

## Fundamental Control of Wake Behind Bluff Bodies : A Review



### Engineering

KEYWORDS :

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### ABSTRACT

*When a body and fluid have relative motion in between them, they experience 'drag', the force which resists this relative motion. Particularly in aeronautics and automotive research, drag reduction is the most investigated topic. In the sub-sonic range total drag force exerted on a body is the sum of skin friction and pressure drag. For a streamlined body 85-90% of the drag is from skin friction while for a bluff body 80-85% of the drag is due to pressure drag. Additionally, the shear layers of the separated flow tend to be unstable, and concentration of vortices results in huge vortices in the wake. Because of this unsteadiness the drag forces are also unsteady with respect to magnitude and direction, thus generating vibrations of the body. An enhanced comprehension of the fluid mechanics around and behind bluff bodies as well as its effect when applying different control methods is essential in order to develop more safety, more energy efficient, and adapted design within many areas of practical application. In this research a passive method of wake reduction is encapsulated in which a duct connects the frontal high pressure region of the bluff body with the low pressure region at the rear. This method is studied and investigated using CFD.*

### INTRODUCTION :

#### What Is A Bluff Body ?

When the cross section of a body perpendicular to the flow is significant then it is termed as bluff body. Bluff body is distinguished from a streamlined body only at high Reynolds numbers when boundary layers exist as a discrete region of flow.

Simplest bluff body is a circular cylinder .

Air moving past buildings and flow over moving vehicles are some examples of bluff-body flow.

#### What Is Wake ?

Because of the shape characteristics of bluff bodies, there exists a region of considerable size behind them where the flow is slowed down. This region is termed the **wake**. This wake region is generated due to the boundary layer detachment which avoids pressure recovery. Thus huge pressure gradients exist between front and rear surfaces of bluff body, resulting in large wake region. The study of wake region is important because it helps to improve aerodynamic characteristics and performance of bluff bodies.

### FLOW CHARACTERISTICS OVER A BLUFF

Flow pattern over a bluff body is often somewhat unpredictable. For a minute geometric changes there can be a drastic change in flow pattern. The streamlines tend to separate from the body and are known as **free shear layers**. The flow region outside the free shear layers is called **free stream** while in between them is the **wake**. There exists a high pressure region or stagnation point on the forebody and then the pressure drops around the body. Very low pressure (well below free stream value) dominates the wake region. This pressure gradient over the bluff body leads to high drag.

### FLOW PATTERN IN WAKE REGION

The turbulence in the wake of a bluff body consists of numerous sizes of eddies, which interact with each other in their unruly motion. Despite of this turbulence, a large group of eddies form a well ordered sequence of **vortices** with a free stagnation point and reverse flow along the centre line. The alternative shedding of strong and highly concentrated vortices leads to the producing of well known '**Karman Vortex Street**' which can make the bluff body to vibrate and may lead to structure failure.

### THE WAKE OF THE BLUFF BODY CAN BE REGULATED BY : PASSIVE CONTROLS :

- Modifying the geometry of the body
- Putting streaks or dimples on the surface

### ACTIVE CONTROLS :

- External energy is input to some actuator to operate at specific condition
- Blowing and suction, synthetic jets

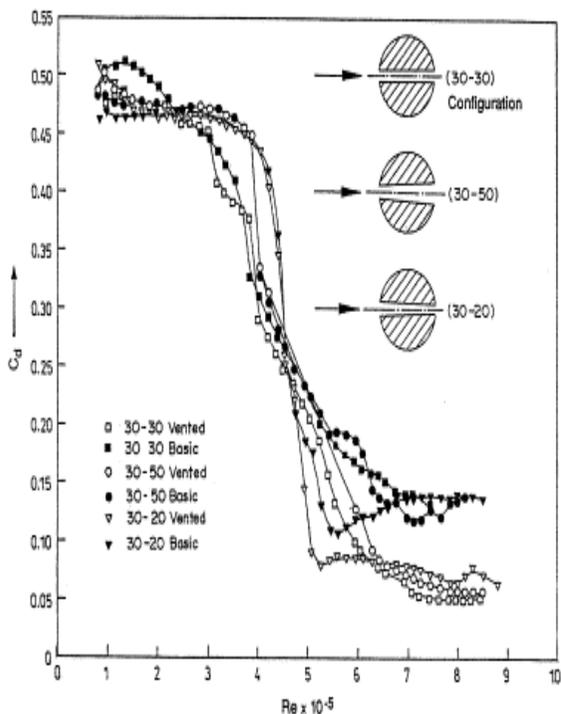
**Boat Tailing :** Consider a bluff body having rear face perpendicular to the flow. The boundary layer remains attached up to the blunt and after that reaches a negative pressure. The changed flow and pressure configuration is obtained by boat tailing (gradual reduction of body cross section) the rear end of the body. This changes the curvature of streamlines to concave before the end of boat tail. Due to increase in boundary layer thickness, there is a significant decrease in velocity and increase of pressure and hence the reduction in wake region.



**Moving Surfaces :** The main procedure adopted in moving surface is to prevent or at least delay the separation of boundary layer from the wall by injecting momentum into the existing boundary layer. As a consequence boundary layer remains attached to the body surface for a longer time. Rotating cylinders are a very promising device for practical applications. Modi (1997) proposed a tractor trailer model with rotating cylinders on the top surface. Substantial drag reduction was observed by varying the rotational speed of the cylinders.

**Passive Wake Ventilation:** Blowing of fluid through the bluff body may significantly reduce the pressure drag which is achieved by altering the amount and vorticity being introduced into wake. Wake ventilation can be provided by a central duct along the model axis connecting the stagnation region in the front of body with the wake region in the rear. When these two regions are connected or ventilated, an internal flow driven by effective pressure gradient is set up automatically. Thus additional mass, momentum and energy are added in the rear wake. A very substantial drag reduction is observed, reaching

up to 66% for a spherical bluff body. Pitching moment is also enhanced by wake ventilation. The experiments conducted by G.K.Suryanarayana on simple plastic foam spheres revealed that only small effects of drag reduction were seen at subcritical Reynolds Number. But at supercritical Reynolds Numbers, around 60% of drag reductions were found. Experiments are conducted with various venting hole configuration i.e. straight, converging and diverging. The graph is plotted across Cd value and Reynolds Number for various hole configurations.



The Jet Flow issuing from the passage aligns the free shear layers of the wake and draws them much closer to the surface of the bluff body. This makes the surrounding flow field more streamlined and thus decreases the body vibrations.

**CONCLUSION:**

The purpose of this review paper is to explore various methods of wake control and their validation in practical applications. Among many of these methods Passive Wake Ventilation has a huge potential to be explored. Researches carried out on spherical bodies showed an impressive drag reduction of 66%. Hence this method can drastically improve the aeronautics and automobile industry in future.

**REFERENCE**

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