PostDoc @ ISAE-SUPAERO, 12 months

High-fidelity simulation of supersonic air intakes

Project SIENA (Simulation numérique haute-fidélité d’entrées d’air supersoniques)

PostDoc advisors: Stéphane Jamme (ISAE-SUPAERO, DAEP), Jérémie Gressier (ISAE-SUPAERO, DAEP), Romain Gojon (ISAE-SUPAERO, DAEP)
Contact: romain.gojon@isae-supaero.fr; jeremie.gressier@isae-supaero.fr; stephane.jamme@isae-supaero.fr
Deadline for applying: 31 of September 2021
Location: Aerodynamics, Energetics and Propulsion Department (DAEP), ISAE-SUPAERO, Toulouse
Funding: DGA
Scientific domain: Compressible fluid mechanics
Keywords: Supersonic flows, shock turbulence interaction, High performance Computing (HPC), Large Eddy Simulation (LES), Flow Instabilities

Summary:

Efficient design of supersonic air intakes 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.

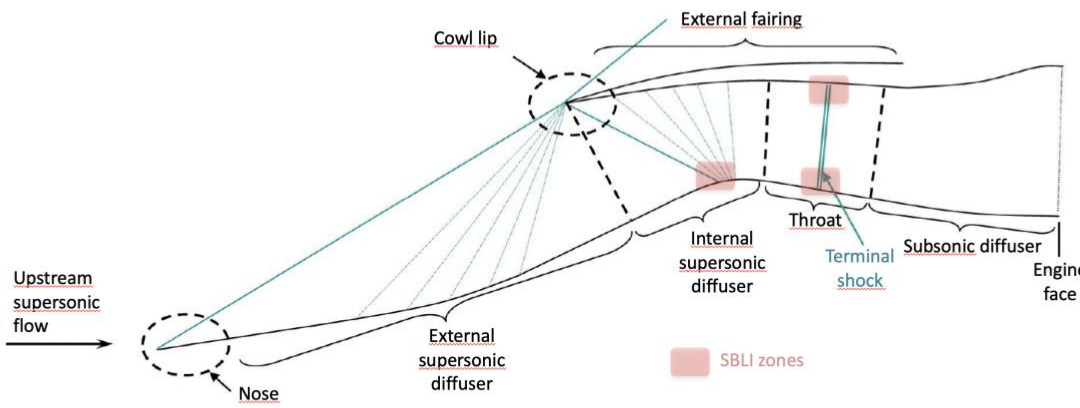

Fig 1: Sketch of a canonical supersonic air intake configuration

Work agenda:

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 previous PostDoc was to perform compressible Large Eddy Simulations of Shock-Boundary Layer interactions and the objective of the present offer is to do the same on a canonical supersonic air intake. A recent high order solver called IC3, based on spectral methods and developed at DAEP [1,2] will be used. It solves the 3-D compressible Navier-Stokes equations on unstructured grids. Thanks to its high scalability, it can be run in parallel on thousands of processors and is applicable to state-of-the-art simulations of turbulent supersonic flows.

In the second part of the PostDoc, a compressible LES will be performed on a canonical supersonic air intake. A companion study will focus on RANS simulation of different supersonic air intakes in order to choose good candidates on which high-fidelity simulations will be performed. One possibility could be to simulate the geometry from a recent experimental campaign [3] (Fig. 2).

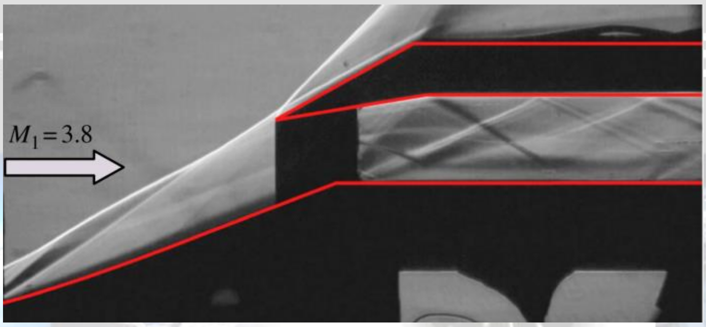

Fig 2: Experimental Schlieren visualization of the flow in a supersonic air intake [3]

Expected skills:

- Compressible flows
- Computational Fluid Dynamics (CFD)
- C++ programming, MPI, HPC, Python
- Aeroacoustics
- High Order schemes

References

[1] Lamouroux, R., Gressier J., and Grondin G. "A High-Order Compact Limiter Based on Spatially Weighted Projections for the Spectral Volume and the Spectral Differences Method." *Journal of Scientific Computing*, 67.1 (2016): 375-403.

[2] Lamouroux, R. Méthodes compactes d'ordre élevé pour les écoulements présentant des discontinuités. *PhD Thesis*, ISAE-SUPAERO, 2016.

[3] Y. Zhang, H.-J. Tan, J.-F. Li and N. Yin. Control of Cowl-Shock/Boundary-Layer Interactions by Deformable Shape-Memory Alloy Bump. *AIAA Journal*, vol. 57(2) :1-10, 2019