PhD Proposal 2017

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Title: Modeling of dissipative interfaces: novel numerical approaches for the resolution of flow duct acoustics problems
Scientific field: acoustics
Key words: aeroacoustics, duct, liner, impedance, time domain, numerical simulation

Details for the subject:

Background, Context:

Noise in the vicinity of airports is one of the main obstacles to the development of air traffic. In the European Union, it is estimated that more than 40 million people are disturbed by aircraft noise [1]. Noise reduction is therefore an important challenge for the aerospace industry. There are two main sources for aircraft noise. The first one is the airframe noise, which is generated through the interaction of turbulent flows with solid bodies, such as high-lift systems and landing gears. The second one is the engine noise, induced mainly by the rotating parts of the engine (fan, turbine) and the jet. Due to the development of high bypass ratio engines, jet noise has been greatly reduced, and fan noise is becoming a major concern over the past years. To reduce fan noise, the current solution is to apply absorbent treatments in the nacelle walls. These absorbent treatments can be honeycomb-like structures, poroelastic materials or perforated plates.

While it has been extensively studied for more than fifty years, sound propagation in an acoustically treated duct with or without the presence of a mean flow remains an unresolved problem. One of the bottleneck is the modeling of the absorbent treatments. They are usually modeled by an equivalent surface impedance, which can be obtained from measurements or analytical models. While this approach is simple and effective, it has two main disadvantages. First, it supposes that the treatment is locally reacting, which is a strong assumption for porous materials. In particular, this representation is not adapted for poroelastic materials. Second, surface impedance is defined in the frequency domain. Its translation in the time domain is not straightforward, as the impedance model has to verify some mathematical conditions, such as causality [2,3]. Additionally, the impedance boundary condition is written in the time domain as a convolution, which is computationally expensive and requires specific computational methods [4].

Research subject, work plan:

The goal of this thesis is to explore new ways to model the behavior of these dissipative interfaces.

The first part will focus on the modeling of poroelastic materials in the frequency domain. We will adopt a fully numerical approach for both the propagation medium and for the interface to be characterized in terms of diffusion. This will allow a 3D design of absorbents by incorporating special features for materials or systems. The work will be based on results recently obtained on the Wave Finite Elements approach (WFE) [5-10]. This approach uses a finite-element representation of a unit cell and the Floquet theorem for the reformulation of the spectral problem. The solutions of the spectral problem are the characteristics of the propagation medium and the wave modes inside the medium. The characterization of the interface diffusion is then done by coupling the WFE and a technique for the dynamic substructuring of the 3D interface model. The objective is to extend these formulations to account for a moving medium.

The second part is concerned with the modeling of dissipative interfaces in the time domain. For predicting acoustic propagation in the presence of a mean flow, time-domain approaches are often used. They allow one to perform broadband computations and to consider nonlinear propagation, which is important for aeronautical applications as sound pressure level inside the nacelle can reach up to 160 dB. Finite-difference time-domain methods can thus be employed to directly solve the Navier-Stokes equations. Dissipative interfaces must then be formulated as a boundary condition in the time-domain, which is generally performed by translating the frequency-domain impedance boundary condition into the time-domain. This approach was recently followed by Troian et al. [11], in which a time-domain solver of the fluid mechanics equations was used to identify the surface impedance of treatments from measurements inside a flow duct. We propose to explore new approaches to model dissipative interfaces. First, to go beyond the assumption of local reaction, acoustic propagation inside the porous material will be explicitly computed. Rigid-frame porous materials can be represented by an equivalent fluid, for which propagation equations have been proposed in the literature. A recent study [12] has shown the feasibility of the method. Second, formulations of dissipative interfaces directly expressed in the time-domain will be investigated. In particular, a state-space representation seems well-suited. The developed models can then be used in real-time control of boundary conditions for noise reduction.

References:

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