ParCFD'2020
32^{nd} International Conference on Parallel Computational Fluid Dynamics
May-11-13 2020, Nice FRANCE

ADJOINT BASED OPTIMIZATION OF A SUBMERGED SUBSONIC INTAKE

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Key words: NACA intake, SU2, GMSH, hybrid grid, turbulent flows, vortex pair

Abstract. The present study describes an adjoint based design optimization of a submerged subsonic intake. The objective function is C_L/C_D value and the total pressure recovery at the intake aerodynamic interface plane constrained with the minimum average pressure. The key flow phenomenon is the formation of a side edge vortex pair which dictates the performance of the submerged intake. The study is performed using SU^2 as the flow solver together with the built-in adjoint solver and the free form deformation tool in a parallel computing environment.

1 Introduction

Subsonic submerged intakes are integral part of air-breathing propulsion systems. These types of intakes are usually used in auxiliary applications but not considered widely for primary air supply units for propulsion systems. Submerged intakes are inherently devoid of creating any form drag. However, the absence of ram pressure adds to the challenge of improved performance. The vortex-pairs emanating from the intake side walls are the key flow phenomenon which entrain the flow into the intake duct as well as contribute to augmented lift. The strength and shape of this vortex pair depend upon the side edge

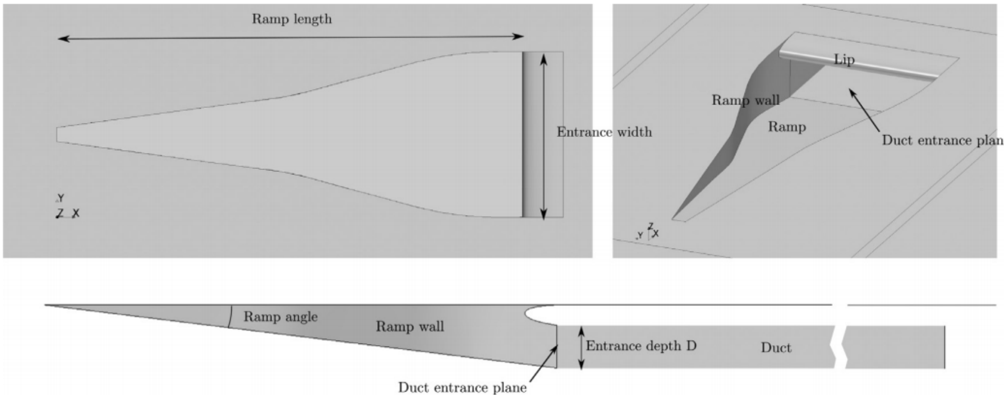


Figure 1: Submerged NACA intake

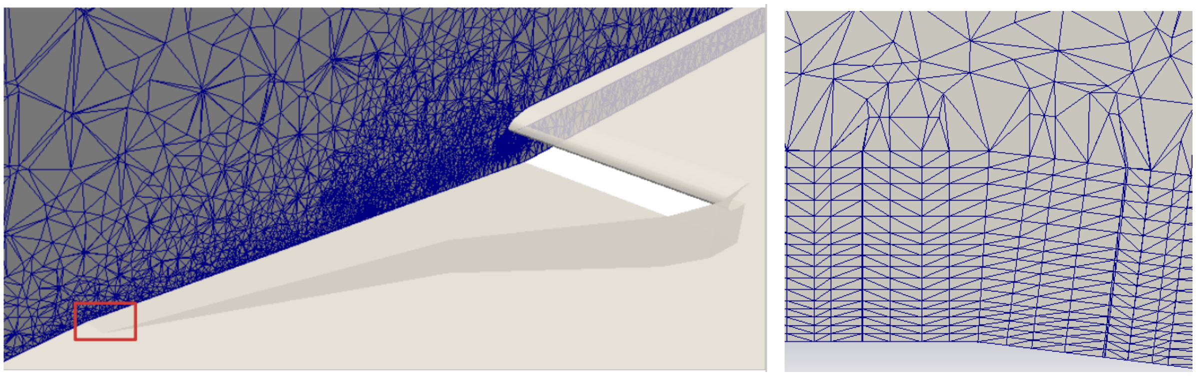


Figure 2: Hybrid computational grid

geometry and the back pressure conditions. The augmented lift along with low drag can be key trade-offs against conventional pitot type subsonic intakes.

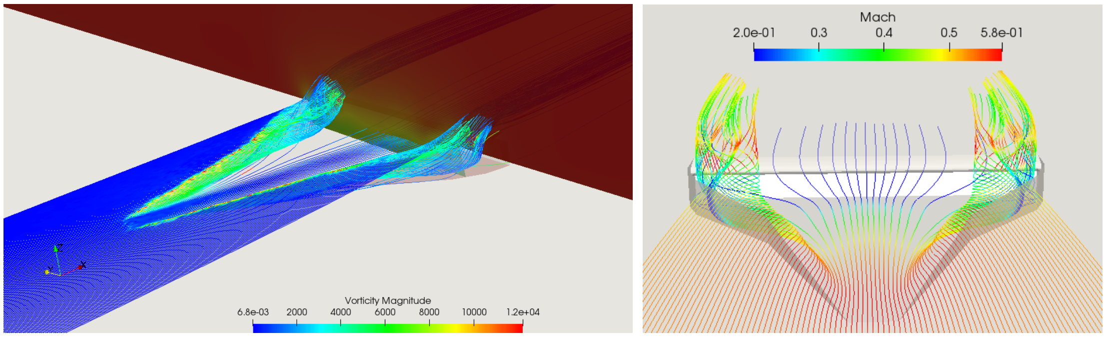
In this study, the open source SU^2 RANS flow solver together with the built-in adjoint based aerodynamic shape optimization and solution adapted grid refinement tools[1] is used to optimize the submerged intake configuration. In an aero-acoustic analysis of NACA submerged intakes on a flat plate Pigneir et al.[2] compare their numerical solutions favorably to the experimental data. Due to high-quality of result and simplicity of geometry this study is chosen as a benchmark case and verification studies are performed. In the full paper, slender bodies with submerged intakes as in the characterization study by Shu Sun et al.[3] will be considered.

2 Preliminary Results

The design of a generic subsonic intake is show in Figure 1. The geometry consists of a 0.5 m long ramp with a 7° ramp angle. The entrance to the duct is 0.07 m in height and the rear lip has an airfoil cross section. The top view is almost triangular and from side the entrainment ramp ushers the flow into the duct along with the favorable effect of the vortex pair generated from the edge of the intake side walls. GMSH[4] is used to generate hybrid grids with a boundary layer zone as shown in Figure 2.

The turbulent flow solutions are obtained on a baseline grid as well as the solution adapted grid. The strong vortex pair emanating from the sharp edges of side walls predicted is shown in Figure 3. Figure 4 shows the pressure distributions along the center line are also compared to the experimental data and to another numerical solution. As observed the prediction on the solution adapted grid is in a good agreement with the experimental data.

In the full paper, the adjoint based shape optimization of the submerged intake mounted on a flat surface and a cylindrical body will be performed in order to improve the C_L/C_D ratio and the total pressure recovery constrained by the average pressure at the intake exit plane. Flow conditions at free-stream Mach numbers of 0,6-0,8 and angles of attack ranging -4 ° to +12 ° will be considered.



(a) (b)

Figure 3: Vortex pair generated over the side walls

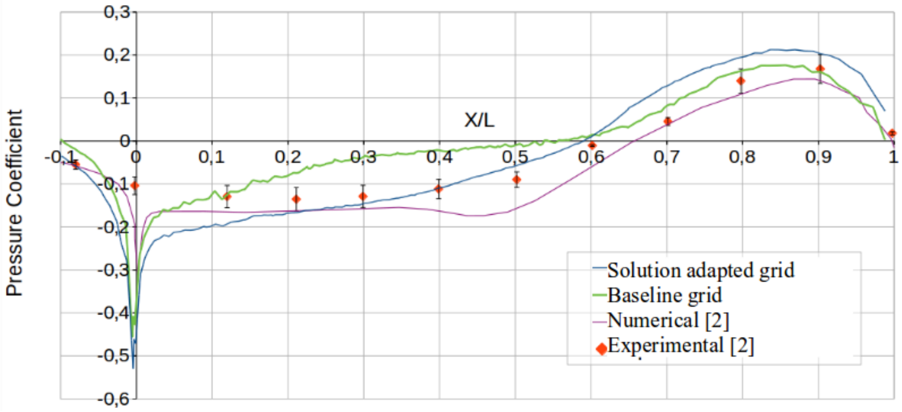


Figure 4: Pressure distribution along the center line

REFERENCES

[1] Thomas D. Economon, Francisco Palacios, Sean R. Copeland, W. Lukaczyk, and Juan J. Alonso. *SU2:An Open-Source Suite for Multi physics Simulation and Design.* AIAA Journal Vol. 54, No. 3, March 2016.

[2] Nicolas J. Pignier , Ciarán J. O'Reilly , Susann Boij, E. *Aerodynamic and Aeroacoustic Analyses of a Submerged Air Inlet in a Low-Mach-number Flow.* Computers and Fluids. (2016) **133**:15–31.

[3] Shu Sun, Rong-wei Guo, and Yi-zhao Wu, E. *Characterization and Performance Enhancement of Submerged Inlet with Flush-Mounted Planar Side Entrance.* Journal of Propulsion and Power Vol. 23, No. 5, September October 2007.

[4] http://gmsh.info/doc/texinfo/gmsh.html