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"A REVIEW ON UNSTEADY FLOW OVER DIFFERENT BLUFF BODIES"

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ABSTRACT

The application of unsteady incompressible flow phenomenon over the bluff bodies has received the attention of many researchers due to the rich and complex physics underpinning these flows, and thus requiring special attention in their modeling and numerical simulations. The wake that forms at the leeside of the bluff body is of particular interest. The application of an unsteady viscous flow around a bluff body has covered a wide range of scientific fields. This paper reviews the wakes of different cross-sectional bluff bodies, including circular, square, triangular and rectangular cylinders. The two most prominent parameters (e.g., Reynolds number and cylinder geometry) that can significantly alter the wake are taken into account. The dependence on the two parameters of Strouhal number, vorticity, circulation, and efflux angle of vortices in the wake of bluff bodies is investigated. The detailed features of the wakes for different bluff-body shapes at different Reynolds are identified and summarized.

Key Words: *Strouhal number, vorticity, circulation, square prism , cylindrical geometry.*

I. INTRODUCTION

When a fluid flows around a stationary body, there is a relative velocity between the body and fluid. These flows are referred as flow over immersed bodies. Depending on overall shape of the immersed body, it is said to be streamlined body or bluff body. In a streamlined body, streamlines in the flow conforms to the boundaries of the body. However, a bluff body tends to block the flow and subdivides it by separation at or near leading edges. Bluff bodies are used to enhance unsteadiness, mixing in the flow and heat transfer. The flow of fluid over bluff body finds wide engineering applications e.g. in electronics cooling, heat exchangers, nuclear reactors, design of flow dividers, probes and sensorsetc. Fundamental aspects related to the fluid flow and heat transfer around bluff-bodies are discussed below.

1.1 Flow past bluff-bodies

When a fluid separates from a bluff body, it forms a separated region behind the body called wake. In all bluff body flows, there is the periodic formation and shedding of circulating flow structures (vortices) in the wake region and is referred to as vortex shedding. Vortex shedding generates unsteadiness in the flow and thermal fields that governs fluid flow and heat transfer behavior around bluff bodies. Bluff bodies of different cross sections (e.g. circular, square, elliptical and triangular etc.) have been studied by the researches.

1.2 Sharp-Edged triangular cylinder

The literature reveals that the most of the studies have been done on circular cross-section cylinder. The significant changes in the flow and thermal field can be obtained with the sharp edged cylinders (e.g., cylinders of square and triangular cross section, etc.).Square cylinder has also received a fair attention in literature due to its importance in

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flows over Buildings, heated electrical components etc. However, triangular cylinder being a potential vortex generator has literature available. The flow past sharp edged cylinders is similar to that of circular cross-section cylinder in terms of flow instabilities, but differs in the separation mechanism. The sharp corners of square and triangular cylinders provide the points of flow separation.

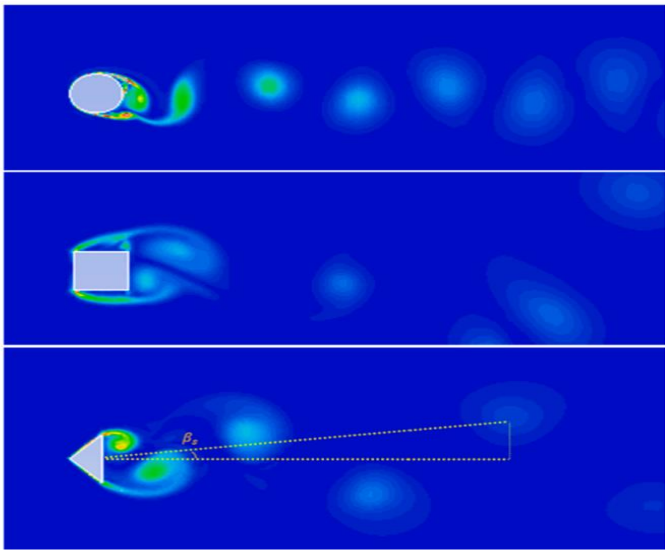

Fig. 1. Instantaneous vorticity contours in the wake of different bluff bodies with identical dimension (D) at Re ¼ 2000; a) circular cylinder, b) square cylinder, and c) triangular cylinder. The angle of βs is the efflux angle of the vortices in the wake of the triangular cylinder.

II. Literature Review

Prasenjit and Das found, for flow past a rounded edge square cylinder, the importance of shape over boundary layer thickness and displacement thickness. The conclusion that proportionality between radius and thickness states it as a character of circular cylinder due to the strong pressure gradient and weak wall shear stress developed around it. A closed type of conic section contributes towards ease of sincere certainty in interpolation of results. Therefore circular cross section cylinder adapts for the study of flow structure behind the bluff body with different shapes. The shape is also in consensus with the common feature of disturbed flow around all bluff bodies, i.e. development of similar flow structures in the separated region. Flow structures over the bluff bodies is extensively affected by Reynolds number [3]. The dimensionless quantity, quantifies the relative contribution and interaction of inertial forces to viscous forces of liquid for a particular flow condition, predicting onset of turbulent flow. Especially for a circular cross section cylinder, complexity of transition intensifies with increase in Reynolds number. Convolution of subcritical flow region is due to simultaneous prevailing of laminar and turbulent regimes.

The modelling become more complicated due to the presence of intermittent turbulence character in wake flow have been mentioned in detail by **Doolan [4].** For its immense vitality in engineering application separated flow structure are widely studied and remains epitome of significant research. Flow separation characteristics are paramount in respect to Reynolds number for analysis of flow transitions, which leads to awareness of vortex shedding character. For expertise in flow regime confined in gradually increasing Reynolds number sets, disturbance-free flow is thoroughly studied by minimizing influencing parameter for actual flow, accounted by Morkovin [5]. With increasing Reynolds number laminar flow separates at adverse pressure gradient point (separation point) in order to reattach at point of confluence. With increase in Reynolds number (Re) further, prompts acute vorticity and eddies formation and shedding which makes turbulent transition in whole of the flow, initiating at reattached region and followed in succession by wake region, free shear layer, and finally in boundary layer. This transition and vortex shedding in subcritical and supercritical region are separately studied in research presented by **Doolan [4] and Roshko [6].** Results of experimental investigation on a circular rotating cylinder by **Labraga et al. [7]** mainly concern the location of

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separation point, shows shift in vortex shedding frequency as dimensionless rotation rate increases. A deliberate concern over the study of the development of the laminar separation bubble, mentioned in above latter paper, is explained by **Miozzi et al. [8].** Wall blockage is an important paramter that affects transition in both boundary and free shear layer. The confining surrounding restricts the flow sidewise and impose interfering pressure gradient. For small gap to diameter ratio blockage becomes a governing parameter. Aspect ratio or the ratio between different axes of cross section has effects on drag coefficient and base pressure coefficient comparable to that of blockage. It becomes a governing parameter for a short finite cylinder with free end.

Zdravkovich [3] presents a detailed review on wake transition and basics for relevant influencing parameters effect. Major and minor axis contribution as governing parameters are also analysed through research contributed by **Jelita et al. [9]** on heat transfer over temperature gradient of elliptical cylinder showing symmetric distribution heat transfer to right angle of major axis. Investigation on disturbed flow around bluff body equivalent to that of fluid flow past a stationary body, is also presented through study of body motion in a fluid at rest. Analytical problem over motion of elliptic cylinder under free surface by **Kostikov and Makarenko [10]** determines asymmetric wave patterns generated on free surface caused due to rotation. And also transversely oscillating cylinder in a uniform flow by **Zheng and Zhang [11]** investigates frequency effects on flow induced wake for both near and away vortex shedding natural frequency. In this paper, the flow over a cylindrical body is concentrated at Re 5 × 103 and10 × 103, which corresponds to the intermediate subcritical regime. Over this range of Reynolds number, transition in free shear layer seek dominance over the wake and transition eddies are formed as a chain along free shear layer and precede the transformation to turbulence. Simulation is performed on a two dimensional mesh configuration of the cylinder with varying shapes having major concern for vortex shedding analysis. On basis of literature review **[12]** which reveals considerable flow distortion for blockage ranging from 6% to 16% compared to that of unblockage. The result presented in this paper is considered for three blockage 6%, 10% and 40% at 5×10^3 Re. The analysis over blockage change is extended to shape change for a particular blockage 6%, by variation in major and minor axis ratio through three different- 0.75, 1 and 1.5 aspect ratio considerations at 10 × 103 Re. The flow analysis behind the bluff body is covered by collection of pressure intensity, velocity intensity in two dimensions and turbulent.

III. CONCLUSION

This paper aims to provide a comprehensive review of the wakes of the bluff bodies, including circular, triangular, square and rectangular cylinders. A wide range of Reynolds number is taken into account, comprising the laminar, subcritical, critical and supercritical flow regimes. At laminar flow regime around a circular cylinder (e.g. 1 < Re < 300), a shift in the absolute value of oblique shedding angle comes into being, particularly at Re ¼ 64–70. Strouhal number is not constant, increasing nonlinearly. A similar increase in Strouhal number is observed for other sharp-edged cylinders as well. However, there is no discontinuity in Strouhal number variations for the sharp-edged cylinders. Therefore, continuously generated vortices in the wake of the triangular and square cylinders are an advantage and can facilitate the design of the converter as compared with a circular cylinder. In addition, among the sharp-edged cylinders, a triangular cylinder can generate stronger vortice.

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