*ISSN 1063-7842, Technical Physics, 2019, Vol. 64, No. 7, pp. 947–949. © Pleiades Publishing, Ltd., 2019.*
*Russian Text © The Author(s), 2019, published in Zhurnal Tekhnicheskoi Fiziki, 2019, Vol. 89, No. 7, pp. 1012–1014.*

# Analysis of Aerodynamic Characteristics of Two Parallel Rotating Cylinders

**N. K. Tanasheva**[a],*, **B. R. Nusupbekov**[b], **A. N. Dyusembaeva**[b], **and N. N. Shuyushbayeva**[c]
[a] *Institute of Applied Mathematics, Karaganda, 100028 Kazakhstan*
[b] *Karaganda State University, Karaganda, 100028 Kazakhstan*
[c] *Ualikhanov Kokshetau State University, Kokshetau, 020000 Kazakhstan*
**e-mail: nazgulya_tans@mail.ru*

Received November 27, 2018; revised November 27, 2018; accepted January 19, 2019

**Abstract**—We report on the results of experimental investigations on determining drag and lift coefficients for a system of two parallel rotating cylinders. The results show that with increasing the distance between rotating cylinders, drag and lift coefficients decrease. It has been established experimentally that the distance beginning with which cylinders almost stop acting on each other is 0.4 of the diameter of these cylinders.

**DOI:** 10.1134/S1063784219070247

## INTRODUCTION

Modern level of development of engineering and high technologies makes it possible to use a rotating cylinder as a special element for obtaining an additional lift force directed across the flow. For a cylinder rotating in an air flow, the flow velocity and velocity of the surface in the upper part of the cylinder coincide; these velocities are added, the flow is accelerated, and the velocity increases [1]. In the lower part of the cylinder, the velocities of the flow and of the rotating surface have opposite directions and are subtracted; deceleration and a decrease in the velocity are observed [2–4]. Such a difference in the velocities leads to the emergence of a transverse pressure difference and of a transverse lift force (Magnus effect). We used this phenomenon for designing a windmill.

The Magnus effect emerging for a cylinder rotating in a flow has been used long ago, but the possibility of its practical application as a driving force of new-generation windmills for low flow velocities has been studied systematically only in recent years.

This communication is aimed at analysis of aerodynamic characteristics of two parallel rotating cylinders based on the Magnus effect.

The dependences of aerodynamic characteristics of rotating cylinders on the bevel angle of the air flow were studied earlier [5].

## 1. EXPERIMENTAL

Experiments were performed at the research laboratory for aerodynamic measurements (Prof. Akylbaev, Department of Engineering Thermal Physics). The test mock-up of two parallel rotating cylinders operating based on the Magnus effect was assembled and later tested in a transverse air flow at different velocities. The mock-up was installed in the working part of a T-1-M wind tunnel fixed to the frame of a three-component aerodynamic balance with the help of thin metal tension wires. Three-component aerodynamic balance makes it possible to measure the drag and lift forces to a high degree of accuracy.

For studying the system of rotating cylinders, we investigated aerodynamic parameters of a system of two rotating cylinders arranged in parallel.

Figures 1 and 2 show an arrangement diagram of two parallel rotating cylinders, in which the air flow incoming on the head part of a cylinder produces a force, which is detected by the balance, and a photograph of the working part of the wind tunnel with the experimental mock-up for testing.

Experiments were made with two rotating cylinders 100 mm in diameter; the air flow velocity was varied from 5 to 10 m/s. The velocity of the incoming flow and the frequency of rotation of cylinders remained unchanged.

Laboratory tests were carried out with a separation between cylinders varied from 0.5 to 10 cm.

During analysis of aerodynamic characteristics of the rotating cylinders, two situations were considered:

(i) both cylinders rotate in the same direction against the air flow;

(ii) the cylinders rotate in opposite directions.

Drag coefficient $C_x$ and lift coefficient $C_y$ were calculated during the experiments using expressions

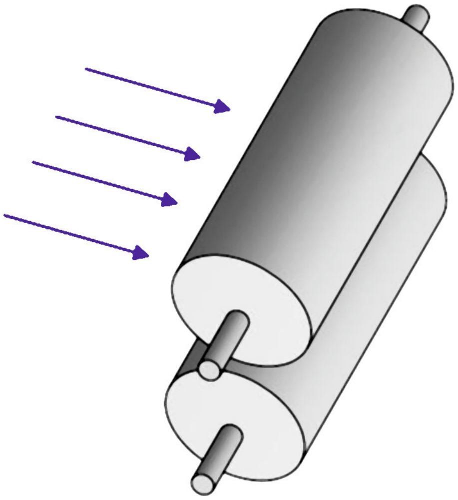

Fig. 1. Diagram of arrangement of two parallel rotating cylinders.

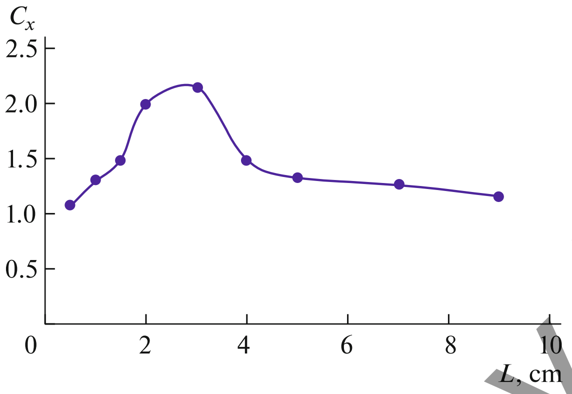

Fig. 3. Dependence of the drag coefficient on the distance between cylinders rotating in the same direction.

$$C_y = \frac{\Delta F_y}{\rho \frac{u^2}{2} S} \quad \text{or} \quad C_y = \frac{2F_y}{\rho u^2 S}. \tag{1}$$

$$C_x = \frac{\Delta F_x}{\rho \frac{u^2}{2} S} \quad \text{or} \quad C_x = \frac{2F_x}{\rho u^2 S}. \tag{2}$$

Here, $C_y$ is the lift coefficient, $C_x$ is the drag coefficient, $\Delta F_x$ is the drag force, [N]; $\Delta F_y$ is the lift force, [N]; $\rho$ is the density of air, [kg/m$^3$]; $u$ is the air flow velocity, [m/s]; and $S$ is the midsection area, [m$^2$].

## 2. RESULTS

From the results of investigation of aerodynamic forces, we calculated and plotted curves describing the dependences of the drag coefficient and lift coefficient on distance $L$ between cylinders.

Fig. 2. General view of the working part of the wind tunnel with installed rotating cylinders being tested.

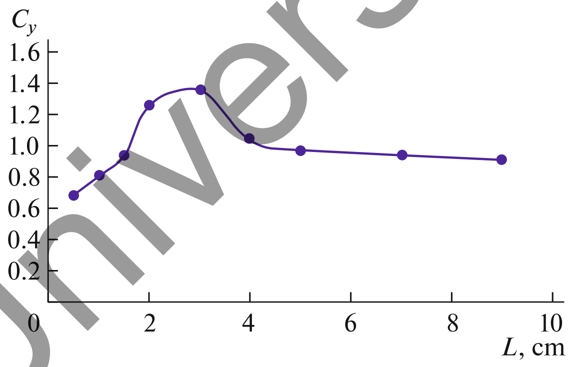

Fig. 4. Dependence of the lift coefficient on the distance between cylinders rotating in the same direction.

Figure 3 shows the dependence of the drag coefficient on the separation between cylinders rotating in the same direction.

With increasing distance between the cylinders to 3 cm, the drag coefficient increases, but upon a further increase in this distance (from 3 to 4 cm), the drag coefficient gradually decreases from 2.3 to 1.4. With a further increase in the distance between the cylinders, their mutual action almost disappears.

Figure 4 shows the dependence of the lift coefficient on the distance between cylinders rotating in the same direction. It can be seen that with increasing distance between the cylinders to 3 cm, the lift coefficient increases. Upon a further increase in distance from 3 to 4 cm, the lift coefficient gradually decreases from 1.3 to 1. With a further increase in distance to 4 cm and larger, the mutual effect of cylinders disappears.

Further, we consider unique graphs describing the dependences of the drag and lift coefficients for cylinders rotating in opposite directions (Figs. 5 and 6). In this case, vortices appearing in the wake behind rotating cylinders approach one another and then merge

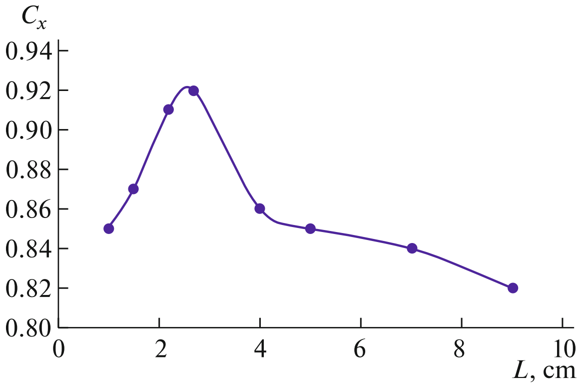

**Fig. 5.** Dependence of the drag coefficient on the distance between cylinders rotating in opposite directions.

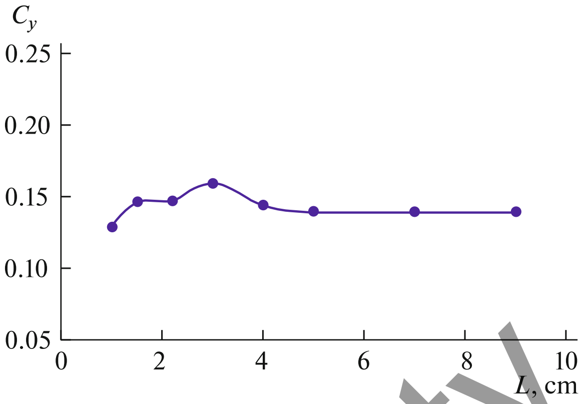

**Fig. 6.** Dependence of the lift coefficient on the distance between cylinders rotating in opposite directions.

together, forming a region resembling a streamline body.

It can be seen from curves plotted in Figs. 5 and 6 that in contrast to cylinders rotating in the same direction, oppositely rotating cylinders almost do not produce a lift force because the lift coefficient almost remains unchanged with increasing distance between cylinders. Upon a further increase in the separation between cylinders, the mutual effect of the cylinders almost disappears.

## CONCLUSIONS

The results of this study lead to the following conclusions:

(i) the optimal variant is that with oppositely rotating cylinders separated by a distance of 3 cm;

(ii) the distance beginning with which the mutual action of cylinders practically disappears is 4 cm (0.4 of the diameter of tested cylinders); this distance is established as a rule for any system of cylinders experimentally.

In contrast to available methods, this approach is based on the active trapping of the air flow by rotating cylindrical elements. The constancy of the cross section ensures optimal aerodynamic drag for rotating elements and a large thrust. Based on the results in this study, we are planning to design a wind turbine with blades having the shape of rotating cylinders with a horizontal rotation axis.

## FUNDING

This research was supported by project no. AP05131520, Designing and Construction of an Experimental Model of a Wind Power Plant for Alternative Power Supply using a Domestic Electric Generator.

## REFERENCES

1. N. M. Bychkov, Thermophys. Aeromech. **15**, 321 (2008).
2. K. Kussayinov, S. E. Sakipova, and N. K. Tansykbaeva, in *Proc. 7th Int. Symp. on Turbulence, Heat and Mass Transfer, Palermo, Italy, 2012*, p. 125.
3. K. Kussayinov, N. K. Shuyushbayeva, Yu. N. Ryzhykh, Yu. O. Stepanova, and S. B. Bagdatova, Vestn. Karagand. Univ. Ser. Fiz. **82** (2), 50 (2016).
4. K. Kusaiynov, N. K. Tanasheva, M. M. Turgunov, and A. R. Alibekova, Tech. Phys. **60**, 656 (2015). https://doi.org/10.1134/S1063784215050126
5. N. K. Tanasheva, N. N. Shuyushbayeva, and E. K. Mussenova, Tech. Phys. Lett. **44**, 787 (2018). https://doi.org/10.1134/S1063785018090134

*Translated by N. Wadhwa*