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DESIGN AND FINITE ELEMENT ANALYSIS OF VORTEX INDUCED VIBRATION (VIV) SYSTEM.

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Abstract: The rapid depletion of fossil fuel reserves, alternate and sustainable energy resources are being sought in order to maintain the growing global energy requirements of the well-researched alternative sources include bio-fuels, solar, wind, hydro and geo-thermal energy. Hydrokinetic energy from flow of rivers, streams and artificial water channels are considered to be a viable resource. One promising new technology to overcome these problems is the hydroelectric power extraction system based on energy harvesting from flow induced vibration, the flow here can be both liquid flow as well as air flow. There are three main types of energy harvesting from vortex induced vibrations (VIV) of bluff bodies, flutter energy harvesting system and energy harvesting with Helmholtz resonators. The vortex induced vibration (VIV) Based power generating system is a new concept in power generation from fluid flow in occasions, rivers and streams.

***Index Terms* - fossil fuel, hydrokinetic energy, vortex induced vibrations, power generation**.

I. INTRODUCTION

Flow-induced vibration, as a discipline, is very important in our daily life, especially in mechanical engineering. Generally, VIV is considered as an undesirable effect. It was first observed by Leonardo da Vinci circa 1500 A.D., in the form of ―Aeolian Tones‖. This technology works by securing a cylinder (bluff body) horizontally with elastic strings, in flowing water and limiting it to a single degree of freedom; thereby allowing it to move only up and down perpendicular to the fluid flow. Fluid flow over this cylinder creates an alternating vortex pattern behind the cylinder which exerts alternating lift forces on it, pushing it up and down and so to make it vibrate. This vibratory motion is then converted into electricity via a power take off mechanism. This technology is superior to traditional hydro-kinetic energy extraction technology in several ways. Most turbines based kinetic energy harvesters only operate efficiently at flow currents greater than 2 m/s, while surface oscillation energy converters only give high output over a small range of water wave frequencies. A vortex induced vibration based energy converter could potentially operate in slow moving waterways over a wide range of frequencies. Further, Large scale tidal and dam type systems are environmentally obtrusive and require huge capital investment. Scalability and versatility are two of the paramount strengths of this technology. The average flow speed required for VIV is significantly lower than the turbine based hydrokinetic technologies.

II. LITERATURE SURVEY

Barrero-Gil et al,. (2011) [1] presents about the vortex induced vibration (VIV) based power generating system discussed in this paper is a new concept in power generation from fluid flows in oceans, rivers and streams. The possibility of harnessing energy from the vibrations incurred in a bluff body due to the phenomenon known as VIV, in which motion is induced on a body facing an external flow due to the periodic irregularities in the flow caused by boundary layer separation is explored. The VIV system is based on the idea of maximizing rather than spoiling vortex shedding and exploiting rather than suppressing VIV. The vibrating bodies are in turn used to harness energy using an efficient power-take-off system.

Kumar et al,. (2016) [2] presents about the harvesting energy from vibrations caused because of alternative vortex shedding due to fluidic flow over a bluff body is under progressive research. The purpose of this study is to harvest wind energy from cross flow vibrations using vented cylinders mounted on the chassis of a train. In this study usage of vented cylinders over a normal baseline cylinder is investigated to enhance vortex shedding and to extract the maximum amount of energy considering a typical single carriage of a train. Using Computational Fluid Dynamics, the Strouhal number is calculated which is validated for the further design of a system for harvesting energy from vibrations.

Khing et al,. (2015) [3] was collected the ocean current is always available around the surrounding of SHELL Sabah Water Platform and data are collected every minutes, 24 hours a day, for a period of 365 days. Due to low current speed, conventional hydro-kinetic power generation is not feasible, thus leading to the study of low current enabled vortex-induced vibration power generation application. this case, the design of vortex induced vibration application was studied to obtain an optimum design for the VIV oscillator.

Pandey et al,. (2016) [4] depicts that the vortex induced vibration based energy converter (VIVEC) satisfies all these criteria. It converts fluid (ocean/river/wind) current hydrokinetic energy to a usable form of energy such as electricity using VIV (vortex- induced vibration). VIV is the motion induced on bluff-body placed in the fluid flow due to alternate vortex shedding behind it, which produces alternating lift forces on it perpendicular to fluid flow. However, in energy harnessing application from fluid flow, rather than eliminating these vibrations, VIV will be exploited to transform these vibrations into a valuable resource of energy.

Rajeshkumar et al,. (2017) [5] VIVACE converts ocean/river current hydrokinetic energy to a usable form of energy such as electricity using VIV successfully and efficiently for the 1st time. VIVACE is based on the idea of maximizing rather than spoiling vortex-shedding and exploiting rather than suppressing VIV. VIV occurs over very broad ranges of Reynolds (Re) no. Only three transition regions suppress VIV. Thus, even from currents as slow as the 0.25 m/s, VIVACE can extract energy with high power conversion ratio making ocean/river current energy a more accessible and economically viable resource

In this paper we have designed a VIV (Vortex induced vibration) system for the use of power generation. The experimental set up is made for the experimentation and the analysis of whole system is also done.

III. RESEARCH METHODOLOGY

A. Problem Statement

The world is facing tremendous problem of demand and the source of over the fossil fuel. The hydro electric energy is high initial cost comparing with the other source of energy that can be used to produce electricity. There is a cheaper phenomenon called vortex induced vibration and it can be used to generate electricity.

B. Need Of The Project

The capital cost of hydro electric source and the thermal energy is so high. So as an alternating source we need to introduce a cheaper technology, The fluid flow from the dam and other turbulent water sources produces vortex induced vibrations and this vibration if we properly designed it can be used as an alternate source of energy.

C. Objective

- To study about the vortex induced vibrations.
- To design a setup to produce the electricity from the vortex induced vibration from the turbulent water sources.
- To fabricate the setup based on the design.

IV. WORKING PRINCIPLE

The flow of water leads to vortex induced vibrations on the cylinder. The cylinder is floating fibre cylinder and the change in water level leads to upward and downward movement of the cylinder. The cylinder is attached to guide ways and spring to properly control the vibrations. PVC cylinder pipe attach to small horizontal bar which connected to side guide. Above this bar two springs are attached for up and down motion. For generation of electricity piezoelectric sensor and piezoelectric circuit are place on main frame. Along with spring small rod are place on bar. Water flow arrangement is done either manually or water pump. When water strike on pipe then pipe is move up and down along with spring. Simultaneously rod strike on piezoelectric sensor. Per striking of rod on piezoelectric sensor generate 0.2 volt electricity. When rod striking continuously10 times on piezoelectric sensor then piezoelectric circuit generate 2 volt electricity for glow LDE bulb.

V. COMPONENTS USED

A. Spring

A spring is an elastic object that stores mechanical energy. Springs are typically made of spring steel. There are many spring designs. In everyday use, the term often refers to coil spring.

In this study springs are used for the up-down moment of the bluff body. The springs can help in the set up to keep the bluff body to a certain height and give vertical constraints. I has used the coil springs in this study and their specifications are given in the below table. An extension or compression spring rate is expressed in units of force divided by distance.

Table no.1.specification of coil

Sr. No.	Specification	Parameters
1.	Spring coil outer diameter	D_o = 28.5mm
2.	Spring coil inner diameter	D_i= 27mm
3.	Spring wire diameter	d = 1.5mm
4.	Pitch of coils	P= 0.5mm
5.	Total number of coils	(N_t) = 138

B. Piezoelectric Sensor

A piezoelectric sensor a device that uses the piezoelectric effect, to measure changes in pressures, accelerations, temperatures, strains, or force by converting them to an electrical charge. In this study we convert the striking force into the electrical energy by using piezoelectric sensors.

C. Cylindrical Bluff Body.

The setup consists of a PVC floating cylinder and from the both sides of the cylinder a pair of guide way mechanism and spring is attached. There are two guide pipes which move with respect to the both guide ways. There will be fixed piezoelectric sensors that are nearby to the guide rods.

Table no.2 Specification of Bluff Body.

Sr. No.	Specifications	Parameters
1.	Length of pipe	L= 280mm
2.	Diameter of pipe	D= 38mm
3.	Material of pipe	PVC

D. Frame And Rectangular Water Tank.

There will be a metal frame in which the whole setup is mounted. There also a rectangular water tank is provided to produce vortex induced vibrations. Water flow arrangement is done either manually or water pump.

Table no. 3. Frame and rectangular water tank.

1. Frame		
Sr. No.	Specifications	Parameters
1.	Frame structure material	1" square MS pipe
2. Rectangular water tank		
Sr. No.	Specifications	Parameters
1.	Length	1280 mm
2.	Width	570mm
3.	Height	310mm
4.	Material	3mm GI sheet

VI. CALCULATIONS.

Input parameters:

i. Spring coil outer diameter(D_o) = 28.5mm
ii. Spring coil inner diameter(D_i) = 27mm
iii. Spring wire diameter(d) = 1.5mm
iv. Total number of coils(N_t) = 138
v. Axial pitch between adjacent coils = 0.5mm

A. Spring Design Calculations:

1. Mean coil diameter (D) = $\frac{Di + Do}{2}$

$$= \frac{27+28.5}{2}$$
$$= 27.75\text{mm}$$

2. Spring index (C) = $\frac{D}{d}$

$$= \frac{27.75}{1.5}$$
$$= 18.5$$

3. Solid length = N_t . d
N_t = Total number of coils
= 138
Solid length = 138 x 1.5
= 207mm

4. Total axial gap = (N_t - 1) x gap between adjacent coils
= (138 - 1) x 0.5
= 68.5mm

5. Permissible shear stress=
T = 0.30 S_{ut}
Ultimate tensile strength for spring material (S_{ut})= 1490 MPa
Therefore, T = 0.30 x 1490
= 447 MPa

6. Wahl factor:
$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

$= \frac{4x18.5-1}{4x18.5-4} + \frac{0.615}{18.5}$

K = 1.07

7. Calculate force:

$T = K\left(\frac{8PC}{\pi d2}\right)$

$447 = 1.07\left(\frac{8 .P .18.5}{\pi .1.5\ x1.5}\right)$

P = 19.95 N

8. Number of active coils:

$\delta = \frac{8PD^3N}{Gd^4}$

$15 = \frac{8x19.95x27.75^3N}{81370x1.5^4}$

N = 1.81 ≈ 2

9. Spring stiffness (k):

$k = \frac{Gd^4}{8D^3N}$

$= \frac{81370\ x\ 1.5^4}{8x27.75^3x2}$

k = 1.204

B. Volume Of Water Tank:

Volume = length x width x height
= 1280 x 570 x 310
= 226176000 mm^3
= 0.2261 m^3

C. *Length Of Centre Guide Rod:*

L = 322 mm

D. *Diameter Of Centre Guide Rod:*

D = 5 mm

VII. ANALYSIS RESULT

A. Finite Element Method (FEM)

It is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). FEM subdivides a large problem into smaller, simpler, parts, called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

1) Element Type- second order tetrahedron.
2) Analysis Type- Vibrational analysis.
3) Material Type- Mild Steel
Young’s Modulus- 2e5 MPa
Poisons Ratio- 0.3
Density- 7850 kg/m3
Yield Strength- 250 MPa

B. Results – Total Deformation

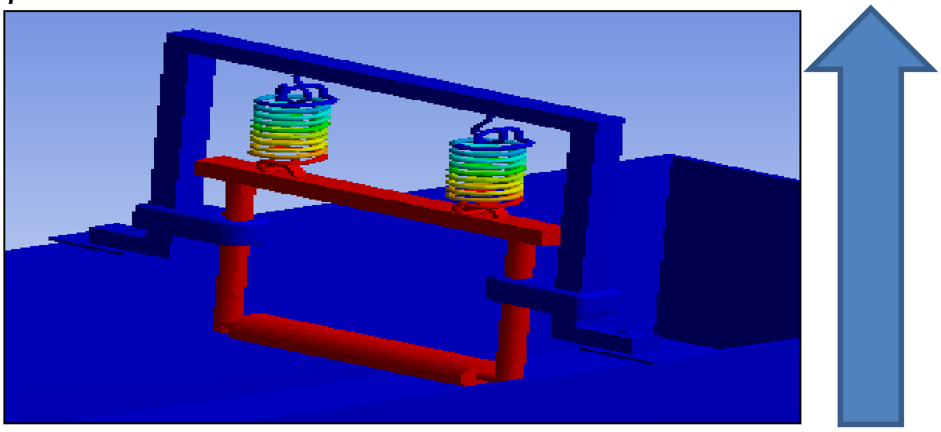

Fig.4. Direction of oscillation at 14Hz in vertical direction

C. Natural Frequencies And Mode Shapes

MODE 1 – Dominant Mode (First Natural Frequency also called as resonant frequency). This also explains that when vortex induced produces a frequency of 14 Hz, maximum output energy will be generated from magnetic power generation assembly

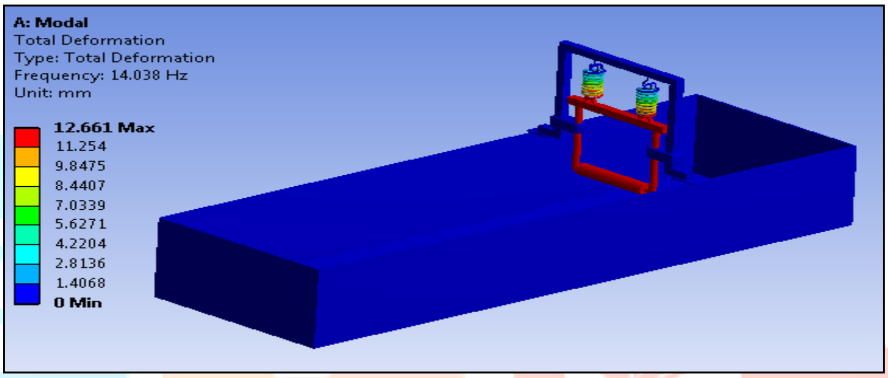

Fig.5. MODE 1 with frequency 14.038 Hz.

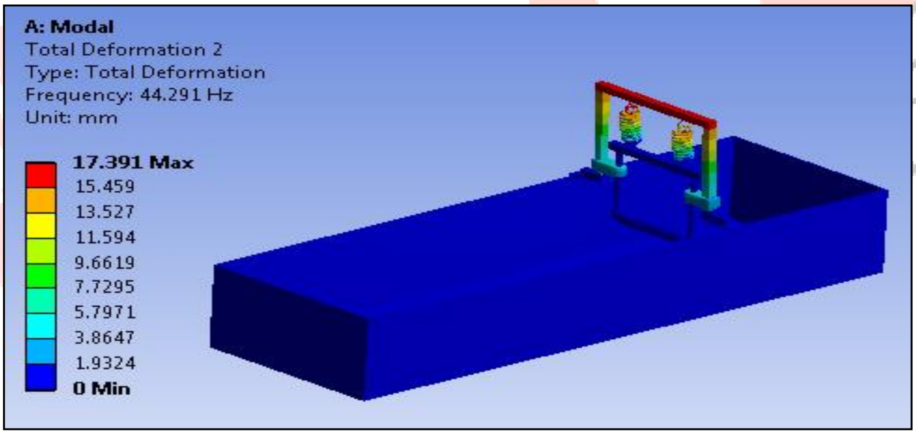

Fig.6. MODE 2 with frequency 44.291 Hz.

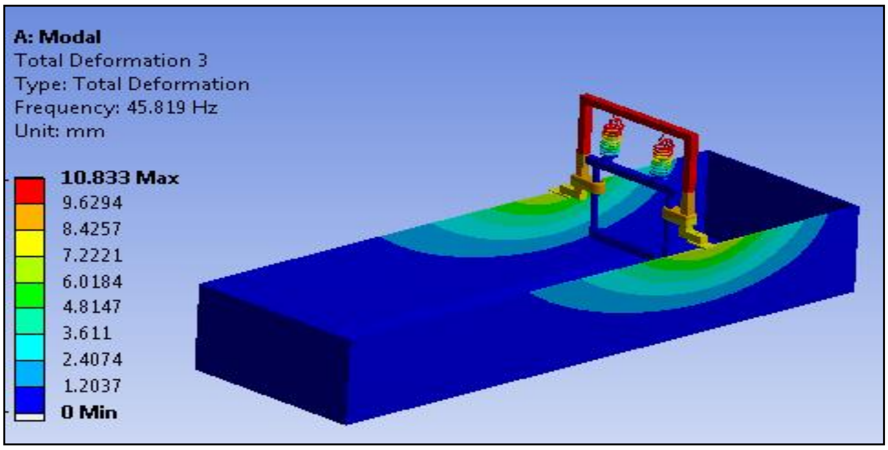

Fig.7. MODE 3 with frequency 45.819 Hz.

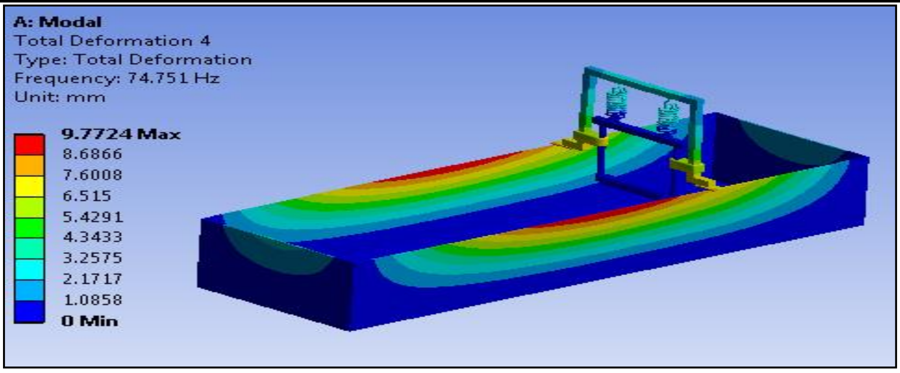

Fig.8. MODE 4 with frequency 74.751 Hz.

Table no. 5. Mode and frequency.

Sr. No.	Mode	Frequency (Hz)
1.	1	14.038
2.	2	44.291
3.	3	45.819
4.	4	74.751
5.	5	81.249
6.	6	85.39
7.	7	100.49
8.	8	101.95
9.	9	107.36
10.	10	108.04

VIII. EXPERIMENATAL SET UP

The experimental set up is shown in the total three figures with the all required elements assembly. That three figures are as follows:-

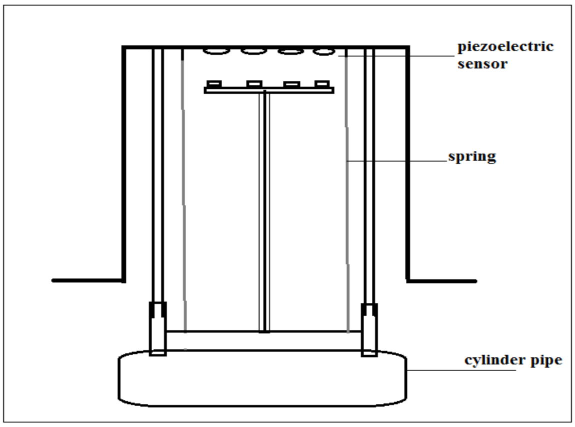

Fig:-1. Schematic 2D diagram of VIV setup

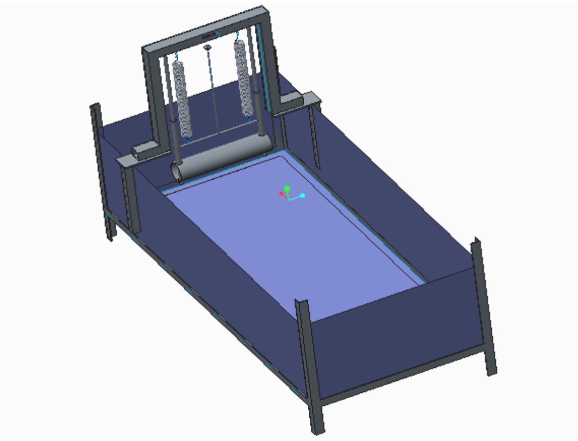

Fig:-.2. Cad Model of 3D VIV setup

Fig:-3. Actual working model of VIV system

IX. FUTURE SCOPE

The scope of the project is it can be implemented on ships and generate the electricity as a secondary source.

X. RESULT'S

Per striking of rod on piezoelectric sensor generate 0.2 volt electricity. After 10 strikes we can store a voltage of 2 volt.

Table no.4 Quantity of voltage produced .

Sr. No.	Strikes	Voltage produced (V).
1.	2nd strike	0.4
2.	4th strike	0.8
3.	6th strike	1.2
4.	8th strike	1.6
5.	10th strike	2.0

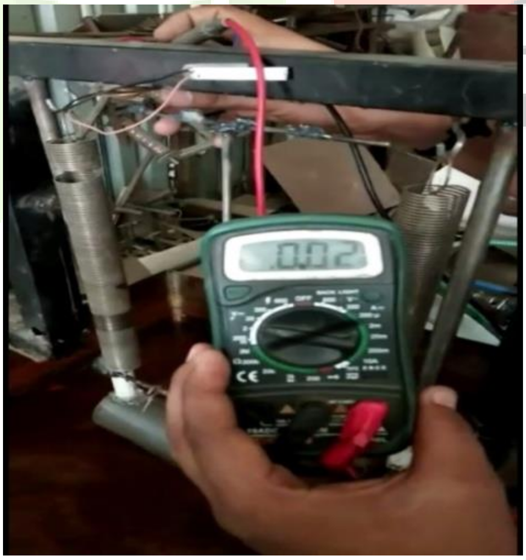

Fig.9.Voltage generated result in Multimeter

XI. CONCLUSION

1] From FEA explains that when vortex induced produces a frequency of 14 Hz, maximum output energy will be generated from VIV power generation assembly.
2] The purpose of this investigation is to design and development of VIV system for power generation.
3] The experimental set up for VIV system is designed developed and power generation is also done.

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