simVoice – Efficient acoustic propagation model of the human voice source using finite element method

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Keywords: Computational aeroacoustics (CAA); finite element method (FEM); larynx; voice disorders

Introduction

The main objective of *simVoice* is the development of a three dimensional aero-acoustic numerical model for a prospective application in a clinical environment. The model consists of a computational fluid dynamics simulation (CFD) model with externally driven vocal folds motion, based on the Finite Volume method [1], and a computational aero-acoustic model (CAA), based on the 3D finite element method (FEM) [2] using the Perturbed Convective Wave Equation (PCWE). This contribution assesses the performance increase of a reference simulation model when changing discretization parameters while maintaining accuracy of the sound spectra in the acoustic far-field.

Methods

Based on the numerical model *simVoice*, the FEM submodel of the computational aeroacoustic simulation (CAA) is optimized, considering the computational efficiency. With respect to algorithmic efficiency at low Mach numbers, a hybrid aeroacoustic approach is applied, which performs in a first step an incompressible flow simulation on a computational grid which is capable of resolving all relevant turbulent scales. In a second step, the acoustic source terms on the flow grid are computed and a conservative interpolation to the acoustic grid is performed. In a third step, the PCWE is solved to obtain the acoustic field (see Figure 1).

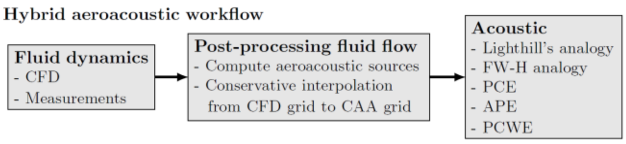

Figure 1: Schematic of the flow diagram of a hybrid aeroacoustic workflow.

The CAA simulation setup consists of an unstructured meshed larynx and simplified vocal tract, a structured meshed propagation domain and perfectly matched layer (PML) region connected to the sub and supra glottal region (see Figure 2). Validation results from experiments are available for this setup. Starting from an initial optimal setup with respect to accuracy, the simulation model was tuned to reduce the computational effort.

Results and Discussion

First, the larynx and vocal tract regions mesh was coarsened. The reduction of the number of equations 195k to 46k in the two regions resulted in a reduction of the computational time from 3.6h to 3.1h. Second, in the PML region the reduction of the number of element layers has been investigated. Thereby total number of equations could be reduced from 243k to 134k by this measure and decreased the computational time from 3.1h to 46min. In a third step, the element size in the propagation region was increased too. The number of equations was lowered from 243k to 37k and the computational time diminishes to 8min.

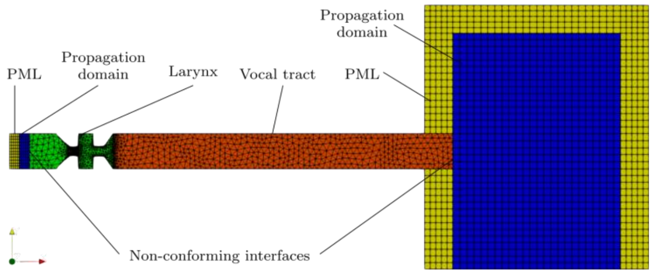

Figure 2: FEM model of the CAA simulation.

Conclusion

The demand for computational efficiency and fast computation is taken into account by the hybrid aeroacoustic approach in combination with the PCWE. Further optimization potential was exploited and the total computational time of the acoustic simulation is reduced to about 5% of the refined reference case.

Acknowledgments

The authors acknowledge support from the German Research Foundation (DFG) under DO 1247/10-1 (no. 391215328) and the Austrian Research Council (FWF) under no. I 3702.

References

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