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DEPARTMENT OF MECHANICAL ENGINEERING
ME333 FLUID MECHANICS LABORATORY

Drag Coefficient of a Cylinder

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Abstract

In this experiment, we investigated the aerodynamic properties of the flow around a cylindrical object via a wind tunnel. We focused on the interaction between fluid velocity, pressure differences, and drag coefficient, varying the height of the velocity component near the cylinder surface. Basic parameters such as current readings, pressure differences, local velocity and kinematic viscosity are systematically recorded under stringent conditions such as a fixed frequency of 19 Hz. It involves rigorous calculations of density, Reynolds number, and drag coefficient using interpolation for room temperature conditions during the experiment. The experiment provides a clear understanding of the fluid dynamics surrounding the cylindrical object and results in integral formulas and a graphical representation of the downstream velocity profile. The results of the experiment provide important information, including pressure changes, local velocity values, and derived parameters for each test case. The findings highlight the impact on drag coefficient, drag force and Reynolds number.

Introduction

This report provides a thorough examination of experimental data obtained from wind tunnel tests conducted to investigate the aerodynamic properties of flow around a cylindrical object. The research focuses on the relationship between fluid velocity, pressure differentials, and drag forces acting on the cylinder.

Changing the height of the velocity component near the cylinder surface and measuring corresponding parameters such as current (I1 and I2), pressure differentials (Delta P), local velocity (u), and kinematic viscosity are all part of the experimental setup. The tests are carried out under strict conditions, such as a constant frequency of 19 Hz in the wind tunnel. For each test case, key variables such as height (h), current readings (I1 and I2), and pressure differentials (Delta P) are systematically recorded. These measurements are used to calculate critical parameters such as density, Reynolds number, and drag coefficient.Based on room temperature conditions, the methodology employs interpolation for density and kinematic viscosity. The analysis includes calculating the free stream velocity, drag force per unit length, drag coefficient, and Reynolds number.The equations and methodologies presented here are intended to provide a clear understanding of the fluid dynamics surrounding the cylindrical object. The report concludes with integral formulas and a graphical representation of the downstream velocity profile.

This study's findings provide important insights into the aerodynamic behavior of cylindrical objects in fluid flow, with implications for a variety of engineering applications.

Procedure

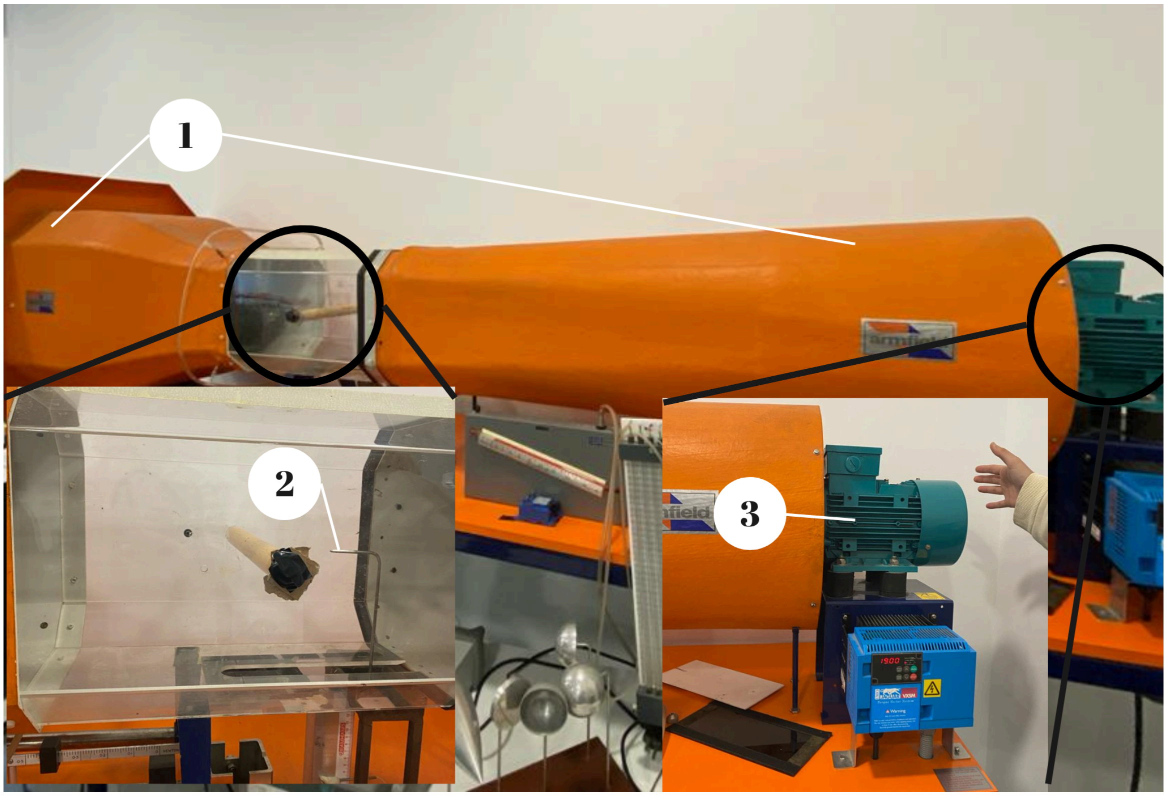

Figure 1 : Test Setup

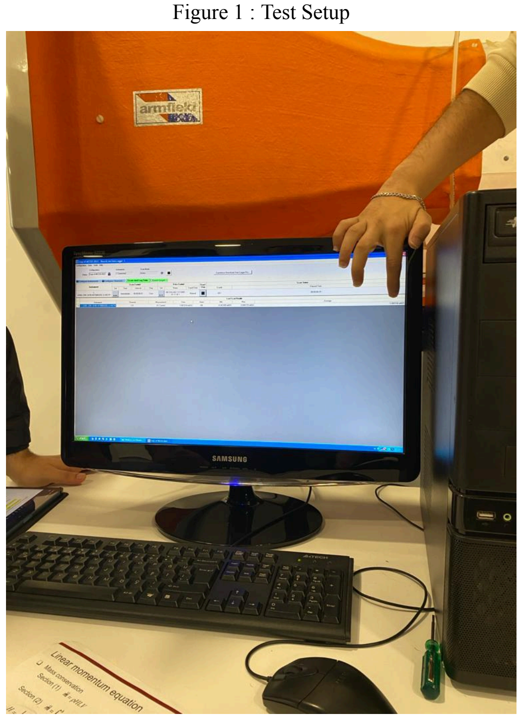

Figure 2 : Computer and DAQ System

The equipment used in the lab can be seen in Figure 1 and Figure 2, respectively:

1) Subsonic wind tunnel
2) Pitot tube
3) Pressure transducer
4) Data acquisition (DAQ) system and Computer (Figure 2)

The cylinder figure was placed in the wind tunnel. The wind tunnel was operated at 19 Hz. The difference between static pressure and stagnation pressure was measured with the pitot tube and the current values were sent to the computer via DAQ. The experiment was repeated times

Data Presentation

Table 1 : Dataset for the experiment

	Test1	**Test2**	**Test3**	**Test4**	**Test5**	**Test6**	**Test7**	**Test8**
height (m)	0.0300	0.0400	0.0500	0.0600	0.0700	0.0800	0.0900	0.1000
I1 (mA)	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92
I2 (mA)	5.0000	5.6300	6.5100	6.9100	7.0800	7.0800	7.0500	7.0450
Delta P Range (Pa)	250	250	250	250	250	250	250	250
I2-I1 (mA)	1.0800	1.7100	2.5900	2.9900	3.1600	3.1600	3.1300	3.1250
Delta P	16.8750	26.7188	40.4688	46.7188	49.3750	49.3750	48.9063	48.8281
Density (kg/m^3)	1.1960	1.1960	1.1960	1.1960	1.1960	1.1960	1.1960	1.1960
Local Velocity (u) (m/s)	5.3122	6.6843	8.2264	8.8388	9.0866	9.0866	9.0434	9.0362
Kinematic Viscosity	1.53E-05							
x(i+1)-xi	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	
(ui+u(i+1))/2	5.9982	7.4554	8.5326	8.9627	9.0866	9.0650	9.0398	
$\int_0^h udx$	0.0600	0.1345	0.2199	0.3095	0.4004	0.4910	0.5814	
Approximate $\int_0^h udx$	0.5814							
Free Stream Velocity (V)	9.0632							
H	0.0641							
(u^2i+u^2(i+1))/2	36.4496	56.1768	72.8992	80.3459	82.5669	82.1750	81.7177	

$\int_0^h u^2 dx$	0.3645	0.9263	1.6553	2.4587	3.2844	4.1061	4.9233	
Approximate $\int_0^h u^2 dx$	4.9233							
L	1							
R	-0.4139							
FD	0.8278							
D (m)	0.0280							
CD	0.6019							
Reynolds Number	1.65E+04							

Where ;

- Wind tunnel is working with 19 hz frequency.
- h represents the height of the velocity component measured at a point close to the cylinder surface. h value is changed from 3 to 10 cm with 1 cm interval.
- I1 and I2 are the ampere values measured with a pressure transducer. I1 is the pressure transducer reading with no flow, I2 is the pressure transducer reading with flow. The pressure transducer in this experiment has an output of 4 to 20 mA.
- P_t is the pressure corresponding to the stagnation point. P_s is the pressure corresponding to the static taps , called static pressure. The relation is given in equation 5.
- Delta P ($P_t - P_s$) is calculated from equation 6, where delta p range (pressure transducer range) is 250 pascal.
- Density is calculated with interpolation for room temperature (22 °C) as 1.1960 °C.

Temp(℃)	Density (kg/m^3)
20	1.204
25	1.184

- The local velocity of the fluid in the free stream region (u) is calculated from equation 7..
- Kinematic viscosity (v) is interpolated from this values , for room temperature kinematic viscosity is interpolated as 0.000015344 m^2/s

Temp(℃)	Kinematic viscosity (m^2/s)
20	0.00001516
25	0.0000156

- $\int_0^h u dx$ is calculated from the method in equation 14.

- There are no integral and below calculations for test 8 because in each test there is an (n+1) velocity and height value is used. This test is used for determining the test 7 values.
- Free Stream Velocity (V) is the average of the last 4 local velocity values.
- H represents the height of the free flow velocity of the fluid, calculated from equation 12 with Approximate $\int_0^h u dx$ value.
- $\int_0^h u^2 dx$ is calculated from the method in equation 15.
- L is the length of the cylinder and equals 1 meter.
- R is the force per unit length of the half cylinder and is calculated from equation 11 with Approximate $\int_0^h u^2 dx$ value.
- The drag force per unit length of the cylinder will be $F_d = -\ 2R$.
- In the present experiment, D = 28.0 ∓ 0.2 mm
- The drag coefficient is a term that defines the magnitude and characteristics of the drag force generated by an object moving through a fluid. This coefficient varies depending on the shape, dimensions, and properties of the fluid in which the object is moving. Calculated from equation 13.
- Reynolds Number is calculated from equation 6 using the free stream velocity and kinematic viscosity.

$$F_d = \frac{1}{2} wAV_\infty^2 \tag{1}$$

$$C_D = \frac{F_D}{A\frac{1}{2}\rho V_\infty^2} \tag{2}$$

$$A = DL \tag{3}$$

$$Re = \frac{\rho V_\infty D}{\mu} = \frac{V_\infty D}{v} \tag{4}$$

$$P_T = P_s + \rho\frac{V^2}{2} \tag{5}$$

$$P_T - P_s = \Delta P = \Delta P_{range}\frac{I_2 - I_1}{20-4} \tag{6}$$

$$V = \sqrt{\frac{2\Delta P}{\rho}} \tag{7}$$

At section (1),

$$\dot{m} = \rho HLV \tag{8}$$

At section (2),

$$\dot{m} = \int_0^h \rho uLdx \tag{9}$$

For steady flow with well-defined inlets and exits

$$\sum_{exits} (\dot{m} * V) - \sum_{inlet} (\dot{m} * V) = -2R = \mathrm{F} \tag{10}$$

Therefore using the section 2 ṁ for ṁ exit and section 1 ṁ for ṁ inlet

$$\int_0^h \rho u^2 Ldx - \rho V^2 HL = R \tag{11}$$

Therefore

$$H = \frac{1}{V}\int_0^h udx \tag{12}$$

$$C_D = \frac{2F_D}{\rho DV^2} \tag{13}$$

Next equations is using for integral formulas.

$$\sum_{i=1}^{N} (x_{i+1} - x_i)(\frac{u_{i+1}+u_i}{2}) \tag{14}$$

$$\sum_{i=1}^{N} (x_{i+1} - x_i)(\frac{u_{i+1}^2+u_i^2}{2}) \tag{15}$$

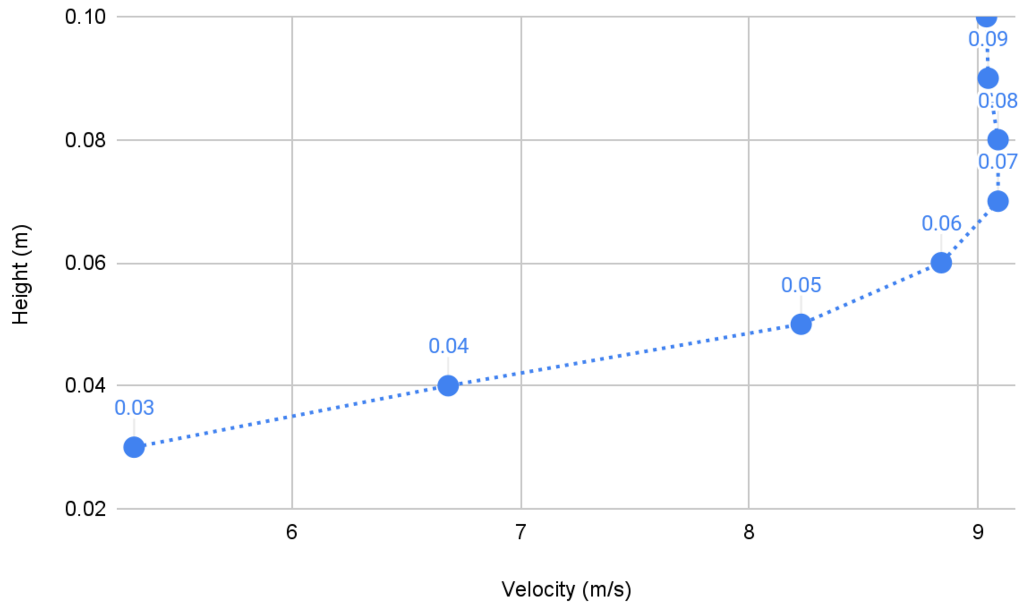

Figure 1: Velocity profile downstream of the cylinder

Results

In this experiment, corresponding to each h value, pressure change values and local velocity values were calculated. Additionally, for each h value, approximate $\int_0^h u dx$ value, approximate $\int_0^h u^2 dx$ value, H value,free stream velocity value, drag coefficient value, drag force value, and Reynolds number value were calculated. The obtained results are specified below.

- Pressure change in Pa, respectively : 16.8750, 26.7188, 40.4688, 46.7188, 49.3750, 49.3750, 48.9063, 48.8281
- Local velocity in m/s, respectively : 5.3122, 6.6843, 8.2264, 8.8388, 9.0866, 9.0866, 9.0434, 9.0362
- Approximate $\int_0^h u dx$: 0.581 m/s
- Approximate $\int_0^h u^2 dx$: 4.923 m^2/s^2
- H : 0.064 m
- Free stream velocity : 9.063 m/s
- Drag coefficient : 0.602
- Drag force : 0.828 N
- Reynolds number: 16538.701

Conclusion

This experiment was carried out to understand the behavior of the fluid due to the interaction of a fluid with a cylinder and to find the drag coefficient. Using the data obtained as a result of the experiment, drag coefficient, drag force, Reynolds number, and pressure changes were found and the velocity profile of the fluid was plotted. Some results were obtained from the variables of this experiment. Drag coefficient and drag force are the main results of this experiment. Reynolds number value is greater than 4000, so the **flow is turbulent flow**. The pressure changes increase as the value of h increases and the value of pressure change in the free stream region is almost constant. This shows that **the pressure difference between the fluid and the stagnation point increases as h increases**. The velocity values increase as h increases and are almost constant in the free stream region. This behavior shows that **the fluid velocity decreases behind the cylinder and increases up to the free stream region**. This experiment also shows that **the velocity of the fluid, the density of the fluid and the kinematic viscosity of the fluid affect the drag coefficient.**

When performing this experiment, errors and uncertainties that may affect the results of the experiment should be taken into consideration. These uncertainties and errors may be caused by length and temperature measurements, precision of the instruments used, calibration error, or accuracy. The results obtained from this experiment are satisfactory. If the accuracy of the results is to be improved, the precision of the devices used should be increased, errors due to human factors should be reduced and the person performing the experiment should work more carefully.