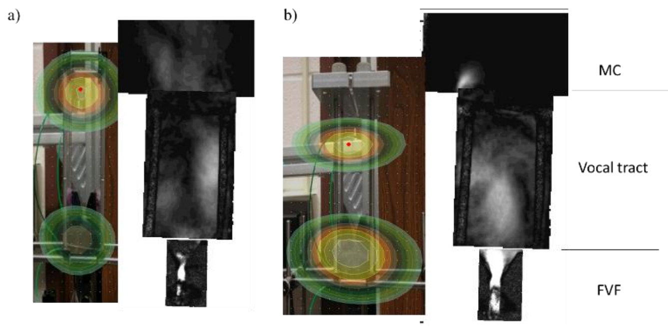

*Figure 2: Contour plots showing mode 1 for **a.** 3mm gap FVF and no MC, and **b.** 3mm FVF gap and MC.*

Discussion

Based on the velocity fields, varying the occlusion at the FVF and mouth affects the energy levels near the source. These preliminary results seem to confirm what was previously observed using NAH. Using PIV yields spatial dynamics of the supraglottal flow fields, and more in-depth comparison of NAH could make possible the use of NAH as a diagnotic tool for voice disorder.

References

[1]. Maynard, Julian D., Earl G. Williams, and Y. Lee. "Nearfield acoustic holography: I. Theory of generalized holography and the development of NAH." *The Journal of the Acoustical Society of America* 78, no. 4 (1985): 1395-1413.

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