An Experimental Study of Vortex Shedding Behind a Bluff Body in a Water Channel

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***Abstract*-When bluff body is placed in the flow vortices are shed downstream of the body. The majority of the studies on VIV of a flexibly mounted rigid cylinder are for this cases where the flow direction is perpendicular to the long axis of the structure. The effect of varying the geometric parameters of fins on bare cylinder and helical strakes on vortex-induced vibration (VIV) is investigated in this paper. The experimental tests are conducted at a circulating water channel facility and the cylindrical models are mounted on low-damping air bearing elastic base with one degree-of-freedom, restricted to oscillate in the transverse direction to the channel flow. The vortex induced vibration is captured by using Fieldpaq Dynamic Signal Analyzer and which has frequency ranges from 0 Hz to 40 kHz. Three strake pitches (p) and heights (h) are tested that are 5p with single start, double start, and triple start and also models with fin which has four fin with .2d thickness. The Reynolds number range is from 2000 to 5000, and the velocity varies up to .4m/s The cases model with fin h= .2d reduce the amplitude response when compared to the plain bare cylinder, however the oscillation still persists. On the other hand, the cases with h=0.2d strakes with triple start almost completely suppress VIV with about 16% reduction in the strouhal number.**

Keywords— Vortex-induced vibration; Helical strakes; Fieldpaq Dynamic Signal Analyzer.

INTRODUCTION

In recent years, the flow around the bluff body has one of the subject of interest to engineers because of its engineering importance. Researchers attention 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 is two main flow control techniques: active control and passive control. Active control which is based on applying some of external energy to the flow field while the passive control techniques control the vortex shedding by changing or modified the shape of the bluff body or by attaching additional devices to the flow. This are the some of passive control techniques are Splitter plates, small rods, base bleed, roughness elements and helical wires are etc.

LITERATURE REVIEW

Bearman (1984)[1] wrote a comprehensive review on the mechanism of vortexshedding 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 circulationfrom 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

Lee KeeQuen 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°.

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
- Stope watch

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

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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

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.

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 visualization of vortex shedding

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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

Objectives

To conduct experimental study of flow characteristics and flow pattern in the wake region of a circular cylinder and understand the relation between the Reynolds number and strouhal number also analyze the different graph

Experiment with a cylinder with 1 cm diameter

SL NO.	Depth of water flow(cm)	Time for 10cm rise of water(sec)	Rate of water flow(m^3/sec)	Velocity of flow(m/sec)	Reynolds number(Re)	Frequency of vibration(Hz)	Strouhal number(St)
1	9.20	10	6.4×10^{-3}	0.346	4335.8	6.53	0.189
2	8.54	12	5.33×10^{-3}	0.312	3909.77	5.70	0.183
3	8.13	14	5.13×10^{-3}	0.281	3521.30	5.17	0.184
4	7.44	17	3.76×10^{-3}	0.253	3170.42	4.45	0.176
5	6.92	21	3.04×10^{-3}	0.22	2756.89	3.82	0.174
6	6.65	26	2.46×10^{-3}	0.185	2318.29	3.20	0.173

Table:1

Experiment with a circular cylinder fitted with helical strakes

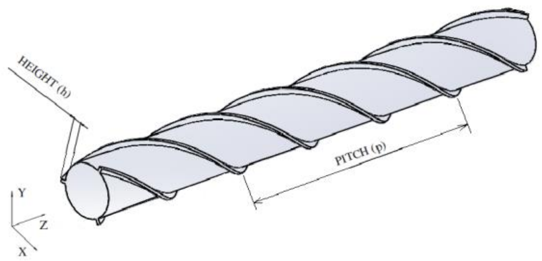


Fig:2 Cylinder with helical strakes

EXPERIMENT WITH A CIRCULAR CYLINDER FITTED WITH SINGLE HELICAL STRAKES

Dimensions

D = 10 mm, H = .0.1D,P = 5D

SL NO.	Depth of water flow(cm)	Time for 10cm rise of water(sec)	Rate of water flow(m^3/sec)	Velocity of flow(m/sec)	Reynolds number(Re)	Frequency of vibration(Hz)	Strouhal number(St)	% reduction in strouhal no.
1	9.20	10	6.4×10^{-3}	0.346	4335.8	5.5	0.168	11.1
2	8.54	12	5.33×10^{-3}	0.312	3909.77	5.15	0.165	9.8
3	8.13	14	5.13×10^{-3}	0.281	3521.30	4.58	0.163	11.4
4	7.44	17	3.76×10^{-3}	0.253	3170.42	4.02	0.159	9.6
5	6.92	21	3.04×10^{-3}	0.22	2756.89	3.36	0.153	12.01
6	6.65	26	2.46×10^{-3}	0.185	2318.29	2.79	0.151	12.7

Table:2

Experiment with a circular cylinder fitted with double start helical strakes

H = .0.1d = 1mm,P = 5d = 5cm,No. of starts = 2

SL NO.	Depth of water flow(cm)	Time for 10cm rise of water(sec)	Rate of water flow (m^3/sec)	Velocity of flow (m/sec)	Reynolds number(Re)	Frequency of vibration (Hz)	Strouhal number (St)	% reduction in strouhal no.
1	9.20	10	6.4×10^{-3}	0.346	4335.8	5.77	0.167	11.6
2	8.54	12	5.33×10^{-3}	0.312	3909.77	5.08	0.163	10.9
3	8.13	14	5.13×10^{-3}	0.281	3521.30	4.53	0.161	12.5
4	7.44	17	3.76×10^{-3}	0.253	3170.42	3.97	0.157	10.79
5	6.92	21	3.04×10^{-3}	0.22	2756.89	3.38	0.154	11.46
6	6.65	26	2.46×10^{-3}	0.185	2318.29	2.73	0.148	14.0

Table:3

Experiment with a circular cylinder fitted with double start helical strakes

Dimensions

D = 10 mm,H = .0.1d = 1mm,P = 5d = 5cm,No. of starts = 3

SL NO.	Depth of water flow(cm)	Time for 10cm rise of water(s)	Rate of water flow (m^3/sec)	Velocity of flow (m/sec)	Reynolds number(Re)	Frequency of vibration (Hz)	Strouhal number (St)	% reduction in strouhal no.
1	9.20	10	6.4×10^{-3}	0.346	4335.8	5.36	0.155	17.9
2	8.54	12	5.33×10^{-3}	0.312	3909.77	4.89	0.157	14.20
3	8.13	14	5.13×10^{-3}	0.281	3521.30	4.24	0.151	17.9
4	7.44	17	3.76×10^{-3}	0.253	3170.42	3.77	0.149	15.3
5	6.92	21	3.04×10^{-3}	0.22	2756.89	3.25	0.148	14.9
6	6.65	26	2.46×10^{-3}	0.185	2318.29	2.66	0.144	16.7

Sample calculation

1. Velocity calculation

$$\text{Velocity (v)} = \frac{RATE\ OF\ FLOW\,(Q)}{AREA\,(a)}$$

Than,

$$\text{Rate of flow (Q)} = \frac{VOLUME\ OF\ WATER\,(V)}{TIME\,(T)}$$
$$= \frac{0.8\times0.8\times0.1}{17}$$
$$= 3.764\times10^{-3}\ m^3/\text{sec}$$
$$v = \frac{3.764\times10^{-3}}{0.2\times0.0744}$$
$$= 0.253 \text{ m/sec}$$

Where, v is volume of water collected in measuring tank

T is time for 10 cm rise of water in collecting tank

2. Reynolds number (R_e)

$$R_e = \frac{\rho v D}{\mu}$$
$$= \frac{1000\times0.253\times0.01}{0.798\times10^{-3}}$$
$$= 3170.4$$

Where, ρ is density of water = 1000 kg/m^3

D is diameter of cylinder in m

μ is dynamic viscosity of water = 0.798×10^{-3} NS/m

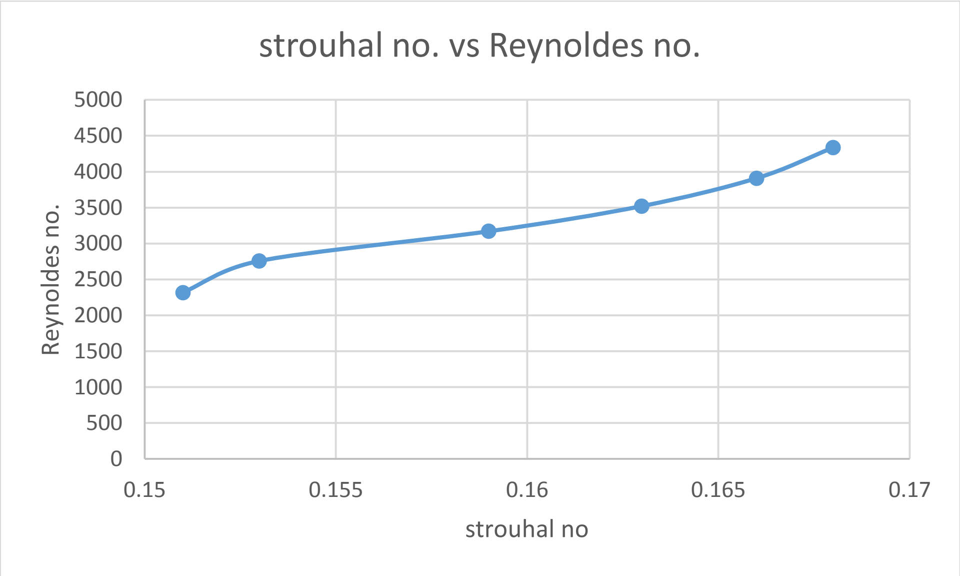
3.Strouhal number (S_t)

$$S_t = \frac{fd}{v}$$
$$= \frac{4.02\times0.01}{0.253}$$
$$= 0.159$$

4. Percentage reduction in Strouhal number

$$\text{\% reduction in strouhal no.} = \frac{0.176-0.159}{0.176}$$
$$= 0.096\times 100$$
$$= 9.65\%$$

Results and discussion



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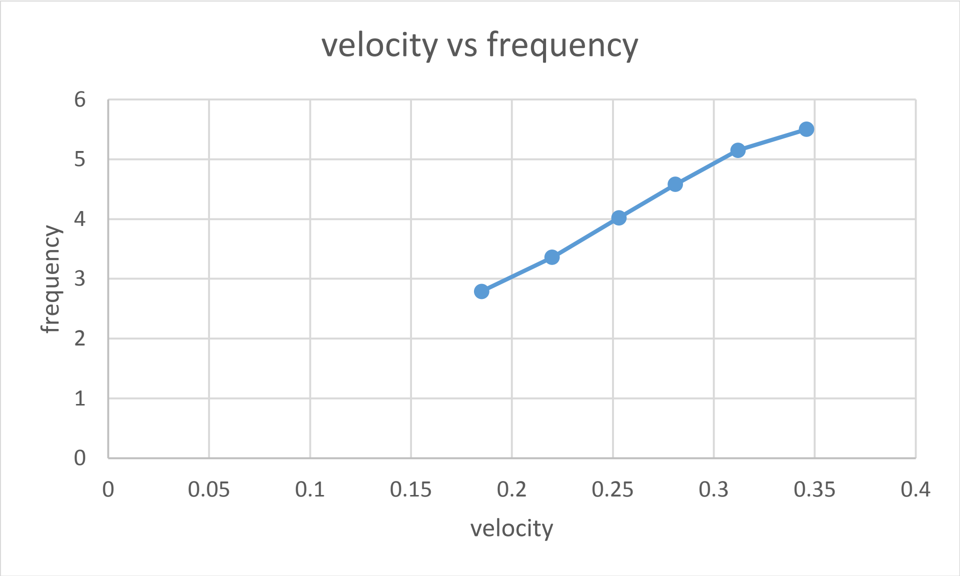
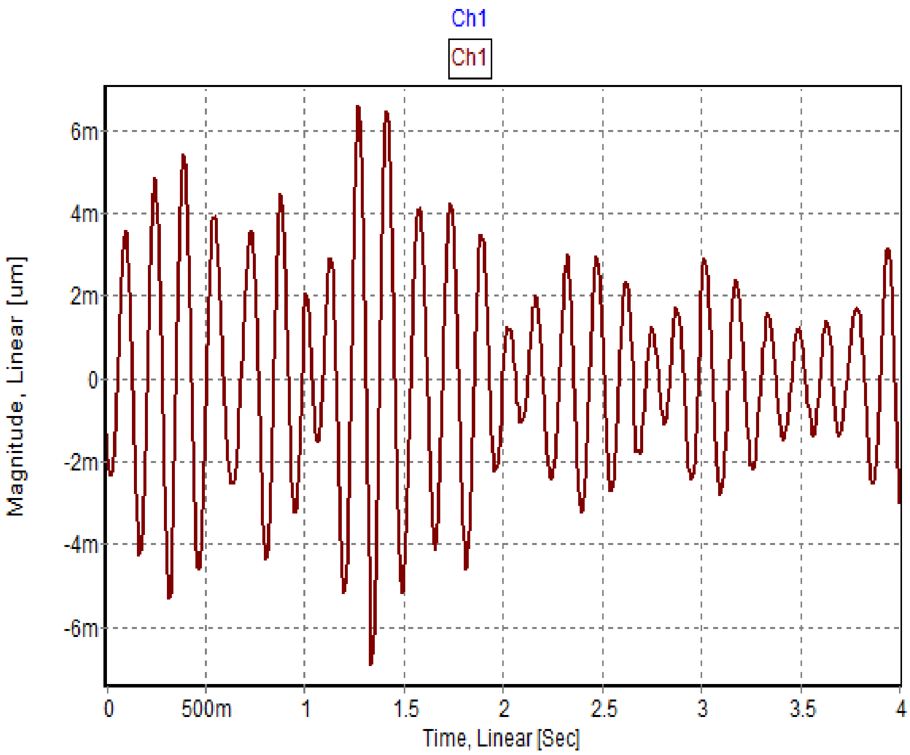
The graph shows the variation of Reynolds number with strouhal number and which indicated that The characteristics of the flow around a cylinder placed near a plane boundary are governed mainly by the Reynolds number and geometric shape of the body and also the gap ratio, i.e., the ratio between the distance from the body to the plane boundary, h, and the body characteristic length, the cylinder diameter. Here we understand the details of the flow around different geometric shape being fully understood





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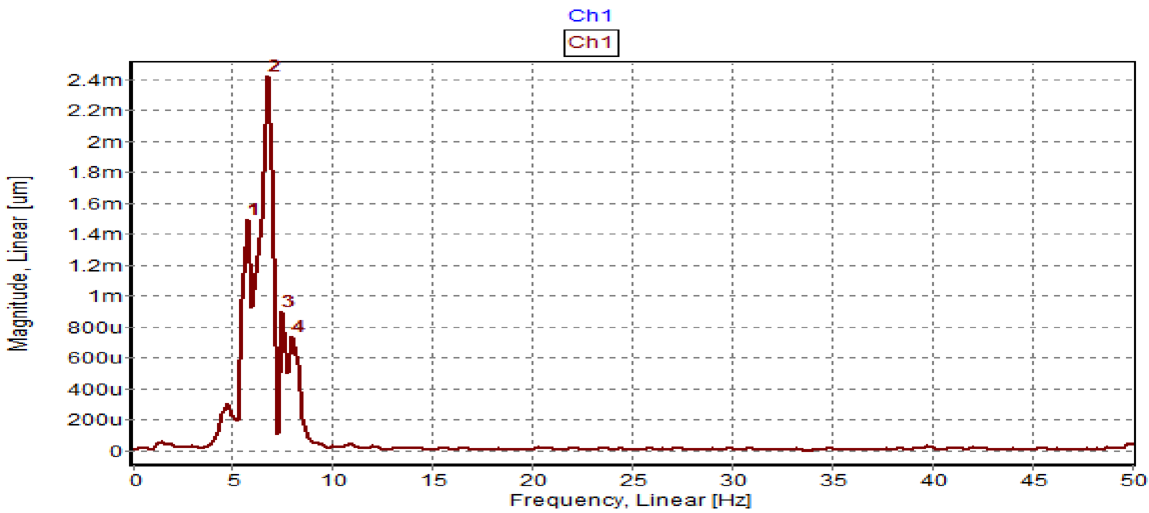
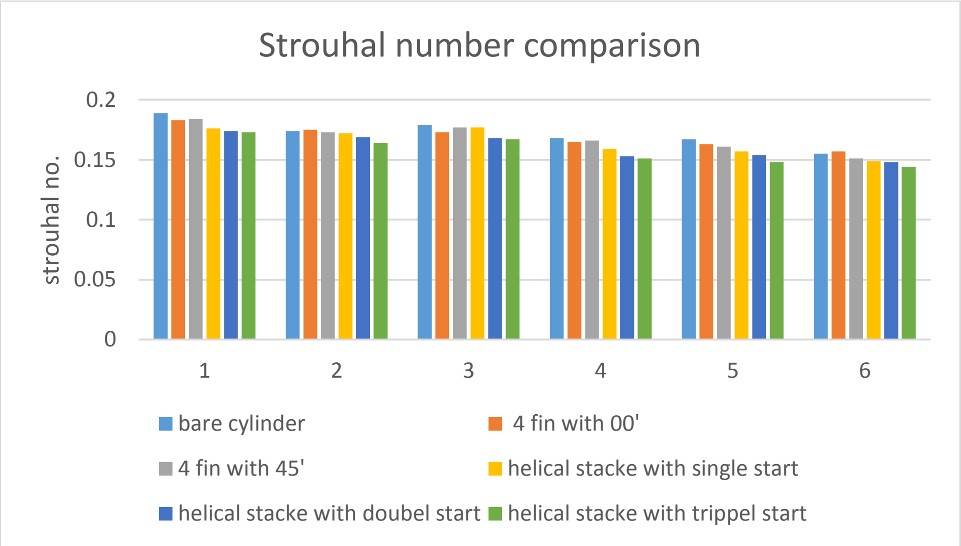


The pitch of the helical and the number of start of the fin are the main parameters that will affect the efficiency of VIV suppression while using helical strakes as a passive vortex suppression device. They adversely affect the of shear layer is to roll up and to disrupt the span wise vortex formation and shedding process. If a fluid flow takes place past a circular cylinder fitted with helical strakes, the strakes breaks the flow and produce vortices at various places along the cylinder. The vortices out of phase with one another and produce destructive interference to the dominant vortex shedding. Due to the partial cancellation of the out-of-phase lift forces at different span wise positions, the lift coefficient for the straked cylinder it is much smaller than that of a bare cylinder, resulting in a significant reduction in the amplitude of VIV



By comparing different geometry models is seen that the 4 fin with 00° have better than suppressing capability than 4 fin with 45° and also which has about 10% reduction in strohual number but by comparing with cylinder with helical stacks which gives the better than fin and also which gives about 16% reduction in strouhal number

Comparison Of Results Of Case Study With Other Authors Works

study	Strouhal number(St)
Moon et al. (2004)	0.164
Park et al. (1998)	0.165
Williamson (1991) Exp.	0.164
Menedhini	0.165
Sam Ryu et al.	0.64
Present study for helical stacks with Triple start	0.150

Table: 5

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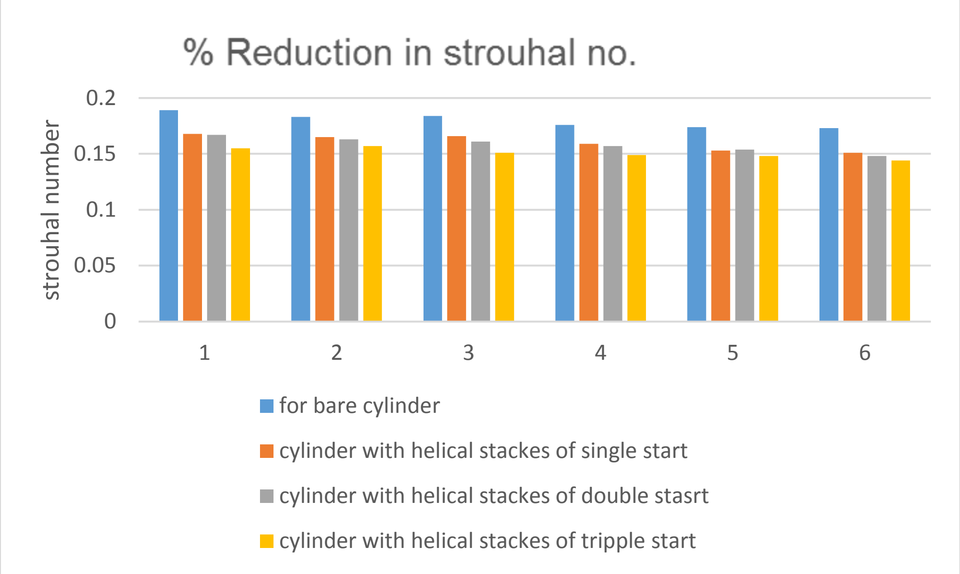

The above graph shows that the comparison of the strouhal number for different geometry models from which we can understand that the geometry model with helical stacks of triple stare have the lowest strouhal number which is the direct indication of highest level of vortex suppressing method. By analyzing we can understand that the cylinder with helical stacks is a one of most effective device for suppressing vortex induced excitations of the cylinder

CONCLUSION

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. Helical 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 helical stackes is the effective device for suppressing vortex induced excitations of the cylinder As a passive vortex control method, helical system of projecting fins is very effective in suppressing vortex shedding. As expected the drag force on thee straked cylinder was higher than a bare cylinder. And also the frequency of vortex shedding reduced dramatically by helical stakes of suitable pitch and height

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