Drag (resistance to flow)

Related topics

Resistance to pressure, frictional resistance, drag coefficient, turbulent flow, laminar flow, Reynolds number, dynamic pressure, Bernoulli equation.

Principle and task

Objects of different cross-section and shape are placed in a laminar air stream. The drag is examined as a function of the flow velocity and the geometry of the objects.

Equipment

Aerodynamic models, set of 14	02787.00	1
Pitot tube, prandtl type	03094.00	1
Precision manometer	03091.00	1
Holder with bearing points	02411.00	1
Double shaft holder	02780.00	1
Precision pulley	11201.02	1
Spring balance 0.1 N	03061.01	1
Vernier caliper	03010.00	1
Blower, mains voltage 220 V	02742.93	1
Rheostat, 500 Ohm, 220 V	06111.93	1
Support base -PASS-	02005.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	3
Rod with hook	02051.00	1
Stand tube	02060.00	1
Rod, pointed	02302.00	1
Silk thread, 200 m	02412.00	1
Rule, plastic, 200 mm	09937.01	1
Rubber tubing, i.d. 7 mm	39282.00	1

Problems

Determination of the drag as a function of:

1. the cross-section of different bodies,
2. the flow velocity,
3. determination of the drag coefficients c_w for objects of various shape.

Set-up and procedure

The experimental set up is as shown in Fig. 1. The dynamic pressure is measured with the Prandtl tube, and the air velocity calculated from equation (2). This measurement must be repeated several times during the test. The double shaft holder must be clamped loosely between the pivot points and adjusted horizontally and vertically. The objects whose resistance is to be measured are statically balanced; to do this it is convenient to use the pointed rod as a reference point. As the anticipated resistance forces are very slight, the balance must

Fig. 1: Experimental set up for determining the resistance to flow.

Fig. 2 : Drag of an object as a function of its cross-sectional area A (q = 0.85 hPa).

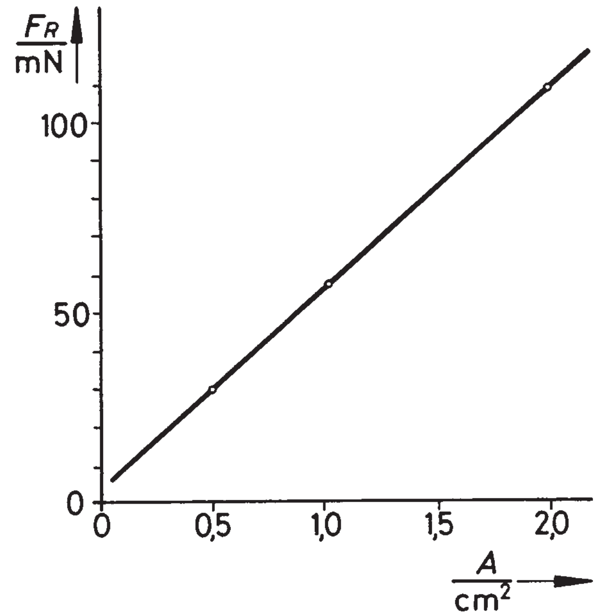
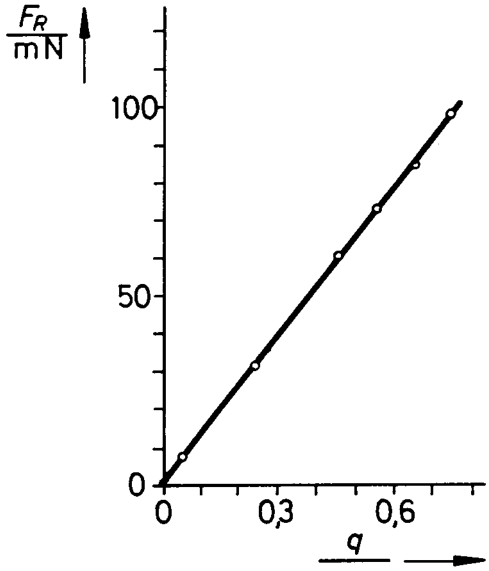


Fig. 3 : Drag of an object as a function of the dynamic pressure.



be very carefully adjusted. The compensation force is produced by way of the precision pulley, using the spring balance. If, in the compensated state, the objects do not return to equilibrium when deflected by hand this is because the double shaft holder is held too loosely between the pivot points (surface friction) or is held too tightly (squeezing effect) and must be corrected accordingly.

Theory and evaluation

The force $\vec{K}$ acting on a body around which air is circulating is:

$$\vec{K} = \int_A \vec{p}\, da\,, \tag{1}$$

where A is the peripheral area of the body. The surface forces $\vec{p}$ are the normal and shearing stresses. These include the pressure p and the frictional forces. If the direction of the flow velocity v is applied in the x direction, then K_x is the drag F_R. This value F_R is appropriately expressed by the dynamic pressure q of the incident flow

$$q = \frac{\rho}{2} \cdot v^2 \tag{2}$$

(ρ = density of the medium)

and by a typical area $f p$ (e g. the cross-sectional area of the body perpendicular to the flow). Equation (1) can thus be written

$$F_R = c_w\, f_p \cdot \rho\, \frac{v^2}{2}\,.$$

The drag coefficient c_w can be expressed by a surface integral. In the case of smooth objects it is to a great extent independent of the Reynolds number

$$Re = \frac{vd}{\nu}\,,$$

where d is a typical parameter, e.g. the width of the object in the stream of air, and ν:

$$\nu = \frac{\mu}{\rho}\,,$$

is the kinematic viscosity (μ is the viscosity).
For air at 278 K and 1013 mbar,

$$\nu = 1.3 \cdot 10^{-5}\, \frac{m^2}{s}\,.$$

Table 1: Drag coefficents of various objects.

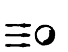
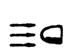
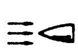
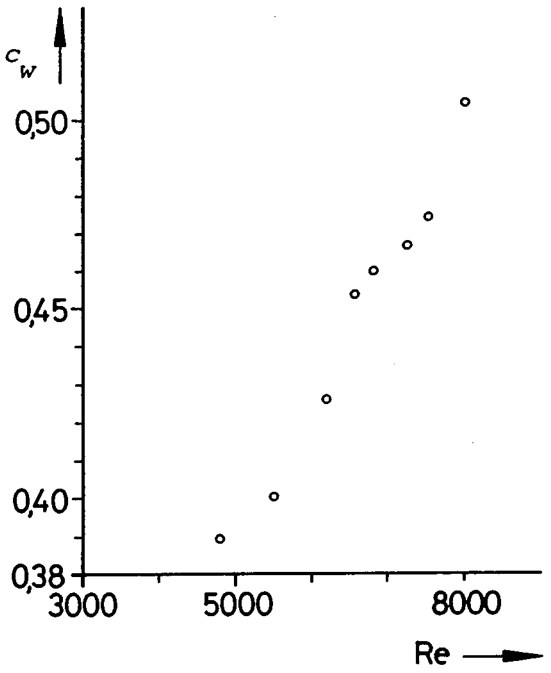
Object										
c_w	0.45	0.37	1.17	0.92	0.24	0.21	0.71	0.14	0.07	1.12

Fig. 4 : Drag coefficient of rough object as a function of the Reynolds number.



For stationary flow in an incompressible medium, the law of conservation of energy gives us

$$p_o + \frac{\rho}{2} v^2 = \text{const} = p$$

(Bernoulli equation)

The dynamic pressure

$$q = \frac{\rho}{2} v^2$$

is thus

$$q = p - p_o$$

and can be measured as a pressure difference, using the Prandtl tube.

Literature:

L. Prandtl, K. Oswatitsch, K. Wieghardt:
“Strömungslehre” (Flow theory),
Braunschweig, Vieweg 1969.
H. Ashley, M. Landahl: Aerodynamics of Wings and Bodies. Reading, Addison
Wesley 1965.