MAE 352 - Experimental Aerodynamics II

Lab 1 – Supersonic Wind Tunnel Block Calibration

Final report due date: 02/04/2018

Objective: Using the pitot tube and wind tunnel transducers:

- Determine the Mach number in the test section.
- Create a calibration curve for the block setting of the supersonic wind tunnel with the Mach number.

Theory: NCSU's supersonic wind tunnel is a blow down tunnel with an adjustable block. The block in a supersonic wind tunnel is the piece that determines the shape of the nozzle throat and thus controls the Mach number, *M*. In the case of our tunnel, the block is continuously adjustable and can generate flow from M = 1.5 – 3.5. Since Mach number is the fundamental similarity parameter in high speed flow, it is desirous to know it to within about 0.1 percent.

Figure 1: NCSU supersonic wind tunnel.

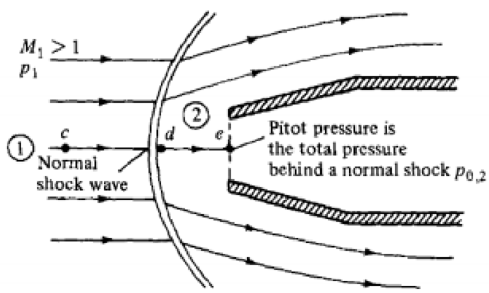

Figure 2: Pitot probe in supersonic flow.

There are a number of ways to obtain information about the Mach number in a supersonic flow, one of which is using a Pitot tube in the test section to obtain the total pressure behind a shockwave. Figure 2 shows a typical Pitot tube used in a supersonic tunnel. The characteristic feature of a supersonic flow is the formation of a shock wave. Therefore, the introduction of a Pitot probe into the flow stream, leads to a detached bow shock (Fig. 2). The Rayleigh Pitot tube formula can be used to determine the Mach number based on the stagnation pressure (P_{02}) measurement obtained from the Pitot probe. The Rayleigh Pitot tube relation is given as,

$$\frac{P_{02}}{P_1} = \left[\frac{(\gamma+1)^2 M^2}{4\gamma M^2 - 2(\gamma-1)}\right]^{\frac{\gamma}{(\gamma-1)}} \left[\frac{1-\gamma+2\gamma M^2}{\gamma+1}\right]$$

where P_1 is the static pressure before the shock and γ is the specific heat of the fluid. If the stagnation pressure before the shock (P_{01}) is known, the isentropic relation given by the equation,

$$\frac{P_{01}}{P_1} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{(\gamma-1)}}$$

can also be used to determine the freestream Mach number.

Experiment: Using the wind-tunnel (WT) temperature and pressure transducers record the following data for different block settings:

Table 1: Data collected for the block calibration experiment

time (s)	P_{01} (psi)	P_1 (psi)	P_{02} (psi)	P_{atm} (psi)	T_{01} (ºF)
system clock	from WT transducer	from pressure transducer	from pressure transducer	from barometer	from WT transducer

You are required to create a plot between the block number setting and the Mach number obtained using the isentropic and Rayleigh Pitot tube relations. Note that all pressures obtained using the transducers are gauge pressures. Also, average out all the data collected after 2.5 seconds of tunnel run time.

The following constants can be used to help with your analysis:

1. Specific heat of dry air, γ: 1.4

In the final report,

- Plot the Mach number (using the two relations) versus block number setting.
- Create two best fit polynomials through the data plotted in the above graphs (one through the Mach number obtained using the isentropic relation and the other through the Mach number obtained using the Rayleigh Pitot tube relation).
- Provide the equations of the polynomial fits.
- *EXTRA CREDIT* – What is the degree of the polynomial that gives the best fit and why?
- Compare the data to the calibration curve provided by the manufacture and discuss the results.
- All results must be presented in SI units.
- Present your code in the Appendix.