Experimental and theoretical study of the influence of time-varying waveguide geometry on fluid flow and aero-acoustics: application to articulation during speech production

Introduction and objectives.

Turbulent flow in the human upper airways plays a significant role in daily life since it intervenes in basic features of human life, e.g. breathing and fricative speech sounds production. Despite this prevalence, few studies are dedicated to the physical understanding of turbulence creation, development and decay and hence laminar- turbulent flow transitions for conditions pertinent for the human upper airways and vocal tract in particular. *This study deals with low to moderate Reynolds number (Re < 10^5) flow and aero-acoustics through complex waveguides with time-varying boundaries.* Results contribute to the understanding of the role of turbulence in respiratory health and speech sound production.

Methods.

A systematic study of the generation, development and decay of turbulence in confined channel flow is assessed combining experimental and theoretical work for simplified parameterised channels grasping some characteristics of the human upper airways.

Time-varying geometrical channel parameters [1], such as constriction degree and constriction position are assessed, in order to mimic conditions pertinent during during breathing and articulation, while imposing different inlet Reynolds numbers. In addition, acoustic forcing is considered in order to take into account the impact of wheezing (respiratory health) or voicing (fricative speech sound) on flow development and laminar-turbulent transition.

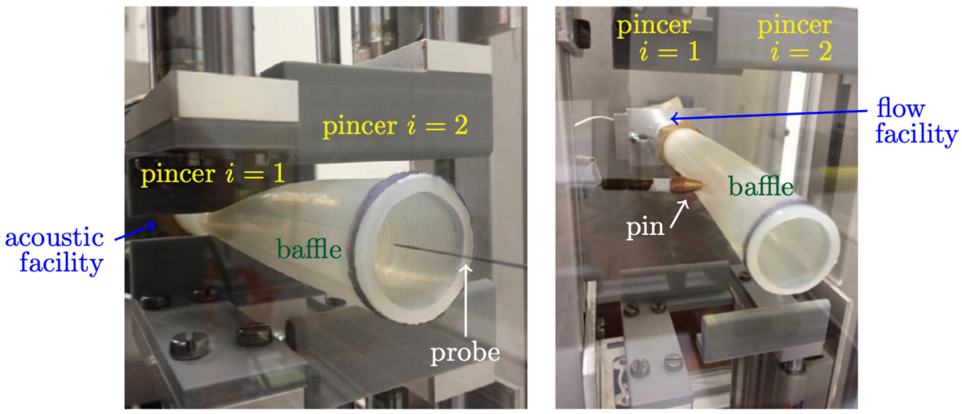

Fig. 1 Illustration of simplified time-varying waveguide set in a baffle and part of the experimental setup [1]: left with constriction and right without constriction.

A simplified experimental replica (see Figure 1) is mounted in a suitable experimental setup [1] in order to experimentally study and characterise [2, 3] the impact of flow, geometrical and acoustic parameters using simultaneous measurements of local wall pressure, velocity (anemometry and Particle Image Velocimetry (PIV)) and acoustic output.

At the same time it is aimed to propose a theoretical model [4] capable to capture and hence predict main channel flow characteristics as a function of varied parameters. In particular, it is sought to model jet formation, associated flow structures and their contribution to turbulence onset and decay.

Proposed models are systematically validated against experimental results. Specific geometries are then selected to further cross-validate against numerical data as well as to get detailed insights in the spatial-temporal flow field [5].

References.

[1] Van Hirtum A., Blandin R., Pelorson X., 2016. A setup to study aero-acoustics for finite length ducts with time-varying shape. Applied Acoustics, 105:83-92.

[2] Van Hirtum A., Grandchamp X., Cisonni J., 2012. Reynolds number dependence of near field vortex motion downstream from an asymmetrical nozzle. Mechanics Research Communications, 44:47-50.

[3] Grandchamp X., Van Hirtum A., Pelorson X., 2013. Centreline velocity decay characterisation in low-velocity jets downstream from an extended conical diffuser. Meccanica, 48:567-583.

[4] Van Hirtum A., 2017. Analytical modeling of constricted channel flow. Mechanics Research Communications, 83:53-57.

[5] Van Hirtum A., Wu B., Gao H., Luo X.Y., 2017. Constricted channel flow with different cross-section shapes. European Journal of Mechanics - B/Fluids, 63:1-8.

Location and contact.
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Competences required.
Strong interest in research in the fields of mechanics fluid mechanics and aero-acoustics. Experimental skills are appreciated. As this internship is within the framework of an ANR project, the internship can be pursued in PhD research depending on the interest and potential of the candidate.