DARK’S WIND TUNNEL

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Introduction

It is a simple wind tunnel for low subsonic speeds and is shown in fig. 1. Air from the outside is drawn in by a fan at the end of the tunnel. The air enters first a nozzle whose cross section gradually decreases in the flow direction. The flow velocity is thus increased.

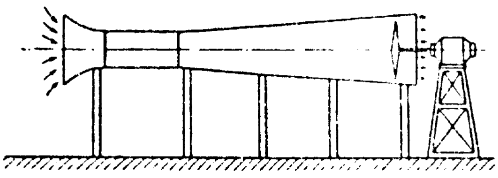


Fig. 1.

After attaining its maximum velocity in the narrowest section of the nozzle, the air enters the test section, whose cross section is constant. The test section contains the body to be tested around which the air flows uniformly at constant velocity. Behind the test section there is the diffuser, whose gradually increasing cross section permits a gradual reduction of the flow velocity. The fan is installed at the end of the diffuser. The velocity in the wind tunnel is changed by adjusting the rotational speed of the fan.

Nozzle

The principal function of the nozzle is the acceleration of the low-speed air entering it from the settling chamber to the velocity required in the test section.

In addition, the shape and dimensions of the nozzle determine not only the magnitude of the velocity, but also its uniformity. The nozzle profile is designed to provide uniform velocity distribution at the outlet. The nozzle profile is usually designed to follow the curve, due to Vitoshinskii

$$r = \frac{r_0}{\sqrt{1-\left[1-\left(\frac{r_0}{r_1}\right)^2\right]\frac{(1-3z^2/a^2)^2}{(1+3z^2/a^2)^3}}}$$

where r is the radius of the nozzle cross section at a distance z along the axis from the inlet, and the inlet and outlet radii are denoted by r_i and r_o respectively. In our wind tunnel we chose the values r_i=40cm, r_o=20cm and a=4r_o. The nozzle inlet-outlet area ratio is therefore 4:1 and the cross-sectional area at the outlet is 40x40cm. The nozzle have a square cross section throughout, and all four walls are curved as shown in fig. 2.

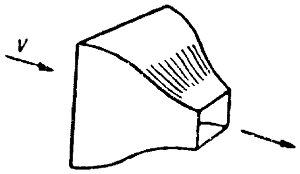


Fig. 2.

Test section

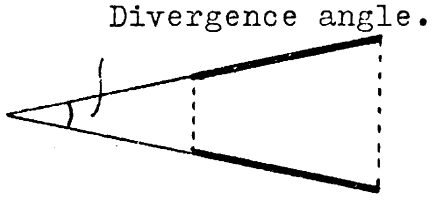
The test section has the same cross section (40x40cm) as the nozzle outlet, and the cross section is constant throughout the test section. The two horizontal walls are made of acryl fore visual observations. It is in the test section that the model is placed in the airstream leaving the downstream end of the nozzle. We can measure the drag and lift as function of flow velocity and angle of attack.

The model is placed in a Cardanic suspension where the forces are balanced with two scales. A Cardanic suspension is a manner of suspending an object by which it may move freely in any direction, as by expanding the limitations of ordinary gimbals. Further can we measure the center of pressure, if we instead place the model in a pivot. To avoid interference between tunnel and model, the cross section of the model is not allowed to exceed 10% of the test section.

The model must be mounted on a rod with a 3mm thread fore placing it in the Cardanic suspension.

Diffuser.

The diffuser of the tunnel is a gradually widening duct downstream of the test section and serving for more efficient conversion of the kinetic energy of the air into pressure energy. The performance of a diffuser, i.e., its capability of converting the kinetic energy into pressure energy, is mainly influenced by the magnitude and distribution of the velocity at its inlet, its divergence angle, and the expansion ratio. The optimum divergence angle is about 6°, but we have chosen 12° because of space considerations. At smaller divergence angles the resistance coefficient increases because of the consequent increase in the diffuser length. At divergence angles above 8°, losses increase due to nonuniform velocity distribution across the diffuser.



Diffuser.

Fan installation

The motor have a power consumption of 370W, and give at maximum charcing a flow velocity in the test section there is equal to 8 m/s and then the propeller run with 750 rpm.

Measurement of velocity

The free-stream velocity can be measured by the static-pressure drop between two sections of the tunnel. These sections are most conveniently chosen in such a way that one is in the settling chamber of the tunnel (section a, fig. 3), while the other is at the entrance to the test section, far enough away from the model to be unaffected by its presence (section b).

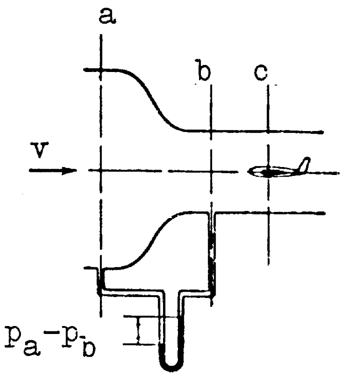


fig. 3.

If it is assumed that the flow is incompressible with the density ρ and that Bernoulli's equation applies between sections a and b,

$$p_a + \frac{1}{2}\rho v_a^2 = p_b + \frac{1}{2}\rho v_b^2$$

where p_a, p_b, v_a and v_b are the static pressures and velocities in section a and b, respectively. If the cross sections at a and b, and the area of the test section at c (where the model is located) are A_a, A_b and A_c respectively, then according to the continuity equation

$$A_a v_a = A_b v_b = A_c v_c$$

In our case $A_b = A_c$. Substituting in Bernoulli's equation the values of the velocity heads in sections a and b, expressed through the velocity head in the test section (section c), we obtain

$$p_a - p_b = \frac{1}{2}\rho v_c^2 \left[1 - \left(\frac{A_b}{A_a}\right)^2\right]$$

With the aid of this last equation we can obtain the velocity head in the test section of the tunnel, we get

$$v_c = \left[\frac{2(p_a - p_b)}{\rho\left[1 - (A_b/A_a)^2\right]}\right]$$

The rate of mass flow Q is given by

$$Q = \rho v_c F_b$$

The measurement of the pressure difference is carried out with a inclined-tube micromanometer, as shown in fig. 4.

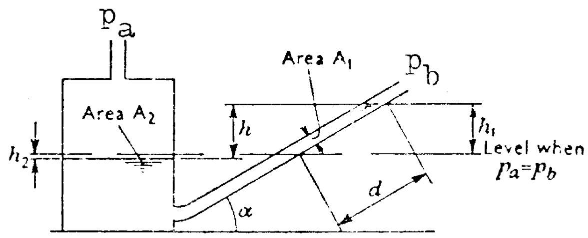


Fig. 4.

If the pressure difference $p_a - p_b$ causes changes in level h_1 and h_2 as indicated in fig. 4, then the difference in level h is given by

$$h = h_1 + h_2$$

The hydrostatic equilibrium equation is

$$p_a + g h_2 (\varrho - \varrho_{liquid}) = p_b + g h_1 (\varrho_{liquid} - \varrho)$$

The volume of fluid displaced into the inclined-tube is

$$A_1 d = A_2 h_2$$

In addition, if we note that

$$h_1 = d \sin\alpha$$

both h_1 and h_2 may be expressed in terms of the deflection d, giving

$$p_a - p_b = g d \left(\sin\alpha + A_1/A_2 \right) (\varrho_{liquid} - \varrho)$$

The sensitivity of the micromanometer can thus be increased by reducing the specific gravity of the liquid, the angle of inclination of the tube α, or the area ratio A_1/A_2. Alcohol is ordinarily used in inclined-tube micromanometers. If it is assumed that $\sin\alpha \gg A_1/A_2$ and $\varrho_{liquid} - \varrho \simeq \varrho_{liquid}$, then we finally obtain the velocity head in the test section of the tunnel, by measuring the difference in liquid length d

$$V_c = \left[\frac{2 g d \sin\alpha \cdot \varrho_{liquid}}{\varrho \left[1 - (A_b/A_a)^2 \right]} \right]^{1/2}$$