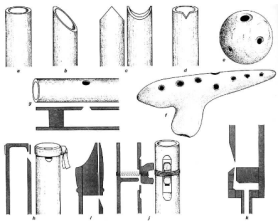
Research internship : Aeroacoustic numerical simulations of flute-like instruments using a CFD/CAA methodology

Keywords

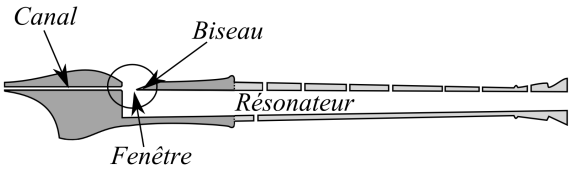
Musical Acoustics, Aeroacoustics, Fluid Dynamics, Turbulent Flows, CFD/CAA

Context and objectives

Flute-like instruments have existed for thousands of years in many parts of the world. While their sound, size and shape are extremely diverse (Figure 1(a)), all these instruments share the same fundamental mechanism to produce sounds.



(a) Different types of flutes (Figure from G. Grove. Dictionary of music and musicians. Macmilan, 2001).



(b) Schematic representation of a flute-like instrument

Indeed, from the mechanical point of view, flute-like instruments is a class of musical instruments in which the sound oscillation is generated and sustained by a coupling that involves on one hand a non-linear fluid interaction between an air jet and an edge, and an acoustic resonator, well described by the theory of linear acoustics, on the other hand (Figure 1(b)). Thus, a comprehensive approach of these instruments requires to adopt an aeroacoustic point of view. In this perspective, modelling and describing flute-like instruments has been, and remains, an area of active research for the past few decades in musical acousics. As of today, there exist two main physical models to predict the sound oscillation, named jet-drive and discrete vortex, respectively.
These models have been successful in predicting some features of the acoustic oscillation in most instruments. However, they also present same drawbacks, as they contain a part of empiricism due to the fact that most tridimensional effects are not taken into account. These models are not valid in crucial phases of the musical expression such as attack transients either. Another limitation of these models is that they do not describe the effect of turbulence (stochastic in nature) on the sound produced.
To overcome these limitations and improve the physical modelling of flute-like instruments on the points mentioned above, we propose to adopt an approach based on Computational Fluid Dynamics (CFD) and Computational AeroAcoustics (CAA). Such an approach has been adopted by Blanc in his PhD thesis, but remains scarce in musical acoustics. *Thus, the main objective of this internship will be to develop a CFD/CAA framework for conducting numerical aeroacoustic simulations of the turbulent flow in flute-like instruments and the associated sound.*

Main steps and methods

To this end, the CFD solver Basilisk developed at the ∂'Alembert institute will be used. After a thorough bibliographical review, the instrument will be subdivided into elementary parts (channel, backward facing step, free jet-edge interation) in which 2D incompressible simulations will first be carried out and thoroughly validated against reference data and/or analytical solutions. Then, a global simulation will be performed on the complete bidimensional geometry. Extension of this work to 3D geometry will finally be done and the resulting flow field will be analyzed to improve physical models. If time permits, compressible aeroacoustic simulations will also be considered.
Depending on the applicant motivation and results during the internship, a follow-up of this work will be considered for a PhD program to start in October 2024 (funding yet to be determined).

Practical information

Time : 5 to 6 months, start expected about March 2024.
Location : Institut Jean le Rond ∂'Alembert, Sorbonne Université, campus Pierre et Marie Curie, Paris, France.
Salary : Legal internship stipend (≃ 570 euros / month).
Profile : The candidate should be a Master's student in applied mathematics, acoustics, fluid mechanics or related fields. Knowledge of aeroacoustics would be much appreciated. They should have a taste for numerical work.
How to apply : The candidates must send CV (including recommendations if possible), grade records and a cover letter.
Supervisors : Antoine Hajczak (antoine.hajczak@sorbonne-universite.fr), Augustin Ernoult (augustin.ernoult@inria.fr)