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About One the Methodology for Conducting Experiments with Models of Trains

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Annotation. The movement of fluid between coaxial cylinders is considered in two cases: The inner cylinder moves at a constant speed that occur under the influence of pressure conditions; a relationship is obtained for the ratio of the radii, provided that the cylinder speed in the first case is equal and the average fluid velocity in the second.

Key words: laminar motion, velocity, friction force, fluid motion.

To determine the resistance of a train model moving in a tunnel, the model is placed at a distance from the wind tunnel wall that is geometrically similar to the distance between the side surface of the train and the tunnel wall. In this case, there is a violation of dynamic similarity, since the model is stationary relative to the pipe wall, while the train is moving relative to the tunnel wall [1].

Material and methods

The experiment showed that when testing a train model moving on an open track, in order to maintain dynamic similarity, the distance between the flat bottom of the model and the wall of the wind tunnel should be equal to three times the distance between the flat lower surface of the train and the ground, provided that the average air flow velocities in the gaps are equal [4].

Results And Discussion

Let us show that it is possible to obtain an analytical dependence between the ratios of radii for a model of a train running in a tunnel tested in a wind tunnel.

Let c_1 and c_1 – be circles of radii R_1 and R_2 $(R_1 < R_2)$ with a common center at the origin, and let the following boundary conditions be satisfied:

$$u|_{c_1} = U, \ \ u|_{c_2} = 0$$

where U is the speed of a real train It is known [2] that the distribution of speeds in the annular gap is given by the expression

$$u = U\frac{lnR_2 - lnR}{lnR_2 - lnR_1}, \qquad R_1 < R < R_2 \qquad (1)$$

And the friction force from the side of the liquid to the movable cylinder, per unit length, is equal to

$$T_1 = 2\pi\mu \neq \frac{U}{lnR_2 - lnR_1} \qquad (2)$$

Now we consider the laminar motion of a viscous incompressible fluid between two fixed coaxial cylinders of radii r_1 and r_2 $(r_1 < r_2)$ arising under the action of a pressure difference [3]. In this case, the fluid velocity in the annular gap is equal to

$$v = \frac{1}{4\mu}\frac{\partial p}{\partial z}\left(r^2 - r_1^2 - \frac{r_2^2 - r_1^2}{lnr_2/r_1} lnr/r_1\right) \quad r_1 < r < \ r_2 \qquad (3)$$

and the speed is average over the cross section

$$v_{cp} = \frac{1}{8\mu}\frac{\partial p}{\partial z}\left[\frac{r_2^2 - r_1^2}{lnr_2/r_1} - (r_2^2 + r_1^2)\right] \qquad (4)$$

Friction force from the liquid side on the surface of the inner cylinder (model)

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$$T_2 = \frac{\pi}{2}\frac{\partial p}{\partial z}\left[2r_1^2 - \frac{r_2^2 - r_1^2}{lnr_2/r_1}\right] \qquad (5)$$

Expressing from equality (4) $\frac{\partial p}{\partial z}$ in terms of the average velocity and substituting into (5), we obtain the following expression for the friction force on the surface of the model

$$T_2 = 4\mu\pi v_{cp}\frac{2r_1^2 lnr_2/r_1 - (r_2^2 - r_1^2)}{r_2^2 - r_1^2 - (r_2^2 + r_1^2)lnr_2/r_1} \qquad (6)$$

We now equate to each other the values T_1 and T_2 determined by formulas (2) and (6), requiring the equality of U and v_{cp}. Hence, in order to maintain dynamic similarity in experiments, the ratios of the radii should be in the following dependence:

$$\frac{R_2}{R_1} = exp\frac{(\frac{r_2}{r_1})^2 - 1 - \left[(\frac{r_2}{r_1})^2 + 1\right]lnr_2/r_1}{\frac{lnr_2}{r_1} - \frac{1}{2}\left[(\frac{r_2}{r_1})^2 - 1\right]} \qquad (7)$$

If this condition is met, the dynamic similarity in laminar flows will be observed. Using the obtained solution, it is possible to solve a similar problem of testing a train model with an elliptical cross section by mapping the area between two confocal ellipses onto a ring using the Zhukovsky function.

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