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Numerical Simulation of Flow in the Human Vocal Tract

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Abstract: Numerical simulation of 2D flow in the human vocal tract is important part for the generation of synthetic human voice. Human vocal folds model is changing its position by prescribed harmonic oscillations. The unsteady flow is computed on a dynamic mesh and the solver is a combination of SIMPLE and PISO algorithms. The simulation is performed within the package OpenFOAM and the computational mesh is generated using the generator SnappyHexMesh.

Introduction

Numerical simulation of airflow in vocal folds combines solution of airflow and structure deformation. The numerical simulations are solved in finite volume package OpenFOAM [5]. Motion of the vocal folds is prescribed as a harmonic function. In this case it is prescribed as a mathematical function on the walls which represent the vocal folds. This motion is combination of rotation and translation (motion with two degrees of freedom)

$$x_1 = x_{10} + X_1 * \sin\left(2\pi f * t + x_{1phase}\right) \tag{1}$$

$$x_2 = x_{20} + X_2 * \sin\left(2\pi f * t + x_{2phase}\right), \tag{2}$$

where values with index 1 are components of rotational motion and with index 2 are components of translational motion. The phase shift between the two motions is $\pi/2$. Starting position of vocal folds is at the minimum gap. Frequency of harmonic motion is 100 Hz. The solver Mesquite [1] used for solution of the mesh deformation gives good results even for small glottal gaps, and allows the vocal folds approaching twice closer than the solver based on solution of the Laplacian equations [2] that was used up to now.

Flow is computed as unsteady with time steps dependent on the Courant number. The computational domain is a simple model of human glottis with vibrating vocal folds which are changing the channel geometry in time. The solver is based on a combination SIMPLE and PISO algorithms [4]. The flow is modeled as an incompressible viscous fluid without any turbulence model. It is described by the continuity equation and the Navier-Stokes equations:

$$\frac{\partial \mathbf{u}}{\partial \mathbf{x}} = 0 \tag{3}$$

$$\frac{\partial \mathbf{u}}{\partial t} + \nabla \cdot (\mathbf{u}\mathbf{u}) - \nabla \cdot \nu \nabla \mathbf{u} + \frac{1}{\rho} \nabla p = 0, \tag{4}$$

where $\mathbf{u}$, p and ρ are fluid velocity, pressure, and density and ν is kinematic viscosity.

The boundary conditions for the velocity are set to zero on fixed walls, and equal to the velocity of the moving surface on the vocal folds. Initial distribution of pressure and velocity is a result of stationary solution for minimal gap in order to eliminate transitional processes at the beginning of a dynamic simulation.

Results

The velocity fields from third period of motion of vocal folds are shown in Fig. 1. Simulation is computed on a 2D tetrahedral mesh, the number of elements is 46 k. The air flow separates from the wall and creates large-scale circulation structure. During the maximally open gap (see two results on the right side of Fig. 1) the flow alternately attaches to the upper or lower vocal folds.

Plan for future is computed simulation in 3D with more complex motion of the vocal folds. The next step is to modify the solver to reduce the gap width until the interruption of the flow.

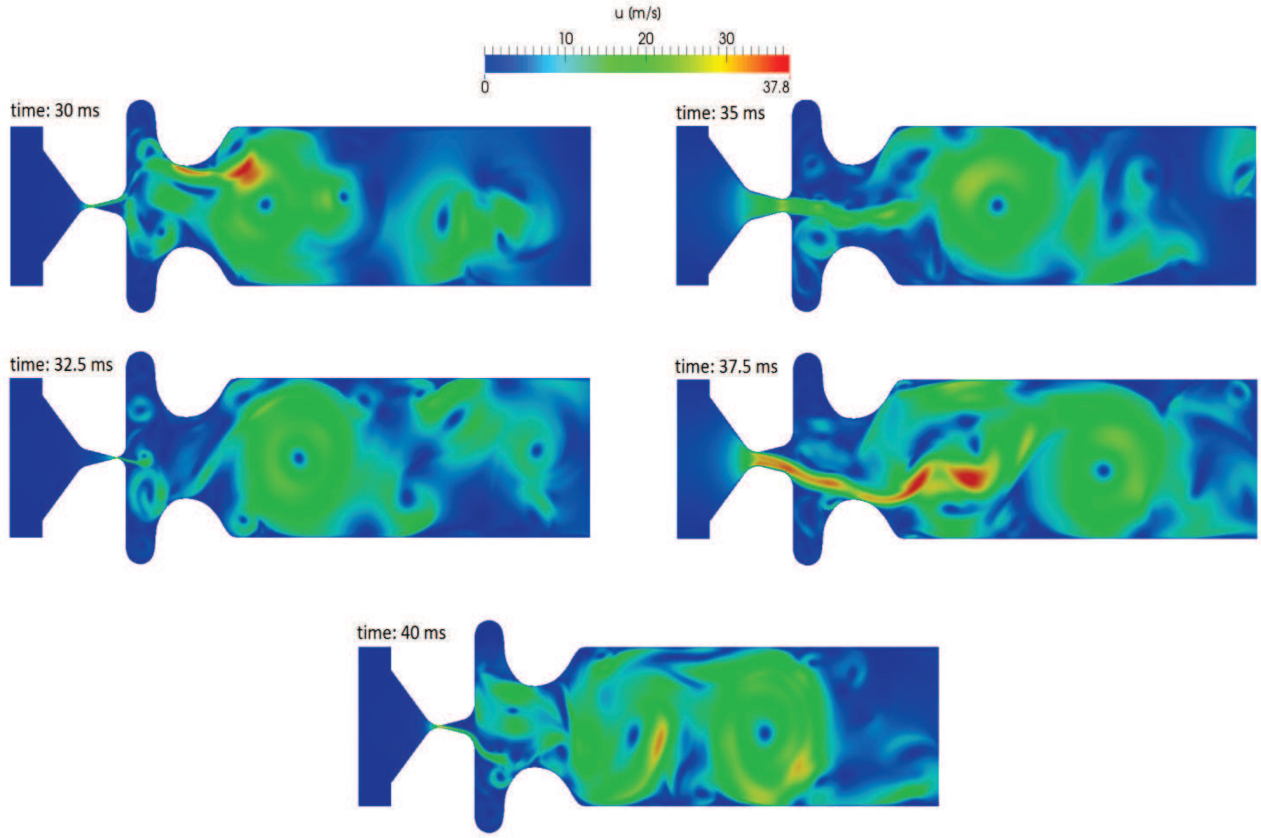

Fig. 1: Velocity fields during the third period of the vocal folds motion

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References

[1] V. Řidký, P. Šidlof, Numerical simulation of deformation of dynamic mesh in the human vocal tract model, EPJ Web of Conferences 69 (2015) 465-468.

[2] P. Šidlof, S. Zörner, A. Hüppe, Numerical simulation of flow-induced in human voice production, Procedia Engineering 61 (2013) 333-340.

[3] J. H. Ferziger, M. Peric, Computational Methods for Fluid Dynamics, third edition, Springer, Berlin, 2002.

[4] H. Jasak, Error Analysis and Estimation for the Finite Volume Method with Applications to Fluid Flows, PhD thesis, Imperial College, London, 1996.

[5] Information on http:// www.openfoam.org.