POWER GENERATION FROM A SMALL WIND TURBINE

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

In

B.E MECHANICAL ENGINEERING

ANNA UNIVERSITY REGIONAL CAMPUS, COIMBATORE

ANNA UNIVERSITY: CHENNAI 600 025

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BONAFIDE CERTIFICATE.

Certified that this Project Report **POWER GENERATION FROM A SMALL WIND TURBINE** is the bonafide work of KAVIYASELVAN K -710021114013, MADHAVAN S -710021114019, MONISH R -710021114023, NAVEENKUMAR A - 710021114315 who carried out the project work under my supervision.

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Submitted for the project viva-voce examination held on ________________

Internal Examiner External Examiner

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ABSTRACT

Energy is the ability to do work and exists in various forms, such as kinetic, potential, thermal, and electrical energy. It follows the law of conservation, meaning it cannot be created or destroyed but can only be transformed from one form to another. Non-renewable energy comes from finite resources like coal, oil, natural gas, and nuclear fuels. These sources take millions of years to form and can deplete over time, often causing environmental pollution. Non-renewable energy pollutes the environment a lot, so it is better to switch to renewable energy. Renewable energy comes from natural sources that replenish over time, such as solar, wind, hydro, and biomass. These sources are sustainable and have minimal environmental impact. our project implementing on renewable energy particularly implementing in wind energy. Wind energy is a renewable source that converts the kinetic energy of wind into mechanical or electrical power using wind turbines. It is sustainable, eco-friendly, and widely used for clean electricity generation. This project aims on power generation from a small wind turbine.

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CHAPTER 1

INTRODUCTION

1.1 ENERGY

Energy is a physical amount that is transmitted from one object to another, to do work or to heat an object. One Joule of energy is considered to be expended when one Newton of force is applied across a distance of one metre. There are two types of energy: conventional and non-conventional.

1.2 CONVENTIONAL ENERGY

The non-renewable energy sources known as conventional energy have been in use for a very long time. They are heavily utilised by humanity, and because of the volume of use, the reserves have been significantly reduced. Examples include coal, oil, and natural gas, nuclear power.

1.2.1 COAL:

The most prevalent fossil fuel in the planet is coal. Carbonaceous materials were first compacted into a spongy substance called "peat," which contains around 90% water, during the creation of coal. The higher pressure and temperature caused by the deeper burial transformed the "peat" into coal

1.2.2 CRUDE OIL:

Liquid petroleum, often known as crude oil, is a fossil fuel that is processed into a variety of energy products, including gasoline, diesel, jet fuel, and heating oil. Shale, a rock type that is abundant in organic compounds, is where oil is formed underground.

1.2.3 NUCLEAR POWER:

Water is heated and turned into steam in the majority of nuclear power plants, which then powers a turbine-generator to generate electricity. Heat is produced in fossil fuel power plants through the burning of coal, oil, or natural gas. The heat needed to create steam for electricity production in a nuclear power plant is produced by the fission of uranium atoms in the reactor.

1.2.4 NATURAL GAS:

Because the two often share subsurface resources, the creation of natural gas is frequently a by-product of the recovery of oil. Methane is the most prevalent gas in natural gas, which is a combination of gases. Furthermore, some butane, ethane, and propane are present.

But conventional sources have the following problems. First one is Pollution which has two sources: point of use and production. To some extent, each of them can be reduced. Next is Cost volatility which everyone who has passed a petrol station while driving is aware of. Fossil fuel prices fluctuate day by day. The price of fuel can skyrocket in response to issues like a geopolitical crisis or refinery fire. Supply is also a major issue in conventional sources. Take into account, for instance, the challenges involved in attempting to get fuel to a distant mountaintop radio installation in the middle of winter. This is the reason why renewable energy sources have gained popularity in remote places.

1.3 NON-CONVENTIONAL ENERGY:

Due to the fact that they are perpetually provided by nature and won't run out any time soon, non-conventional energy sources are also frequently referred to as renewable energy sources. They are easily accessible. Since they have not been widely utilised in our daily lives up until this point, they are referred to as non-conventional.

Moreover, these energy sources do not harm the environment. Some of the non conventional types of energies are Tidal energy, Wave energy, Wind energy, Small scale hydro-electric energy, geothermal energy, Ocean thermal energy conversion (OTEC), solar thermal technologies and Bio fuels

1.3.1 BIOMASS:

Biomass is a sustainable energy source that is produced from carbonaceous waste that results from a variety of natural and human activities. It originates from a range of sources, including agricultural products, unprocessed forest products, sizeable amounts of residential garbage, and wood by-products from the logging industry.

1.3.2 HYDROELECTRIC ENERGY:

Electricity can be generated using the energy from the moving water called as hydroelectric energy. Waves are the outcome of the wind's contact with the water's surface and are an energy transfer from the wind to the sea. Energy from tides can be obtained by constructing a reservoir behind a barrage and using the water flowing through the barrage's turbines to generate electricity.

1.3.3 SOLAR ENERGY AND PHOTOVOLTAIC:

Solar energy is easily transformed into heat and might meet a significant amount of the global demand for home hot water and space heating. Photovoltaic (PV) cells, which convert sunlight directly into electricity, are made of silicon or other materials. The electricity generated by solar farms, which utilise mirrors to direct sunlight across acres of solar cells, may power thousands of houses. Floating solar farms, often called as "floatovoltaics," can be deployed in waterways that are not environmentally sensitive. The core issue with solar energy is, there are many winter days in high latitude countries like the UK where the total amount of radiation received is insufficient to be of any help.

1.3.4 GEOTHERMAL ENERGY:

The earth's temperature is roughly equal to that of the sun's surface due to the slow radioactive particle disintegration in the planet's core. Deep well drilling brings hydrothermal resources, such as extremely hot subterranean water, to the surface, where they are used to power turbines. Geothermal operations frequently have low emissions, provided they recycle the water and steam they use. Although it is possible to construct geothermal plants without utilising underground reservoirs, there are concerns that doing so would increase the likelihood of seismic activity in areas that are already considered to be geological hot zones.

1.3.5 TIDAL ENERGY:

Tidal energy is a type of hydropower that transforms tide energy into usable forms of power, much as electricity. The gravitational pull of the moon and sun on the earth causes cyclical movement of the swell, which is what causes tides. The main issue with tidal energy harvesting in tidal turbines is the collision and capture of marine animals by the blades. The risk of marine life being pushed close to or through these biases increases with high-speed water

1.4 WIND ENERGY

The usage of wind energy as a renewable energy source has considerably increased since the end of the 1970s.Wind turbines produce sustainable electricity without the need for fuel transportation, which harms the environment. Over the past few decades, wind power has transformed from an alternative energy source to a brand-new, rapidly growing industry that no longer needs subsidies and produces wind turbines at affordable rates[1]. The following graph shows the amount of electricity produced by wind energy according to International Renewable Energy Agency.

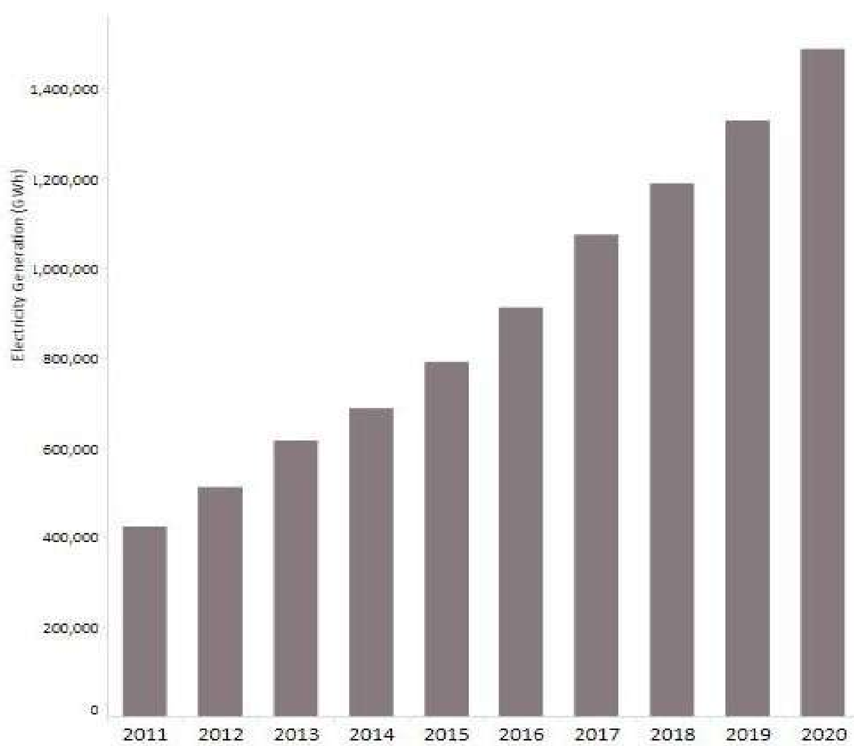


Fig. 1. Electricity generation from wind energy

1.5 WIND TURBINES:

Modern wind turbines provide electricity in an efficient, reliable, and affordable manner. Research and development as well as an energy strategy that created a market for renewable energy have been used to achieve this. The technology of wind turbines has progressed in a number of ways. More wind energy may be captured through better rotor blade profiles, more advanced and inexpensive control systems, and new power electronic equipment that enables variable speed operation and capacity optimization of the turbines.

Due to wind shear and a diminishing gravitational force, wind speed often increases with height. The cost of energy harvested from a wind turbine decreases as hub height and rotor diameter are raised due to higher wind speeds and rotor swept areas. Nevertheless, structural concerns, the size of the blade and nacelle unit, the transportation of exceptionally large items to the potential location, technical installation constraints, and material stability restrictions limit the hub height and rotor diameter. On the other hand, the increasing demand for electricity calls for effective wind turbines that abide by the aforementioned restrictions. Thus, efforts are concentrated on improving the design of the turbine blades and developing new, lighter, and more durable materials to increase the performance of wind turbines and, subsequently, the energy output

1.6 CHARACTERICTICS OF WIND TURBINE:

1.6.1 WIND SPEED:

This is very important to the productivity of a windmill. The wind turbine only generates power with the wind. The wind rotates the axis and causes the shaft on generator to sweep past the magnetic coils creating an electric current

1.6.2 BLADE LENGTH:

The length of blade is directly proportional to the swept area. Larger blades have greater swept area and thus catch more wind with each revolution. Because of this, they may also have more torque.

1.6.3 BASE HEIGHT:

The height of the base affects the windmill immensely. The higher a windmill is, the more productive it will be due to the fact that as the altitude increases so does the wind speeds

1.6.4 BASE DESIGN:

Some base is stronger than others. Base is important in the construction of the wind mill because not only do they have to support the windmill, but they must also be subject to own weight and the drag of the wind. If a weak tower is subject to these elements, then it will surely collapse.

1.7 OBJECTIVE :

The proposed project is significant since the Green energy (electrical power) can be extracted from wind flow. An international survey of Green Energy predicts that this type of energy would be extracted more in future say up to the year 2050 using free flow helical turbines. Also, Mission Innovation (MI) countries of which India is a member is interested in providing 100% Green energy by 2050, which is expected to reduce the pollution levels. This present research project would be the prelude for such developments.

1. The main objective of the project is to produce renewable energy power that homes and businesses can utilize.

2. Wind turbines can also help offset the use of fossil fuels, such as coal and natural gas, used to generate electricity.

3. The long-term objective of the project is to help reduce the greenhouse gas emissions contributing to climate change.

4. Wind energy is a clean and renewable resource that does not emit carbon dioxide or other pollutants when it is generated.

5. By using wind turbines to generate electricity, we can help reduce our reliance on fossil fuels and positively impact the environment.

Developing and applying technical principles, such as learning about wind energy and various methods of turning it into usable power and also to learn the impact of energy & our rules as engineering students to provide is the goal of this project.

1.8 TYPES OF WIND TURBINES:

Around the world, there are numerous types of wind turbines in use. Some of them are Horizontal Axis Wind Turbine (HAWT), Small Wind Turbines, Vertical Axis Wind Turbines (VAWT), Diffuser Augmented Wind Turbines, Counter-Rotating Wind Turbines, Airborne Wind Turbines.

1.8.1 HORIZONTAL AXIS WIND TURBINE:

HAWT is composed of blades that rotate on a horizontal axis while being parallel to the ground and capturing wind energy. When the blades are directed perpendicular to the wind flow, aerodynamic lift drives their rotation and operation. Due to its major advantages over VAWT, HAWT is the most widely used type of wind turbine and has received more funding for research and development.

1.8.2 SMALL WIND TURBINES:

For local use, small wind turbines are typically chosen. They are typically installed in isolated, rural, and off-grid places where there is no connection to the national grid and have a production capacity of less than 100 KW.

1.8.3 VERTICAL AXIS WIND TURBINES:

VAWT revolve around the vertical axis and perpendicular to the ground. This type of turbine uses lift, drag, or a combination of the two to operate. There are typically two basic VAWT designs, and each design operates according to a different set of principles. The first design is by Savonius, which turns the turbine using drag forces similar to a water wheel, while the second is by Darrieus, which turns the turbine using aerodynamic blades.

1.8.4 DIFFUSER AUGMENTED WIND TURBINES:

Difminer Augmented Wind Turbines (DAWT) are a form of wind turbines that have been optimised and employ a diffuser to speed up and direct air flow onto the rotor of the wind turbine to operate it at greater rpm and power output than they would be able to without it. Usually, the power augmentation is used to rate this power output.

1.8.5 COUNTER-ROTATING WIND TURBINE:

A counter-rotating wind turbine (CRWT) is a device that consists of two rotors that are spaced apart appropriately. The two rotors alternately rotate in clockwise and anticlockwise directions.

1.8.6 AIRBORNE WIND TURBINES:

In order to reach higher altitudes, where the wind is typically stronger and more persistent, airborne wind energy (AWE) systems use tethered flying objects.

1.9 MAGNUS WIND TURBINE:

There are a number of issues with the conventional blade turbines now in use. The biggest drawback is their poor performance at the greatest reproducible wind speeds. Magnus force generates lift force with amazing results, leading to its utilisation. One use entails swapping the airfoil-shaped blades of the wind turbine for rotating cylinder blades. It is known as a Magnus Wind Turbine and produces lift force on a rotating cylinder that is parallel to the incoming wind flows (MWT). due to the threats to the health of both people and the earth that continued consumption of fossil fuels, natural gas, and coal poses. In order to overcome this problem, MWT is one of the innovative ways to capture low wind energy.

Use of the Magnus effect to generate lift from rotating cylinders in various engineering applications has been one of the more intrigiving ideas. It is essential to precisely measure the power output and offier features of generators

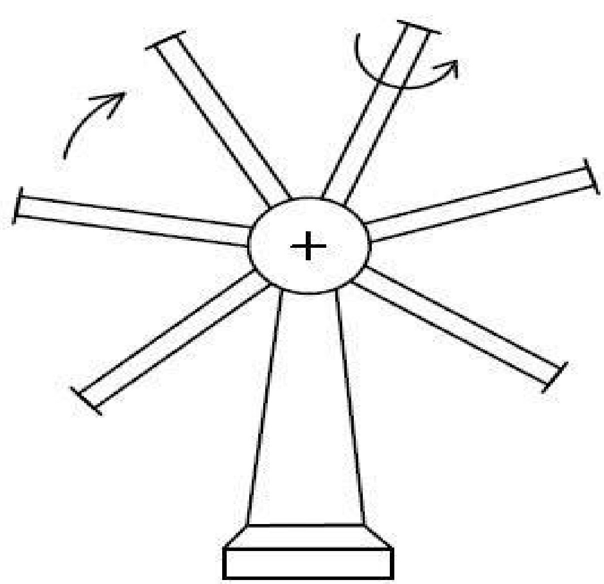


Fig. 2 Horizontal axis Magnus wind turbine

1.10 MAGNUS EFFECT:

A spinning body submerged in a flow stream encounters a lift force in addition to the anticipated drag force is called Magnus effect. The rotating axis and the direction of free stream velocity are both perpendicular to the lift force. In honour of Heinrich Gustav Magnus (1802-1870), who conducted the first investigation of these phenomena în 1851, this effect was given his name. A spinning body moving in fluid can be greatly affected by the Magnus effect. It is what causes the trajectory of rotating projectiles and sports balls, such as footballs, golf balls, and baseballs, to deviate. [7]. The Magnus effect is an observable phenomenon that is commonly associated with a spinning object moving through a fluid. The path of the spinning object is deflected in a manner that is not present when the object is not spinning. The deflection can be explained by the difference in pressure of the fluid on opposite sides of the spinning object. The Magnus effect is dependent on the speed of rotation. The Magnus force is used to rotate the blades of the Magnus wind turbine. Instead of using conventional horizontal axis wind turbine blades, a Magnus wind turbine is equipped with rotating cylinders, which rotate around their own axes according to the principle of the Magnus effect

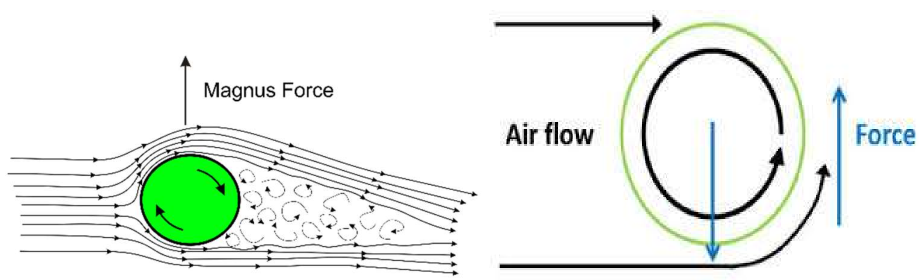


Fig. 3 Magnus effect

CHAPTER – 2

LITERATURE SURVEY

- **Nazgul K. Tanasheva et al** conducted a study on an improved Magnus wind turbine by first designing a two-bladed turbine with cylindrical blades and adding a deflector to enhance airflow and eliminate the need for an electric drive. They created a 3D model using COMPASS 3D, dividing the workspace into three subdomains for simulation. Using Ansys Meshing, they generated a computational grid with 375,650 cells and set boundary conditions like air flow speeds (3 to 15 m/s). Numerical simulations were performed in Ansys Fluent, solving Reynolds-averaged Navier-Stokes equations with the Realizable k-ε turbulence model. They analyzed airflow, pressure, drag, and thrust at speeds of 5, 10, and 15 m/s to assess performance. Experimental tests in a T-1-M wind tunnel validated the simulation results. The study found a 20% higher power coefficient (Cp = 0.24) compared to traditional Magnus turbines, confirming the deflector's effectiveness.

- **NM Bychkov et al** in his study on Magnus wind turbines as an alternative to the blade ones conducted experiments and calculated data about a wind turbine that uses revolving cylinders rather than regular blades. In comparison to those of blade wind turbines, optimal parameters and the associated operational properties of the wind wheel are provided. It is concluded that the number of rotating cylinders equal to 6 with their aspect ratio of 15 is the best suitable for the WT design. The Magnus WT is most advantageous in the wind speed range V<8 m/s where the wind wheel power and wind velocity repetition are nearly at their maximums and the blade turbines are significantly less efficient.

- **Ainura Dyusembaeva et al** designed a three-bladed Magnus wind turbine with cylindrical and fixed blades using Design Modeler and 3D COMPASS, testing fixed blade angles (0° to 60°). They simulated airflow in Ansys Fluent 19.2 with the realisable k-ε turbulence model, using a 785,452-cell grid. Wind speeds of 5, 10, and 15 m/s and blade speeds of 300, 500, and 700 rpm were analyzed. The study found a maximum power coefficient (Cp) of 0.28 at a speed coefficient of 4.9. A 0° fixed blade angle increased efficiency by 35-40%, optimizing performance.

- **O.F. Marzuki et al** review horizontal-axis Magnus Wind Turbines (MWTs), which use rotating cylindrical blades to generate lift at low wind speeds, outperforming airfoil turbines. Surface enhancements like spiral fins, dimples, or sandpaper roughness boost torque up to five times, with fins doubling lift. Bychkov's six-bladed MWT (aspect ratio 15) and Murakami's five-bladed spiral MWT excel in low wind conditions. Innovations include the Chiral Rotor for hydroelectricity and solar-enhanced cylinders. Further research on blade number and surface roughness is needed.

- **Aleksandr Lukin et al** investigate simulation models for small Magnus Wind Turbines (MWTs) with two cylindrical blades (575×125 mm, 2 kW max power), designed for low wind speeds (2–8 m/s). Using Blade Element Momentum theory, they compare three models—analytical, regression, and correlation—to estimate the power coefficient (Cp). The analytical model, achieving a maximum Cp of 0.569, proved most accurate against experimental data, reaching 23.8 Nm torque at 10 m/s, while regression (Cp 0.247) and correlation (Cp 0.047) models were less accurate due to Reynolds number limitations.

The study emphasizes maximum power point tracking (MPPT) via cylinder speed control, highlighting MWTs' potential for distributed energy systems in low-wind areas, with further research needed for electrical and electromechanical model integration.

- **Ahmed T. Nile et al** analyze small-scale diffuser-augmented wind turbines (DAWTs) with six diffuser configurations, comparing three with and three without inlet nozzles using 2D and 3D CFD simulations. A novel compact flange design reduces drag significantly while maintaining output, unlike traditional flat flanges. Inlet nozzles boost the power coefficient (Cp) by up to 2.5 times in 2D at C_load=0.2, with 3D showing smaller gains (e.g., 11–83% per Ohya et al. at 12.3–16.6 m/s). At λ=3, nozzles lower drag in 3D due to a stronger low-pressure region. Nozzles improve performance in yawed flow but have minimal impact in straight flow (3% Cp difference). Cost analysis suggests higher initial costs with nozzles, offset by performance, though data is limited. The study validates 2D simulations for drag trends and highlights DAWTs' potential for low-wind urban areas, recommending further experimental and cost studies.

- **Galina L. Demidova et al** in his work on Magnus Wind Turbine: Finite Element Analysis and Control System describes a two-blade Magnus wind turbine with embedded motors that rotates its cylinder Finite element analysis is used to establish the ideal ratio between the wind speed and the cylinder rotation speed in order to prevent a von Karman vortex street effect that happens when the cylinders rotate in the air flow and to provide maximum power.

- **R. Mdouki et al** in his Parametric Study of Magnus Wind Turbine with Spiral Fins using BEM Approach uses The Blade Element Momentum BEM analysis method to analyse the configuration of spinning cylinders with spiral fins using experimental lift coefficient data. Losses are not taken into account in this analysis. With this kind of wind turbine, axial and angular interference coefficients are assessed. The former is determined by solving aquadratic equation, and the latter is determined using a traditional formulation that includes the spinning factor.

- **Ogretim et al** proposed a new wind turbine design using spinning cylinders based on the Magnus effect. This setup improves aerodynamic efficiency and replaces traditional blades. The cylindrical surfaces are also fitted with solar panels, creating a hybrid wind-solar system. Analytical models were developed to estimate power output and optimize performance. Results show the design can reach near Betz limit and perform well at low wind speeds. The system can produce 24–35% more power than conventional turbines. Solar panels add about 30% efficiency of a flat panel, helping power the rotating cylinders.

- **Ueki et al** studied how different fin shapes on a rotating cylinder affect lift in Magnus wind turbines. They tested three models: no fins, straight fins, and spiral fins in a wind tunnel. The spiral fin model produced the highest lift, especially at higher rotation speeds. At low speeds, straight and spiral fins performed similarly. Smoke flow tests showed that spiral fins kept the airflow closer to the cylinder, improving lift. They found that the vortex behaviour caused by fin shape directly influences lift generation. The results suggest that spiral fins are best for improving performance in low-wind conditions.

- **Zhang et al** reviewed how CFD is used to study floating offshore wind turbines (FOWTs).They explained how CFD helps analyze both water (hydrodynamics) and air (aerodynamics) flow around FOWTs. Different CFD software (open-source and commercial) and modeling methods were compared. The paper discusses popular FOWT platforms like spar, semi-submersible, TLP, and barge types. It also highlights the importance of CFD in understanding complex forces like wave and wind impacts. The study identifies challenges in simulating large structures and how scale effects matter. It concludes that CFD is essential for designing safe and efficient next-generation floating wind turbines.

- **Tanasheva et al** conducted a numerical study to optimize Magnus wind turbine blades by adding fixed blades to cylindrical ones to improve efficiency. Published in *CFD Letters* (2025), the research used Ansys Fluent with the Realizable k-ε turbulence model to analyze airflow around a two-bladed turbine. The fixed blade's angle was varied from 0° to 60°, finding that 0° is optimal, minimizing drag (1.48 at Re=1·10^4) and maximizing torque (26 Nm at 15 m/s, 700 rpm). Vortex formation increased with higher angles, reducing lift and efficiency. The study highlights that a 0° fixed blade reduces aerodynamic losses, enhancing turbine performance. Results align with prior research but show a 29% error compared to experimental data due to smaller blade size. This work aids in designing more efficient Magnus wind turbines for low wind speeds.

CHAPTER – 3

DESIGN, FABRICATION AND TESTING

3.1 DESIGN:

Mechanical design is a crucial aspect of mechanical engineering services, Mechanical design is more than just the application of technical knowledge, it's an art form that blends creativity with precision. At its core, this design involves translating conceptual ideas into tangible solutions, whether it's designing cutting-edge automotive engines or optimizing manufacturing processes. This marriage of innovation and meticulous planning forms the bedrock of modern engineering.

Mechanical design encompasses a wide array of disciplines, from structural analysis and thermodynamics to fluid mechanics and materials science. By leveraging scientific principles and engineering methodologies, mechanical designers and engineers can develop innovative engineering solutions to complex problems, driving progress and innovation across diverse industries.

There are 7 phase in the process of design used product lifecycle management they are

- Conceptualization
- Drafting
- Modelling
- Analysis
- Visualization
- Documentation
- Collabration

3.1.1 TURBINE BLADE:

The blade is modelled according to the dimensions using "Siemens NX" software.

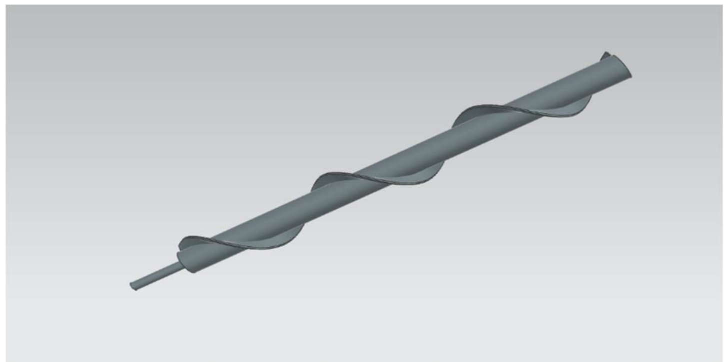


Fig.4 Model of blade

3.1.2 HUB

The hub of the turbine is modelled by using "Siemens NX" according to the dimensions.

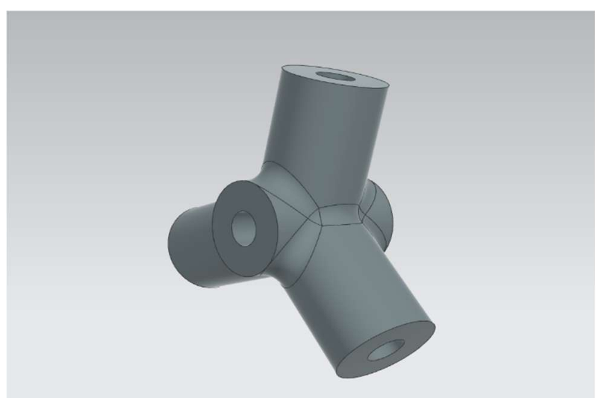


Fig 5 Model of Hub

3.1.3 TURBINE BASE:

This base is designed or modelled according to the required dimensions using " Siemens NX" software

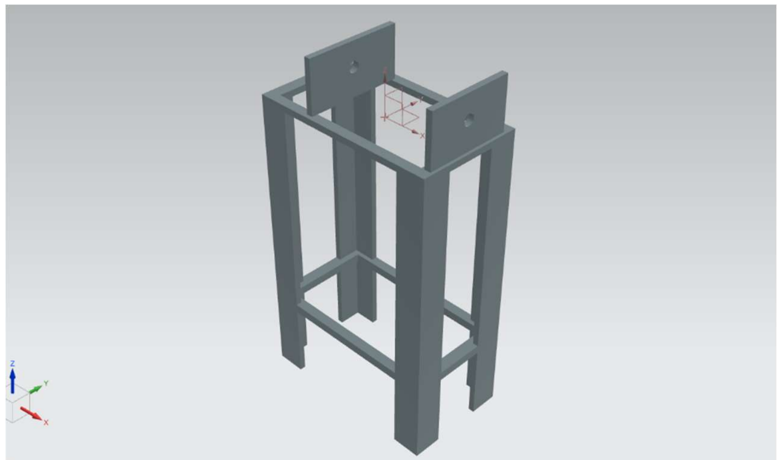


Fig. 6 Model of base

3.1.4 SHAFT

The shaft is designed according to the dimensions using "Siemens NX" software

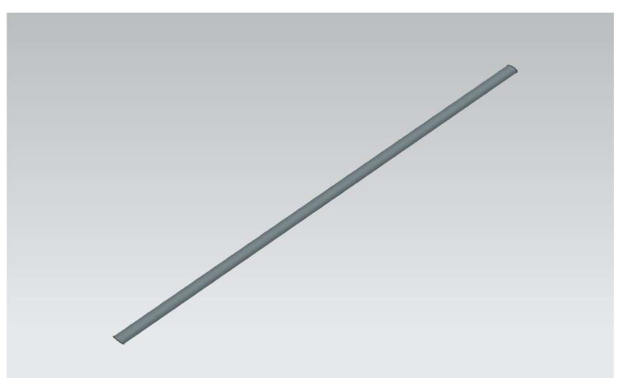
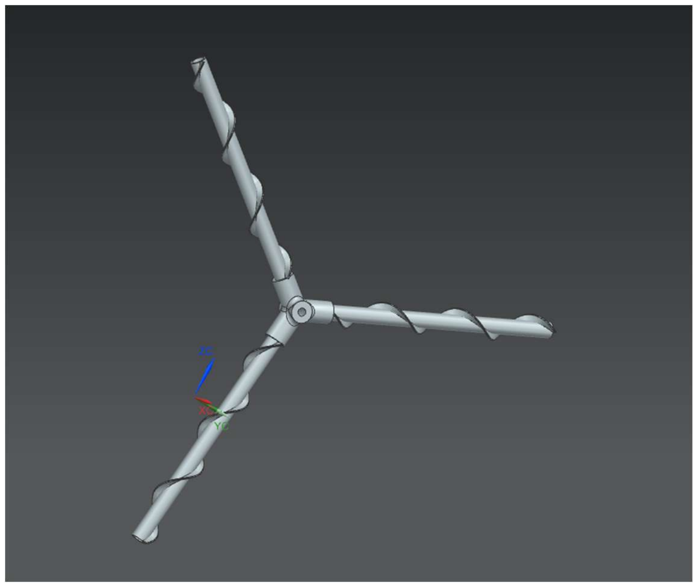


Fig 7 Model of shaft

3.1.5 ASSEMBLY

The frame is kept as base and all other parts such as shaft, bearings, blades are assembled according to the required model.



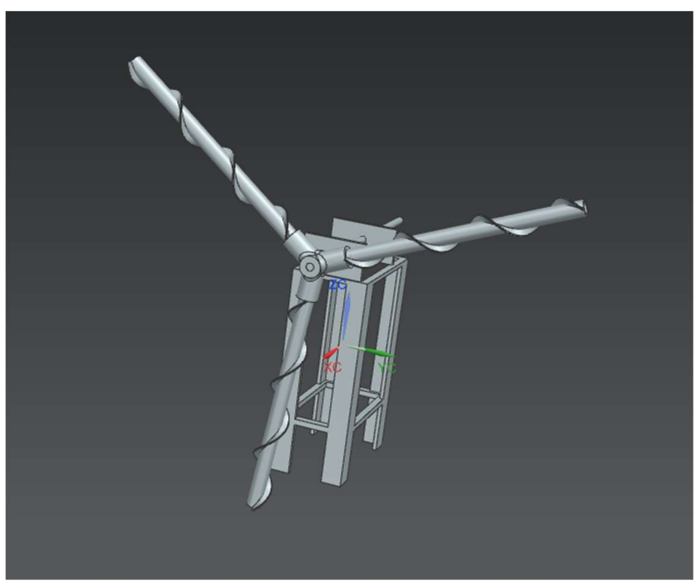


Fig. 8 Assembly drawing of HAMWT

3.1.6 SOFTWARE USED:

For this project, Siemens NX software was used for both part design and assembly modeling. NX is a powerful CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), and CAE (Computer-Aided Engineering) software suite widely used in the mechanical and automotive industries. It provides advanced tools for creating precise 3D models, detailed part designs, and complex assemblies. The software enabled the efficient creation, visualization, and simulation of components, ensuring accurate fit and function within the assembled product. NX's integrated environment significantly streamlined the design-to-manufacture workflow, enhancing overall project productivity and quality.

3.1.7 DESIGN CALCULATION:

The wind turbine works on the principle of converting kinetic energy of the wind to mechanical energy. The kinetic energy of any component is given by,

$K.E=\frac{1}{2}mv^2$

Where m, mass = volume × density.

$m= \rho Av$

V, velocity of wind in m/s.

The power of the wind turbine can be calculated by, $P= \frac{1}{2}\rho AV^3$

For 100 Watt power, calculating the design parameters of turbine,

$P= \frac{1}{2}\rho AV^3$

V, assuming wind velocity 5 m/s

ρ, Density of air (1.225 kg/m3)

$P= \frac{1}{2}\rho AV^3$

$100 = \frac{1}{2} \times 1.125 \times A \times (5)^3$

On solving the above equation, $A= 1.422\ m^2$

Diameter of shaft, d = 25mm

3.3 CFD ANALAYSIS:

After the completion of assembly of the horizontal axis magnus wind turbine, the components mainly the turbine blade with spirals is simulated and analyzed for various parameters. The sequence of analyses done are listed below

3.1.3 GEOMETRY FORMATION:

The CAD model is first created in Siemens NX, where the rotating blade and surrounding fluid domain are designed and exported in a format like STEP or Parasolid. This file is imported into ANSYS Workbench and optionally cleaned in Space Claim, where named selections (inlet, outlet, wall, blade wall) and interfaces (contact regions) are defined. The geometry is then meshed with proper refinement near the blade and interfaces between rotating and stationary zones. In ANSYS Fluent, solver settings, material properties (e.g., air), and boundary conditions are applied. The rotating zone is modeled using a Moving Reference Frame (MRF) or Sliding Mesh method. Mesh, physics, and solution reports are enabled, as seen in the image. This setup allows CFD analysis of rotating machinery inside a defined fluid domain.

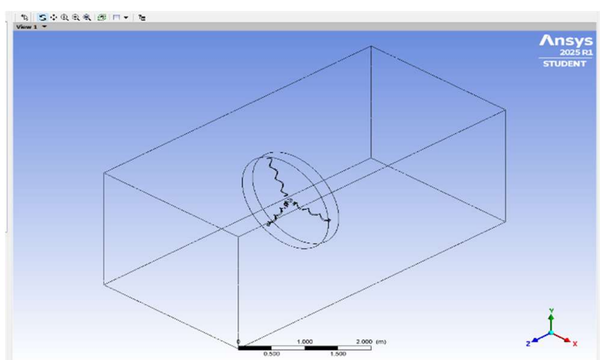


Fig.16 Geometry formation

3.3.2 MESH FORMATION:

This image shows the computational domain and mesh setup, including rotating and stationary zones. It is essential for understanding boundary conditions and mesh density. A fine mesh near the cylinder ensures accurate capture of boundary layer effects, while a coarser mesh in the far field reduces computational cost. The mesh quality directly impacts the accuracy of the results.

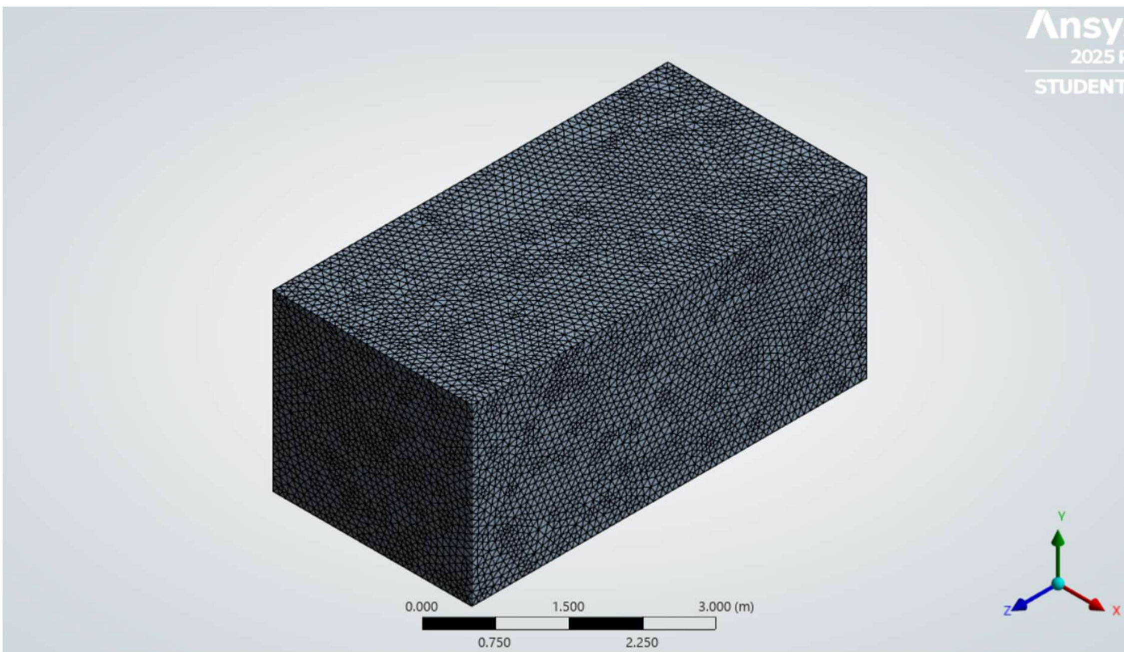


Fig.17 Mesh formation

3.3.3 VELOCITY COUNTOUR:

The velocity contour clearly shows high-speed flow on one side of the rotating Magnus cylinder and low-speed flow on the other. This asymmetry is caused by the Magnus effect, where rotation adds to the flow velocity on one side and subtracts from it on the other. The resulting velocity gradient confirms the creation of lift-like forces, which drive the rotor's motion.

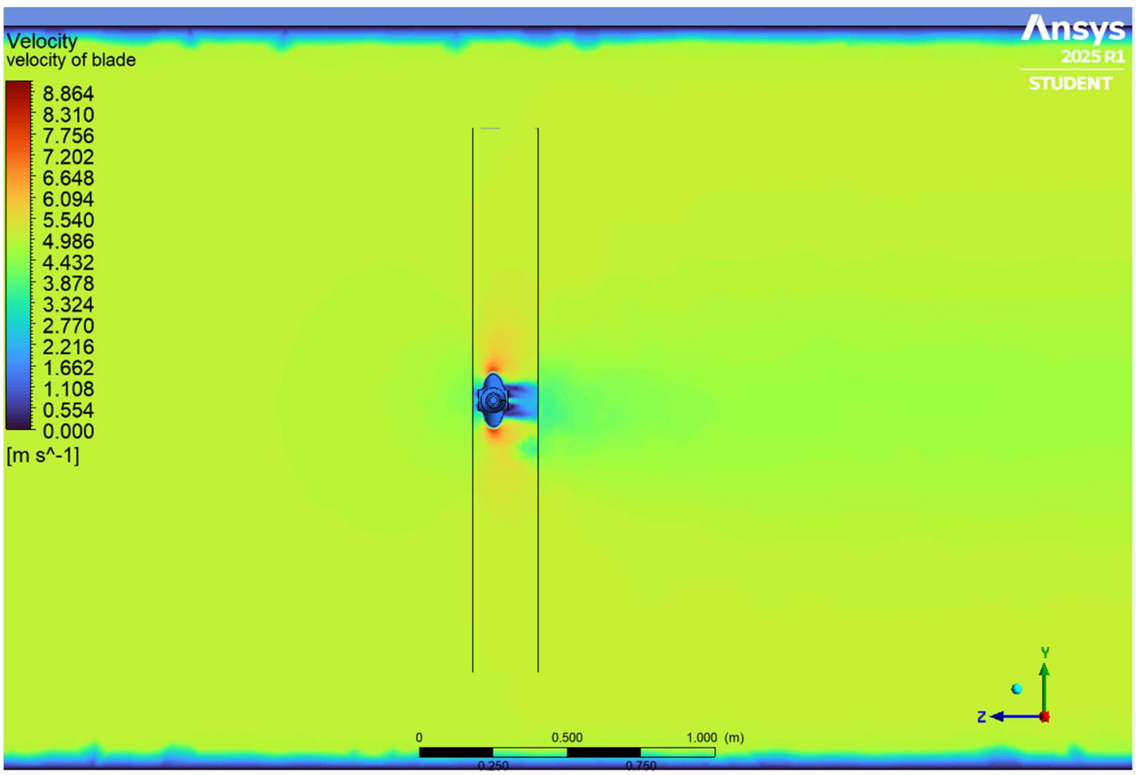


Fig.18 Velocity contour

3.3.4 PRESSURE CONTOUR:

The pressure distribution shows a low-pressure zone on the side where rotation and airflow align and a high-pressure zone on the opposite side. This pressure difference is the driving mechanism for torque generation in a Magnus-effect rotor. These contours validate the lift-producing nature of the rotating cylinder, a key principle in this type of turbine.

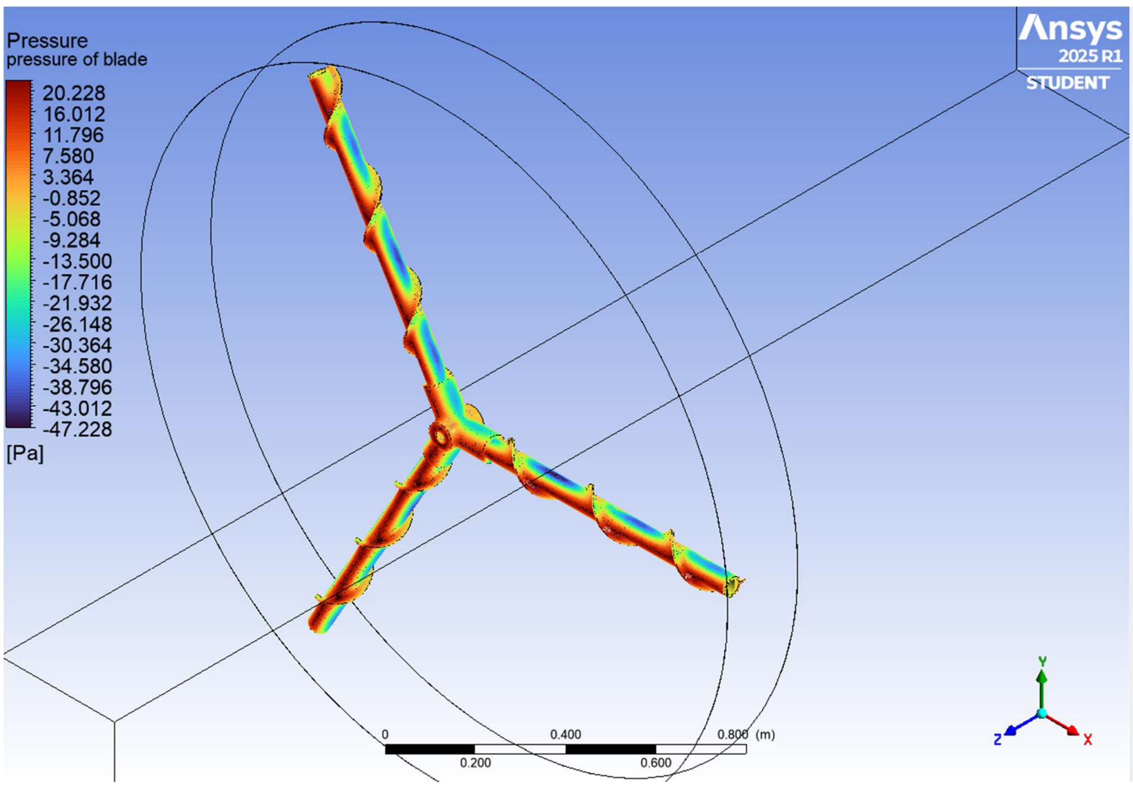


Fig.19 Pressure contour

3.3.5 WALL SHEAR VECTOR:

vector plots illustrate the actual flow path of air around the rotating body. The bending and deflection of streamlines indicate circulation induced by the Magnus effect. This circulation causes the airflow to wrap around the rotor differently on each side, leading to torque. These visuals help us understand how flow separation and reattachment contribute to turbine performance.

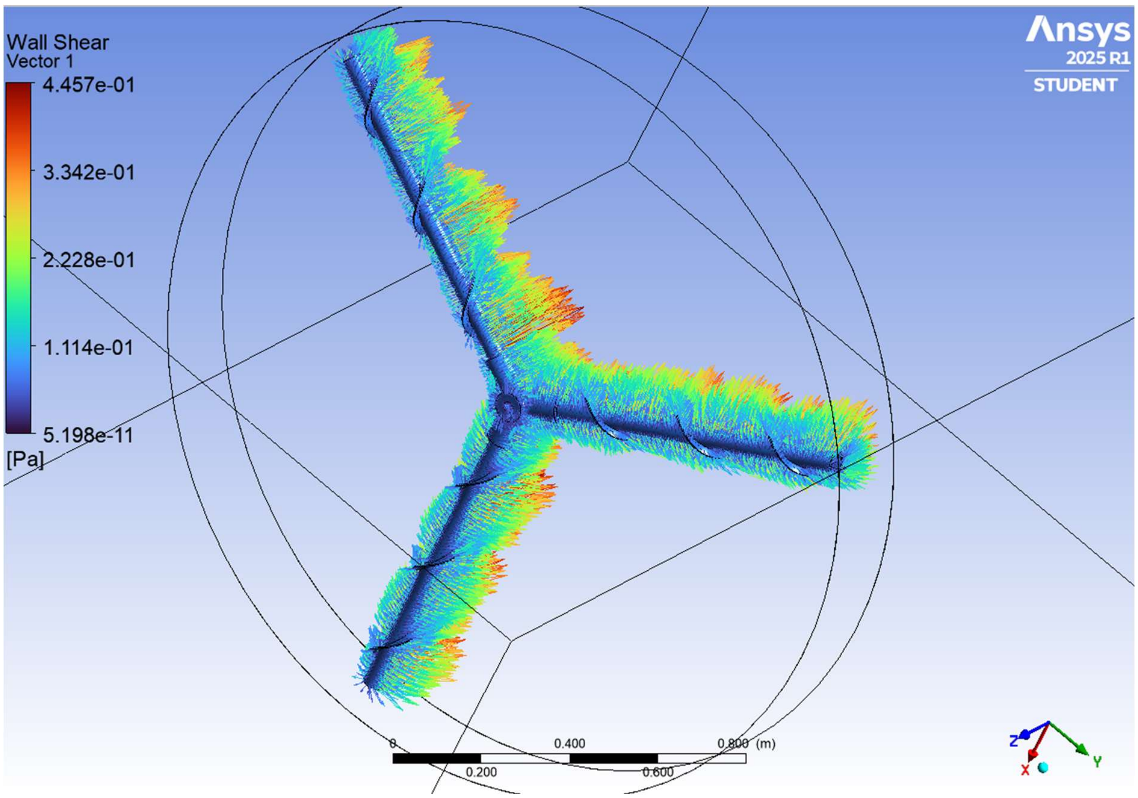


Fig.20 Wall shear vector

3.3.6 RESIDUAL PLOT:

The residual plot shows the solution's convergence behavior over time. All key residuals (continuity, momentum, and turbulence quantities) dropped below the recommended threshold (typically 10^-3 or 10^-6). This assures that the simulation reached a numerically stable solution, enhancing the credibility of the torque and pressure results.

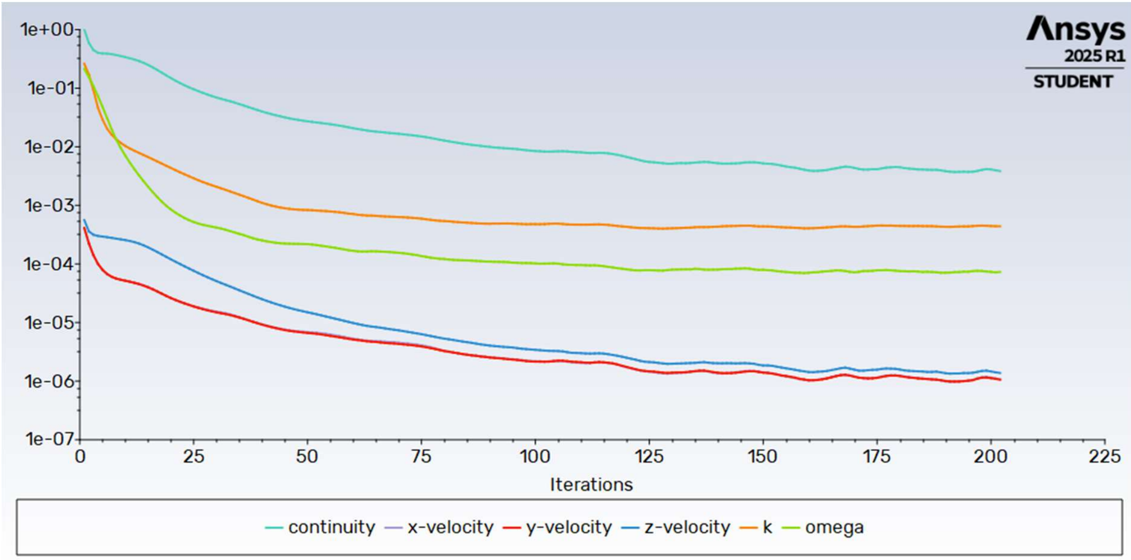


Fig.21 Residual plot

3.2 FABRICATION:

A Magnus wind turbine is fabricated in this project and tested for its performance by varying the number of blades. The components of the Magnus wind turbine are as follows:

- Turbine blade
- Turbine base
- Hub
- Bearings
- Shaft
- Permanent magnet generator

The Fabrication includes welding, cutting, bending, machining of components and assembling in proper order so as to get the output we desired. The various components are fabricated one by one and finally all the components are assembled to get the final model. The image of the final model is shown in the fig 15.

3.2.1 TURBINE BLADE:

Turbine blades are the most important component of a wind turbine. The design of the individual blades also affects the overall design of the rotor. Rotor blades take the energy out of the wind; they capture the wind and convert its kinetic energy into the rotation of the hub. As this turbine works on the principle of Magnus effect, a surface roughness is required on the blade. So, a spiral profile is created on the outer surface of each cylindrical blade as shown on fig 2. A total of three blades are used in this project. The cylindrical blade is made up of Polyvinyl Chloride (PVC) which is a widely used polymer. While the plasticized version holds various uses across multiple industries, the rigid version of PVC also has its share of uses. Industries such as plumbing, sewage, and agriculture can utilize rigid PVC across many functions. Due to its versatility, PVC is widely utilised in a variety of industrial, technical, and everyday applications. The spiral profile on the outside surface of the blade is made up of Fibre-reinforced plastic (FRP); also called fibre-reinforced polymer, is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass (in fibreglass), carbon (in carbon-fibre-reinforced polymer), aramid, or basalt. Rarely, other fibres such as paper, wood, boron, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic, though phenol formaldehyde resins are still in use. Totally three number of blades are used. The end of each blade is connected to 18 mm shaft which will be connected with the hub.

1.	Blade length	750mm
2.	Blade diameter	50mm
3.	Blade diameter with spiral	90mm
4.	Pitch of the spiral	90mm

Table 1 Dimensions of turbine blade

Fig. 9 Turbine blades

3.2.2 TURBINE BASE:

The base of the turbine is much important as it provides stability of the turbine. Since the wind flows at higher speed, it is important for a turbine to be strong and it is provided by the base which helps to increase the efficiency of the turbine. In this project, the base is made up of mild steel. The base built in this project is a tapering structure with a firm upper base as shown in fig 10 where the hub and the generator are mounted.

1.	Total height of base	1270 mm
2.	Width at top of base	460 mm
3.	Length at top of base	260 mm
4.	Width at bottom of base	460 mm
5.	Length at bottom of base	520 mm

Table 2 Dimensions of the base

3.2.3 HUB:

The part that typically holds the blades and attaches them to the wind turbines main shaft is called the rotor hub. The rotor hub is the component that usually holds the blades and connects them to the main shaft of the wind machine. It is a key component not only because it holds the blades in their proper position for maximum aerodynamic efficiency, it also rotates to drive the generator. Hubs come in many different shapes and configurations, mostly dependent on the type of generator used and the design of the rotor blades. The hub consists of the bearings in which the shaft and the turbine blades are connected.

Fig. 11 Front view of hub with bearing

3.2.4 BEARINGS:

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts. The bearing used in this project is SKF Bearing. The image of bearing attached with the hub is already shown in the fig 6. The diameter of the bearing in which the blades are connected are of used is 25 mm. It is same as the diameter of the base part of the turbine blade so that it can be fixed properly. Totally 6 bearings are used in this project. The shaft is connected to one pillow block bearing and an 18 mm bearing.

3.2.5 SHAFT:

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another. A shaft is the most central part of a wind turbine, subjected to highly dynamic loads and operating conditions. The energy from wind is converted into mechanical energy with the help of blades and rotors, which is then transferred to a generator through the shaft. It is essentially an item that is used in machine designed for producing continuous power. The system it is used in basically extracts energy from a fluid flow and then converts it into a usable form or medium. In this turbine the shaft is made up of mild steel. The shaft connects the hub and the generator. One end is fixed to the hub and the other with the generator. The view of shaft is shown in fig 13.The wind turbine generally consists of two types of shaft i.e.main shaft and generator shaft. The main shaft is a low speed shaft with the turbine rotor bolted through a strong disc. The generator shaft is a high speed shaft

1.	Diameter of the shaft	25 mm
2.	Length of the shaft	850 mm

Table 3 dimensions of shaft

Fig. 13 Top view of shaft

3.2.6 PERMANENT MAGNET GENERATOR:

Permanent magnet generators are devices that convert mechanical movements to electricity using their own magnetic fields. These devices are commonly used in wind turbines, steam turbines, gas turbines, and engines to create electrical power. The most significant feature of these generators is that they do not require extra current supply. Such apparatus employs the intrinsic magnetism generated by permanent magnets. We chose generator made up of neodymium permanent magnets. Permanent magnet generators do not need any special operating environments. Hence, they can offer reliable performance compared with wind turbine motors.

Additionally, permanent magnet generators do not suffer from energy loss, while induction generators typically lose 20-30% of energy. Additionally, there are no temperature rises in the magnetic machines, so the life of the bearings can be prolonged. Compared with induction generators, permanent magnet generators could produce reliable electricity with a free energy source and lower maintenance fees. Residual magnetic flux in the iron poles produces a small generated voltage as the machine is brought up to speed. This causes a field current that increases the flux and in turns the generated voltage. The voltage builds up until saturation in the iron limits the voltage produced.

Fig. 14 Permanent magnet generator

The PMG of such specification are selected and used for high power output that can be taken out from the Magnus turbines so as to reach the maximum efficiency.

3.2.7 SPECIFICATION OF PMG:

Sl. No.	Description	Parameter
01.	Rated Power	0.2 KW
02.	RPM	200
03.	Number of Pole	30 Pole
04.	Rated Voltage	12Volts (Three-Phase)
05.	Power Factor	0.9
06.	Rated Amp	10.6 Amps
07.	Frequency	50 Hz
08.	Insulation Class	H Class
09.	Working Temperature	-30º C to 80º C
10.	Starting Torque	0.1 NM
11.	Rated Torque	9.1 NM
12.	Magnet Type	Neodymium (NdFeB)
13.	Warranty	24 Months
14.	Type	Radial Flux Foot Mounting
15.	Generator shell material	Cast Iron
16.	Winding material	100% Copper
17.	Shaft material	EN8
18.	Bearing Brand	SKF
19.	Efficiency	More than 90%
20.	Protection	IP54

TABLE 4 SPECIFICATION

3.2.8 FINAL MODEL:

Fig.15 Horizontal axis Magnus wind turbine

COST ESTIMATION

3.2.9 RAW MATERIAL COST:

S.NO	MATERIAL	COST in Rs
1.	M.S shaft (25 mm)	1500
2.	PP rod (18mm)	1000
3.	L angle (50×50 mm)	3000
4.	Ball bearing (6)	2000
5.	PVC tubes	2400
6.	Flange bearing(25mm)	1800
7.	FRP	1600
8.	Aluminum rod	1500
9.	CNC M.S plate	2850
10.	Bolts and Nuts	1800
TOTAL		19,450

Table 5 Raw Material cost

3.2.10 FABRICATION COST:

S.NO	MACHINING	COST in Rs
1.	Cutting & drilling	3200
2..	PP rod fabrication	1500
3.	Aluminum rod hub machining and drilling	2500
4.	PVC Tubes helical cutting	1800
5.	Welding	5000
6.	Lathe works	3000
TOTAL		17,000

Table 8 Fabrication cost

3.2.11 ELECTRONIC COMPONENET COST :

S.NO	COMPONENTS	COST in Rs
1.	Anemometer	1530
2.	Tachometer	1180
3.	Multimeter	700
4.	Permanent Magnet Generator	29,850
TOTAL		33,260

Table 9 Electronic components cost

3.2.12 TOTAL COST:

1.	Raw material cost	19,450
2.	Fabrication cost	17,000
3.	Component cost	32,260
4.	Overhead cost	2000
TOTAL		70,710

Table 10 Total cost

3.4 TESTING & RESULTS:

3.4.1 INTRODUCTION TO TESTING

To evaluate the performance of the horizontal axis Magnus effect wind turbine, open field testing was conducted under real-world wind conditions. The primary objective of the testing phase was to validate the turbine's ability to generate electrical power using the Magnus effect and to assess its response to varying wind speeds and directions.

3.4.2. TEST SETUP

The turbine was installed in an open field environment to ensure exposure to unobstructed wind flow. The following instruments were used during the testing:

- **Tachometer** – To measure the rotational speed (RPM) of the turbine rotor.
- **Anemometer** – To record the wind speed and direction during the tests.
- **Voltmeter** – To measure the DC voltage output from the power generation unit (PGU).

3.4.3. TESTING PROCEDURE

1. The wind turbine was set up in an open field with a clear flow of wind.
2. Initial no-load tests were conducted to observe rotor behavior and baseline rotational speed under varying wind speeds.
3. Subsequent tests were performed with the generator connected to measure the electrical output.
4. Wind speed was continuously monitored using the anemometer.
5. The tachometer was used to measure RPM of the rotating Magnus cylinders and turbine shaft.

6. Voltage generated was measured using a voltmeter across the output terminals of the generator.
7. Multiple test sessions were conducted at different times of the day to account for changes in wind speed and direction.

3.4.4. OBSERVATIONS AND DATA COLLECTION

Test No.	Wind Speed (m/s)	RPM	Wind Direction	Voltage Output (V)
1	2.8	120	NE	3.2
2	3.5	150	N	4.1
3	4.2	180	NW	5.0
4	5.0	210	NW	6.2
5	3.0	140	NNE	3.8

3.4.5. ANALYSIS OF RESULTS

- A clear correlation was observed between wind speed and turbine RPM. As wind speed increased, the Magnus rotors exhibited higher rotational speeds, leading to increased turbine output.
- The turbine responded effectively to wind from multiple directions due to its horizontal axis design.
- The generated voltage showed a proportional increase with RPM, confirming the operational efficiency of the generator coupled with the Magnus turbine.
- The system showed good performance even at relatively low wind speeds (starting from around 2.5 m/s), which indicates the potential of Magnus effect turbines in low-wind regions.

CONCLUSION:

The project titled **"Power Generation from Horizontal Axis Magnus Effect Wind Turbine"** successfully explored and implemented an innovative approach to wind energy generation using the Magnus effect principle. The primary goal was to design, develop, and test a functional prototype capable of generating power efficiently, especially under low to moderate wind conditions.

A comprehensive workflow was followed starting from the conceptualization and design phase. The turbine's design was based on horizontal axis configuration integrated with rotating cylinders to exploit the Magnus effect for lift generation. Detailed **CAD models** were developed to visualize and validate the mechanical structure. These models provided the foundation for further analysis and fabrication.

To evaluate aerodynamic behavior and performance, **Computational Fluid Dynamics (CFD) simulations** were carried out. The CFD results showed enhanced lift generation and stable airflow behavior around the Magnus rotors, confirming the design's suitability for real-world application.

Following the design validation, the prototype was **fabricated** using accessible materials, and a complete **cost estimation** was prepared to ensure the project's affordability and scalability. The assembly process was systematically carried out, ensuring alignment, balance, and smooth rotation of all moving parts.

Finally, the turbine underwent **open field testing** to measure its real-time performance. Using instruments such as a tachometer, anemometer, and voltmeter, data was collected on RPM, wind speed, and voltage output. The testing results validated the working of the Magnus effect turbine and its ability to generate electrical energy consistently.

In conclusion, this project successfully demonstrated the feasibility of a Magnus effect-based wind turbine for sustainable energy generation. The compact design, reliable performance at lower wind speeds, and low manufacturing cost suggest that this technology holds promise for small-scale renewable energy applications. Future work can focus on optimizing rotor design, improving energy conversion efficiency, and integrating storage or grid systems for real-world deployment.