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Aerodynamic Analysis of the Influence of Canopy Shape in the Supersonic Dorsal Intake Design

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ABSTRACT

This work presents a computational analysis of the performance of an air intake under the influence of the canopy shape on a non-conventional supersonic fighter aircraft.

A Two-Dimensional mixed compression intake was designed, aiming to accept slightly more airflow than the used engine requires. Accordingly, it was selected the intake geometry that optimize the total pressure recovery and prevent internal boundary layer separation at the engine entrance.

The intake was top mounted in a fuselage, in order to analyze its performance changes.

For the preliminary design of the supersonic intake, some geometric characteristics of an engine were taken into account. Therefore, the engine chosen for this analysis was the Volvo RM-12.

Two different positions on the fuselage were studied. Thereby, the integration of the canopy with the fuselage produce a low-energy flow from the canopy to the dorsal-intake. Consequently, the performance of the dorsal-intake undergoes a few reduction. However, it increases the potential intake-engine compatibility problems.

INTRODUCTION

In this paper is studied the effect of the intake / airframe integration in a 2D CFD analysis, where the main objective is to analyze the aerodynamic effect of the canopy shape in the performance of an air intake, which was designed for a non-conventional fighter aircraft using the VOLVO RM-12 engine.

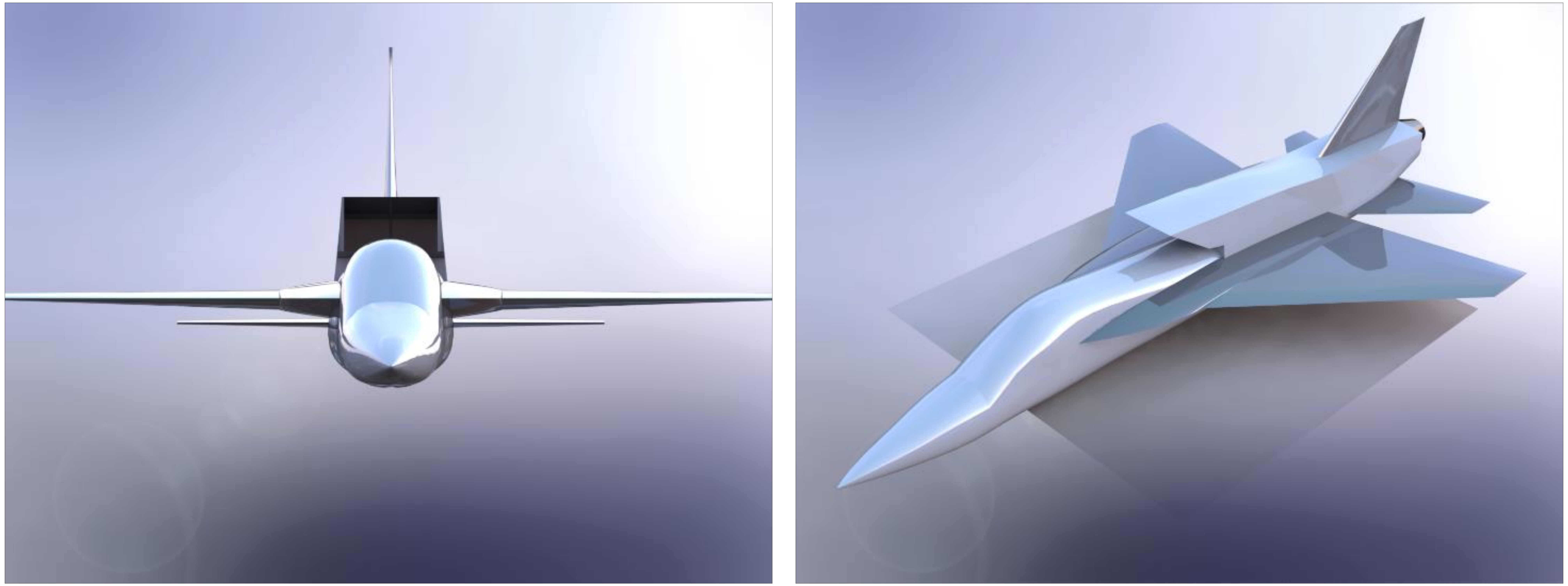

Figure 1. Geometric model of the fighter aircraft under study.

INTRODUCTION

A Two-dimensional mixed-compression air intake was designed, according to the "Escape-Dash" phase in the mission profile for fighter aircraft, developed by Nicolai et al (2010).

The intake designed for this research aims to optimize the pressure recovery in this condition with a uniform distribution at the engine face.

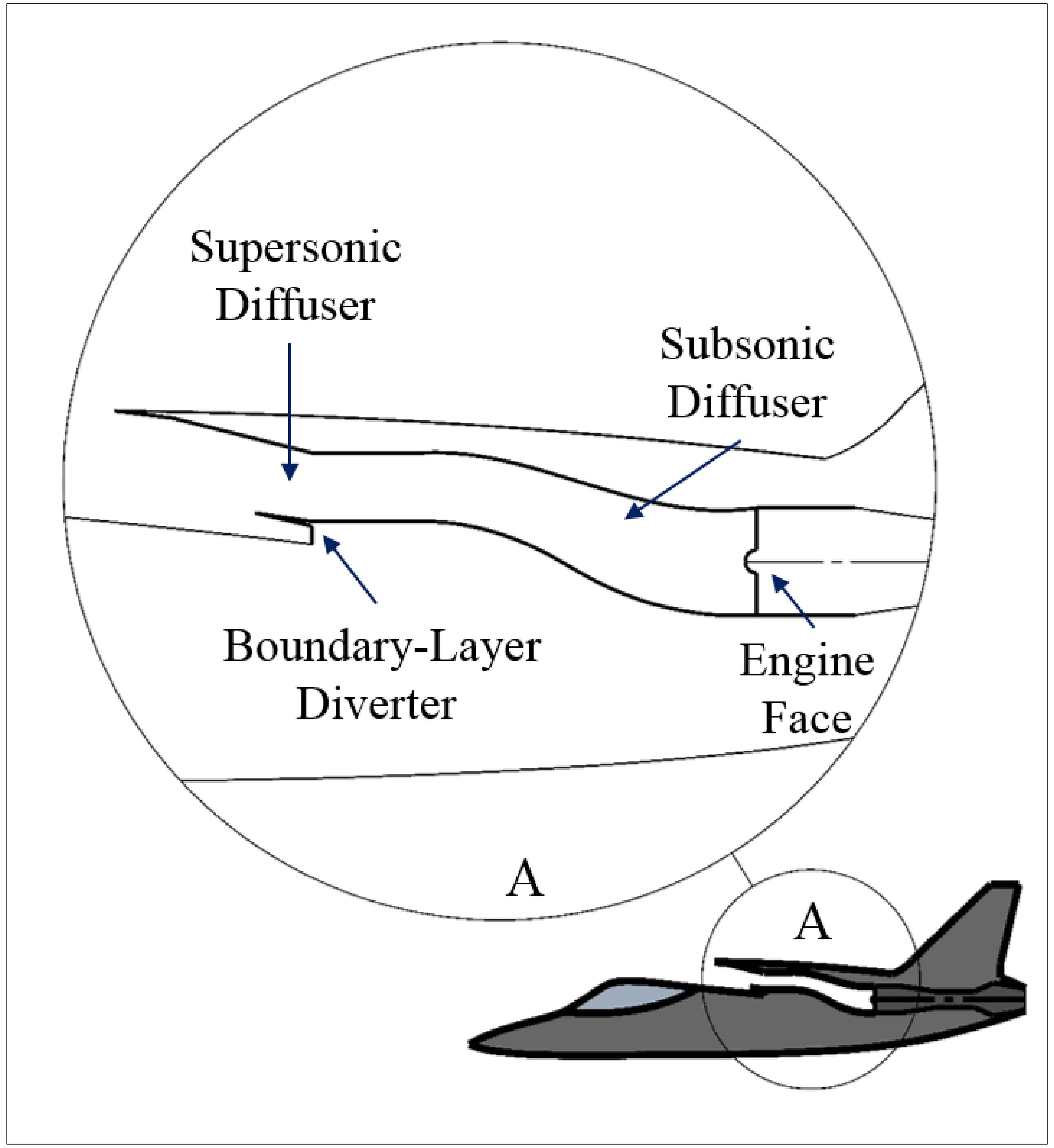

Figure 2. Detail of the intake system.

INTRODUCTION

Some researches of modern fighter aircraft design have suggested that combat survivability might be improved by mounting engine intakes above the aircraft fuselage.

- The supersonic diffuser of the intake was remained fixed.

- The subsonic diffuser was modified in its length, allowing the movement forward and backward in relation to the canopy aircraft, in two different locations.

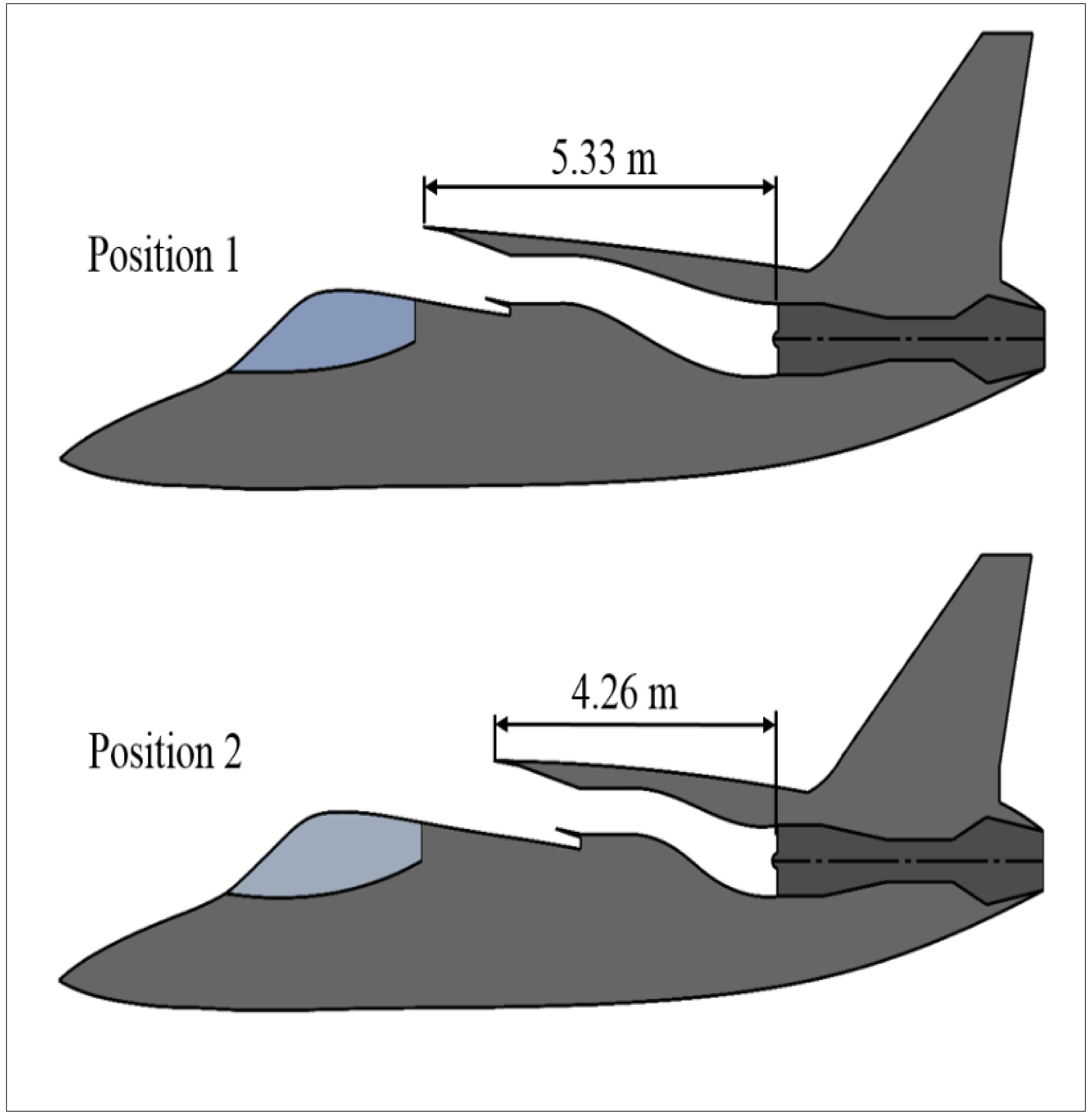

Figure 3. Intake/Airframe model.
Two Dorsal Intake Positions.

METHODOLOGY

Intake Design

- The intake was designed for maximum demand of the engine operation.
- The ramps angles selected must provide the maximum theoretical total pressure recovery, according to MIL-E-5008B.

Canopy Dorsal Effects

- The aim of the canopy design is to reduce the frontal area of the fuselage, allowing good visibility for the pilot.
- The integration of the canopy with the fuselage produce a low-energy flow from the canopy to the dorsal-intake.

CFD Analysis

- Unstructured and Structured Meshes.
- Boundary Conditions.
- ANSYS-FLUENT.

AERODYNAMIC DESIGN OF THE INTAKE

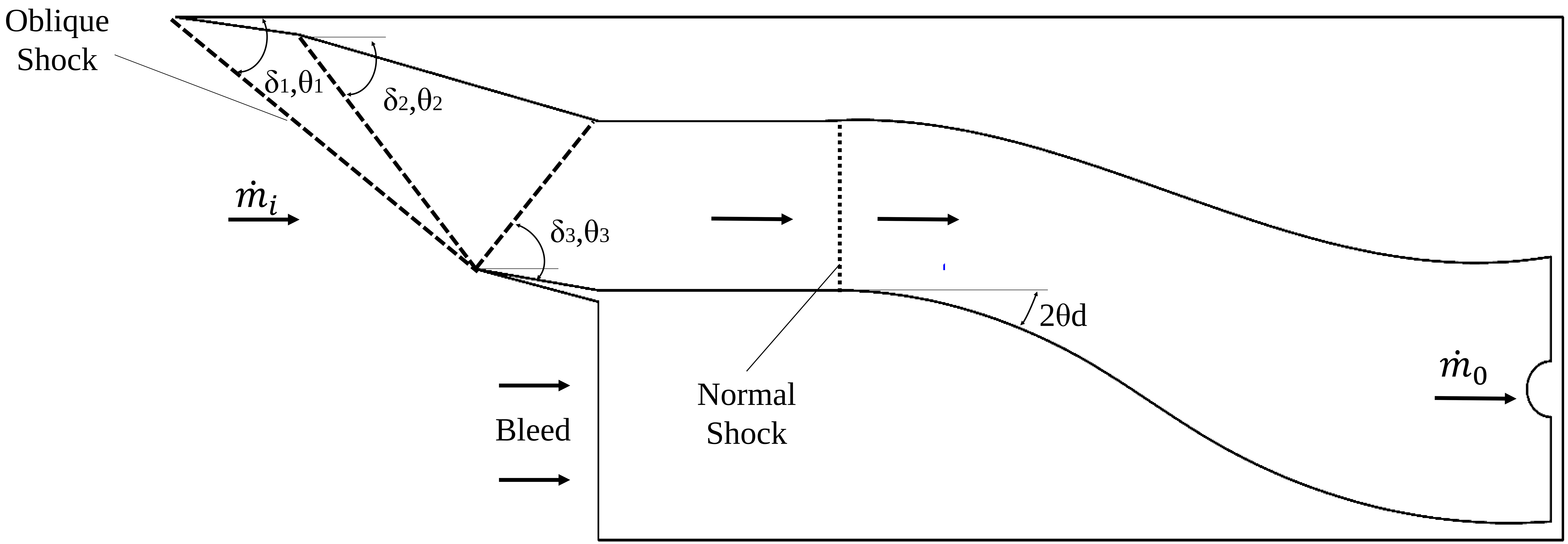

Figure 4. Intake geometry.

CANOPY / DORSAL INTAKE EFFECTS

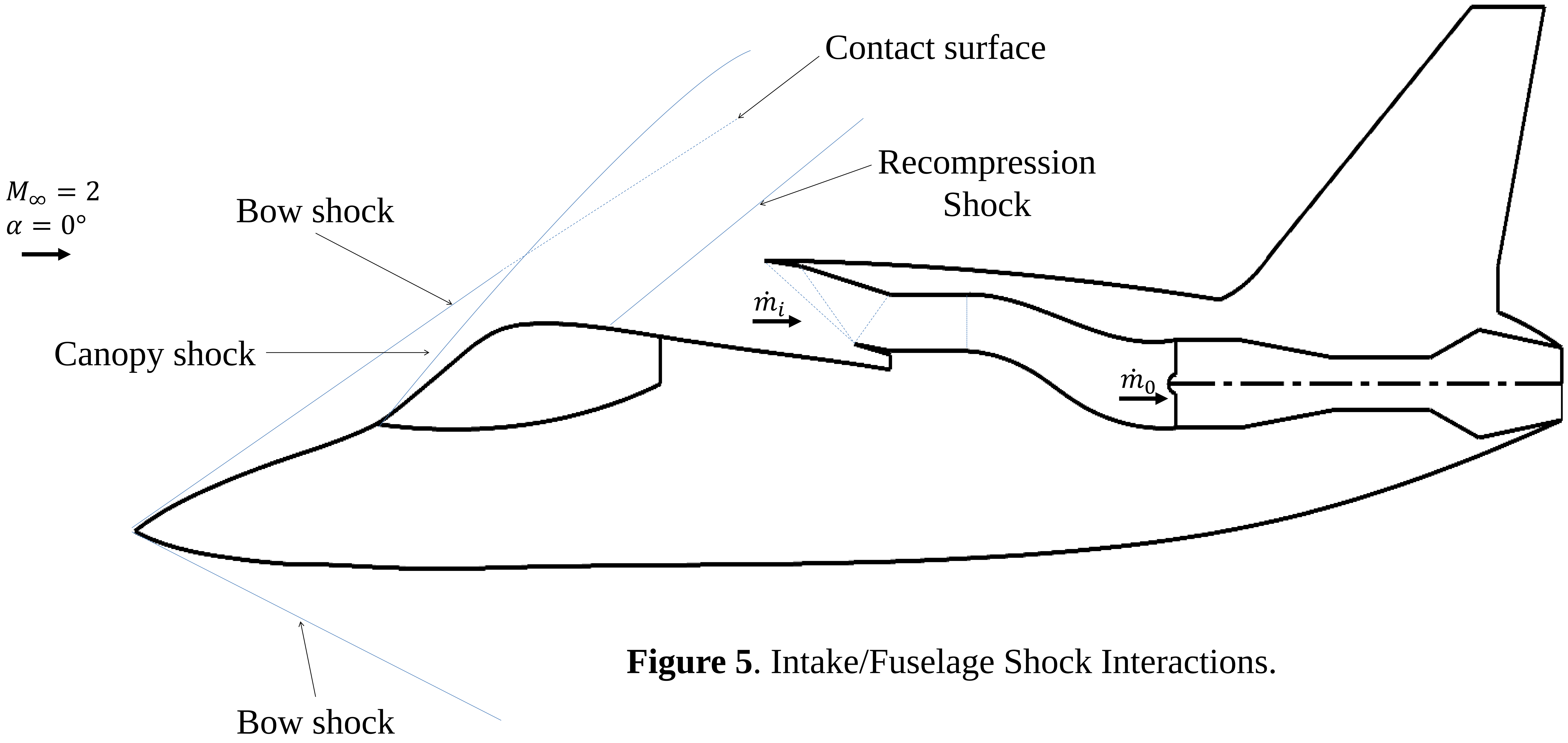

Figure 5. Intake/Fuselage Shock Interactions.

CFD ANALYSIS

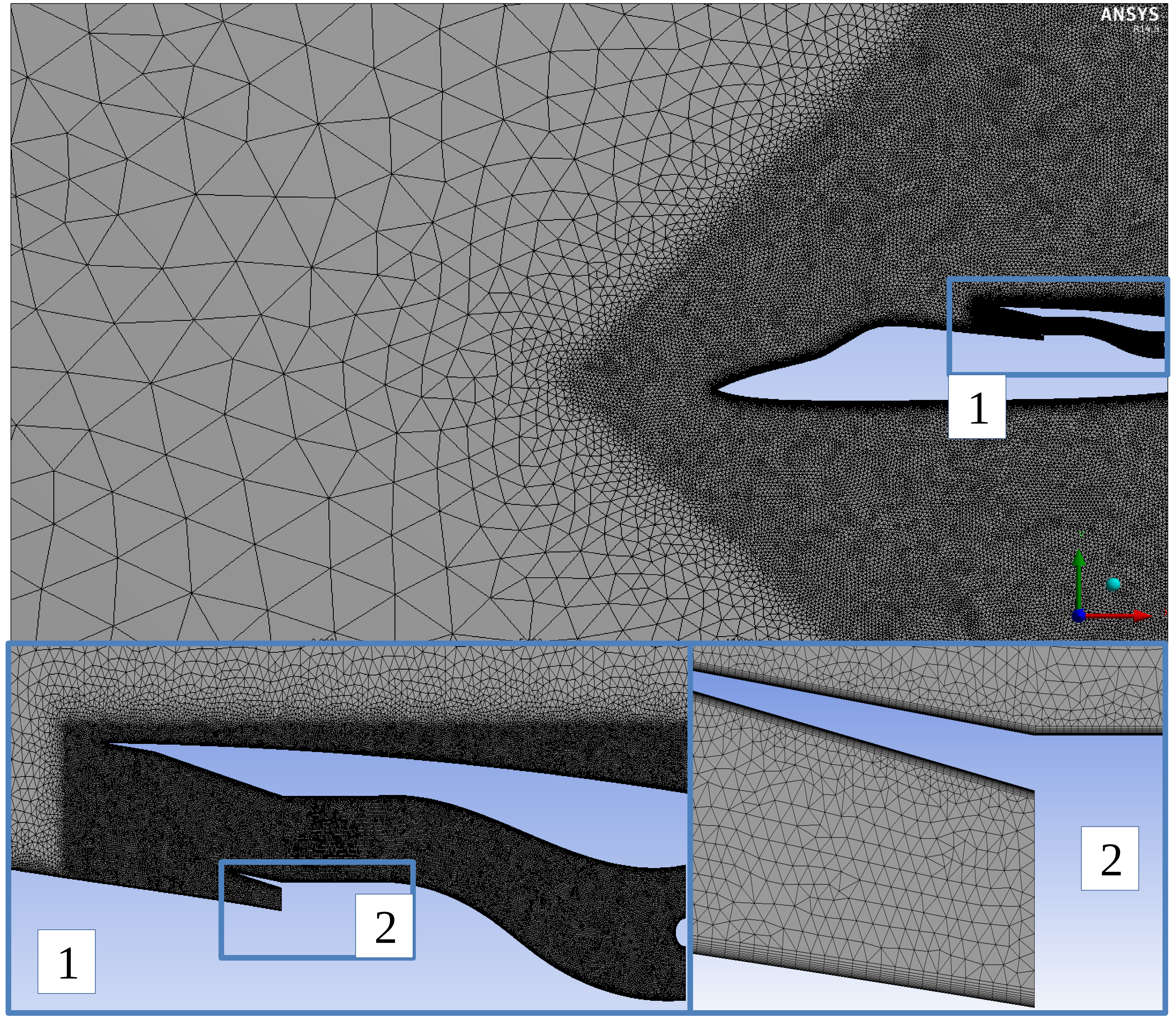

Figure 6. Computational mesh.

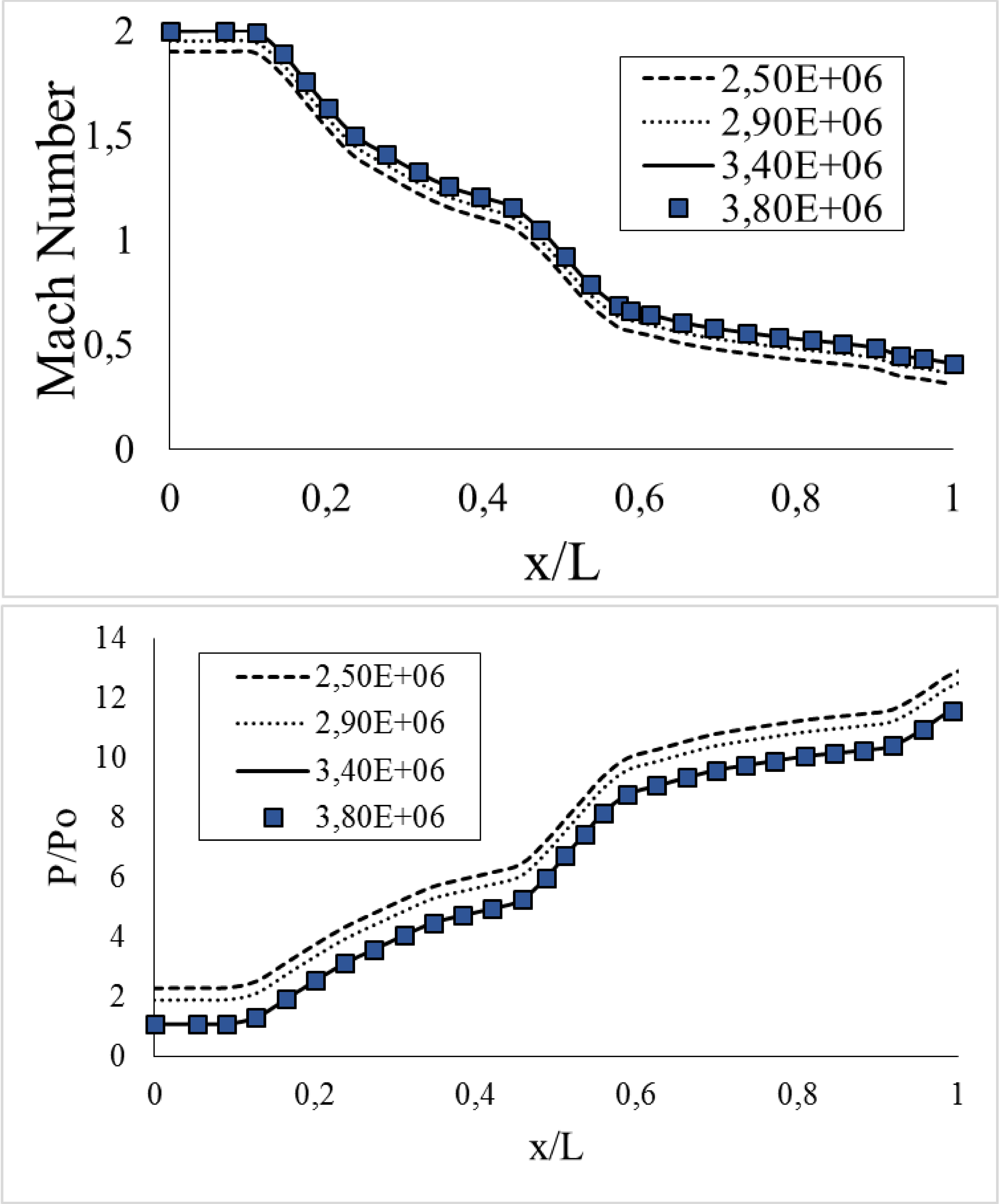

Figure 7. Independence mesh analysis.

CFD ANALYSIS

Table 1. Boundary conditions.

LOCATION	BOUNDARY CONDITION
Inlet	Velocity and pressure
Outlet	Supersonic outlet
Engine face	Pressure
B. I. Diverter	Porous wall (4% capture area)
Fuselage	No-Slip wall
Intake	No-Slip wall
Symmetry	Symmetry

RESULTS

Total Pressure recovery

$$\eta_\sigma = \frac{P_A - P_\infty}{q_\infty}$$

Where:

P_A: Average total pressure at the engine face station.

P_∞ : Free Stream pressure.

q_∞ : Dynamic pressure.

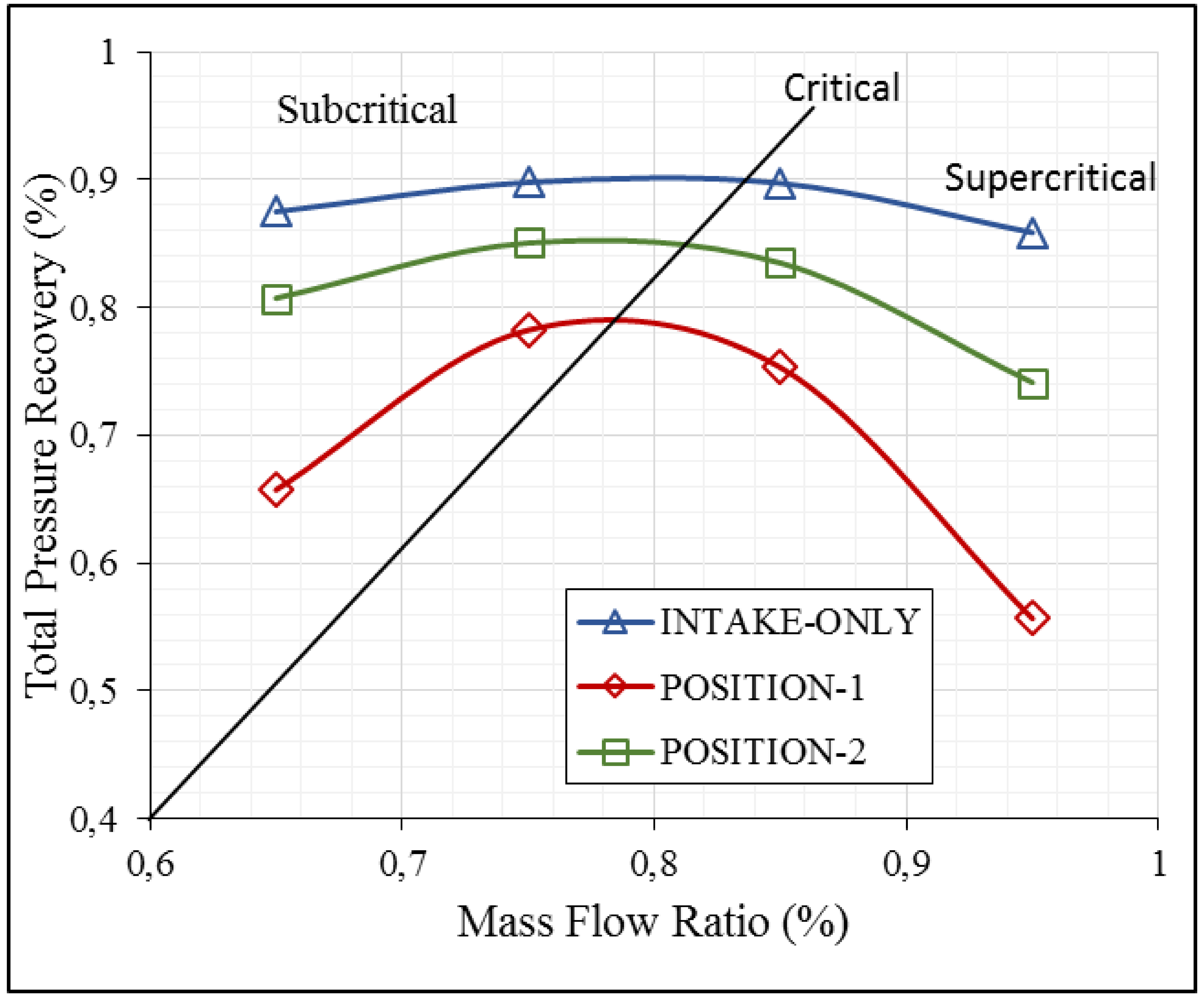

Figure 8. Mixed compression intake performance characteristics

Critical condition

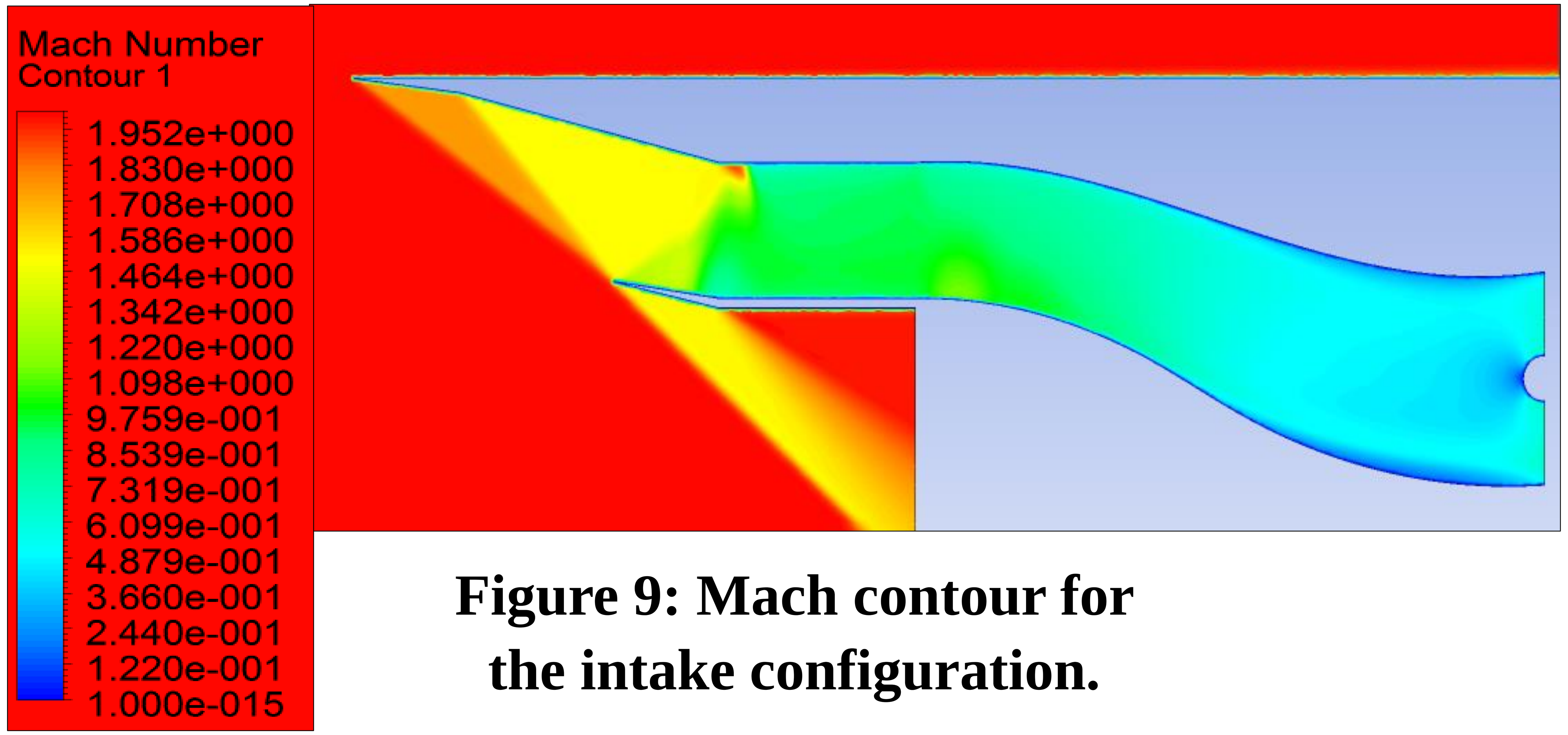

Figure 9: Mach contour for the intake configuration.

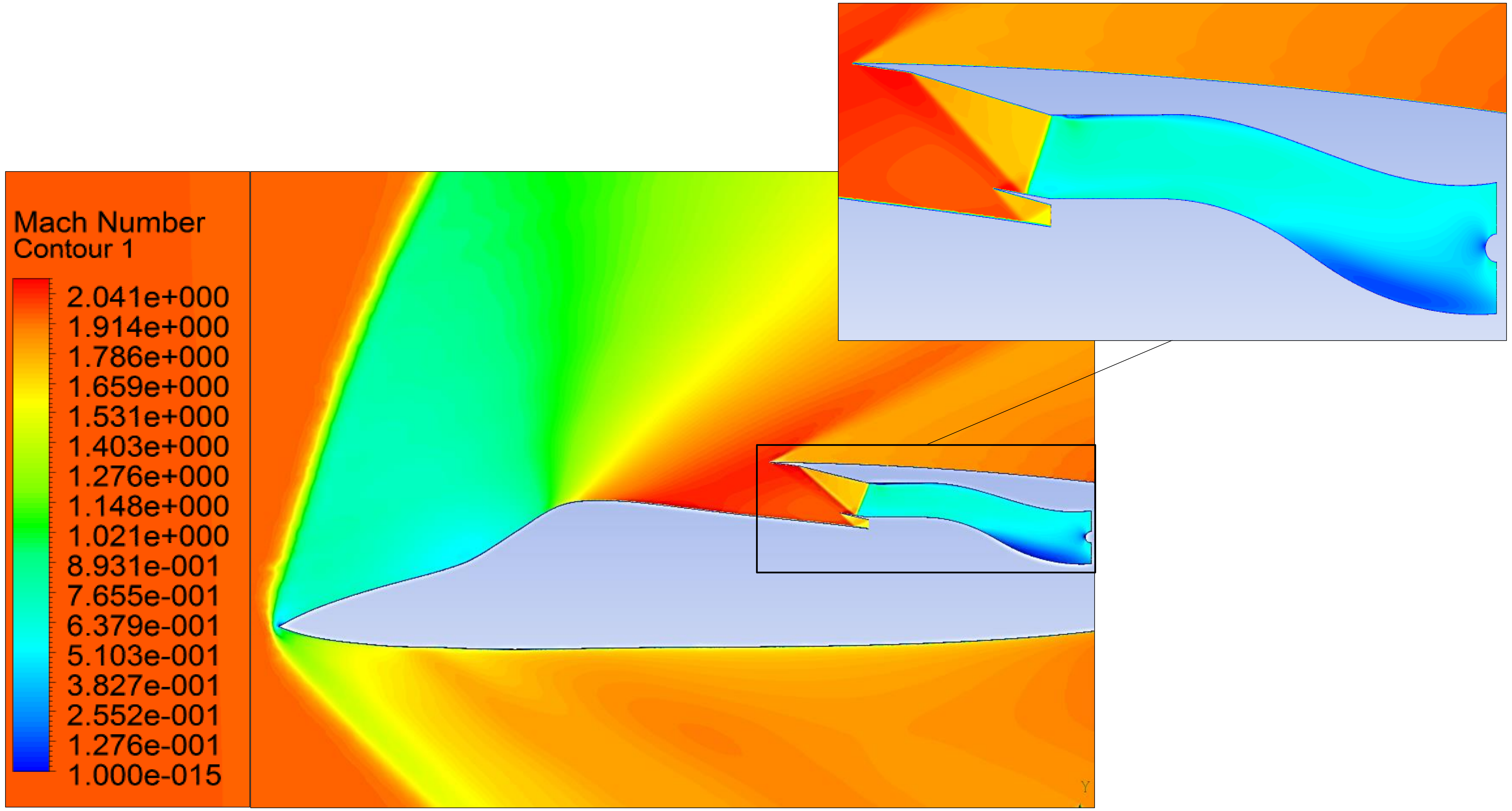

Figure 10: Mach contour for the position 2.

Supercritical condition

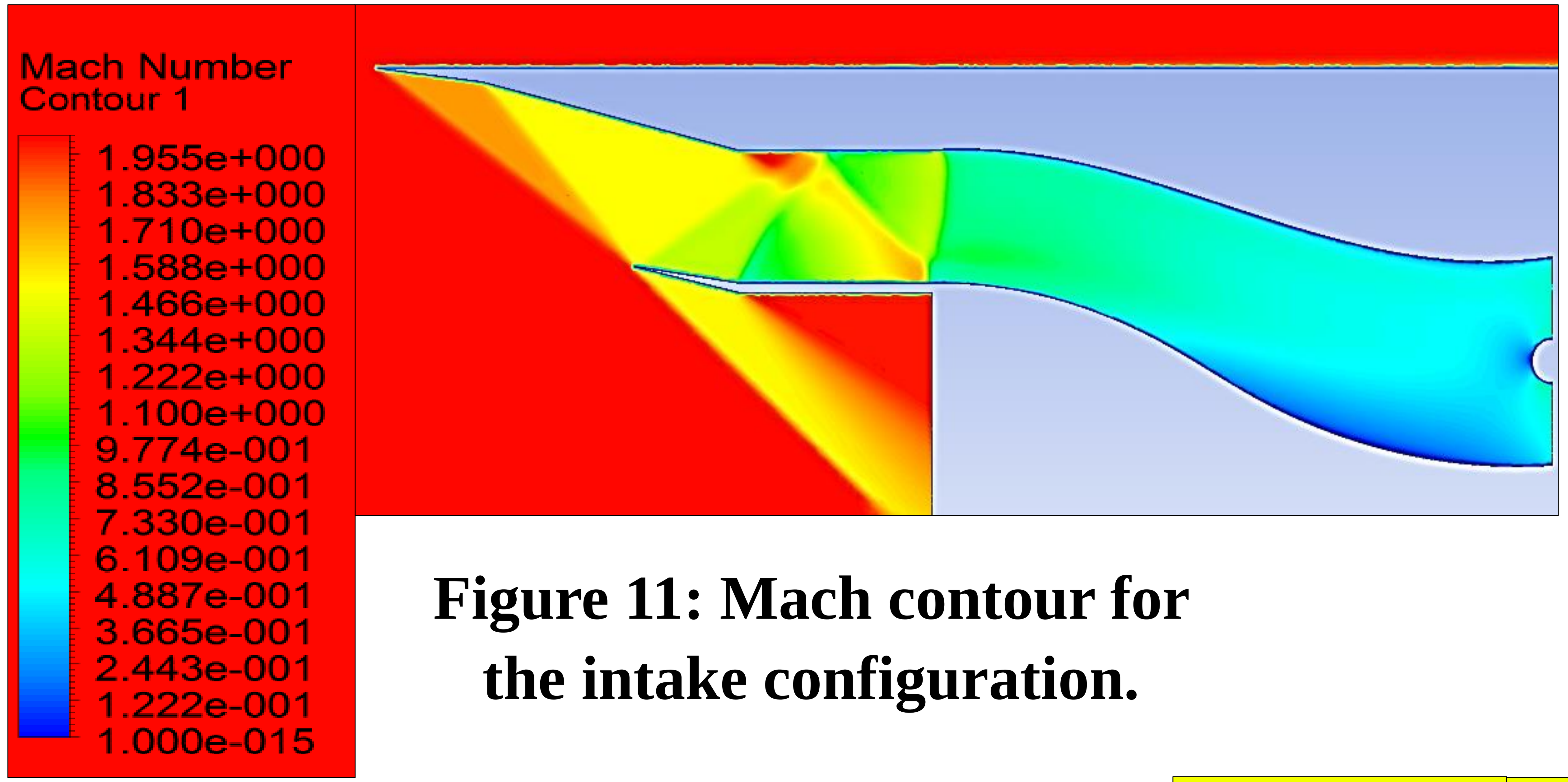

Figure 11: Mach contour for the intake configuration.

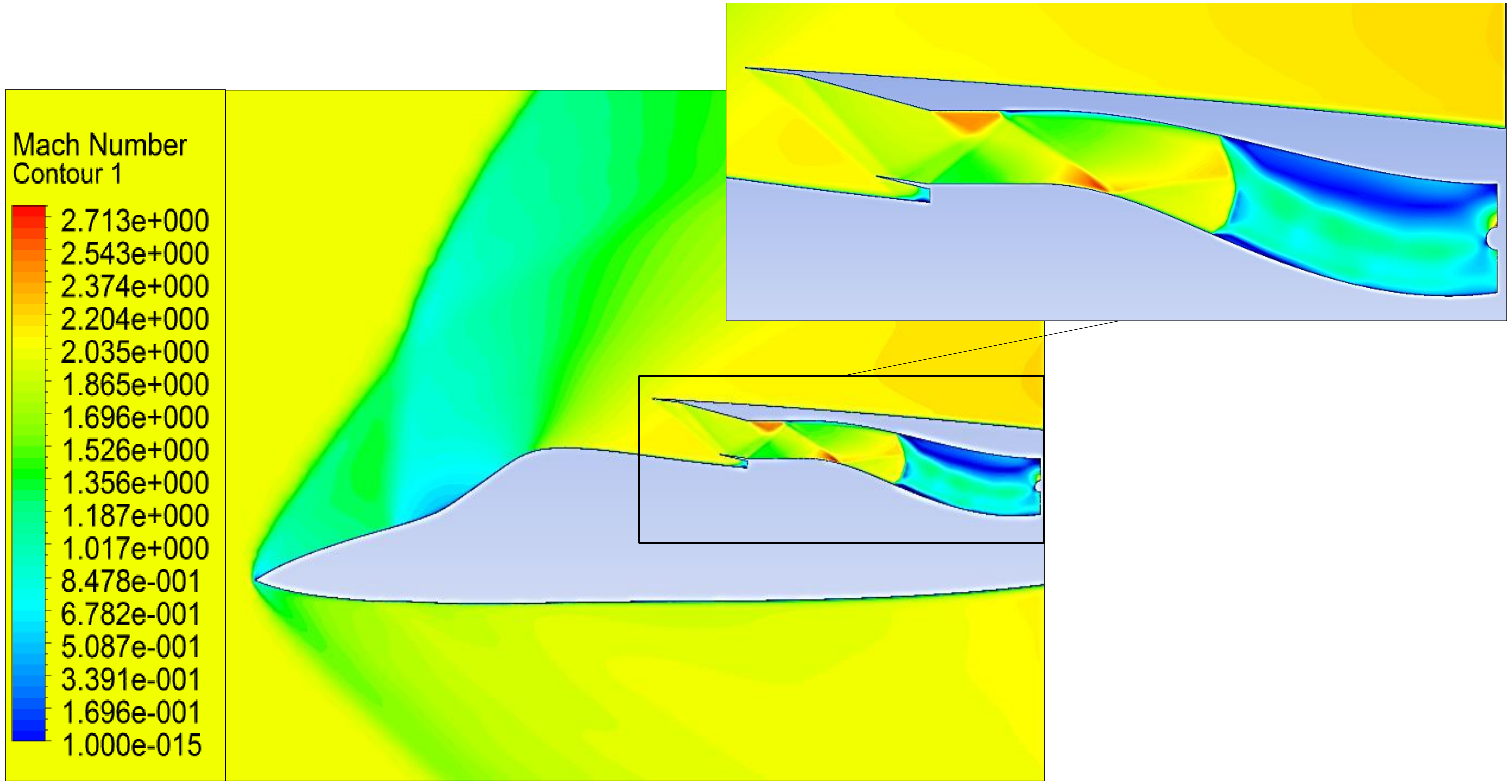

Figure 12: Mach contour for the position 1.

Supercritical condition

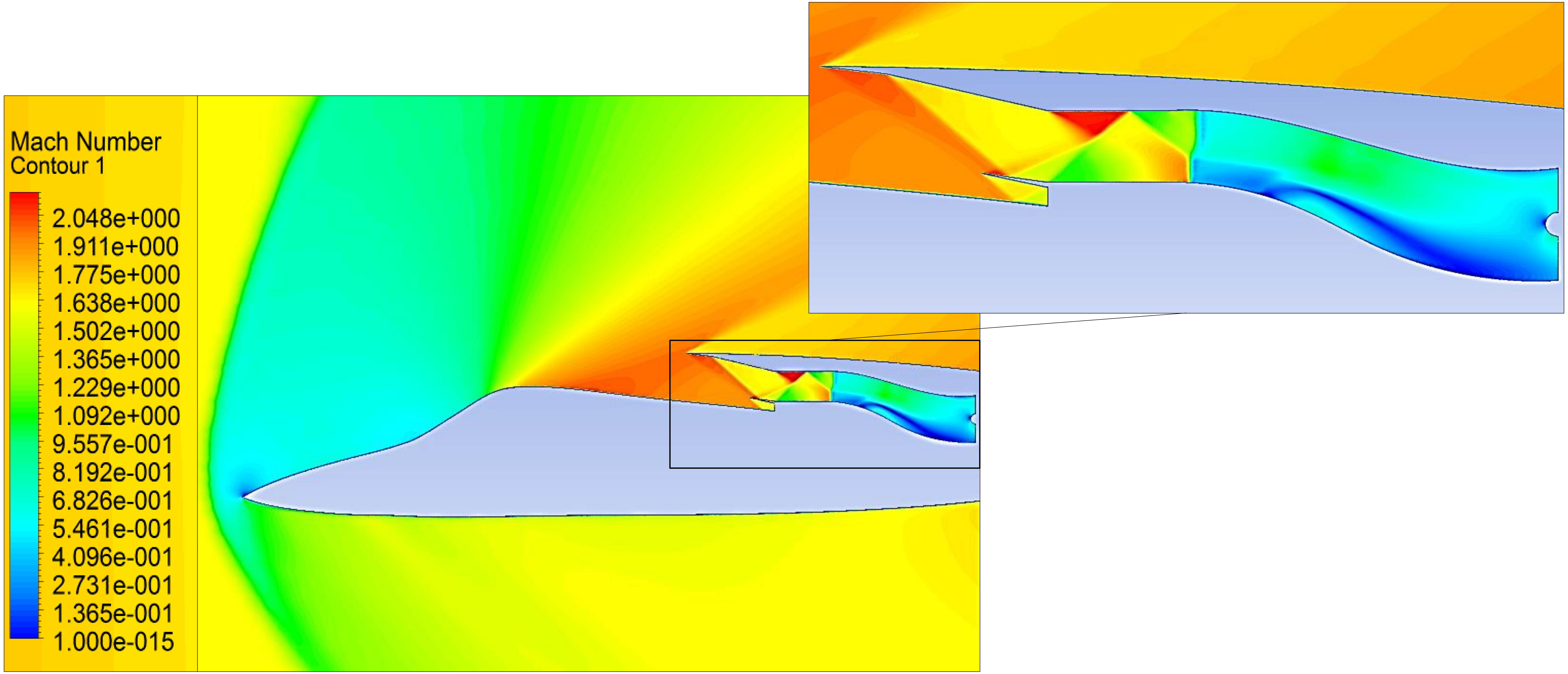

Figure 13: Mach contour for the position 2.

RESULTS

Distortion Index

$$D_I = \frac{P_{MAX} - P_{MIN}}{P_A}$$

Where:

P_{MAX}: Maximum pressure at the engine face station.

P_{MIN} : Minimum pressure.

P_A : Average total pressure.

Table 1. Computational distortion index.

Configuration	Intake-Only	Position 1	Position 2
Distortion Index (%)	6.8512	17.874	9.458

CONCLUSIONS

During the design process, the integration of the intake with the fuselage was realized using two different pos itions, keeping the configuration of the supersonic diffuser and changing the geometry of the subsonic duct.

The position 2 represents the best performance and lowest distortion than the position 1, when these positions ar e compared with the performance of the intake itself.

The subcritical operation range of the two positions resulted in smaller values of pressure recovery, in relation to the intake-only configuration. This confirm that the presence of the canopy/fuselage affected the flow field inside the intake. However, the position 2 is the best location to be used in the aircraft, due to its close performance values in relation to the intake-only configuration.

Future studies will be realized in a 3D concept, because with the advent of vortex-lift generating devices on the fuselage and forward extension of the wing, some experimental studies have shown that it is possible to improve the quality and quantity of the intake mass flow by controlling the vortex pattern on the upper surface of the fuselage and thereby maintain acceptable flow quality to the intake over the mission of the aircraft.

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THANK YOU