"DESIGN AND PROTOTYPE FABRICATION OF VORTEX WIND TURBINE"

Project Work submitted to

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

in partial fulfillment of the requirements
for the award of degree of

BACHELOR OF ENGINEERING

in

MECHANICAL ENGINEERING

Submitted by

RAKESH K	1KG19ME010
VINAY M	1KG20ME003
PRATHWIN BR	1KG20ME007
G PAVAN	1KG21ME411

Under the Guidance of

Dr. Abhishek M R
Associate Professor
Department of Mechanical Engineering
K S School of Engineering and Management

Department of Mechanical Engineering
K.S. School of Engineering and Management
No. 15, Mallasandra, off Kanakapura Road, Bengaluru-560109
2023-2024

K.S. SCHOOL OF ENGINEERING AND MANAGEMENT

MECHANICAL ENGINEERING

CERTIFICATE

This is to certify that the project work entitled **"DESIGN AND PROTOTYPE FABRICATION OF VORTEX WIND TURBINE"** is a bonafide work carried out by

RAKESH K	**1KG19ME010**
VINAY M	**1KG20ME003**
PRATHWIN B R	**1KG20ME007**
G PAVAN	**1KG21ME411**

in partial fulfillment for the award of **Bachelor of Engineering** in **Mechanical Engineering** of **Visvesvaraya Technological University, Belagavi,** during the year 2020- 2021. It is certified that all the suggestions indicated during internal assessment have been incorporated in the report and this report satisfies the academic requirement with respect to **Project Work (18MEP83)** prescribed for the degree.

Guide	**Head of the department**	**Principal**
Dr. Abhishek M R Associate Professor Dept. of Mechanical Engineering	**Dr. Balaji B** Professor & Head Associate Director for Admission Dept. of Mechanical Engineering	**DR. K. Rama Narasimha** Principle/Director KSSEM Bangaluru-109

28/5/24

Professor & Head
Department Of Mechanical Engineering
K.S. Group Of Institutions
K.S. School Of Engineering & Management
Bangalore-560 109

Dr. K. RAMA NARASIMHA
Principal/Director
K S School of Engineering and Management
Bengaluru - 560 109

Examiners

Dr. BALAJI. B, 29/5/24
Name and Signature of Examiner-1

Dr. GIRISH M
Name and Signature of Examiner-2

KSSEM

K.S. SCHOOL OF ENGINEERING AND MANAGEMENT
DEPARTMENT OF MECHANICAL ENGINEERING

DECLARATION

We,

RAKESH K	1KG19ME010
VINAY M	1KG20ME003
PRATHWIN B R	1KG20ME007
G PAVAN	1KG21ME411

the students of **BE VIII Semester (Mechanical Engineering)** declare that the project entitled "DESIGN AND PROTOTYPE FABRICATION OF VORTEX WIND TURBINE" is carried out by us as a partial fulfillment of academic requirement of degree under **Visvesvaraya Technological University.** The content in the report are original and are free from plagiarism and other academic dishonesty and are not submitted to any other University either partially or wholly for the award of any other degree.

NAME	USN	Signature
RAKESH K	1KG19ME010	K. Rak
VINAY M	1KG20ME003	M
PRATHWIN B R	1KG20ME007	prathwin
G PAVAN	1KG21ME411	PAVAN.

Date:

Place: Bengaluru

ACKNOWLEDGEMENT

The successful completion of this internship was made possible with the help of guidance received from our faculty members. We would like to avail this opportunity to express our sincere thanks and gratitude to all of them.

We are grateful to our management for providing the necessary infrastructure and an ambience environment to work. We express our profound gratitude to **Dr. K Rama Narasimha, Principal/Director** and **Dr. Balaji B, Professor, Head and Associate Director for Admission Department of Mechanical Engineering, KSSEM, Bengaluru** for giving us opportunity and support to complete the project work.

We are grateful to my guide **Abhishek M R, Associate Professor, Department of Mechanical Engineering, KSSEM, Bengaluru** for his valuable suggestions and advice throughout our work period.

We would also like to thank all the staff members of Department of Mechanical Engineering for their support and encouragement. Finally, we would like to thank all of our friends without whose help and encouragement this project would have been impossible.

Definitely most, we want to thank our family. Words cannot express our thanks to our family members for all their love and encouragement.

RAKESH K	**1KG19ME010**
VINAY M	**1KG20ME003**
PRATHWIN B R	**1KG20ME007**
G PAVAN	**1KG21ME411**

ABSTRACT

In present situation, India is one of the top growing economies. The various sectors contributing to this, need electricity for its functioning. Non-renewable resources being depleted day by day, importance is given to develop power from renewable sources of energy like wind, solar, hydro energy etc. In the year 2017-2018 the total utility power generated in India is 1,303,493 GWh and captive power generated is 183,000 GWh making a total of 1,486,493 GWh. Out of 1,303,493 GWh, 52,666 GWh (4% utility power) is generated using wind power. The aim of this project is to utilize wind power to its maximum potential to generate electricity. The region of highspeed wind is limited and the area required for installation of conventional windmill is high due to the wake effect. Research is done to find new innovative methods that can operate under optimum wind conditions, under less area by minimizing wake effect and provide an efficient output. One such technology is Bladeless turbine that provides a quiet, safe, simple and efficient alternative to the conventional bladed turbines. Bladeless turbine is not actually a turbine, since it does not rotate. This new approach captures wind energy based on the phenomenon of aeroelastic resonance. Harnessing energy from the vortexes, a process called vortex shedding or Vortex Street. This causes the device to oscillate with little movement which is perfect to be placed anywhere without lubricants and without disturbing wildlife. Aeroelastic resonance phenomenon is usually considered as a problem but this has been used as basic technology for power major advantage of this turbine is that it has fewer moving parts, thereby reducing losses to a minimum. This is a new age turbine with improved performance that is economic, eco-friendly and less complex generation. Bladeless turbines are also the only ones with almost no harmful effects on the environment. Another with wear prone transmission being eliminated.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Introduction

Wind power is one of the most readily available sources of renewable energy in nature and is abundantly found in the environment; however, the construction of wind turbine generators itself is costly. This inspired the researchers to design a vortex bladeless wind generator that applies the principle of oscillation through vortex and pendulum motion. Instead of harnessing its power from the rotational motion of turbines, it uses the pendulum motion brought by vortices to generate electricity. When wind passes one of the cylindrical tubes, it shears off the downwind side of the cylinder in a spinning whirlpool or vortex. That vortex then exerts force on the cylinder, causing it to vibrate, and allows the pendulum to move. The kinetic energy of the oscillating pendulum is converted into electricity through a linear generator similar to those used to harness wave energy.

This study gathered output voltages from two types of VBW pendulums intended to light up LED bulbs. It also applies the principle of vortex oscillation and pendulum motion in an innovative and eco-friendly way of harnessing electrical energy. The main objective of this study is to construct a bladeless wind generator prototype and demonstrate its performance on disc-shaped and arc-shaped pendulums. Specifically, it aims to determine the amount of voltage that was harnessed from different wind speeds, power up LED bulbs, and select the type of pendulum that can provide better oscillation while inducing vortex vibration. The scope of the research covers the following: the main component used in constructing the prototype is a linear generator made from neodymium permanent magnets; cylindrical frustum body used as flow path of wind to utilize wind vortices; pendulum is directly connected to the upper cylindrical frustum body to produce the oscillating back-and forth motion acting as the prime mover of the linear generator; and a wind monitoring system used to record wind speeds. Furthermore, the delimitations of this study are as follows: it was placed on a certain height above the ground and on roofs exposed to a windy atmosphere; consumed less space; test limit of wind speed should not exceed 12.5 m/s given that the tropical depression wind speed ranges from 12.5 m/s to 17.22 m/s; the height of the prototype should not exceed 10 feet for a miniature design scale; the geometry of the cylindrical structure's diameter is 60 cm; and neodymium-type magnets were used to produce appreciable measured value.

Fig 1.1 structure of bladeless wind turbine

The impact of the current generation's energy consumption on the next generations poses issues that need to be effectively addressed. In 2018, global energy consumption peaked at 13,864.9 Mtoe. This year's increase in total energy consumption of 2.9%, which is double the average growth of the 10 preceding years, highlights the urgency and importance of these issues.

1. Facing this enormous problem, national governments need to work closely together to develop timely, coherent, and considered policies. Renewable energy plays an important role in mitigating and adapting to climate change in countries around the world.

2. Electricity generation from sustainable sources achieved 7% growth in 2020, accounting for a large proportion of the 3% increase in renewable energy use.

3. Renewable electricity generation in 2021 is expected to expand by more than 8% with a major contribution of solar photovoltaics (PV) and wind.

4. Besides the obvious advantages of renewable energy, such as zero greenhouse gases (GHG) emissions and low operational costs, solar panels and wind turbines also have their own drawbacks. The use of solar panels raises enormous questions about expired solar cells, while wind turbines have been considered unsuitable for urban areas. Harnessing wind power in urban areas requires overcoming the disadvantages of vibration and noise as well as challenges related to the space of installation.

5. Bladeless wind turbines (BWT) are an advanced technology that converts wind energy to electrical energy in cities. BWT can easily be deployed in urban areas and even integrated into the overall architecture of buildings. The advantages of this approach are that it reduces noise, avoids intermittent shade effects, and prevents impacts on migratory birds.

6. Considered a solid-state wind energy transformer, the maintenance costs are generally lower than those of conventional wind turbines.

7. BWT can be combined with solar energy panels to form a hybrid system, which could be considered for increasing electrical power production and improving the system's overall efficiency. Accordingly, BWT could be considered a sustainable solution for wind energy in cities.

8. Occupying only vertical space, the cylindrical form of BWT was judged by experts to be suitable for implementation in residential areas.7,8 With the advanced design, BWT would contribute to the modernity in urban architecture.

9. In this policy brief, we aim to explore the opportunities and challenges, as well as investigate feasible scenarios, of implementing BWT technology. The policy brief is composed using the knowledge from a literature review and multi-stakeholder interviews.

1.2 Current State

The innovative aspects of bladeless wind turbines and their capacity to produce electricity at low wind speeds under turbulent flow conditions in the city surroundings are the key factors that promote the deployment of this technology in built-up areas with significant potential for wind energy. Such areas in cities include rooftops of high-rise buildings, areas around multistory buildings, city roads, railway tracks and subway networks.

Despite being in the prototype stage, the vortex bladeless has proven its value as a new wind energy technology particularly designed for on-site generation as it can be placed in an open environment or residential areas. In addition, bladeless wind turbines can work on or off grid, along with solar panels or other generators.

Two commercial-scale bladeless turbines have been developed with generation capabilities of 100 W and 4kW. Smaller-scale turbines measure 3 meters in height and weight only 10 kilograms but supply enough power for lighting and some utilities. Since such small turbines are not yet industrially produced, an investment is estimated to cost about $250.9 Larger-scale turbines with a height of 13 meters and total weight of about 100 kilograms can generate continuous electricity for a house if installed in a location with enough wind.

Fig 1.2: Structural Design

A tentative price for this model is evaluated to be about $5000.9 In addition to the two commercial models, development of a giant vortex turbine model is also underway. Such a bladeless turbine would measure 150 m in height and 100 tons in weight and was calculated to be able to generate 1MW.21 The estimated costs for this model have not been determined yet but are expected to have a lower price in proportion to its capacity compared to the two smaller models. The average cost of power generation per Watt for bladeless wind turbines may be higher than that for solar panels. However, bladeless turbines are still economically attractive in windy regions where the system are able to function more effectively than solar panels do.

1.3 Components

1. Coil

2. Neodymium Magnets

3. Frame

4. Ball Bearing

5. Needle Bearing

6. Thrust Bearing

7. Coil Holder

1. Coil

Fig 1.3.1: Coil

An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it. An inductor typically consists of an insulated wire wound into a coil.

When the current flowing through the coil changes, the time-varying magnetic field induces an electromotive force (emf) (voltage) in the conductor, described by Faraday's law of induction. According to Lenz's law, the induced voltage has a polarity (direction) which opposes the change in current that created it. As a result, inductors oppose any changes in current through them.

An inductor is characterized by its inductance, which is the ratio of the voltage to the rate of change of current. In the International System of Units (SI), the unit of inductance is the henry (H) named for 19th century American scientist Joseph Henry. In the measurement of magnetic circuits, it is equivalent to weber/ampere. Inductors have values that typically range from 1 μH (10−6 H) to 20 H. Many inductors have a magnetic core made of iron or ferrite inside the coil, which serves to increase the magnetic field and thus the inductance. Along with capacitors and resistors, inductors are one of the three passive linear circuit elements that make up electronic circuits. Inductors are widely used in alternating current (AC) electronic equipment, particularly in radio equipment. They are used to block AC while allowing DC to pass; inductors designed for this purpose are called chokes.

2. Neodymium Magnets

Fig 1.3.2: Neodymium Magnets

A neodymium magnet (also known as NdFeB, NIB or Neo magnet) is a permanent magnet made from an alloy of neodymium, iron, and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure. They are the most widely used type of rare-earth magnet. Developed independently in 1984 by General Motors and Sumitomo Special Metals, neodymium magnets are the strongest type of permanent magnet available commercially. They have replaced other types of magnets in many applications in modern products that require strong permanent magnets, such as electric motors in cordless tools, hard disk drives and magnetic fasteners.

In the field of information technology, neodymium magnets are particularly used in hard disc drives, mobile phones, video and audio systems of television [1]. Neodymium magnets are also commonly used in magnetic separators, filters, ionizers, in production of on–off buttons, safety sector and security systems.

3. Supporting Frame

Fig 1.3.3: Supporting Frame

The stand is a bottom part which bares the load of all other components. The remaining parts are mounted on the base. The stand material must have the capability to bare the load and the base material must goes under less deformation due to the load applied on the base.

A frame is often a structural system that supports other components of a physical construction and/or steel frame that limits the construction's extent. A structure supporting or containing something. Frame, skeletal frame, skeleton, underframe. The internal supporting structure that gives an artifact its shape. Support. Supporting structure that holds up or provides a foundation.

4 Ball Bearing

Fig 1.4.4 Ball Bearing

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.

The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races.

A ball bearing is a type of rolling-element bearing that serves three main functions while it facilitates motion: it carries loads, reduces friction and positions moving machine parts. Ball bearings use balls to separate two "races," or bearing rings, to reduce surface contact and friction across moving planes.

5. Needle Bearing

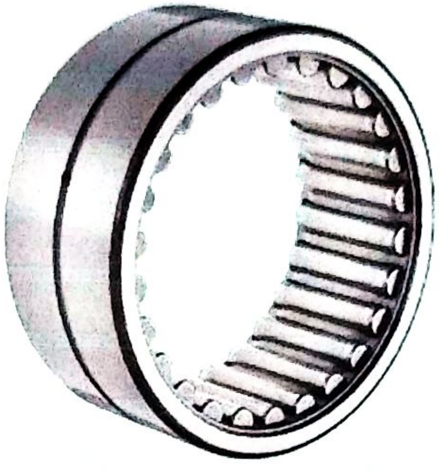

Fig 1.4.5: Needle Bearing

A needle roller bearing is a special type of roller bearing which uses long, thin cylindrical rollers resembling needles. Ordinary roller bearings' rollers are only slightly longer than their diameter, but needle bearings typically have rollers that are at least four times longer than their diameter. Like all bearings, they are used to reduce the friction of a rotating surface.

Compared to ball bearings and ordinary roller bearings, needle bearings have a greater surface area in contact with the races, so they can support a greater load. They are also thinner, so they require less clearance between the axle and the surrounding structure.

Needle bearings are heavily used in automobile components such as rocker arm pivots, pumps, compressors, and transmissions. The drive shaft of a rear-wheel drive vehicle typically has at least eight needle bearings (four in each U joint) and often more if it is particularly long, or operates on steep slopes.

Like all bearings, they are used to reduce the friction of a rotating surface. Compared to ball bearings and ordinary roller bearings, needle bearings have a greater surface area in contact with the races, so they can support a greater load.

Needle rollers have a smaller diameter than cylindrical rollers, and so the bearings have a smaller cross-sectional height and contributed to the down-sizing of machinery.

6. Thrust Bearing

Fig 1.4.6 Thrust Bearing

A thrust bearing is a particular type of rotary bearing. Like other bearings they permanently rotate between parts, but they are designed to support a predominantly axial load. Thrust ball bearings, composed of bearing balls supported in a ring, can be used in low-thrust applications where there is little axial load.

Tapered roller thrust bearings consist of small tapered rollers arranged so that their axes all converge at a point on the axis of the bearing. The length of the roller and the diameter of the wide and the narrow ends and the angle of rollers need to be carefully calculated to provide the correct taper so that each end of the roller rolls smoothly on the bearing face without skidding. These are the type most commonly used in automotive applications (to support the wheels of a motor car for example), where they are used in pairs to accommodate axial thrust in either direction, as well as radial loads. They can support greater thrust loads than the ball type due to the larger contact area, but are more expensive to manufacture.

Thrust bearings are used in cars because the forward gears in modern car gearboxes use helical gears which, while aiding in smoothness and noise reduction, cause axial forces that need to be dealt with.

Thrust bearings are also used with radio antenna masts to reduce the load on an antenna rotator. One kind of thrust bearing in an automobile is the clutch "throw out" bearing, sometimes called the clutch release bearing.

7. Coil Holder

Fig 1.4.7 Coil Holder

Motor coils are used in a variety of applications and industries. Field coils are series, compound, shunt, and edge wound coils used with DC motors, synchronous AC motors, and generators. Edge wound coils can range in size from several inches to over 10 feet.

The induction coil that is placed around the object is called the work coil. This work coil is often a copper tube through which water flows to cool the coil. The eddy currents in the work piece cause eddy current losses which result in heating.

Induction coils are water-cooled copper conductors made of copper tubing that is readily formed into the shape of the coil for the induction heating process. Induction heating coils are cold and do not themselves get hot when water is flowing through them.

Electrical appliances such as an induction unit create Non-Ionizing or Low-Frequency EMF. According to the National Cancer Institute there are no current studies that have been able to provide a link that non-ionizing radiation causes any adverse health issues such as cancer.

Chapter 2

LITERATURE REWVIEW

1.Prof. Harshith K , Srinivas Institute of Technology, Mangalore, Karnataka, India.

Blayan Santhosh Fernandes, Srinivas Institute of Technology, Mangalore, Karnataka, India; Bladeless Wind Power Generation uses a radically new approach to capturing wind energy. The device captures the energy of vorticity, an aerodynamic effect that has plagued structural engineers and architects for ages (vortex shedding effect).

2. Williamson C.H and Govardhan, R., "Vortex-Induced Vibration", Journal Of Fluid Mech.

Vortex-induced vibration (VIV) of structures is of practical interest to many fields of engineering. For example, it can cause vibrations in heat exchanger tubes; it influences the dynamics of riser tubes bringing oil from the seabed to the surface; it is important to the design of civil engineering structures such as bridges and chimney stacks, as well as to the design of marine and land vehicles; and it can cause large-amplitude vibrations of tethered structures in the ocean.

Chapter 3

METHODOLOGY

1. Process flow and construction of prototype

The prototype was first constructed based on the design of the cylindrical shape body where wind will pass through and produce vortex vibration. Cylindrical structure is considered as the best path for vortex vibration; where the wind passes through this body would create a better wind tail swirling to induce enough vortex shedding, in order to make the cylinder oscillate. The oscillation structure is directly coupled to a pendulum underneath. This pendulum acts as prime mover of a linear generator. While the cylindrical structure above oscillates, the pendulum underneath moves back and forth. A magnetic coupling device is installed at the lower part where it serves as the linear generator. Coils and permanent magnets are used in this part. The measured parameters is tabulated as it varies on the wind speed. The wind speed is measured through an anemometer attached in the vortex bladeless generator.

2. Prototype and its Physical Set - up

The construction of pendulums for vortex bladeless wind generator plays an important consideration of this study as well as the application of Faraday's Law in cutting the maximum flux when pendulum moves sideways across the face area of the coils to induce voltage. The arc pendulum where five coil groups are constructed on both sides and the sliding arc shaped pendulum with permanent magnets swings back and forth such that, this magnetic field in the middle is cut through. For this type of construction, the cutting of magnetic field is maximized since the arc pendulum covers the entire face area of the coil groups. The stator on the sides of the pendulum is a coil that has 220 turns each. The vortex bladeless wind generator produces induced voltage by cutting the magnetic flux between coils and magnets while swinging. The other type of pendulum constructed was disc type. However, the limitation was the weight of its body; as such, constructing a bigger disc would cause difficulty in its swinging action but most area under coil face can be covered for higher induced voltage. In line with this observation, a smaller disc size was designed and constructed so it can move freely on that portion of coil group's face area as it swings back and forth.

However, cutting of flux in this manner is not maximized as compared to the first type. The design in this process was based on physical set up for both pendulums, which aims to harness more induced voltages. The experiment was held in Balanga City Bataan, Philippines on a 4-storey commercial building. Vortex Bladeless wind generator was placed on roof top of the commercial building. The experiment was monitored in morning, afternoon and evening on a fair day. A constant wind speed is quite difficult to achieve. Thus, the data considered was the highest wind speed recorded during the experiment.

Chapter 4

DESIGN AND FABRICATION

4.1 Design

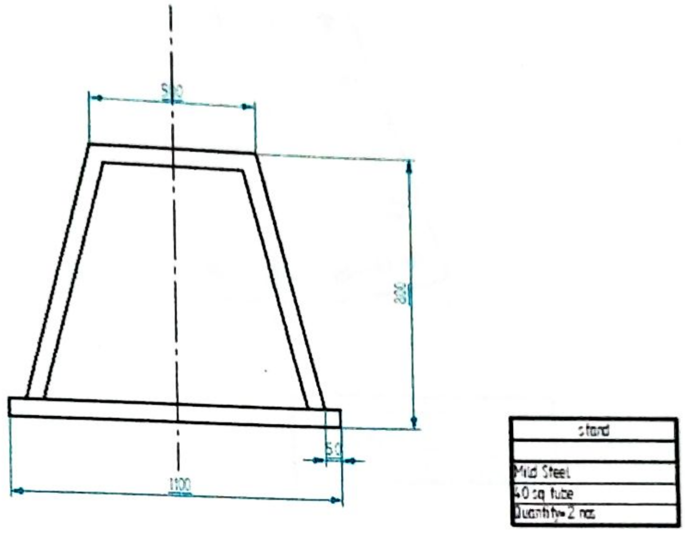

Fig 4.1.a: Stand

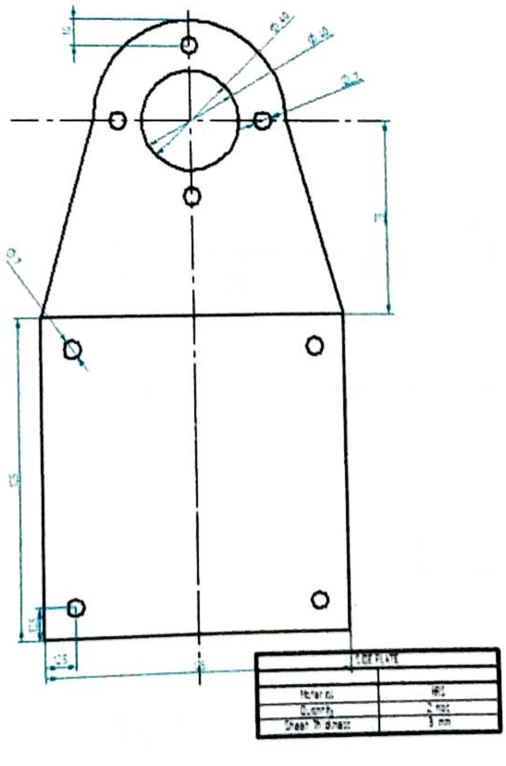

Fig 4.1.b: Side Plate

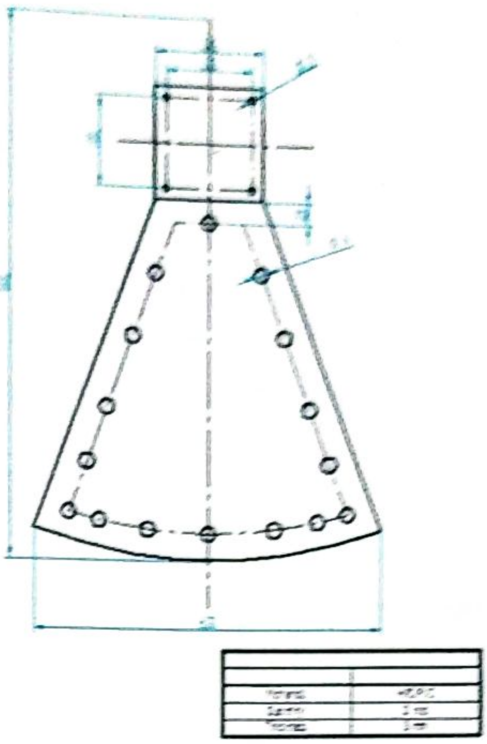

Fig 4.1.c: Arc Pendulum

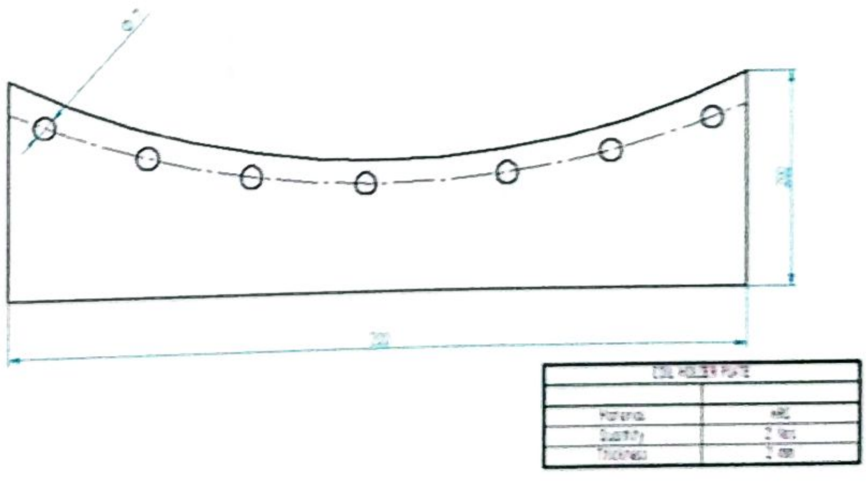

Fig 4.1.d: Coil Holder

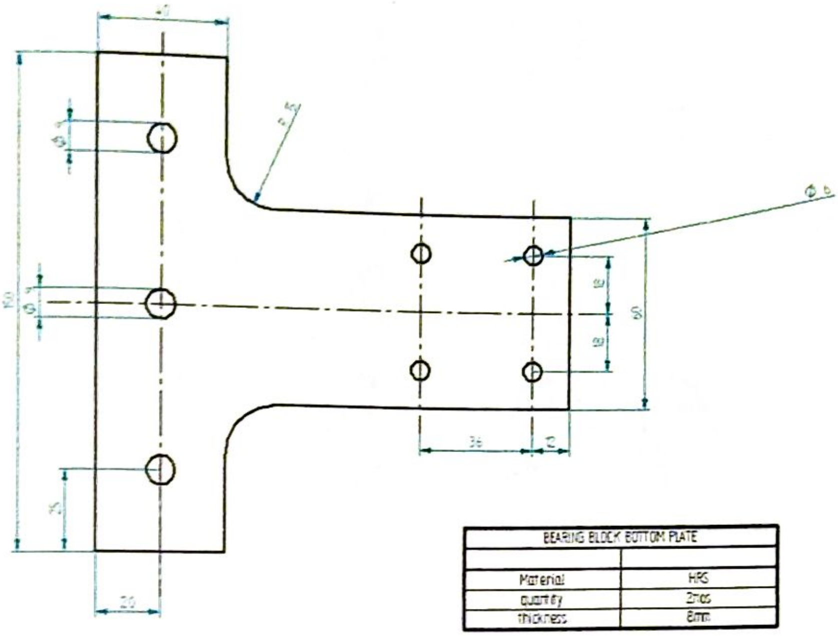

Fig 4.1.e: Bearing

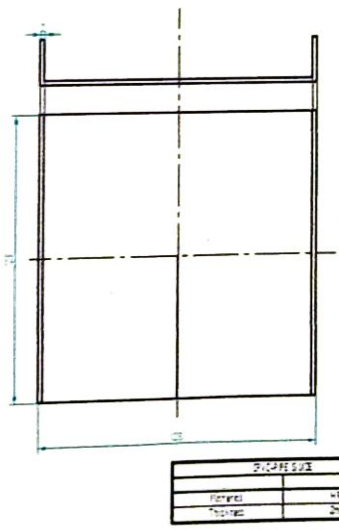

Fig 4.1.f: CPVC Pipe Guide

4.2 WHILE FABRICATING

Fig 4.2.1 While Fabricating Frame

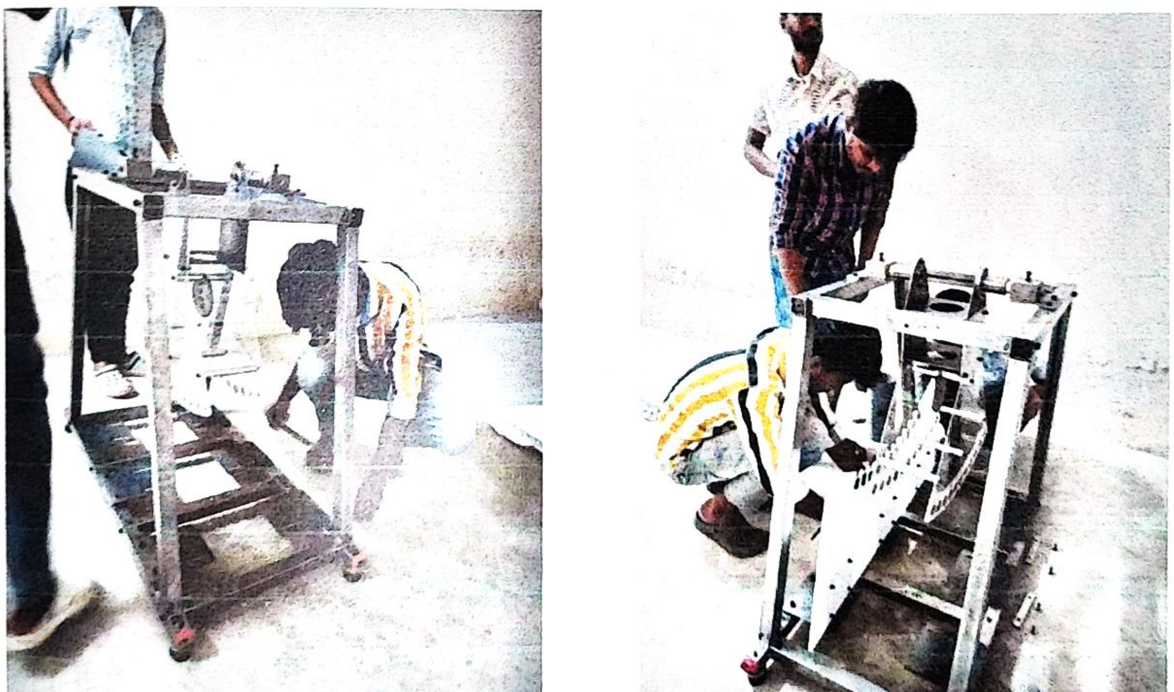

Fig 4.2.2 While Assembling Coils

Fig 4.2.3 While Assembling Supports

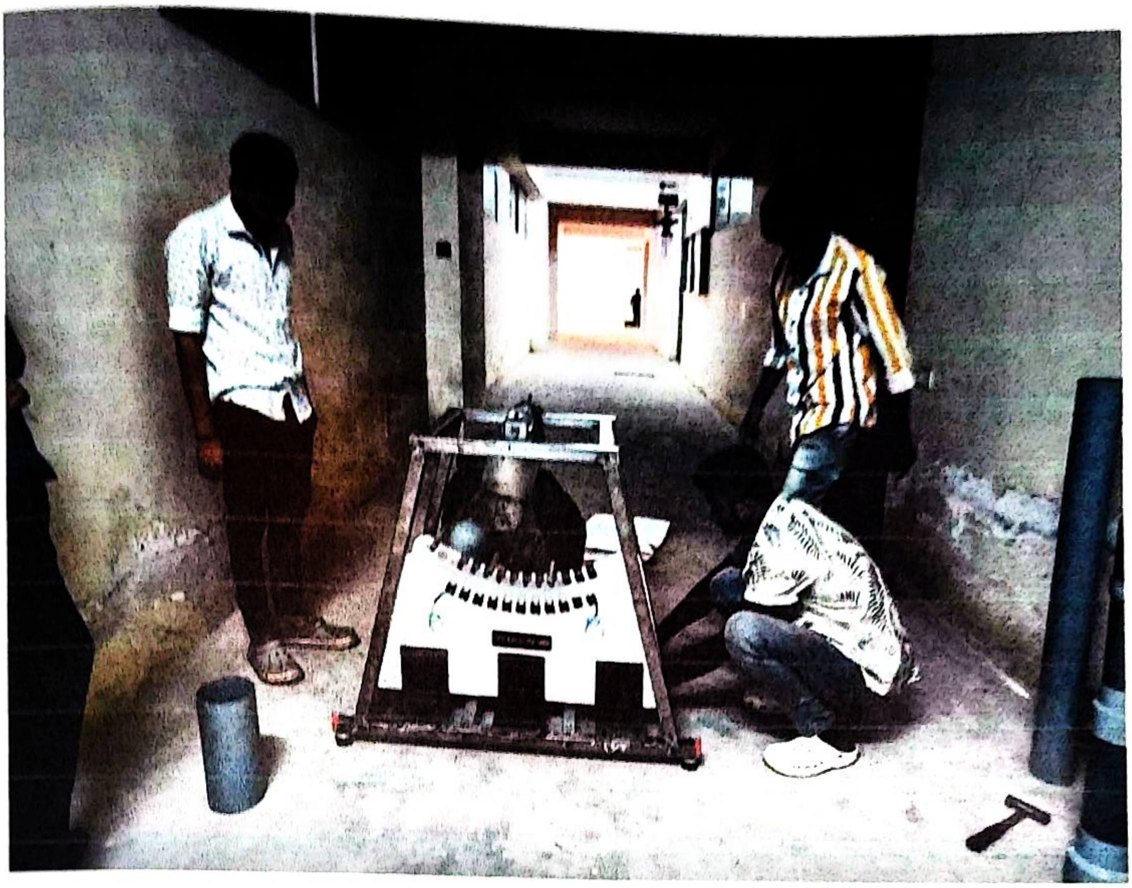

Fig 4.2.4 While Assembling Pendulum

Fig 4.2.5 Finished Model

Advantages, disadvantages and applications

Advantages

- No gears and bearings, reduces manufacturing and maintenance drastically.
- No lubricants needed, noise less, more environmental friendly.
- It reduces foundation at the bottom by 50%.
- Cost of energy production is 40% less than the conventional turbines
- Birds can fly around them without fear of being sucked in.
- We can put large number vortex bladeless turbine units in an area when compared to convention wind turbines

Disadvantages

- The efficiency of the energy absorbed from the wind is comparatively less than that of the conventional wind turbine.
- The requirement of control systems for controlling the oscillation to meet the natural frequency of the mast and control of the frequency at higher velocity winds. The height of the mast can be increased based on the output required

Chapter 5

CONCLUSION

When it comes to clean energy, wind power is considered one of the most reliable and sustainable alternatives. In summary, the generation of electricity is made possible by the small structure of bladeless turbine. High efficient power is generated. This technology will satisfy the need of continuous generation of electricity. The overall project uses less space area hence highly economical for the rural electrification of India.

Chapter 6

SCOPE OF FUTURE IMPROVEMENT

- The following Designs are extracted from some of the concepts based blades less wind turbines, designs for our work is by Thumb rule which can be used for further development .
- The global Wind Power market size was valued at USD 127580.09 million in 2022 and is expected to expand at a CAGR of 7.52% during the forecast period, reaching USD 197071.32 million by 2028. Wind power is the use of air flow through wind turbines to provide the mechanical power to turn electric generators.
- Wind turbines installed in the "Future" period (2023–2025) are expected to increase in size by an average of 60% from the average of those installed in the "Then" period (2011–2020), growing in total height (from base of the tower to the tip of the blade at its apex) from 122 to 202 meters.

REFERENCE

1. Prof. Harshith K , Srinivas Institute of Technology, Mangalore, Karnataka, India.
2. Williamson C.H and Govardhan, R., "Vortex-Induced Vibration", Journal Of Fluid Mech.
3. Gaurao Gohate, Abhilash K hairkar, Sameer Jadhav, "The capacity of wind power in India ranks fifth in the world", 11, 3, (2016)
4. Banafsheh Se yed-Aghazadeh, Yahya Modarres-Sadeghi, T. Senior, A. Alderson, " Vibrations are build to change over vortex vibrations into power ", 5, 8-10, (2014)
5. Barrero-Gila, Santiago Pindado b, Sergio Avilac, "Extracting energy from VortexInduced Vibrations: A parametric study", 7, 41-43, (2012)
6. Cajasa, G. Houzeauxa, D.J. Yanezb, M. MierTorrecillaa, " Problems involving fluid structure interaction ", 14, 46, (2020)