Module #4 - Test Section Calibration

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I. OVERVIEW

The calibration of a low-speed wind tunnel (LSWT) test section had been made in the present work. The test section design speed is 70 m/s. Frictional loses and uniformity of the flow inside the test section had been tested and calibrated based on the British standards for flow inside ducts and conduits.

Pitot-static tube, boundary layer Pitot tube were the main instruments which were used in the present work to measure the flow characteristics with emphasize on the velocity uniformity and boundary layer growth along the walls of the test section. It is found that the maximum calibrated velocity for empty test section is 55 m/s.

Three speeds are tested for uniformity and walls boundary layer at inlet and mid-section of test section. The results show that the flows are uniform at inlet and mid-section with turbulent flow from inlet to outlet.

II. LEARNING OUTCOMES

➢ Understand the effects of air flow through a test subject (airfoil) with varying angle and learn how to calibrate from the test section.

III. DISCUSSION

Introduction

Wind tunnel is rapid, economical and accurate mean for conducting aerodynamic researches and obtaining aerodynamic data to support design decisions. There is a considerable and growing volume of aerodynamic research in the development of aircrafts, automobiles, marine's vehicles, and architectural structures. The first step in the design of a tunnel is to determine the shape and size of test section based on the intended use of the facility.

The test section size, speed and design will determine the required power. The overall aerodynamic objective for most wind tunnels is to obtain a flow in the test section that is as near as possible to a parallel steady flow with uniform speed throughout the test section.

LOW SPEED WIND TUNNEL DESCRIPTION is an open circuit downstream fan type designed for studying the subsonic aerodynamics. It is to be used with optional accessories and models below. The air enters the tunnel via an entrance flare. A flow straightener, three wire mesh screens, and a high contraction ratio section ensure uniform velocity across the transparent test section. Downstream of the working section is a low angle diffuser which terminates at the tunnel fan. The diffuser and contraction sections have a high-quality internal finish to minimize the boundary layer effects. The fan impeller blades are of an airfoil design cast aluminum to ensure maximum aerodynamic efficiency and minimum turbulence. A brief description of the tunnel components is given below.

Contraction Section and Settling Chamber

The contraction section and settling chamber were made of steel sheets and both have rectangular cross section. A contraction ratio with 7:1. The settling chamber contains three screens and is connected to the bell mouth at the inlet and contraction inlet at the exit section. The contraction section is joined to the test section by a mating flange.

Test Section

The test section of (300 mm x 300 mm x 600 mm long, transparent on three sides.) was designed to be suitable size for different model's sizes. The test section also provides with Plexiglas window on one side of the test section to allow viewing the model setting inside wind tunnel.

Diffuser

The diffuser is made of steel sheets and it is used to connect the test section with the fan housing by converting the square cross section inlet plane to circular cross section at exit plan. Rubbers are used to reduce vibration and provide an air tight seal between sections. A coarse screen is fixed to protect the fan from damage

Fan: - Diameter: 500 mm with an Impeller: Single stage, airfoil aluminum blade. Motor: 2.2 kW.

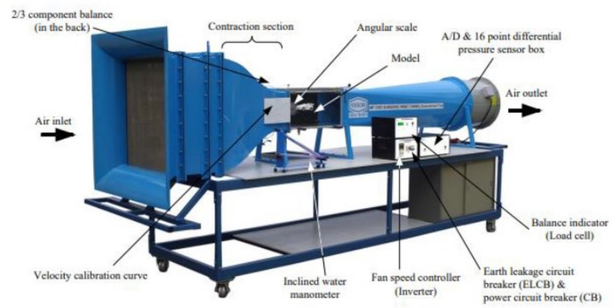


Figure 10. Subsonic Wind Tunnel

Here is the list of optional equipment in the wind tunnel.

Optional Equipment

- MP 100-011M Multi port differential pressure digital display instead of inclined water manometer.
- MP 330-003A Three component balance with digital display and model holder for measurement of lift, drag, and pitching moment instead of two component balance.
  - Lift ±10N
  - Drag 10N
  - Pitching ±1Nm
  - Angular scale, ±180 degrees.
- MP 330-005 Velocity (differential pressure) digital display.
- MP 330-007 Exhaust silencer.
- MP 330-110 Anemometer for velocity measurement.
  - Range : Upto 40 m/s.
- MP 330-111 Angle digital display for model angular position.
- MP 330-114 Multitube inclined water manometer : 16 tubes x 450 mm x 1 mm. graduation. : multiple slope, 1:10, 1:5, 1:2 and 1:1.
- MP 330-114D 16 point differential pressure sensor with sequential readings (To be used with computer).
- MP 330-121 Pitot-static probe, stainless steel : 4 mm diameter x 300 mm long
- MP 330-122 Yaw probe, three tube type with clamp : Stainless steel tubes, 1 mm. To be used with MP 330-114 (separately supplied).
- MP 330-125 Wake survey rake : 16 stainless steel tubes. To be used MP 330-114 (separately supplied).
- MP 330-130 Smoke generator, set : The set includes smoke generator, smoke fluid, smoke chamber and stream line distributors, light and 4 models.
- Additional smoke fluid : 4 l.

Air velocity is calibrated from a Pitot tube. Pressure differential for the Pitot tube is that in the contraction section. The Pitot tube is used for the measurement of air velocity. The required air velocity for the test is to be measured at the point of installation of the model. Differential pressure is measured by inclined manometer. The air velocity V can be obtained per following formula:

$$V = \alpha \sqrt{\frac{2\,\Delta P}{\rho}}$$

Where V = Air velocity, m/s

α = Flow coefficient depending on the Reynolds Number Re

ΔP = Differential pressure of the Pitot tube in relation with the atmospheric pressure,

$$Pa = \frac{N}{m^2} = \frac{Kg}{m^2 s^2} \bullet m \ \left(1\ \mathrm{N} = 1\ \frac{Kg \bullet m}{S^2}\right)$$

Procedures

1. Install the Pitot tube at the same point as model holder in the test section with the probe pointing against the air flow direction.

2. Rotate the Pitot tube slightly to ensure it is exactly against the airflow to obtain the maximum differential pressure.

3. Change the air velocity by adjusting the inverter as required.

4. Record the differential pressure of the Pitot tube and room temperature.

5. Calculate air velocity per above formula.

Sample calculations:

Differential pressure from Pitot tube ΔP $= 48$ mm H_2O (Slope 1: 2)

$\therefore$ Actual ΔP $= 24$ mm H_2O

Room temperature $= 30$ °C

From Appendix 8, air density $= 1.166$ kg/m^3

$$\Delta P = 24 \text{ mm H}_2\text{O} \times \frac{249.1 \text{ Pa}}{25.4 \text{ mm H}_2\text{O}}$$

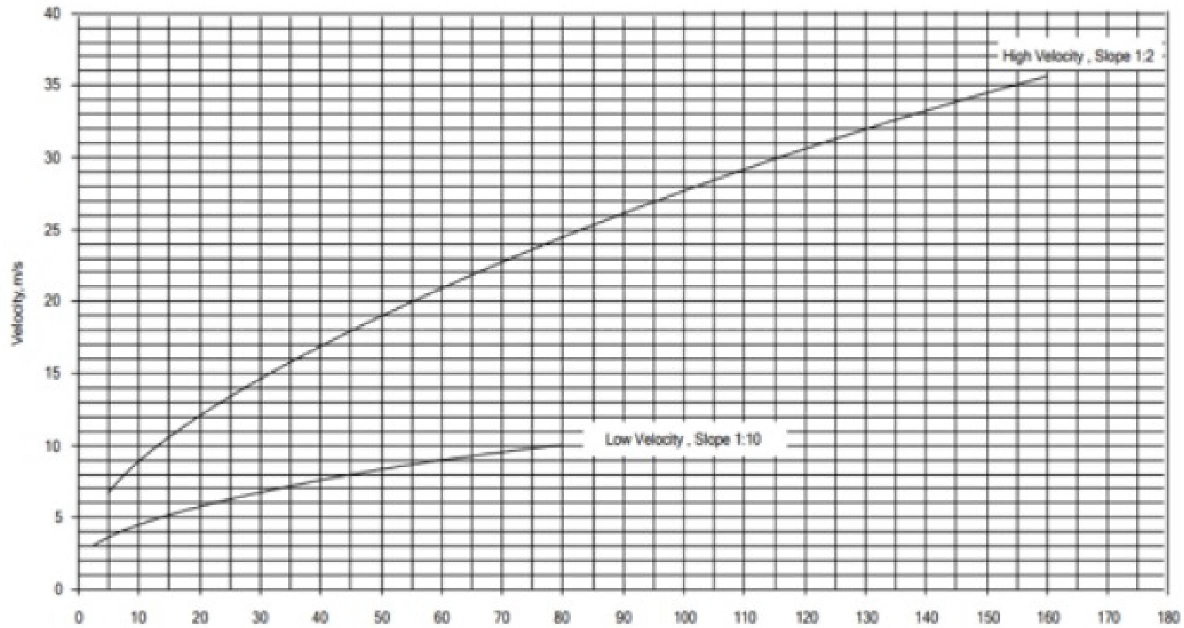
$$= 235.37 \frac{\text{N}}{\text{m}^2}$$

$$V = \alpha \sqrt{\frac{2\Delta P}{\rho} \times \frac{\text{N}}{\text{m}^2} \times \frac{1}{\text{kg/m}^3}}$$

$$= 0.99 \sqrt{2 \times \frac{235.37}{1.166} \frac{\text{kg}}{\text{m} \cdot \text{s}^2} \times \frac{\text{m}^3}{\text{kg}}}$$

$$= 19.89 \text{ m/s}$$

Contraction Section Differential Pressure VS Velocity



Contraction Section Differential Pressure, mmH$_2$O

Conclusion:

Part of the wind tunnel section is placing the test subject accurately on its holder. Resetting the angle of the test subject helps the wind tunnel to have reference/basis to its calculations. Thus, helping the wind tunnel, to provide accurate and detailed data to the user. The test subject and the equipment should be at the same reference of data to produce exact and detailed measurements.