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Toward aeroelastic-aeroacoustic phonation model validation

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Introduction

Standards for validation of models and simulations have been implemented in the defense and energy industries, and for FDA certification of medical devices [1-4], but have not yet been completely implemented in phonation. Standard practice for validation dictates that system response quantities (such as velocity, pressure, vibration, etc.) over a wide range of a difficulty spectrum would provide the most useful dataset for validation purposes [5]. The data also require a quantification of uncertainty (both experiment and simulation) to aid in the validation process. Lastly, the measurements should be non-intrusive, using optical techniques where possible.

To provide a validation dataset that meets the stringent requirements described in [5], system response quantities (SRQs) and boundary conditions (BCs) are measured simultaneously. Simultaneous measurements of acoustic pressure, transglottal pressure, volume flow, vocal fold surface motion are reported using the Penn State Upper Airway Model (PSUAM) [6, 7]. This simplified model provides a fully-quantifiable and controllable test apparatus. The as-built dimensions, material properties, and eventually the inflow conditions are or will be measured as the system BCs. In particular, the frequency-dependent modulus of loss factor of the vocal fold are characterized using dynamic mechanical analysis of the rubber layers [8]. These are used as direct inputs to simulations with the intent of validation. Using those BCs, the simulations compute the same SRQs as those that are measured in the experiment for comparison.

Experiment

The PSUAM [6-7] with a multilayer swept-ellipse vocal fold (VF) model, in a hemilarynx configuration was modified to allow for the simultaneous acquisition of pressures, glottis motion, and the velocity field. The setup is shown in Figure 1 showing the PSUAM, camera layout, and the location of the pressure sensors. The modification was merely to use half of the glottis rather than a symmetric VF with two sides.

Pressure and volume flow measurements were conducted as described in [6-7], and VF surface motion was acquired by imaging the surface with three high-speed cameras. The surface motion was computed from the video.

The flow rate of the airway was set to several different magnitudes, with data acquired at 10kHz, sampled for 10 seconds.

Results

Results will include the VF surface motion, pressure and acoustic response, and flow rate with uncertainties for the purpose of validation of aeroelastic-aeroacoustic models.

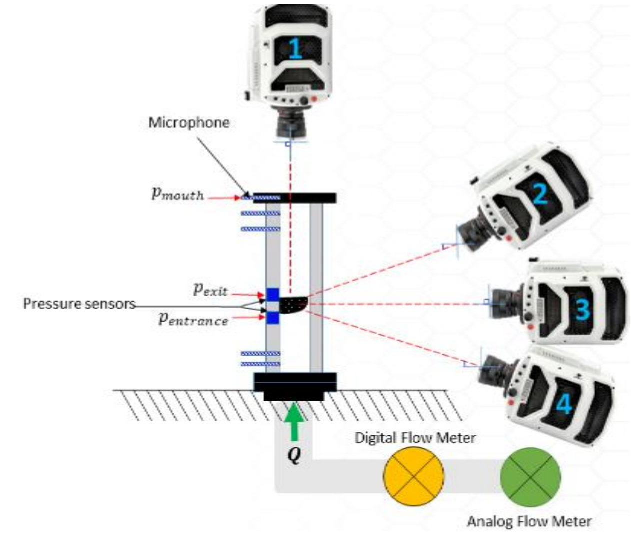

Figure 1: The PSUAM model with a hemilarynx. Camera 1 gives direct video of glottal gap, cameras 2-4 for DIC of VF surface. The flow meters, microphones, and pressure sensors are shown.

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