ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 7, July 2017

An Experimental Study on Suppression of Vortex Shedding with Different Structural Configurations

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***Abstract*— The flow phenomena around bluff bodies or non-streamlined bodies in fluids are always of some engineering importance. Most of the engineering structures like buildings, bridges etc. can be considered as bluff bodies as far as the air or water flow in which the structure is being situated, is considered. This paper aims at the study of vortex induced vibration and suppression of the VIV on some common models of structures which can be considered, of having some engineering importance. The main parameter associated with the VIV formation is the Strouhal number (St.) which is the non-dimensional frequency of vortex shedding. The VIV was captured by using Fieldpaq Dynamic Signal Analyzer which has frequency ranges from 0 Hz to 40 kHz. The cylinders with varying number of fins and splitter plate length are tested. The methods to control VIV can be classified into three as active, passive or compound method. The passive method, would give some structural modifications on the model and considered to reduce the VIV formation. On the other hand,. Among these, the active and compound methods are costlier compared to the passive method. Therefore on an economic point of view the engineers are keen to develop more and more methods to suppress the VIV effectively with a lesser cost i.e., by employing the passive method. My study is on employing the model with straight fins.**

***Index Terms* — bluff bodies, vortex induced vibration, vortex shedding**

I.INTRODUCTION

In recent years, the flow around the bluff body has one of the subject of interest to engineers because of its engineering importance. Researcher's attention were on the control of vortex shedding behavior behind the bluff body which cause the flow-induced vibration and acoustic noise, and also resonance by increasing the mean lift and drag fluctuations. For prevent the problems due to the vortex shedding, there are two main flow control techniques: active control and passive control. Active control which is based on applying some external energy to the flow field while the passive control techniques control the vortex shedding by changing or modifying the shape of the bluff body or by attaching additional devices to the flow. Some of passive control techniques are Splitter plates, small rods, base bleed, roughness elements and helical wires.

Bearman (1984)[1] wrote a comprehensive review on the mechanism of vortex shedding from bluff bodies. He explains that the formation of a vortex-street wake is a mutual interaction between two separating shear layers is a key factor .It is find by Gerrard that a vortex continues to grow, fed by circulation from its connected shear layer, it is enough to draw the opposite shear layer across the near wake and also the approach of oppositely signed vorticity, in sufficient concentration, which cuts off further supply of circulation to the growing vortex, which is then shed and moves off downstream."

S. Ozono (1999)[2] conduct numerical study on flow Control of vortex shedding by a splitter plate that are asymmetrically arranged downstream of a cylinder and he find the Suppression of vortex shedding is possible when the splitter plates were arranged asymmetrically also Length of splitter plate did not have much effect on flow structure.

In the paper put forward by D Sumner[3], an extensive study of the Reynolds number effect for the aerodynamic force would also be beneficial, similar to what has been conducted for the strouhal numbers. For side by side cylinders there is general lack of aerodynamic force measurements in particular the mean lift force, over a range of Reynolds number, compared to the other two basic configurations

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Lee Kee Quen et al. (2003) [4]presented a paper on Investigation of the effectiveness of helical strakes in suppressing VIV of flexible riser and find out that the Experimentally Studies effectiveness of strakes by varying the height (h) and pitch (p) Effective configuration :p= 10D,h=0.10D (considering hydrodynamic forces)

Zachary J. Taylor (2012)[5] worked on Effects of leading edge geometry on the vortex shedding frequency is an elongated bluff body at high Reynolds numbers and summarizes that Results show that the linear decrease in the shedding frequency of nearly about 40% as the leading edge separation angle is increased from 0°–90°.

II.COMPONENTS AND DESCRIPTION

The instrument and component that are used in the experimental study are given below

- Water channel
- FieldpaqDynamic Signal Analyzer
- Collecting tank with water level measuring scale
- Hook gauge
- Pitot tube

II. EXPERIMENTAL SET UP

The experiment in the present study were performed in fluid mechanics laboratory of department of mechanical engineering. The Experiments were performed in two steps: Dye visualization experiments and vibration analizing experiments. description of apparatuses used in the experiment is given below.

Facility

Tests were carried out in a recirculating water channel with a test section 0.25m wide, 0.30m deep and 4.5m long, as seen in Fig.1. Side walls and bottom of the section were made of glass mounted on a steel frame for flow visualization. This is particularly useful for test conditions with very low Reynolds number.

Fig:1 .water channel

The baffles are provided in the flow field in order to stabilize the accelerated fluid and flow of fluid can controlled by valves provided on the inlet pipe. The inclination of water channel can be also adjusted by hand wheel mechanism. A movable platform with height gage is provided on the top of water channel for measuring the height of domain of flow. All experiments presented in this work were conducted at the test section of the water channel.

Fieldpaq Dynamic Signal Analyzer is used as vibration meter for getting vibration of geometry model due to the vortex shedding .the frequency of this is called as vortex shedding frequency

The optional Vibration Meter software on the Fieldpaq allows you to measure four The Vibration Meter software also has built in ISO 10816-3 Standard for checking vibration severity. The user may also import his own severity standard if desired.

III. VISUALIZATION OF VORTEX SHEDDING

Flow visualization produced by photographing particles travelling in water current is shown in Fig.2 As the free stream approaches the cylinder the flow splits around the body. Viscous boundary layers will develop from the front stagnation point while the flow remains attached to the walls. It is within the boundary layer that fluid viscous forces are playing a important role. The geometry of the body generates an adverse pressure gradient that, acting on the viscous prole of the boundary layer, will cause the flow to separate from the wall at the separation points on each side.

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The visualization is done in this experiment by NIKONE DSLR CAMERA and also by using the die in the flow. For different velocity of flow the vortex shedding phenomenon was observed and some image are given below.

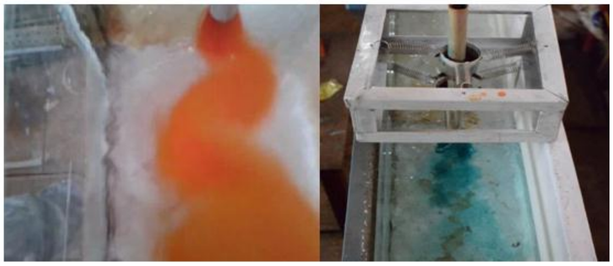

Fig 2: vortex shedding visualization

IV. EXPERIMENT AND TABULATION

The experiment was conducted in water channel installed in fluid mechanics lab. The procedure for doing the experiment was make the constant velocity for all geometry models by adjusting the inlet valve and depth of flow. Then note the reading like time and vibration frequency etc. the experimental values and obtained graphs are given below.

Experiment with a circular cylinder fitted with rectangular fins

Fig:2 Cylinder with rectangular fins

V. EXPERIMENT WITH A CIRCULAR BARE CYLINDER

sentence punctuation follows the brackets [2]. Multiple references [2], [3] are each numbered with separate brackets [1]–[3]. When citing a section in a book, please give the relevant page numbers [2]. In sentences, refer simply to the

Depth Of flow	Water height	velocity	Reynolds number	Strouhal frequency	St.
9.42	0.56	0.3215	3855.06	8.80	0.2737
8.54	0.47	0.3037	3412.36	8.02	0.2641
8.13	0.45	0.2971	3338.20	7.80	0.2625
7.44	0.36	0.2657	3067.98	6.67	0.2510
6.92	0.30	0.2626	2725.84	6.10	0.2323
6.65	0.28	0.2344	2633.71	5.23	0.2231

Table 1:experiment for bare cylinder

CIRCULAR CYLINDER FITTED WITH TWO FINS
Dimension : D = 10 mm, H = .0.2D

Flow velocity(m/s)	Reynolds Number	Strouhal frequency	Strouhal number (St.)	% reduction (St.)
0.2971	3338.20	7.65	0.2575	1.9

Table 2

CIRCULAR CYLINDER FITTED WITH THREE FINS Dimension : D = 10 mm, H = .0.2D

Flow velocity(m/s)	Reynolds Number	Strouhal frequency	Strouhal number (St.)	% reduction (St.)
0.2971	3338.20	7.12	0.2396	8.70

Table 3

CIRCULAR CYLINDER FITTED WITH FOUR FINS
Dimension : D = 10 mm, H = .0.2D

Flow velocity(m/s)	Reynolds Number	Strouhal frequency	Strouhal number (St.)	% reduction (St.)
0.2971	3338.20	6.78	0.2282	13.06

Table 4

CIRCULAR CYLINDER FITTED WITH FIVE FINS
Dimension : D = 10 mm, H = .0.2D

Flow velocity(m/s)	Reynolds Number	Strouhal frequency	Strouhal number (St.)	% reduction (St.)
0.2971	3338.20	4.75	0.1598	39.09

Table 5

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Vol 2, Issue 7, July 2017

CIRCULAR CYLINDER FITTED WITH SIX FINS

Dimension : D = 10 mm, H = .0.2D

Flow velocity(m/s)	Reynolds Number	Strouhal frequency	Strouhal number (St.)	% reduction (St.)
0.2971	3338.20	4.88	0.1643	38.57

Table 6

VI. RESULTS AND DISCUSSION

Strouhal number v/s Reynolds number.

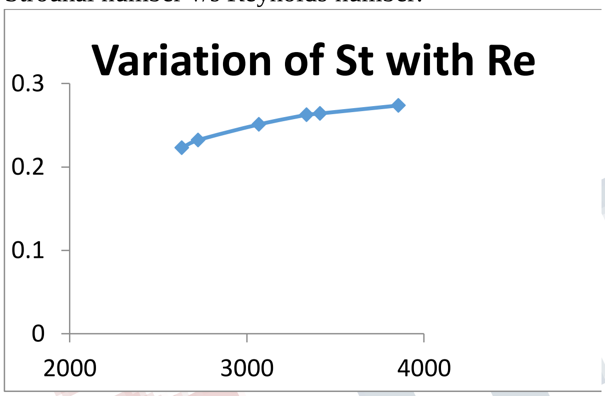

Fig 3:variation of St with Re

The graph shows the variation of Reynolds number with strouhal number and which indicated that The characteristics of the flow around a cylinder placed near a plane boundary are governed mainly by the Reynolds number and geometric shape of the body and also the gap. As the velocity increases, the Reynolds number inrceases , but the VIV frequency also increases with increase in flow velocity.

Variation of St. with frequency

As the value of velocity (or Reynolds number) increases, the Strouhal number St also increases. This is because of the fact that increased flow velocity will produce more and more disturbances on the cylinder, so the induced vortex shedding frequency will also be high. But the variation in the velocity is small , as compared to the corresponding variation in the value of frequency. So as a result the corresponding value of Strouhal number will also be high, as compared to the value of St for low Reynolds number (ie, flow velocity).

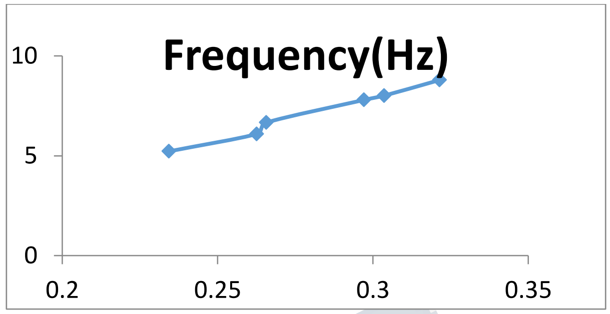

Fig 4: variation of St. with frequency

Variation of strouhal number for different structural configurations

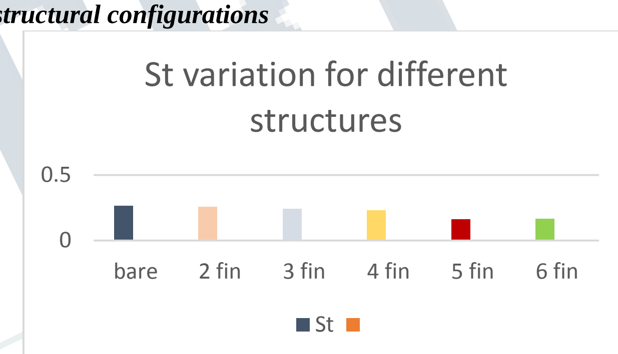

Fig 5: variation of St. for various models

From the figure, it is clear that the value of Strouhal number is minimum for the cylinder with five fin configuration. As the number of fins increased further, the VIV frequency also increases, thereby increasing the strouhal number ,St.

In the downstream or the wake region, due to boundary layer separation and adverse pressure gradient, the fluid particles flow gets reversed. This result in the formation of eddies. There is no vortex shedding occurs at Re=40. At Re=100, flow around the cylinder becomes unstable. Vortex shedding still occurs in the wake of finned tubes. The system of projecting fins was the most effective device for suppressing vortex induced excitations of the cylinder. From this study we can concluded that the cylinder with rectangular fins is an effective device

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for suppressing vortex induced excitations of the cylinder. As a passive vortex control method, linear array of projecting fins is very effective in suppressing vortex shedding. Also the frequency of vortex shedding reduced drastically by fins of suitable height.

VII. CONCLUSION

- The vortex shedding frequency of a circular cylinder is found out for different structural configurations in terms of Strouhal number.
- The frequency variation was minimum for cylinder with 5 fins. Hence it is a more stable configuration..
- Increasing the number of fins beyond a certain limit has adverse effect on the VIV reduction property of the finned cylinder configurations.
- As the number of fins increases the VIV suppression capability is reduced beyond a certain limit.
- In this experiment, the addition of fins beyond 5 nos reduced the stability of the structure.

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