EXPERIMENTAL INVESTIGATION OF WAKE SURVEY OVER A CYLINDER WITH DIFFERENT SURFACE PROFILES

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ABSTRACT

Laminar air flow over a surface results in turbulent flow at higher Reynolds number due to flow separation. An attempt to delay Flow separation by using different surface profiles has been made. The paper involves experimental investigation of drag on circular cylinder by implementation of smooth, rough and channeled surfaces at three different velocities. The investigation has been carried out in a subsonic wind tunnel to determine how different cylinder surface profiles vary the drag in the wake region of a circular cylinder. The coefficient of pressure and drag has been calculated from the values measured from the wake probe for three different surface profiles at speeds 30, 35 and 40m/s respectively. Graphs has been plotted to show the variation of coefficient of drag along the wake region. This study will help us to correlate and select an appropriate surface profile which delays the separation point and also has a less drag. The results will have a direct application on all circular cylindrical structures such as fuselage, landing gears and towers. It has been found in the study that the channeled surface cylinders has less drag and wakes compared to the smooth and rough surface profiles.

Key-Words: wind tunnel; cylinder; wake survey; coefficient of pressure; coefficient of drag.

INTRODUCTION

The flow characteristics over a cylinder are one of the most relevant topics of research. A circular cylinder generates a high mean drag and large fluctuating forces (4).The cylinder subjected to low Reynolds number experiences flow separation, and oscillations in the wake region. The periodic nature of the vortex shedding phenomenon can sometimes lead to unwanted structural vibrations, which leads to structural damage.From the studies done it is evident that for a fluid particle flowing

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within the boundary layer around the circular cylinder, the pressure is a maximum at the stagnation point and gradually decreases along the front half of the cylinder. The flow stays attached in this favorable pressure region as expected. When vortices shed from the cylinder, uneven pressure distribution develops between the upper and lower surfaces of the cylinder, generating an oscillatory aerodynamic loading on the cylinder. This unsteady force can induce significant vibrations on a structure, especially if the resonance condition is met.

The experiments involve study of flow past a circular cylinder in a uniform stream. Different objects are cylindrically shaped since its volume is much higher than any other structures. The studies here are concentrated on cylindrically shaped aircraft parts such as fuselage. On a typical airplane, cylindrical fuselage is a significant source of drag, even though it generates no lift. An attempt has been made to study the flow characteristics over different cylinder surface profiles.

APPARATUS AND METHODS

The experiments are carried out in a low subsonic suction type wind tunnel with a test section of size 600mm×600mm with a contraction ratio of 11:1, run by an axial flow fan driven by DC motor with thyristore speed controller.

The cylinder of 50 mm diameter and a span of 600mm is mounted span wise across the wind tunnel test section. The Reynolds number at three different velocities has been calculated by using the formulae

$$Re = \frac{\rho V D}{\mu}$$

Where

ρ-Density of air=1.033Kg/m3

μ-Dynamic viscosity of air, 1.789e-5Ns/m2

D-Diameter of the cylinder=0.05m

L-Span length=0.6m

The testing has been done at Reynolds number $1.08e^5$, $1.26e^5$ and $1.44e^5$ respectively at velocities 30, 35 and 40m/s for three cases such as cylinder with smooth surface, rough surface and channeled surface. Initially, the wind tunnel was calibrated and then, the smooth cylinder was mounted in the test section.The flow characteristics of the smooth cylinder at three different velocities of 30m/s , 35m/s and 40m/s . The wake probe was placed at a distance of 1D from the trailing edge of the cylinder. In order to compare the variation of pressure around a bluff body for a variety of flow conditions, it is conventional to use a dimensionless ratio called the pressure coefficient Cp (5).The coefficient of pressure and hence the coefficient of drag has been calculated using the formulae

$Cp=\frac{hi-h\alpha}{ho-h\alpha}$ and

$Cd = 2\int\left(\sqrt{\frac{qw}{qf}} - \frac{qw}{qf}\right)\frac{dy}{c}$, where

Cp-Coefficient of pressure

Cd-Coefficient of drag

hi –Local static pressure measured around cylinder

hα-free stream static pressure measured by Pitot static probe

ho-Free stream total pressure measured by Pitot static probe.

$qw=(h_0-h_\alpha)_w$ calculated in wake region

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$qf=(h_0-h_\alpha)_f$ calculated for free stream.

dy-lateral spacing between wake probes

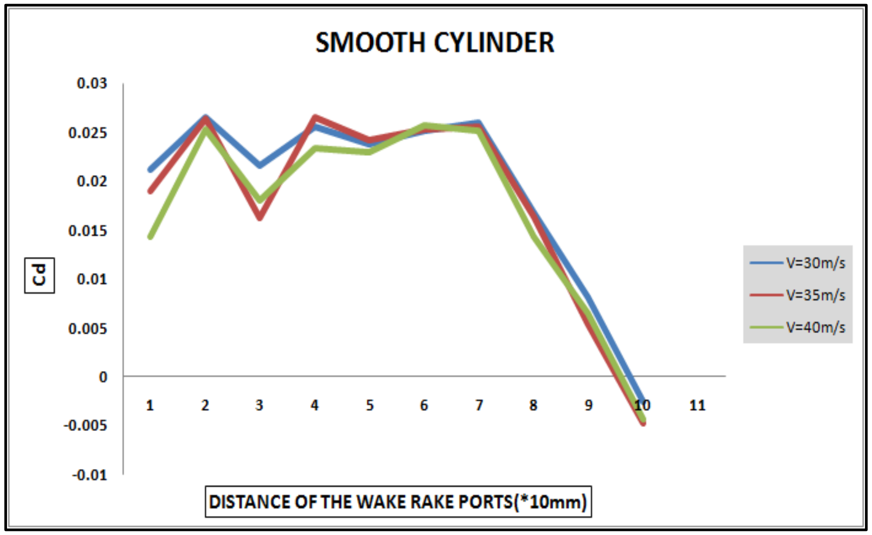
C-circumference of the cylinder

CASE: 1- CYLINDER WITH SMOOTH SURFACE

Figure 1.1 The smooth cylinder 0.05x0.6m.

Tabular column of smooth surface cylinder

Port Distance in mm (x10)	V = 30m/s		V =35m/s		V = 40m/s	
	Cp	Cd	Cp	Cd	Cp	Cd
1	0.5827	0.0211	0.58770	0.0189	0.7047	0.0143
2	0.2414	0.0265	0.2719	0.0264	0.3691	0.0253
3	-0.0805	0.0216	0.0351	0.0162	0.4697	0.0180
4	-0.1609	0.0255	-0.2544	0.0265	0.1074	0.0234
5	0.115	0.0238	-0.1228	0.0242	-0.1006	0.0230
6	0.1494	0.0252	0.1491	0.0252	0.1678	0.0257
7	0.3218	0.0260	0.3509	0.0256	0.3758	0.0252
8	0.6337	0.0168	0.6579	0.0163	0.7047	0.0143
9	0.839	0.0082	0.8947	0.0053	0.8724	0.0065
10	1.046	-0.002	1.0877	-0.0048	1.081	-0.0044



Graph 1: Cd vs Port Distance for a smooth surface of the cylinder

The above tabular column and the graph shows the pressure distribution and the drag coefficient along the ports and the above values of pressure and the graph would be taken as the standard values to compare with the further surface variation of the cylinder as shown below. The structures are mainly made of smooth surface to avoid the friction losses as the drag involved is mainly due to the friction. A comparative study is made with other surface topology for an effective comparison

CASE :2-CYLINDER WITH ROUGH SURFACE

The smooth cylinder is covered with sandpaper of negligible thickness, to make the cylinder surface rough. The experiment has been repeated with the rough surface cylinder as the model and the reading has been noted for velocities 30m/s,35m/s and 40m/s.

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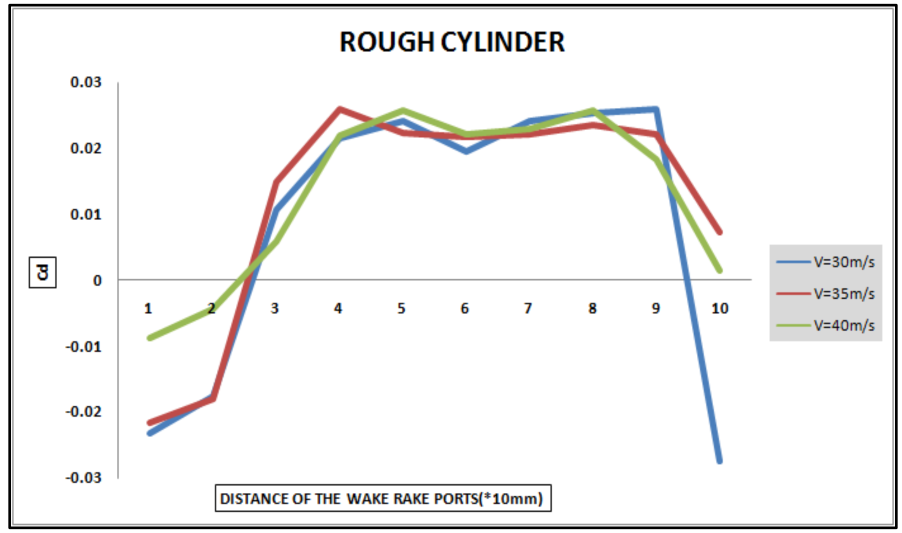
Figure 2.1 The cylinder with rough surface.

The coefficient of pressure is calculated and computed to find the variation of drag in the wake region.

Tabular column of rough surface cylinder

Port Distance in mm (x10)	V = 30m/s		V =35m/s		V = 40m/s	
	Cp	Cd	Cp	Cd	Cp	Cd
1	1.4023	-0.0231	1.3772	-0.0216	1.1611	-0.0089
2	1.3103	-0.0176	1.3158	-0.0179	1.081	-0.0044
3	0.7816	0.0108	0.693	0.0148	0.8859	0.0058
4	-0.0805	0.0216	-0.1842	0.0259	0.5033	0.0219
5	-0.4253	0.0241	-0.4912	0.0222	0.1678	0.0257
6	-0.5747	0.0195	-0.5088	0.0217	0.872	0.0221
7	-0.4253	0.0241	-0.5	0.0220	0.1007	0.0229
8	-0.3678	0.0253	-0.4774	0.0235	0.3423	0.0258
9	0.3218	0.0260	-0.0877	0.0221	0.604	0.0184
10	1.4713	-0.0274	0.8596	0.0072	0.9732	0.0014



Graph 2: Cd vs. Port Distance for a Rough cylindrical surface

A circular cylinder produces large drag due to pressure difference between upstream and downstream direction of the flow. The difference in pressure is caused by the periodic separation of flow over surface of the cylinder (6)

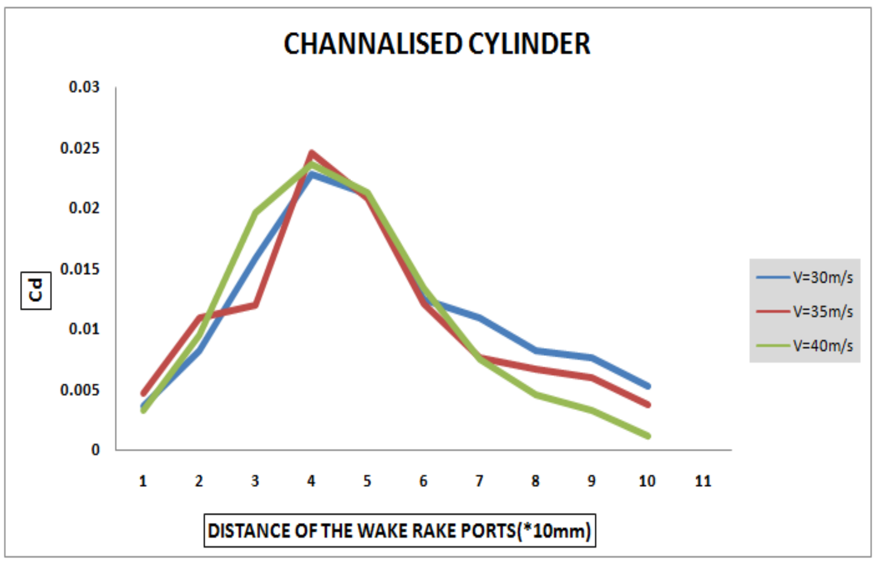
CASE: 3-CYLINDER WITH CHANNELED SURFACE

The cylinder surface has been channeled using thin films of negligible thickness.

ISSN: 2278 – 7798

Tabular column of channeled surface cylinder

Port Distance In mm (x10)	V = 30m/s		V =35m/s		V = 40m/s	
	Cp	Cd	Cp	Cd	Cp	Cd
1	0.931	0.0036	0.9123	0.0046	0.9396	0.0032
2	0.839	0.0082	0.7807	0.0109	0.8121	0.0095
3	0.667	0.0159	0.5614	0.0120	0.5705	0.0196
4	0.4712	0.0228	0.4035	0.0246	0.443	0.0236
5	0.5287	0.0211	0.535	0.0208	0.5235	0.0212
6	0.747	0.0124	0.7544	0.0121	0.7248	0.0134
7	0.7816	0.0109	0.8509	0.0076	0.8523	0.0075
8	0.839	0.0082	0.8684	0.0067	0.9128	0.0045
9	0.8506	0.0076	0.886	0.0059	0.9396	0.0032
10	0.8966	0.0053	0.9298	0.0037	0.9799	0.0011



Graph 3: Cd vs Port for the Channeled Cylindrical Surface

From the graph values of coefficient of pressure and coefficient of drag it has been found that the cylinder with channeled surface has reduced drag. This is because the air is channeled without separating on the surface.The size of vortices and vortex formation region behind a channelized cylinder are smaller, compared to a smooth cylinder(1).

RESULTS AND DISCUSSION

The graphs of three surface profile cylinders have been studied in detail to compare the flow characteristics. From the comparison point of view, it can be seen that the fine channeling over the surface induces the flow over the cylinder. The fluid will follow in the channeled path instead of getting separated. This technology can be well implemented in large structure bodies subjected to low reynolds number to reduce the drag. According to the studies made (2) it has been found that as the Reynolds number is increased to the supercritical regime, the effect of surface roughness on aerodynamic damping becomes small. Large structures subjected to low Reynolds number can be well made as channeled surface to reduce the damping. The drag force increases with increase in diameter of the cylinder. Also, for a cylinder of particular diameter, drag force has been found to increase with increase in air velocity (3).Hence the large structures subjected to low reynolds number can be well made in to channeled surface to reduce the wakes behind and hence the drag. This study opens the doors to further research, needed to determine the optimal channeled surface profile. .The further investigation would be made in detail on the optimization of channeling effect on the circular cylinder structures.

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