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APPLICATION OF IMPULSES METHOD FOR DEFINITION PROFILE DRAG OF CYLINDER

The main purpose of this paper is to verify the impulses method for experimental study drag of bluff body. It is well-known application of the impulses method for streamlined bodies [1]. The experimental two-dimensional model is built for investigation drag of cylinder.

The formula for calculation of profile drag coefficient C_D can be expressed as follows [2] (see Figure 1)

$$C_D = \frac{D}{H_\infty \cdot d \cdot 1} = 2\int_a^b \left[\sqrt{\frac{H_2 - p_2}{H_\infty - p_\infty}} \left(1 - \sqrt{\frac{H_2 - p_\infty}{H_\infty - p_\infty}} \right) \right] d\left(\frac{y_2}{d} \right), \qquad (1)$$

where D is drag force, H_∞, H_2 are dynamic pressure at planes 0 and 2 respectively; p_∞, p_2 are static pressure at planes 0 and 2 respectively; d is diameter of the cylinder; y_2 is integration axis; a, b are boundaries range of integral on y axis (boundaries of the aerodynamic wake, see Figure 1), respectively.

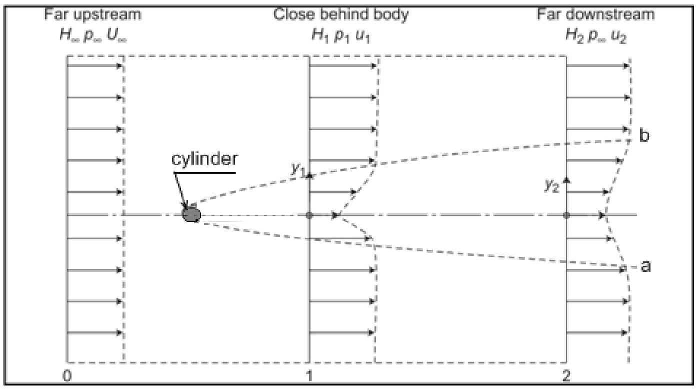

Figure 1 – Two-dimensional control volume around cylinder model for using impulses method

Formula (1) needs to transfer to a practical integral about profile drag coefficient which is shown as follows

$$\begin{cases} \phi = \sqrt{\dfrac{\Delta l_s \cdot g \cdot K'_m}{\Delta l_q \cdot g \cdot K_m \cdot (\lambda \cdot \mu)}} \cdot \left[1 - \sqrt{\dfrac{\Delta l_\infty \cdot g \cdot K'_m}{\Delta l_q \cdot g \cdot K_m \cdot (\lambda \cdot \mu)}} \right], \\ C_D = \dfrac{2}{d} \displaystyle\int_a^b \phi(y) dy, \end{cases} \qquad (2)$$

where $\Delta l_s, \Delta l_\infty$ are measured with Pitot tube rake and Δl_q is measured with micromanometer (see Figure 2); g is the acceleration of gravity; K_m, K'_m are conversion coefficients of micromanometer and liquid battery gauge), respectively; $(\lambda \cdot \mu)$ is the coefficient for wind tunnel.

The equipment of this experiment is shown in Figure 2. As the figure shows, experimental data are obtained by Pitot tube rake in aerodynamic wake behind the cylinder, then displayed in the liquid battery gauge and measured by a scale.

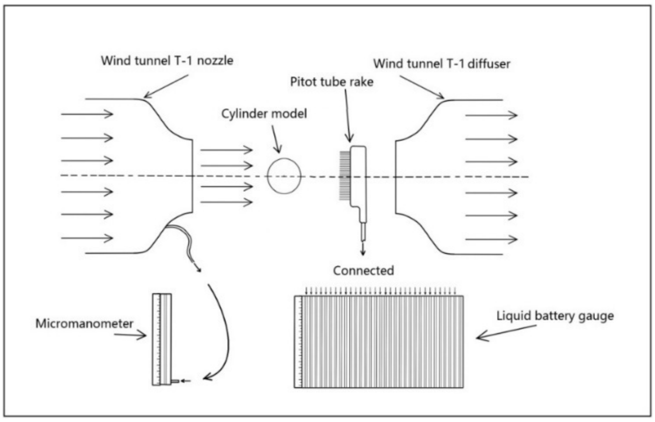

Figure 2 – Experimental equipment content

In this experiment, two different materials and diameters of cylinders are considered: plastic cylinder ($d_{plastic} = 40\ mm$) and steel cylinder ($d_{steel} = 32\ mm$). These cylinders have different surface roughness. The plastic cylinder has a greater roughness than the steel cylinder. The Figure 3 shows a circular cylinder drag vs Reynolds number $\mathrm{Re} = \dfrac{V_\infty \cdot d}{\nu}$ (here ν is air viscosity) at different surface roughness [3]. In Figure 3 notes h is high roughness.

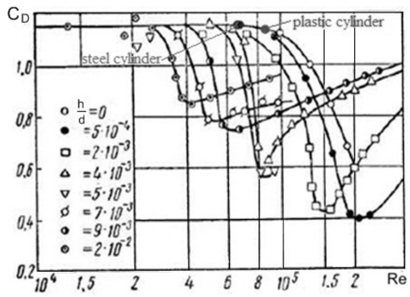

Figure 3 – Dependence circular cylinder drag coefficient versus Reynolds number and roughness of the cylinder surface [3]

The experimental data and fitted curves are shown in Figure 4.

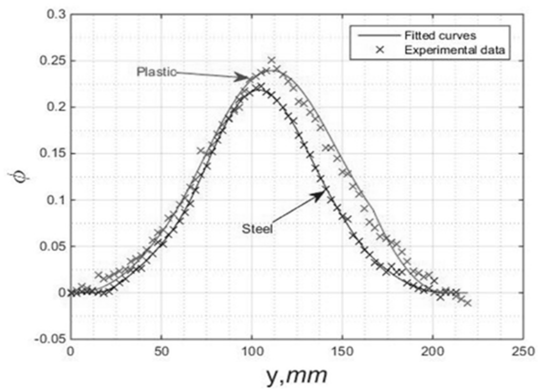

Figure 4 – Function $\phi(y)$ for two cylinders

The drag coefficient and other data are shown in Table 1, where Max number notes $M = \frac{V_\infty}{a}$ and a is sound velocity.

Table 1 – Comparison experimental data

Cylinders	M	Re·10^{-4}	C_D	C'_D [3]	δ,%
Plastic (d= 40 mm)	0.0972	8.46	1.110	1.116	0.54
Steel (d= 32 mm)	0.0961	6.48	1.116	1.144	2.45

Notice that C'_D is taken from [3] and it is used to calculate relative error this experimental result and data [3]. The formula for calculation relative error is shown as follows

$$\delta = \frac{|C_D - C'_D|}{C'_D} \times 100\% . \quad (3)$$

As Table 1 shows, relative errors of these two experiments are low. In other words, verification of the impulse method for the experimental determination of the drag coefficient of bluff body was done. Further, it is planned to apply this method to other bluff bodies such as airfoil with spoiler.

Reference

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3. Gorlin, S.M. Experimental Aeromechanics, Moscow; High school, 1970.