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Control of Vortex Shedding Behind a Circular Cylinder in Various Flow Regimes Using Optimized Surpass Component

Sunil A S[1], Benphil C Mathew[2], Nidhul K[3]

Associate Professor, Dept of Mechanical Engineering , Government Engineering College ,Thrissur, India.

Post Graduate Student, Government Engineering College Thrissur, Kerala, India

Post Graduate Student, Government Engineering College Thrissur, Kerala, India

ABSTRACT: This paper paves the way to geometry analysis of surpass component of the main structure using the vortex instabilities. From the literature review it is found out there is no study developed or arranged with the geometry influences. The influence of the fluid flow, main structure and the distance between surpass body and the main structure is involved in each study. So this paper may have new investigation results in the field of vortex analysis. The present paper also focuses on the analysis of two dimensional flow past a circular cylinder in a specific laminar and turbulent flow regimes. In this simulation, an implicit pressure-based finite volume method is used for time-accurate computation of incompressible flow using second order accurate convective flux discretization schemes. The computation results are validated against measurement data for coefficient of drag, coefficient of lift on the body due to vortex instabilities. The project also look upon how to reduce the vortex instabilities using surpass component.

KEYWORDS: vortex shedding, Reynold number, Strouhal number, main structure, surpass component.

I. INTRODUCTION

Most structures on land and in the ocean are in multiple forms and are confronted by a fluid flow. Vibrations of these structures due to fluid flows reduce the life of the respective installations and must therefore be taken into account in the design of the structure. For assessment of this vibration, it is important to understand the interaction of multiple structures in a flow. An elementary shape of a structure or a component of a structure is a circular cross-section, and a tandem arrangement of two circular cylinders is a basic example of an array of multiple structures. Flow past a bluff body such as a sphere and cylinder from engineering application point of view is a generic flow–structure interaction with important implications for flow-induced vibration and noise generation. Periodic vortex shedding patterns and fluctuating velocity fields downstream of the bluff bodies can cause structural damage because of periodic surface loading, acoustic noise and drag forces. Most work has been done on the flow passing a circular cylinder rather than a sphere. Coefficient of drag (Cd) and coefficient of lift (Cl) are the parameters used or developed here to obtained the results since these are the basic parameters that can give an idea on the vortex instabilities of the structures.

II. LITERATURE REVIEW

This work review in detail the literature for a better understanding of the problems discussed in this area .Suppression of fluid force on a square cylinder by flow control by Mohamed Sukri Mat Ali etal revealed that the amplitude of the fluctuating lift on the square cylinder is well suppressed if the control plate is used. Flow structure in the downstream of square and

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circular cylinders by S. Pasto formulated vortex formation lengths decrease with increasing Reynolds number for all the patterns presented. Flow around four cylinders arranged in a square configuration developed by X.K. Wang shows that not only do the cylinders shed vortices individually, but interactions amongst themselves and with the cylinders also occur.Vortex dynamics of a cylinder wake in proximity to a wall developed the mutual interactions of the wall vortices with the shed vortices create a remarkable difference in the wake dynamics. Fluctuating fluid forces acting on two circular cylinders in a tandem arrangement at a subcritical Reynolds number proposed by D. Sumner shows that cylinder which is placed in the downstream has an effect at a critical distance. On the suppression of vortex shedding from circular cylinders using detached short splitter-plates by Behzad Ghadiri Dehkordi and Hamed Houri Jafari shows that single & dual splitter plates (parallel arrangement) in the downstream of the cylinder. The optimum location of the splitter-plate to achieve maximum reduction in the lift and drag forces is determined. All these studies and observations led me to this specific project where immense optimisations are needed in this area.

III.THEORY BEHIND THE VORTEX SHEDDING

1. Flow around a cylinder

Flow around a circular cylinder has been the subject of both experimental and numerical studies for decades. This flow is very sensitive to the changes of Reynolds number, a dimensionless parameter representing the ratio of inertia force to viscous force in a flow. Flow around a circular cylinder has been chosen as pilot study for the investigation on the flow around a bridge deck section due to the effect of vortex shedding on such structures. The first stage of the validation process involves the simulation of the flow around a static cylinder specific turbulence models at low Reynolds number of 150 to simulate the basic flow parameters and to capture the vortex shedding phenomenon in the wake region of the flow. To begin with, the basic overview of the flow around a circular cylinder and the flow characteristics such as the Strouhal number, vortex shedding, drag, lift, and pressure coefficients are introduced.

2. Conceptual overview of flow around a circular cylinder

Flow around a circular cylinder tends to follow the shape of the body provided that the velocity of the flow is very slow, this is known as laminar flow. Flow at the inner part of the boundary layers travels more slowly than the flow near to the free stream. As the speed of the flow increases, separation of flow occurs at some point along the body due to the occurrence of the adverse pressure gradient region Flow separation tends to roll up the flow into swirling eddies, resulting in alternate shedding of vortices in the wake region of the body known as the von Karman vortex street.

a) Reynolds number

Flow around a circular cylinder varies with the Reynolds number. Small Reynolds number corresponds to slow viscous flow where frictional forces are dominant. When Reynolds number increases, flows are characterised by rapid regions of velocity variation and the occurrence of vortices and turbulence. Mathematically, Reynolds number of the flow around a circular cylinder is represented by,

$$\mathrm{Re} = \frac{uD}{\nu}$$

where D is the diameter of the cylinder, u is the inlet velocity of the flow, and ν is the kinematic viscosity of the flow.

b) Drag and lift coefficients

In sub-critical Reynolds number region (100 <Re<10,000), increase in the Strouhal number is generally accompanied by a decrease ofthe drag coefficient. Drag coefficient is calculated as follow:

$$C_d = \frac{F}{\frac{1}{2}\rho u^2 A}$$

where A is the projected area in the flow direction and F is the sum of the pressure force and the viscous force components on the cylinder surface acting in the along-wind direction. Lift coefficient is calculated similarly but vertical force is considered rather than along-wind force. Theoretically, the drag force is changing at twice the frequency of the lift force for

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the flow around a circular cylinder or generally flow involving separation. When a vortex is shed from the top of the cylinder, a suction area is created and the cylinder experiences lift. Half a cycle later, an alternate vortex is created at the bottom part of the cylinder. Throughout the process, the lift force changes alternately in a complete cycle of vortex shedding but the cylinder experiences drag constantly, where drag is changing at twice the frequency of the lift. It is important that any turbulence models can simulate all the above-mentioned parameters correctly for the analysis of the flow around bluff bodies.

IV. **PRESENT STUDY**

4.1 Introduction

As part of my study, the project is restricted to low Reynold regime which is specified to Re=150. Here the two parameters which is considered to reduce the vortex instabilities happens across the cylinder are coefficient of drag and coefficient of lift. Reduction of these quantities clearly reduces the instabilities and thus provides efficient flow past a cylinder.

4.2 Need for the study

Need of the study is to provide further refine mesh and optimizing the gap distance between the cylinders.

4.3 Objectives of the study

- To study the characteristics of flow pass a cylinder.
- To study about application level of this project.
- To study the functional aspects of circular cylinder.
- To study the different gap distance between the tandem cylinders and their flow characteristics.

4.4 Scope of study

This study is restricted to circular cylinder geometry for both main and surpass structures. The flow regime is fixed to Re=150 and Re=22000 which can be listed under laminar and turbulent flow conditions.

4.5 Problem discussion

After the literature survey we concluded that the regimes that to be considered for the problem are to one in laminar and other in turbulent region, thus obtained the specific regimes of 150 and 22000 Reynold numbers for the same. The structure under study to be always under the practical application so that this study will lead others to better idea on further planning of the design. The structure under consideration is of diameter .04m and the surpass cylinder diameter is optimized to half the diameter of the main cylinder.

4.5.1 Simulation methodology

a) Domain and Grid Independent Study

The figure below depicts the domain size and mesh structure. The domain consist of four boundary regions named inlet, outlet, upstream and downstream. Domain length provided is 30d and domain width is provided with 20d (d is the diameter of the main structure).

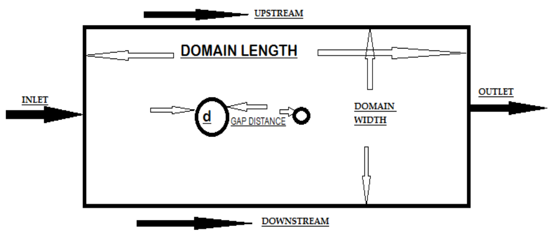

Fig.1

Next step is develop corresponding optimized mesh for the figured out domain. This is done with the help of grid independent study. The optimization of grid is done and finally obtained 120000 cell mesh having unique aspect ratio and

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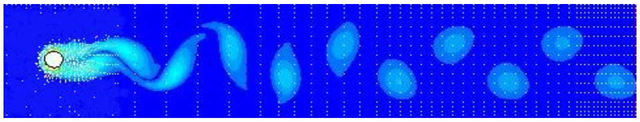
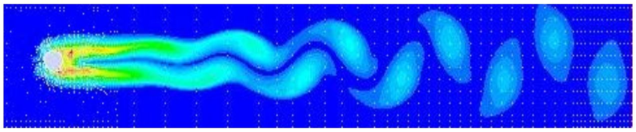
orthogonal ratio for a fair mesh is developed and is used for the simulation study. Corresponding developed mesh is shown below

b) Basic Contour Of Vortex For Re=150



Vortex contour without surpass cylinder
Fig.2

c) Basic Contour Of Vortex For Re=22000



Vortex contour without surpass cylinder
Fig.3

V. EFFECTS AND RESULTS

5.1Introduction

In this project we aim at to reduce the vortex instabilities due to flow pass a cylinder. How this to be achieved is the biggest question. Suggestions and observations from the literature survey lead this project to use surpass component reduce the instability of the structure. The size of the surpass cylinder and the gap distance between them plays a crucial role in this study. Most of the study concern about the size of the surpass component but in this project we are more concerned about the gap distance that may result in further reduction of the instabilities of the structure.

5.2EffectOfGapDistanceOnCoefficientOfDrag

One of the main parameter that can exhibit the vortex instabilities of a structure is its drag motion in line with the flow. The velocity and the area of projection of the structure effects how much drag force to be influenced on the structure..To represent the drag force Coefficient of Drag (Cd) can be well effective to understand the circumstances. In this study of laminar regime having Re=150 is considered at first. The various gap distance provided to reduce the instabilities are shown in figure 3. Corresponding Cd graph for different gaps shown below. This shows that usage of surpass component reduces the Cd value and thus we get an optimized value for Cd at gap distance of .06m. but this drag effect will not provide a clear speech on the instabilities so we should consider the lift aspects of the structure due to the flow over the same structure.The effect on the main cylinder alone is diagrammatically represented on the above graph. This shows that a surpass component reduces the coefficient of drag and it can be reduced to maximum at .06 gap. But this happens to be good when the main structure and surpass component are detached from each other.

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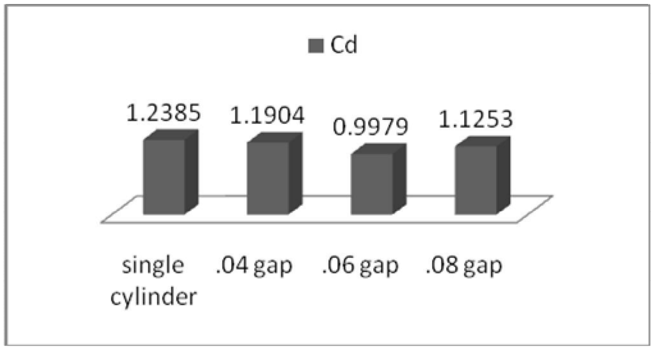

Fig.4 Effect of Cd on the main cylinder alone due to various gap distance of the surpass cylinder

Considering the situation when these two structures form single unit then the net effect of drag should be considered. In this case the net effect is much lower than individual values. Thus the second result is much suitable for the design of the same structure in a fluid flow.

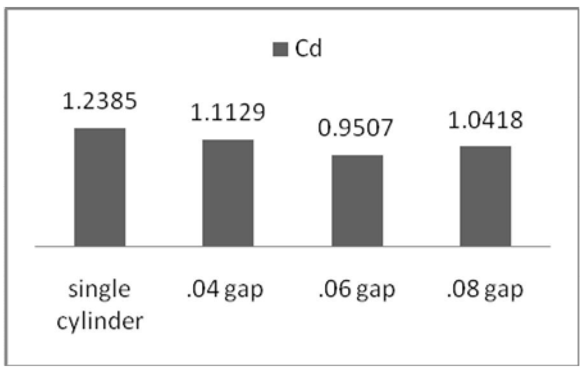

Fig.5 Net effect of Cd on both the cylinders

Now let us look upon the turbulent case having a Re=22000, as the same case for the gap distance that obtained for the laminar flow. The effect of the single cylinder is considered at first and reduction in Cd is obtained at the same gap distance of .06m diagrammatic representation is shown below:

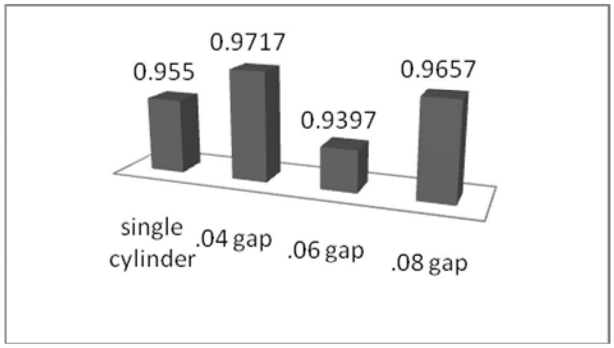

Fig.6 Effect of Cd on the main cylinder alone due to various gap distance of the surpass cylinder

Consider a case when both the cylinders are attached the net effect of the cylinder to be obtained and analyzed. By observing the same we found out a slight decrease in Cd. This condition is not prominent as laminar case so can discarded.

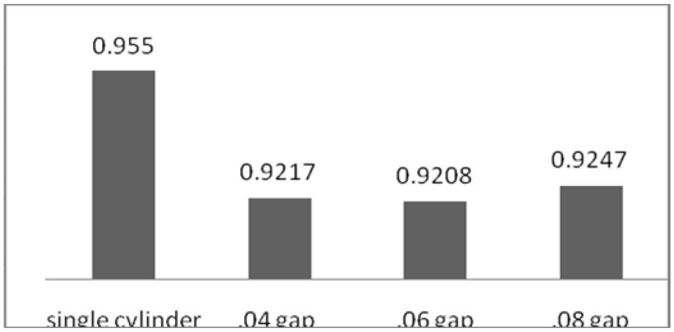

Fig.8 Net effect of Cd on both the cylinders

5.3 Effect Of Gap Distance On Coefficient Of Lift

Coefficient of drag does not fully describes the instability of the structure, it only give flow direction vibration on the component it also has got two axis more. But one axis has got very low vibration so that axis vibration is neglected. In this section we analysis about the lift coefficient on the structure due to the surpass component . The single cylinder consideration is taken in the first case and is diagrammatically shown in Fig.7. For this also .06 gap is the optimum gap distance that has shown.

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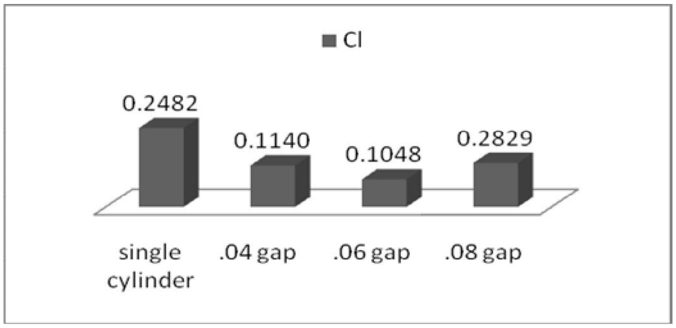

Fig.9 Effect of Cl on the main cylinder alone due to various gap distance of the surpass cylinder

Considering the fact that net effect on the structures decrease when both the structures attached to each other, but in Cl shows anon linear variation of the same. But at an optimal gap distance of .06m the Cl values decreases considerably.

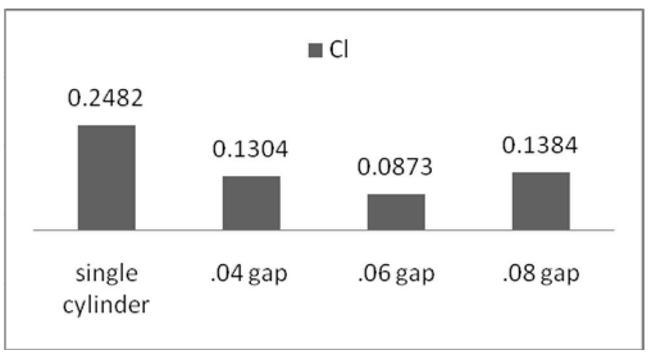

Fig.10 Net effect of Cl on both the cylinders

The lift effect on the cylinder in turbulent case is least and can be neglected hence study and analysis of that particular field is not mentioned in this paper.

VI. CONCLUSION

Regarding the two regimes in laminar and turbulent region of Re=150 and Re=22000, the vortex instabilities is figured out by coefficient of lift and coefficient of drag. Coefficient of drag shows the intensity of instability in the flow direction and coefficient of lift shows the instability of the structure across the flow. When we featured out these two parameters for various streams and gap distances, an optimal solution is obtained where the reduction in instabilities are significant. When the structures are located apart and when it is attached together the solutions on the instabilities are significant, and thus it can be said that the maximum reduction in the vortex stability is provided when these two structure are attached together. This result is less prominent when considering coefficient of lift, but it too has significant variation in attached case.

The gap distance for various measurements are provided and optimized result for instabilities are obtained at .06m . This is same for both laminar and turbulent regimes. The optimization is done with the help of coefficient of drag and coefficient of lift. One major finding if this project is that at optimized result attached cylinder provides a decrease in

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coefficient of drag by 4.7% and for coefficient of lift reduces to 16.69%. this finding clearly speaks that attached cylinder is always better than detached plate design.

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