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TO THE QUESTION OF TRANSVERSE FLOW AROUND THE CYLINDER WITH GAS AND LIQUID STREAMS

Abstract*: The analysis of the movement of air and water flows on the cylinder surface is presented in the article. The calculated contours of the distribution of the flow velocity and vorticity on the cylinder surface and behind it were determined under the condition of changing the initial velocity of gas and liquid flow (from 0.1 to 10.0 m/s). The plots of pressure on the flow velocity on the cylinder surface were obtained.*

Key words*: gas, liquid, flow around the cylinder, the flow velocity, pressure.*

Language*: English*

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Introduction

Aerodynamics and hydrodynamics, as fields of science, study the movement of gases and liquids flows and their effect on solids located in space [1-2]. To reduce the drag force during the flow movement, solids are given a streamlined shape (for example, the geometric shape of the wing profile of an aircraft). The formation pattern of gas or liquid flow can be studied on the cylinder surface having the simple geometric shape [3-11]. The cylinder is represented by a circle on which the following parts are distinguished: front, lateral and aft (in the conditions of transverse flow around). On the front and aft parts of the cylinder, it is possible to distinguish the forward and rear stagnation points located at angles of 0 and 180 degrees on the *X*-axis relative to the Cartesian coordinate system. The front part of the cylinder is directed at moving flow of gas or liquid. The aft part is located on the opposite side of the cylinder along the *X*-coordinate axis. The vortex flow fronts are formed on the lateral parts of the cylinder. The formation of vortex flows depends on the initial velocity of gas or liquid flow. The purpose of this study was to perform an experiment to determine the numerical values of the aerodynamic and hydrodynamic parameters during transverse flow around the cylinder with air and water streams moving at the different initial velocities.

Materials and methods

Modeling the process of transverse flow around the cylinder with streams of air and water was implemented in the Comsol Multiphysics program. The process of gas and liquid flow in space was stationary. The infinitely long cylinder with the radius of 8 mm was placed in space. The initial flow velocities of gas and liquid, at the temperature of 298.15 K, were taken as 0.1, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0 and 10.0 m/s.

The conditions for modeling the process of transverse flow around the cylinder with air and water streams are presented in the table 1.

Table 1. The conditions for modeling the process of transverse flow around the cylinder with air and water streams.

Description	Value
Discretization of fluids	*P1+P1*
Compressibility	Incompressible flow
Turbulence model type	RANS
Turbulence model	*k-ε*
Reference pressure level	1[atm]
Streamline diffusion	On
Crosswind diffusion	On
Turbulence model parameter	1.44
Turbulence model parameter	1.92
Turbulence model parameter	0.09
Turbulence model parameter	1.0
Turbulence model parameter	1.3
Law of the wall constant	5.2
Turbulence model parameter	0.41
Use pseudo time stepping for stationary equation form	On
CFL number expression	Automatic
Velocity scale	1[m/s]
Length scale factor	0.035

Results and discussion

The calculation results were presented graphically in a two-dimensional form. The movement of gas and liquid flow during flow around the cylinder can be considered on a vector diagram. The value of the vector indicates the flow velocity. A slight increase and decrease in the flow velocity of gas and liquid behind the cylinder was noted. The numbers indicate the areas of space in which the changes in the aerodynamic and hydrodynamic parameters were analyzed (*1* is the area in front of the front part of the cylinder, *2* is the area near the lateral part of the cylinder, and *3* is the area behind the aft part of the cylinder). The vector diagram of the air/water flow velocity and the areas of space near the cylinder are presented in the Fig. 1.

The calculated contours of the flow velocity and vorticity of gas and liquid streams, under the conditions of transverse flow around the cylinder, are presented in the Figs. 2 and 3. The calculated contours were obtained at the initial air and water flow velocity of 1 m/s. The dark red color of the contours of the calculated flow velocities and the vortex formation of gas and liquid characterizes the maximum value of the parameters, the light red color of the contours characterizes the minimum value of the parameters.

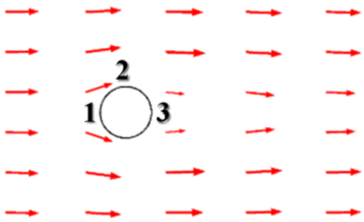

Figure 1 – The vector diagram and the areas of space (*1*, *2* and *3*), where the values of the gas and liquid flow velocity were determined.

The distribution of the gas and liquid flow velocity near the cylinder surface has the number of features. In both cases, near the forward and rear stagnation points located on the front and aft parts of the cylinder, the areas are formed where the flow velocity is zero. Streams fronts with the high flow velocity are formed between the front and aft parts of the cylinder. Decreasing the flow velocity is observed behind the aft part of the cylinder. The calculated flow velocity becomes equal to the initial velocity after a certain distance. The high gas flow velocities are distributed over a larger space, taking into account viscosity of the two environments. This leads to the formation of the more developed transition process of gas and liquid flows. This fact is confirmed on the contours of vorticity, where the formation of vortices occurs already from the front part of the cylinder.

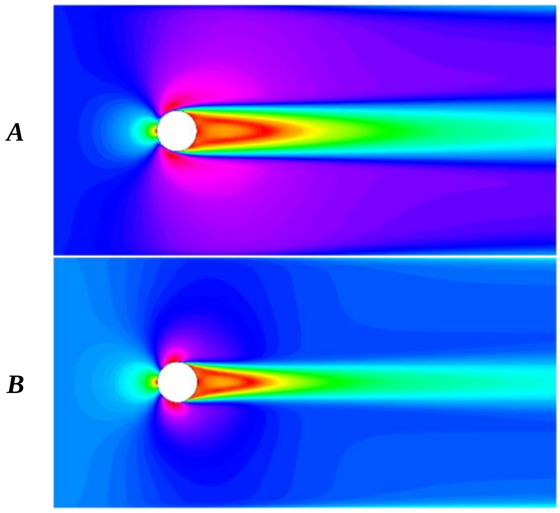

Figure 2 – The flow velocity contours (*A* – air, *B* – water).

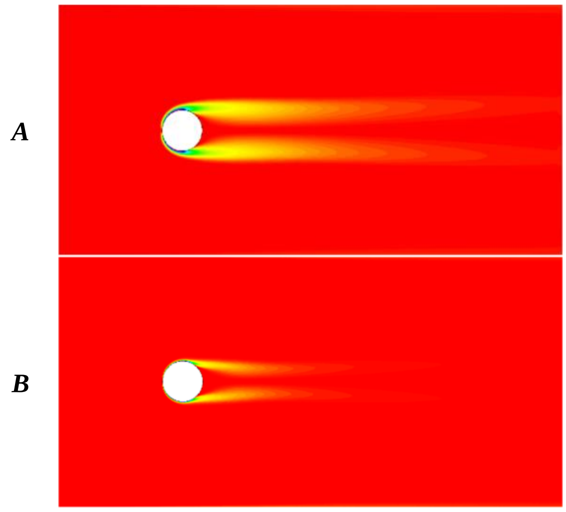

Figure 3 – The vorticity contours (*A* – air, *B* – water).

Let us consider the change in pressure and the flow velocity near the front, lateral and aft parts of the cylinder. The plots of pressure on the air and water flow velocity, at the initial gas and liquid flow velocities of 0.1, 1.0 and 10.0 m/s, are presented in the Figs. 4-6.

Changing the flow velocity of gas and liquid near the front part of the cylinder occurs proportionally (pressure increases with decreasing the flow velocity). The highest flow velocity near the front part of the cylinder is equal to the initial flow velocity of gas or liquid. Changing pressure and the flow velocity is the same in all cases. Pressure is positive.

On the lateral parts of the cylinder, there is an increase in the flow velocity by 1.5-1.8 times, compared with the initial velocity. The negative flow pressure gradients occur due to the formation of a turbulent wake. Discrepancies in the pressure values on the corresponding plots indicate the asymmetric formation of vortex flows on the lateral parts of the cylinder.

The negative pressure gradient of the gas or liquid flow is also formed on the aft part of the cylinder and behind it. The flow velocity and pressure in this area are less than near the front and lateral parts of the cylinder. The flow velocity near the aft part of the cylinder is almost similar to the flow velocity near the front part, but pressure varies in the small range.

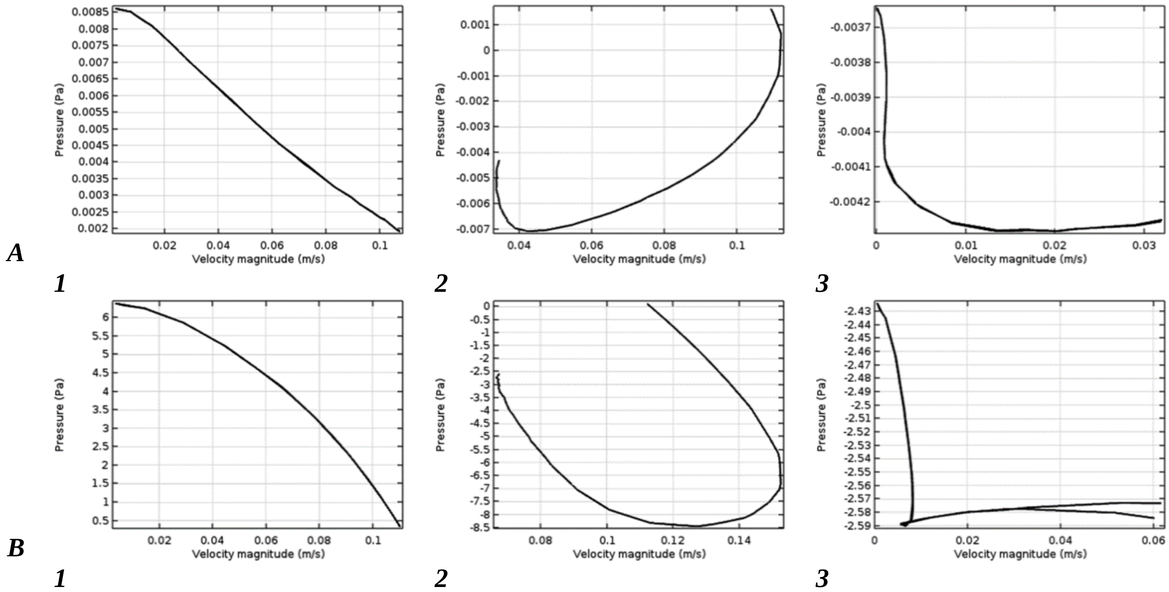

Figure 4 – The plots of pressure on the flow velocity of air (*A*) and water (*B*). *1*, *2* and *3* are the areas in which the parameters values were obtained. The initial velocity of air and water flow is 0.1 m/s.

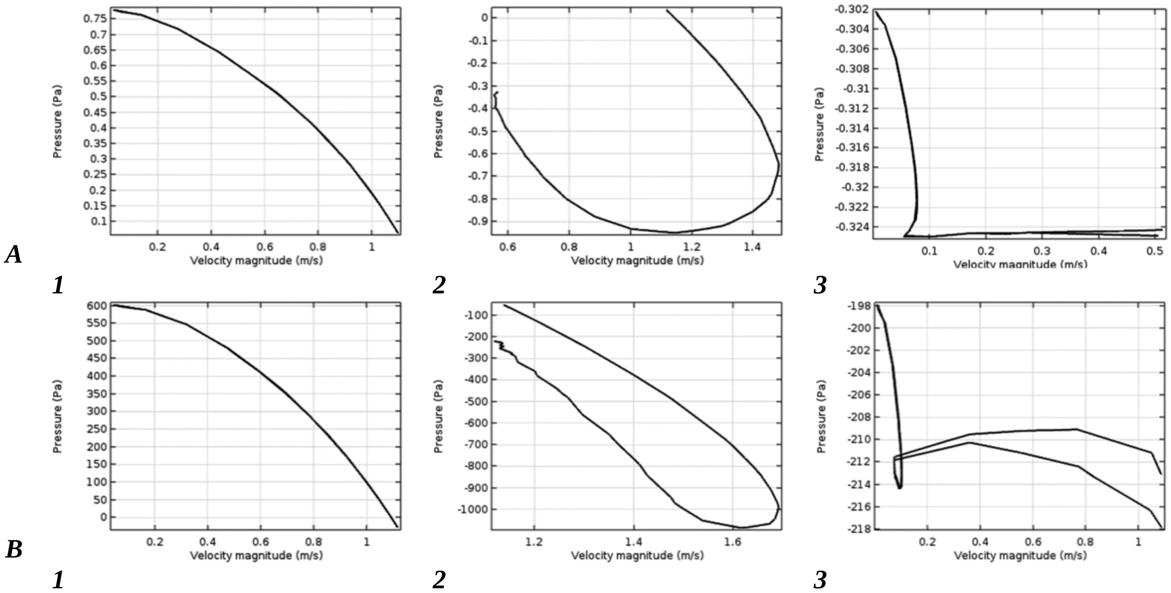

Figure 5 – The plots of pressure on the flow velocity of air (*A*) and water (*B*). *1*, *2* and *3* are the areas in which the parameters values were obtained. The initial velocity of air and water flow is 1.0 m/s.

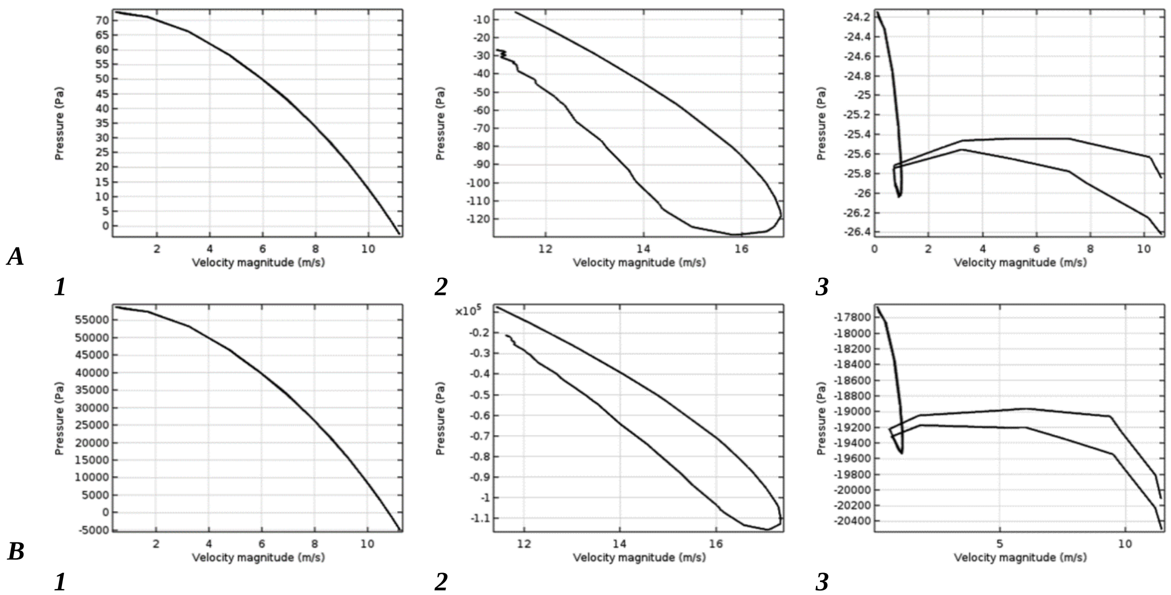

Figure 6 – The plots of pressure on the flow velocity of air (*A*) and water (*B*). *1*, *2* and *3* are the areas in which the parameters values were obtained. The initial velocity of air and water flow is 10.0 m/s.

Conclusion

Numerical simulation has shown that the positive and negative pressure gradients are formed near the front and aft parts of the cylinder, respectively, at almost the same flow velocity of air and water. Increasing the flow velocity on the lateral parts of the cylinder leads to the formation of uneven vortex flow of gas and liquid. The calculated velocity of liquid flow acquires the value of the initial velocity after passing the distance equal to 4.5 of the cylinder diameter, relative to the rear stagnation point located on the aft part of the cylinder.

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