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Computational aeroacoustics in a human vocal tract

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1. Introduction

The usage of computational analyses in the research of human voice generation have a justified reason, because of the restricted access in a larynx just during phonation. The voice research allows merely visual tools to study a vibration of vocal folds (VFs) such as stroboscopy and videoendoscopy.

2. Mathematical model

Mathematical models of turbulence add up to some limitations regarding a capture of a physical phenomenon. This contribution tackles a laryngeal flow through the domain, the used parametres are taken over from the Scherer's M5 model [3] of a human larynx. The used CFD grids are built up with tetrahedral control volumes (CVs) by Šidlof et al. [4] for cases (A1, A2) and with hexahedral CVs by Lasota and Šidlof [2] for a case (A4). The computational aeroacoustic (CAA) simulation was performed on a domain consisting of the CFD domain (larynx) and a vocal tract model with a propagation region and perfectly matched layer (PMLs), see Fig. 1. The acoustic grid was made by Zörner et al. [6] via geometrical parameters from the study of Story [5]. The fine CFD meshes are used for computation of the laryngeal flow at first, then the results is used for the aeroacoustic sources and afterwards the right-hand side (RHS) is interpolated to the coarser CAA mesh for a decrease of computational costs, see Hüppe [1]. The transient aeroacoustic simulation is solved in a last step.

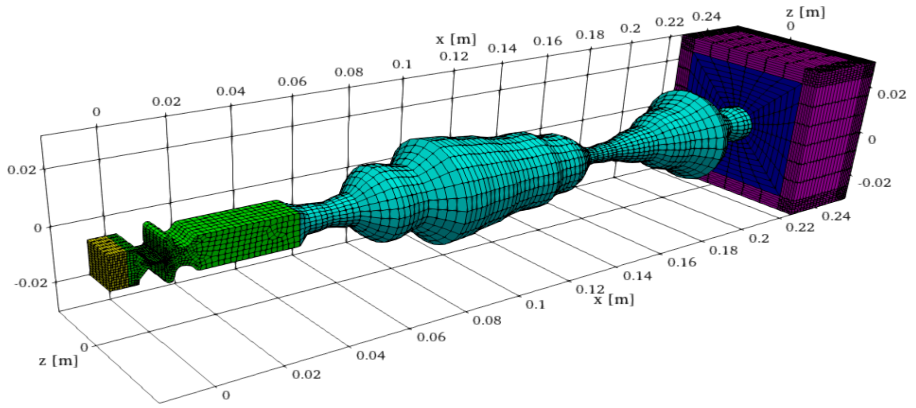

Fig. 1. Mesh for acoustic simulation: a) PML at inlet (yellow), b) larynx (green), c) vocal tract (light blue), d) propagation field (dark blue), e) PML at outlet (purple)

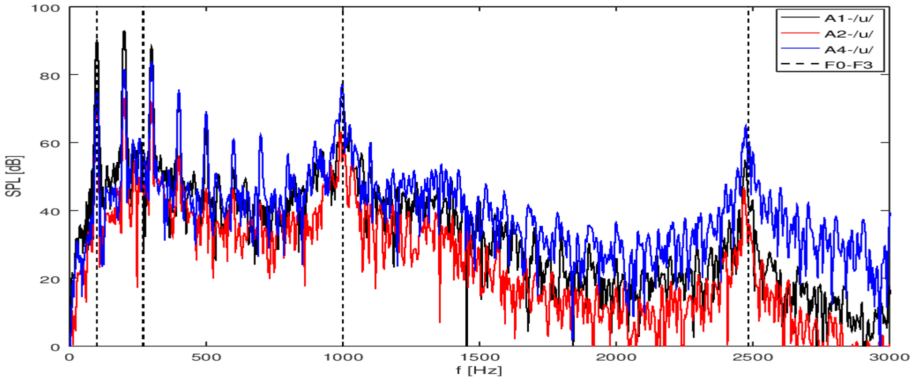

Fig. 2. Acoustic sound spectrum at monitoring point; dashed vertical lines: formants, A1: laminar model, A2: Smagorinsky model, A4: WALE model

3. Results

Fig. 2 presents a frequency spectrum for the three cases with the same prescribed kinematic pressure drop $dP = 300\,\mathrm{m}^2\,\mathrm{s}^{-2}$ and the laryngeal flow externally forced by oscillating VFs, but for different turbulent LES models: A2-Smagorinsky model, A4-WALE model. The spectrum is computed from the probe, which is located 1 cm at the propagation zone (1 cm from mouth). The shape of the vocal tract refers to the vowel [u:], hence the dashed lines are positions of formants in accordance with a magnetic resonance imaging (MRI) study carried out by Story [5]. The acoustic sources are computed with the Lighthill tensor on the RHS. The transient simulation is done with $\Delta t = 1.10^{-5}$ s, the resolution $\Delta f = \pm 2.5$ Hz. The oscillation of the VFs accounts for the fundamental frequency 100 Hz. The amplitudes of higher harmonic frequencies (blue) are stronger, owing to the property of the WALE model, it is caused by y^3 near-wall scaling considering the eddy-viscosity behaviour with no additional damping in equations and its ability to predict the transition from laminar to turbulent regime.

Acknowledgements

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