Task 1 – Reference Flow Conditions

1 Task 1 – Definition of Reference Flow Conditions

The objective of Task 1 is to determine the reference flow properties at the Pitot-static probe location using the experimental data provided in Table 2. These reference quantities are later used consistently to define inlet conditions and fluid properties in the CFD simulations.

1.1 Experimental Reference Data

Stagnation and static pressure and temperature measurements were obtained using a Pitot-static probe located at $x = 3.502\,\mathrm{m}$, $y = -6.08 \times 10^{-1}\,\mathrm{m}$, $z = 0\,\mathrm{m}$ (Figure 2). The experimental quantities available at this location are: the reference Mach number $\mathrm{Ma}_{\mathrm{ref}}$, the stagnation temperature $T_{0,\mathrm{ref}}$, the stagnation pressure $p_{0,\mathrm{ref}}$, the static pressure p_{ref}, and the ratio u_{ref}/ν.

Air is assumed to behave as a perfect gas, with $\gamma = 1.4$ and $R = 2.8705 \times 10^2\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

1.2 Reference Temperature and Velocity

The static temperature at the reference location is obtained from the stagnation temperature relation for a calorically perfect gas:

$$T_{\mathrm{ref}} = \frac{T_{0,\mathrm{ref}}}{1 + \frac{\gamma-1}{2}\,\mathrm{Ma}_{\mathrm{ref}}^2}. \tag{1}$$

The local speed of sound follows as

$$a_{\mathrm{ref}} = \sqrt{\gamma R T_{\mathrm{ref}}}. \tag{2}$$

Using the definition of the Mach number, the reference velocity is

$$u_{\mathrm{ref}} = \mathrm{Ma}_{\mathrm{ref}}\, a_{\mathrm{ref}}. \tag{3}$$

1.3 Reference Density

The reference density is computed from the ideal gas law using the local static pressure and temperature:

$$\rho_{\mathrm{ref}} = \frac{p_{\mathrm{ref}}}{R\,T_{\mathrm{ref}}}. \tag{4}$$

1.4 Kinematic and Dynamic Viscosity

The experimental ratio u_{ref}/ν is provided in Table 2. The kinematic viscosity is therefore obtained as

$$\nu = \frac{u_{\mathrm{ref}}}{(u_{\mathrm{ref}}/\nu)}. \tag{5}$$

The corresponding dynamic viscosity is

$$\mu = \rho_{\mathrm{ref}}\,\nu. \tag{6}$$

1.5 Justification of Incompressible and Isothermal Assumptions

For all experimental cases, the reference Mach number remains below 0.2. At such low Mach numbers, compressibility effects on the mean flow are negligible, and the flow can be reasonably modeled as incompressible.

Furthermore, the temperature difference between stagnation and static conditions, $T_{0,\mathrm{ref}} - T_{\mathrm{ref}}$, remains below approximately 2.3 K for all cases. This variation is negligible compared to the absolute temperature level of approximately 3.00×10^2 K, justifying the use of an isothermal flow model with constant fluid properties.

1.6 Summary of Reference Flow Properties

Table 1 summarizes the reference quantities obtained from the experimental data and the above calculations.

Table 1: Summary of reference flow properties at the Pitot-static probe location.

Case	$\mathrm{Ma}_{\mathrm{ref}}$	u_{ref} [m/s]	ρ_{ref} [kg/m^3]	ν [m^2/s]	μ [Pa·s]
1	0.082	28.32	1.103	1.67×10^{-5}	1.84×10^{-5}
2	0.136	47.01	1.091	1.68×10^{-5}	1.83×10^{-5}
3	0.193	66.81	1.073	1.71×10^{-5}	1.84×10^{-5}