INTERNSHIP PROPOSAL 2023-2024

Title : Influence of flow parameters and geometry on quarter-wave modes for deep cavities (MAMBO project)

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Duration: 6 months (April-September 2024)
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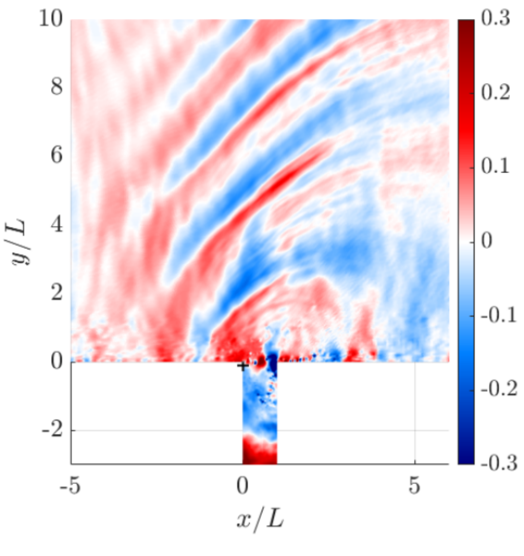
Background

Certification of aircraft door openings for icing conditions requires the presence of a cavity along the interface between the door and the fuselage. However, in the presence of a grazing turbulent flow, the coupling between hydrodynamic instabilities and acoustic waves can lead to different resonance mechanisms that take place over a broad range of flow conditions. This mechanism generates a strong tonal noise that has been observed experimentally at Mach numbers typical of aircraft cruise conditions, $Ma=0.7-0.85$. Such resonance has been extensively studied in flow configurations for which the incoming boundary layer is thin compared to the cavity length. However, there is a lack of studies that consider the case where the boundary layer thickness is comparable to, or larger than, the cavity dimensions, which is typically the case for the current application. This is the problem addressed in this project.



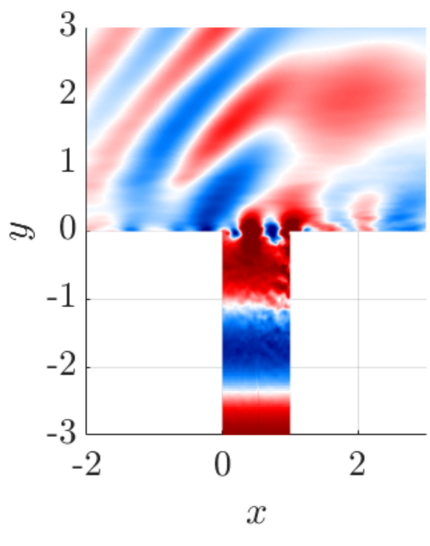


Figure 2: Instantaneous fluctuating pressure field
Figure 1 first quarter-wave mode

A large-eddy simulation (LES) was performed on a cavity with $D=30\,mm, \frac{L}{D}=\frac{1}{3}$ for $M=0.85$ and with a thick boundary layer $\frac{\delta}{L}>1$. The evidence of acoustic resonance in the cavity region is shown in Fig 2. In deep cavities, two mechanisms can be present: (i) purely acoustic modes (box modes), and (ii) the Rossiter mechanism which is an aeroacoustic feedback loop consisting of the hydrodynamics instabilities convected downstream and upstream traveling acoustic waves. Thus, for a given configuration, the two mechanisms are characterized by two different frequencies and stronger resonances appear and when those frequencies are close. This internship will focus on the frequencies for the quarter-wave modes (depthwise modes) to predict them rapidly without a costly LES. An analytical formulation exists [1] : $f_n=\frac{c_0(2n-1)}{4D_{corr}}$, and to overcome its lack of precision, a Helmholtz solver or a correction can be used. In 1D (Fig 3), the formulation is based on a rigid wall and a pressure-release line ($p' = 0$). Depending on the configuration the position of this line is not at a distance D from the bottom of the cavity, it is approximated with an end-correction on the depth D in the formulation. Some values are known for some given configurations in the literature [2]. For the cavities studied in the project, the correction and its evolution with flow parameters are unknown, which leads to doubts in the analysis of the phenomena causing cavity noise. The purpose of this internship will be to obtain the frequencies of the quarter-wave modes and quantify their dependence to the Mach number, the shear layer and the frequency itself. This will be done using an analytical model such as end-correction and/or a Helmholtz solver to obtain the frequencies of the purely acoustic modes for a given geometry, first without the effect of the flow. The final objective is to find the exact frequencies of these modes for each cavities studied (academic and industrial) to have a reliable information, on the modes presents and on a possible coupling with the Rossiter modes, for the analysis of cavity noise.

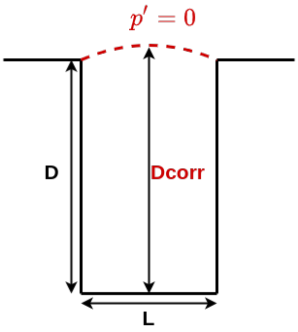


Figure 3:Principal quarter-wave model

Program of internship

The research program will follow the different steps described below.

1. Bibliographic research;
2. Familiarization with the Helmholtz solver;
3. Carrying out of a parameter study to quantify the influence of the geometry, the Mach number and the frequency on the prediction of quarter-wave modes for academic cavities;
4. Predictions of the quarter-wave modes for the industrial cavity

Remarks: It is an end of master/engineering school internship, knowledge in Fluid Mechanics is required. An additional knowledge of acoustics would be appreciated.

References:

[1] Tam, C. K. (1976). The acoustic modes of a two-dimensional rectangular cavity. *Journal of Sound and Vibration*, *49*(3), 353-364.

[2] Rienstra, S. W., & Hirschberg, A. (2004). An introduction to acoustics.