INTERNSHIP PROPOSAL 2021-2022

Title : Large Eddy Simulation of the control of the inlet buzz phenomenon in a supersonic air inlet

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Background

Efficient design of supersonic air inlets is still a challenge today due to the occurrence of violent transitions between subcritical and supercritical regimes inherent to high-speed vehicles operating conditions. These different configurations are all very sensitive to shock wave / boundary layer interactions (SBLI): in all regimes, weak and attached shock waves, arising from the compression ramp (supersonic diffuser) or the cowl lip, impinge on the boundary layers developing on the opposite walls (see Fig. 1). In the subcritical regime, a strong shock wave is positioned upstream of the inlet as a result of the blockage, whereas in the supercritical regime, the shock wave is placed in the subsonic diffuser where the boundary layer is particularly sensitive to separation. A detailed analysis of these high-speed air inlets is thus necessary not only to predict their performance, but also to control the switching margins between the two previously mentioned flow regimes.

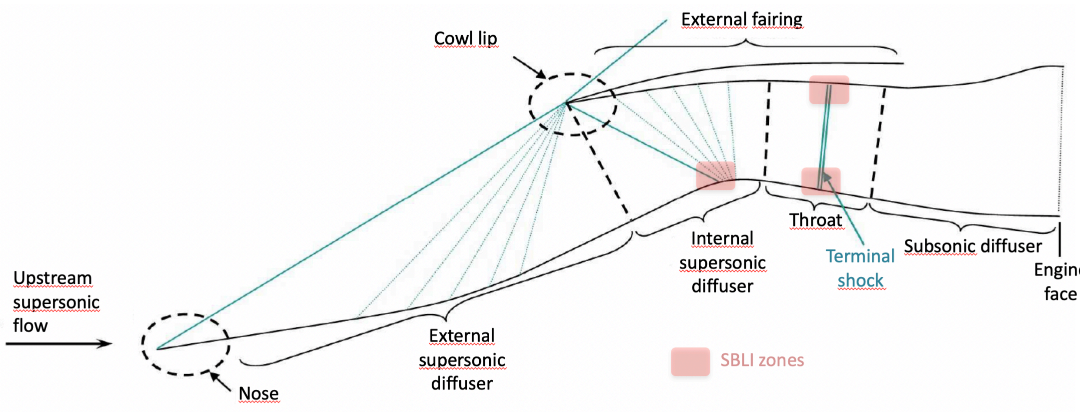
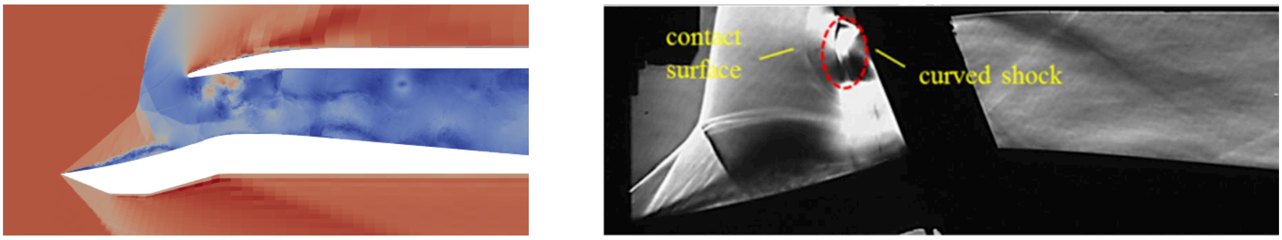


Figure 1: Sketch of a canonical supersonic air inlet configuration

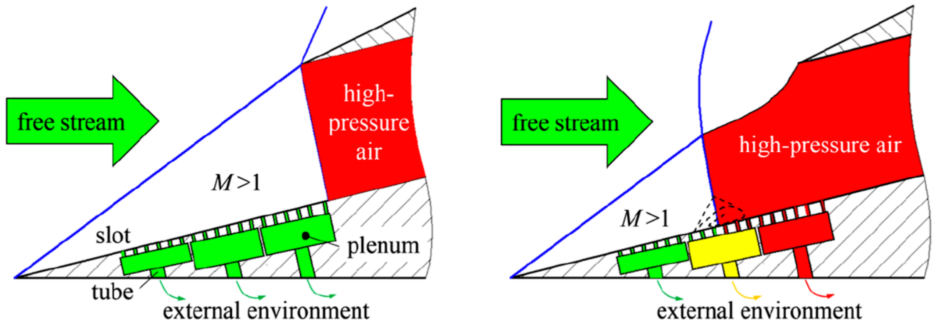
One major well-known problem of these configurations is the supersonic inlet buzz [1] which can be a great threat to air-breathing supersonic vehicles. Usually, it is triggered by an accidental downstream pressure- or thermal-driven flow blockage, which can throw the inlet into the undesirable subcritical mode featuring a terminal shock standing upstream of the inlet entrance (see Fig. 2). Once the buzz occurs, self-excited streamwise normal-shock oscillations are generated along with periodic duct pressure fluctuations, provoking a sharp drop in captured air flow and the consequent engine thrust penalty. Inlet buzz with intense fluid unsteadiness should thus be avoided as much as possible. We propose in this study to assess numerically a control strategy which aims to reduce this undesirable phenomenon. This method is based on a bleed system embedded in the air inlet ramp body as illustrated in Fig. 3. This configuration corresponds to the experimental set-up of Chen *et al.* [2] where the effect of the control device has been assessed by comparing to an uncontrolled baseline air inlet.

The numerical simulation of such flow configurations is still a challenging task due to the unsteady turbulent nature of the problem and the presence of shocks and acoustic waves that interact with each other. The objective of the present work is to perform Large Eddy Simulations (LES) of this complex flow configuration using an in-house solver (IC3), in order to assess the control strategy proposed by Chen et al. [2].



(a) (b)

Figure 2: Supersonic air intake experiencing "Buzz"
(a) LES: Magnitude of velocity ; (b) Schlieren visualization (experiment [2]).



a) Normal state **b) Deep subcritical state**

Figure 3: Illustration of the bleed control system used to mitigate buzz in a supersonic air intake [2]

Internship program

The research program will follow the different steps described below.

1. Getting started with IcemCFD in order to generate adequate meshes on the geometry of Chen *et al.* [2];
2. Getting started with the IC3 code;
3. Carrying out of two-dimensional simulations of the chosen air inlet with and without the control device and the flow conditions corresponding to the experimental campaign of Chen *et al.* [2]: we can start with a non-viscous approach to verify the positioning of the shock waves, then introduce the viscous effects in order to take into account the SBLI phenomenon in this configuration;
4. Analysis of the results obtained in the light of experimental results from the literature and previous studies conducted at the lab on the SBLI topic [3];
5. Depending on the time available, preparation of three-dimensional configurations.

Références :

[1] K. Oswatitsch. Pressure Recovery for Missiles with Reaction Propulsion at High Supersonic Speeds. NACA TM-1140, 1947.

[2] H. Chen, H.-J. Tan, Y.-Z. Liu and Q.-F. Zhang. External-compression supersonic inlet free from violent buzz. *AIAA Journal*, vol. 57(6) :2513-2523, 2019

[3] A. Grébert, J. Bodart, S. Jamme and L. Joly. Simulations of shock wave/turbulent boundary layer interaction with upstream micro vortex generators. *International Journal of Heat and Fluid Flow,* vol. 72: 73-85, 2018.