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Calibration of reference velocity and longitudinal static pressure variation in the test section of an open type subsonic wind tunnel

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The measurement of reference wind velocity inside the test section of an open type subsonic wind tunnel is obtained from the measurements of dynamic pressure using average static wall pressure difference between stations at upstream of the test section and at the settling chamber. A wind tunnel calibration factor was established which relates the dynamic pressure inside the test section with the average static wall pressure at a station near upstream of the test section and at the settling chamber. An average wind tunnel calibration factor was found to be 0.8189. The longitudinal variation of static pressure inside the test section is also obtained using the pitot-static tube.

***Keywords*:** wind tunnel calibration factor K and longitudinal static pressure variation

1. Introduction

During an aerodynamic experiment, actively using any flow measuring device (Pitot-tube or anemometers) to determine the flow conditions in the test-section is not advisable. The presence of induced flow by the test object may alter the actual flow conditions inside the test section, and hence a flow measuring device will not measure the actual flow conditions[1]. So, prior to any aerodynamic experiment in a wind tunnel, it is essential to assess the flow condition with an empty test section. This prior assessment of the flow condition inside the test section is carried out during the calibration process. A complete calibration process involves the determination of velocity variation in the plane of the model supports, longitudinal static pressure variation, flow angularity, turbulence, and extent of large scale fluctuations[4].

In the present work, calibration of reference velocity and longitudinal static pressure variation in the test section of an open type subsonic wind tunnel has been carried out.

2. Calibration Process

The dynamic pressure and consequently the reference velocity inside the test section can be obtained by measuring the static pressure drop between the ring of static orifices at the settling chamber and just upstream of the test section [2-3]. Fig.1 shows the typical measurement stations at the settling chamber and test section of the wind tunnel.

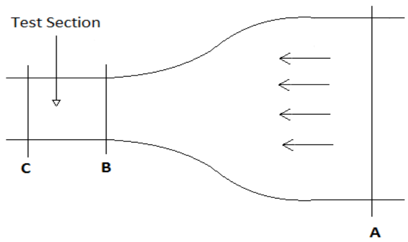


Fig. 1. Typical measurement station for wind tunnel

Referring to Fig.1, and applying the energy equation between station A and B gives,

$$P_A + \frac{1}{2}\rho V_A^2 = P_B + \frac{1}{2}\rho V_B^2 + K_1 \frac{1}{2}\rho V_A^2 \tag{1}$$

Where P is the static pressure, V is the velocity, ρ is the density of air, and K_1 is the coefficient of pressure loss between stations A and B due to tunnel contraction geometry and flow irregularities. Subscript A and B denotes the stations at settling chamber and upstream of the test section respectively. Considering incompressible flow, the continuity equation gives,

$$A_A V_A = A_B V_B = A_C V_C \tag{2}$$

Where A is the cross-sectional area at the respective station and subscript C denotes the station in the test section. Using Eqs. (2), the energy equation can be reduced to Eqs. (3) which can further be simplified to Eqs. (4) or (5).

$$P_A - P_B = \frac{1}{2}\rho V_C^2 \left[\left(\frac{A_C}{A_B}\right)^2 (1 + K_1) - \left(\frac{A_C}{A_A}\right)^2 \right] \tag{3}$$

$$\frac{1}{2}\rho V_C^2 = K(P_A - P_B) \tag{4}$$

$$q_C = K(P_A - P_B) \tag{5}$$

Where K is the tunnel calibration factor and q_C is dynamic pressure at station C. The dynamic pressure inside the test section can be directly measured by a pitot-static tube.

An independent measurement of stagnation pressure and static pressure by pitot-static tube can provide the local static pressure in the test section[1]. And thus by traversing the pitot-static tube in the test section, static pressure variation inside the test section can be obtained.

3. Experimental Setup

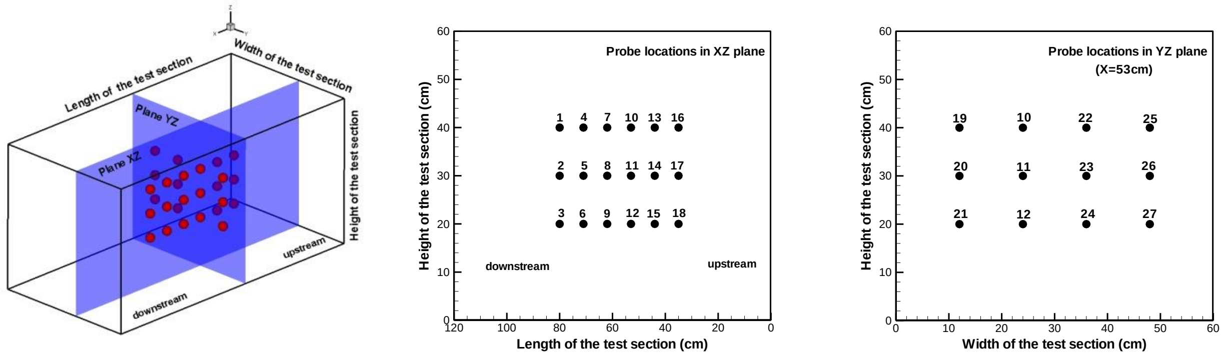
The experimental setup mainly comprised of wind tunnel facility, pitot-static tube, and pressure transducers. The wind tunnel facility under consideration is an open type subsonic wind tunnel with a contraction ratio of 8.95 and a test section of 60x60x120cm^3. The wind tunnel is powered by a 15hp a.c. motor. Fig. 2, shows the wind tunnel facility.

Fig. 2. Wind tunnel Facility

To measure the dynamic pressure, a calibrated, Dwyer make pitot-static tube of 750mm length is used. To measure the pressure, silicon microstructure incorporated make differential pressure transducer with a range of $0.3psi$ was used.

4. Test Procedure

The test was carried out at five different wind speed, corresponding to which the VFD settings for different fan speeds were 10Hz, 15Hz, 20Hz, 25Hz, and 30Hz. A total of 27 probe locations inside the test section were selected. The probe locations were grouped into two vertical planes (plane XZ and YZ), which were perpendicular to each other, as shown in Fig. 3(a). Fig. 3, shows the schematic of the test section with probe locations.



(a) Test section with pitot-static probe locations

(b) Side view of the test section (XZ plane, Y=36cm)

(c) Front view of the test section (YZ plane, X=53cm)

Fig. 3. Schematic view of the test section with probe locations

At each probe location, stagnation pressure and static pressure were measured independently with the help of a pitot-static tube. By independently measuring the static pressure from the pitot-static tube at each probe locations, a longitudinal variation of static pressure was obtained. Dynamic pressure is obtained by simply subtracting the stagnation pressure with the static pressure. The average static wall pressure was also measured at the settling chamber (referring to Fig. 1, station A) and upstream of the test section (referring to Fig. 1, station B). All the 27 probe locations represent the different locations for station C in Fig. 1.

A linear regression of pressure data obtained from station A and B (static pressure) and the pitot-static tube (dynamic pressure) at each probe location provides the required range of calibration factor K.

5. Results and Discussion

Calibration was carried out with five different wind speeds. Fig. 4, shows the longitudinal variation of static pressure at all speed range along the longitudinal center plane of the test section. At low speed, static pressure does not remarkably change. The lowest difference between the maximum and minimum pressure was 4.07Pa. But at higher speeds, the magnitude of the difference between the maximum and minimum pressure rises to a maximum of 14.17Pa.

Fig. 5, Shows the variation of the dynamic pressure at various probe location with the static pressure difference between station A and B. The slope of the regression fit gives the necessary wind tunnel calibration factor (K). Fig. 6, shows the variation of the calibration factor at various probe locations on the center plane (plane XZ and YZ) of the test section.

Generally, a test model is mounted at the center plane of the tunnel (Z=30cm). Referring to Fig. 3, probe locations 2, 5, 8, 11, 14, 17, 20, 23, and 26 sufficiently covers the center plane of the test section. Thus to determine a single wind tunnel calibration factor, an average of calibration factor obtained at probe locations covering the center plane of the test section was used and found to be K=0.8189.

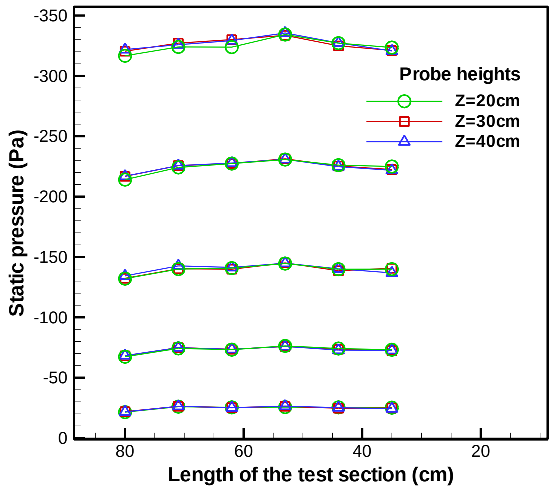


Fig. 4. Longitudinal variation of static pressure in the test section at different velocities

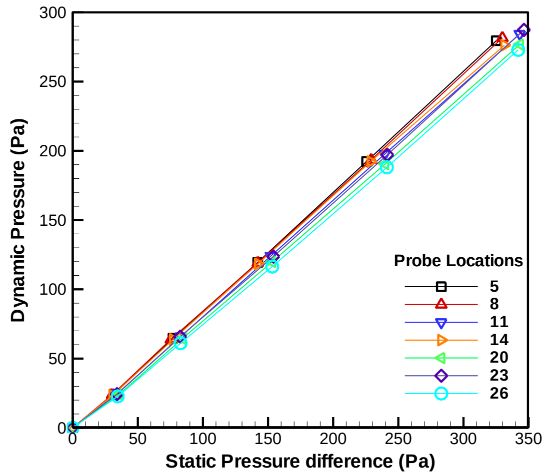
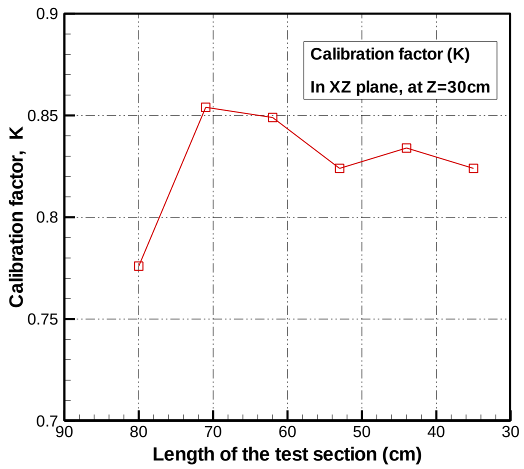
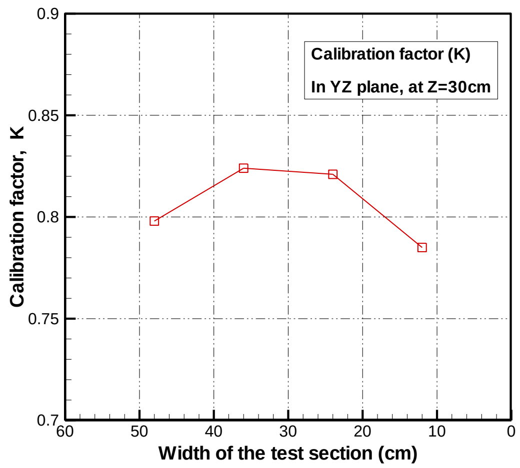


Fig. 5. Variation of dynamic pressure (at various probe locations) with respect to static pressure difference at station A and B

Fig. 7, Shows the variation of the wind velocity in the test section with respect to static pressure difference at station A and B. Fig. 8, Shows the variation of wind velocity along the length of the test section at different fan speed.



(a) At center line of Longitudinal plane XZ



(b) At center line of cross-sectional plane YZ

Fig. 6. Variation of wind tunnel calibration factor (K) in different planes

6. Conclusion

Calibration of an open type subsonic wind tunnel was carried out. To measure the reference velocity inside the test section of the wind tunnel, a calibration factor was established. Calibration factor along with static pressure difference at the test section and the settling chamber will provide the dynamic pressure inside the test section. A single wind tunnel calibration factor of the wind tunnel was found to be 0.818.

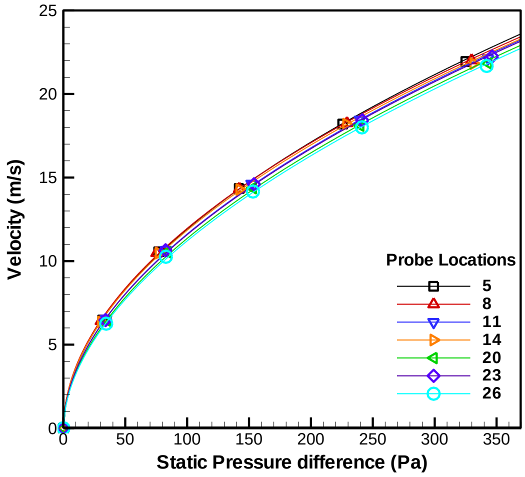


Fig. 7. Shows the variation of wind velocity with respect to the static pressure difference between station A and B

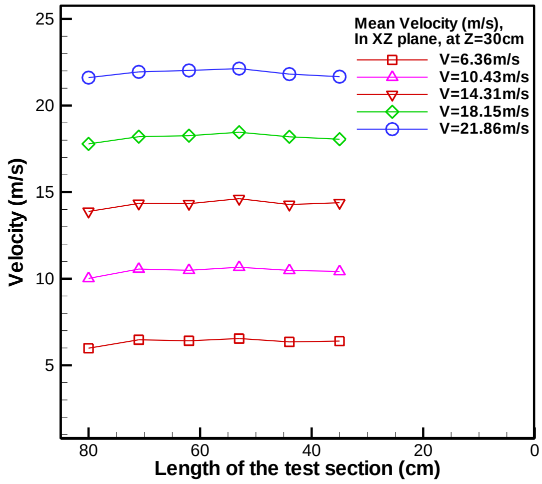


Fig. 8. Shows the variation of wind velocity along the length of the test section at different fan speeds

The variation of the static pressure along the length of the test section was also obtained. A lowest and highest difference in maximum and minimum pressure was found to be 4.07Pa and 14.17Pa, respectively. Finally the variation of wind velocity as against average static wall pressure difference between upstream of the test section and settling chamber was established. The mean reference velocity at different fan speed was found to be 6.36m/s, 10.43m/s, 14.31m/s, 18.15m/s, and 21.86m/s.

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