

IMPACT OF THICKNESS AND CHORD LENGTH OF DARRIEUS H-ROTOR WIND TURBINE

submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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DEPARTMENT OF AERONAUTICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC.

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Siva Saravanan. M (40260023)** and **Yugesh. A (40260026)** who carried out the project entitled **"IMPACT OF THICKNESS AND CHORD LENGTH OF DARRIEUS H-ROTOR WIND TURBINE"** under my supervision from November 2023 to April 2024.

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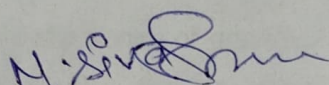
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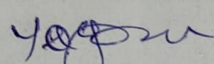
DECLARATION

We **SIVA SARAVANAN M (40260023)** and **YUGESH A (40260026)**, hereby declare that the project report entitled "**IMPACT OF THICKNESS AND CHORD LENGTH OF DARRIEUS H-ROTOR WIND TURBINE**" Done by us under the guidance of **Mr. S . VENKATESH .,M.E .,(Ph.D)** is submitted in partial fulfillment of the requirement for the award of Bachelor of Engineering degree In Aeronautical Engineering.

Date: 14-10-2023

Place: Chennai


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ABSTRACT

The project represents the study that uses Computational Fluid Dynamics (CFD) simulations in ANSYS software to investigate the variations in the thickness and chord length of Darrieus h rotor wind turbine blades which affects the performance and efficiency of the Vertical axis wind turbine. By enhancing the parameters like power output, efficiency, and aerodynamic forces, the study provides the optimization of wind turbine blade design for better performance. The variations in the thickness and chord length of the turbine blades results in the enhancement of efficiency and performance when compared to the horizontal axis wind turbine. The GOE444-il series airfoil is selected and designed in helical shaped blade which can be attached in a wind turbine. Airfoil series is selected for the wind turbine blade to increase its coefficient of lift and decreased coefficient of drag. We verified the performance of vertical axis wind turbine with the variation of its geometric properties by varying its thickness between 18 mm, 20mm, 22 mm and chord length 180mm, 190mm, 200mm. These dimensions are chosen based the dimensions of the wind tunnel test section(600mmx600mmx300mm). The dimensions of the thickness and chord length of the wind turbine is choosed according to the efficiency and performance through CFD software. The selected airfoil blade is attached to the wind turbine model and fixed inside the wind tunnel for testing purposes. The results of the wind turbine have been improved when compared to the other researches on the vertical axis wind turbine.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS	DESCRIPTION
C_L	Coefficient of lift
C_D	Coefficient of drag
C_M	Coefficient of moment
P	Power output
D	Rotor diameter
ρ	Density
A	Swept area
V	Wind velocity
L	lift
r	Rotor radius
AR	Aspect ratio
E	Efficient factor
AOA	Angle of attack
RPM	Rotation per minute
H_F	Manometer
C_P	Coefficient of pressure
P_s	Static pressure
P_t	Total pressure
V_{avg}	Average velocity

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

The Darrieus wind turbine, named in honour of its visionary inventor Georges Darrieus, emerges as a unique member within the vertical-axis wind turbine (VAWT) category. Diverging from its horizontal-axis counterparts, the Darrieus turbine features a vertical orientation, characterized by elegantly curved blades reminiscent of an eggbeater. This distinct design offers a notable advantage, enabling the turbine to effectively harness wind energy from various directions, especially in intricate urban and turbulent wind settings. Central to the aerodynamics of the Darrieus turbine is the lift generated by the asymmetrical aerofoil shape of its rotating blades around a vertical axis. Despite presenting promising advantages, these turbines face challenges such as starting torque, stability issues, and the prominent "stall" problem at elevated wind speeds. In response, a range of innovative designs and modifications have been explored to overcome these hurdles and enhance the overall efficiency of Darrieus wind turbines. In recent times, the domain of Darrieus wind turbines has experienced a notable increase in research and development initiatives. These efforts concentrate on advancing the performance and reliability of Darrieus turbines by integrating state-of-the-art materials, sophisticated control systems, and finely tuned blade designs. The overarching goal is to position vertical-axis wind turbines, including the Darrieus variant, as competitive and viable contributors to the broader field of renewable energy generation.

1.2 TYPES OF WIND TURBINE

Horizontal-axis wind turbines (HAWT) and vertical-axis wind turbines (VAWT) are the two basic types of generating units. HAWTs (horizontal axis wind turbines) are wind generators resemble regular propellers in that their rotors also revolve around the y axis. The much more conventional turbines, or HAWTs, are employed to generate significant amounts of renewable energy. Generators need a structure to be put atop that either elevates the blade or increases renewable power absorption. Vertical axis wind turbines (VAWT) are the generators do not require that they be

oriented straight through into the wind because their motors are running together around a central plane. When there isn't enough room or for producing wind energy on something like a lesser level, VAWTs are frequently employed. Instruments can be positioned farther from the surface while remaining less susceptible to harm during weather. In general, the weather conditions, the size of the installation, and the intended production of renewable energy all determine the kind of power station that is employed.

1.2.1. Horizontal Axis Wind Turbines (HAWT)

The far more prevalent form of generating units is horizontally inclined wind generators (HAWTs), which may have propellers that revolve together around a horizontal plane like those of a conventional engine. Listed below are some essential

HAWT characteristics and modules:

- Rotor blades: small wind turbines feature a shaft with multiple propellers connected to it, though. The spinning shaft will receive the momentum of the wind through the rotors, which are built to do just that.
- Nacelle: The fuselage, which is attached to the structure's base, houses the spinning and transmission. The electromagnetic motor and some other parts that turn the spinning rotor's motion into electrical power are housed in the fuselage.
- Tower: The turbine as well as the fuselage are supported by a high building called the windmill. Considering mostly the platform's weather conditions, HAWTs are quite often erected on structures that have been 60 to 120 meters high.
- Yaw system: The propellers are angled through the airflow using the pitch mechanism. Often, a laptop and an automatic gearbox are used to power it.
- Gearbox: The rotor's rotating velocity is accelerated by the transmission, which also produces additional grid energy. It changes the rotor's moderate angular velocity into the engine's required high rate of motion.
- Generator: The producer transforms the rotor's motion into electricity. Most contemporary generating units employ a converter to create variable-frequency (AC) energy that operates on the electromotive force theory.

HAWTs were made to work in a variety of weather conditions, usually between and 25 m/s. Generators can indeed generate power at lower wind speeds; somewhere between 12 and 14 m/s is when they're most effective. The diameter of the blade, the air velocity, and the effectiveness of something like the generator parts all affect how much electricity a type of motor could generate.

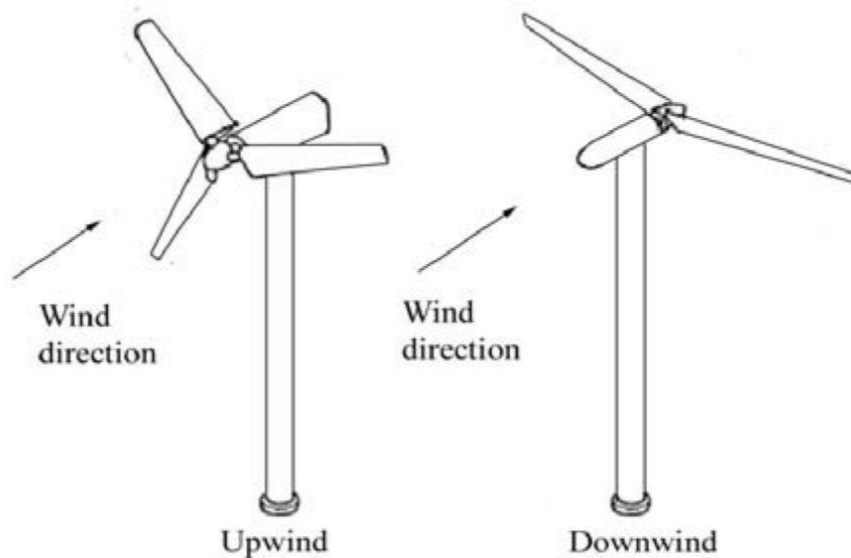


Fig:1.1 : Horizontal axis wind turbine

1.2.1.1. Types Of Horizontal Wind Turbines:

Notably popular kinds of wind generators that are being used currently are horizontally oriented wind power stations (HAWTs). Wings come in a variety of forms, each of which has special benefits and qualities of its own. Some renowned and typical designs of horizontally oriented wind generators are listed below:

- Upwind turbines: During an advection generator, the structure is situated behind the shaft, which confronts the airflow. The far more prevalent turbine is an air flow generator, and air flow generators seem to be typically more effective with downstream rotors.
- Downwind turbines: In a downstream generator, the structure is placed closest to the shaft, which faces the direction of the wind. Despite being less frequent than air flow generators, downstream windmills remain utilized generally throughout windy regions.

- Pitch-controlled turbines: In a harmonically driven generator, the power of the rotation is managed by varying the inclination of something like the propellers. Although this kind of generator is far more effective than a repaired turbine, it's also considerably more costly and intricate.
- Stall-controlled turbines: The rotors of a shaft propeller are intended to malfunction at a specific airspeed. This slows the spinning downward, reducing the risk of damaging the generator in windy conditions.
- Variable-speed turbines: In an electronically controlled windmill, the velocity of the energy produced is changed to regulate the rotor's rotational velocity. Although this kind of propeller seems to be more effective than a repaired jet engine, it is also more costly and complicated.

The option of a rotor could very well depend on several variables, including the weather surroundings, the expense of something like the rotor, and thus the necessary wattage. Also, every form of windmill with a horizontal axis comes with its own distinct benefits and drawbacks.

1.2.1.2. Advantages Of Horizontal Wind Turbines:

The horizontal axis wind turbines (HAWTs) are among the most widely used windfarms being used presently, as they offer several benefits over all other varieties. The following are some of the primary benefits of horizontal axis wind turbines:

- High Efficiency: Because of their outstanding efficiency, small wind turbines could really produce electricity from approximately 50% of the wind's momentum. They make up the most economically advantageous types of clean electricity because they are extremely effective.
- Scalability: Converters come in a variety of sizes, from tiny generators used mostly for private neighborhood or agricultural uses to enormously efficient windmills being used to operate urban areas or sizable factories.
- Proven Technology: Small wind turbines are both proven devices that have been in operation for many years. It also indicates the existence of a substantial body of information and skills that could be tapped into to guarantee the rotors' dependable as well as effective operation.

- Low Maintenance: Small wind turbines are a premium choice for very many industries because of their minimal upkeep. Examining and repairing components like propellers, clutches, and joints are common management chores.
- Compatible with the Grid: Small wind turbines make it simple to combine renewable energy into current energy networks since they may be quickly attached to the main supply.
- Quiet operation: Current Converters are ideal for implementation in domestic as well as urban locations because of their simple construction.
- Environmentally Friendly: Generators are indeed an eco-friendly power source because they create power without emitting any dangerous substances. In comparison to other forms of energy production, like power stations powered by fossil fuels, they additionally have a comparatively small effect upon that neighboring environment.

Ultimately, converters provide an assortment of benefits that already make each other a preferred option for producing wind-powered power generation.

1.2.1.3. Disadvantages Of Horizontal Wind Turbines:

Although horizontally oriented wind turbines (HAWTs) have several benefits, there are a few drawbacks that ought to be considered before deciding whether to use them to make energy. The following constitute a few of the major flaws of horizontal axis wind turbines:

- Wind Dependence: For small wind turbines to produce power, the flow velocity needs to be at least 3-5 m/s. A generator might cease to be capable of generating energy or might have to be shut down in order to prevent destruction if gusts have become too fluctuating.
- Visual Impact: Huge Small wind turbines can indeed be visually bothersome, particularly in beautiful locations. Animals that encounter both the rotors, like bats and bird species, could be affected. Noise: Even though advanced HAWTs have been made to run peacefully, a few real folks still might discover the sounds they generate to really be bothersome, particularly if they are placed near residential neighborhoods.

- **Land Use:** HAWTs require a significant amount of space to operate and can impact land use for farming or other purposes. In addition, the installation of turbines and associated infrastructure can cause disruption to the local environment.
- **High Initial Cost:** Although wings have the potential to be expensive in the grand scheme of things, their manual setup costs and accompanying equipment may be prohibitive for some users.
- **Maintenance:** Small wind turbines could really affect how to utilize property for agriculture and perhaps other activities because they need a great deal of room to function. The surrounding ecology may also be impacted by the deployment of the blades and critical facilities.

Small wind turbines have quite several benefits generally, yet they additionally provide some drawbacks that ought to be examined before deciding on using them to produce wind-generated electrical power.

1.2.2. Vertical Axis Wind Turbine (VAWT)

In contrast to something like a wind turbine's horizontal rotational blade, a vertical axis breeze generator (VAWT) has an inclined propeller. Compared to the horizontal axis wind turbines, converters are often more compact, easier to build, and even more adaptable (HAWTs). These following outlines a few of the essential qualities of wind turbines:

- **Design:** These fans of both VAWT's, for example, turbine is positioned in a helical shape and around the propeller. At every angle of the air can operate the turbines, which have a blade that revolves around a center line.
- **Efficiency:** Because of their reduced ratio of tip velocity and smaller screen resolution, wind turbines almost always have inferior effectiveness in comparison to horizontal axis wind turbines. Yet, turbines can function in heavy winds and make electricity from every wind velocity.
- **Scalability:** Because of their relatively reduced effectiveness and electric production, wind turbines are typically not appropriate for large-scale practical production. Those are particularly perfect for tiny businesses and domestic purposes, nonetheless.

- **Maintenance:** Wind turbines are simpler to operate than horizontal-axis wind turbines because there are fewer components that move. Moreover, devices contain smaller components as well as require less cleaning, which lowers ongoing expenses.
- **Noise:** In comparison to horizontal-axis wind turbines, wind turbines typically generate greater pollution, particularly since they're placed near population centers.
- **Bird-friendly:** Because of their quicker cutting velocity and lesser proportion of tip speed than horizontal axis wind turbines, wind turbines have become less likely to injure raptors as well as other animals.

In general, wind turbines have had several distinctive features that render them appropriate for special purposes. These can function in a variety of circumstances and are perfect for small-business and household applications.

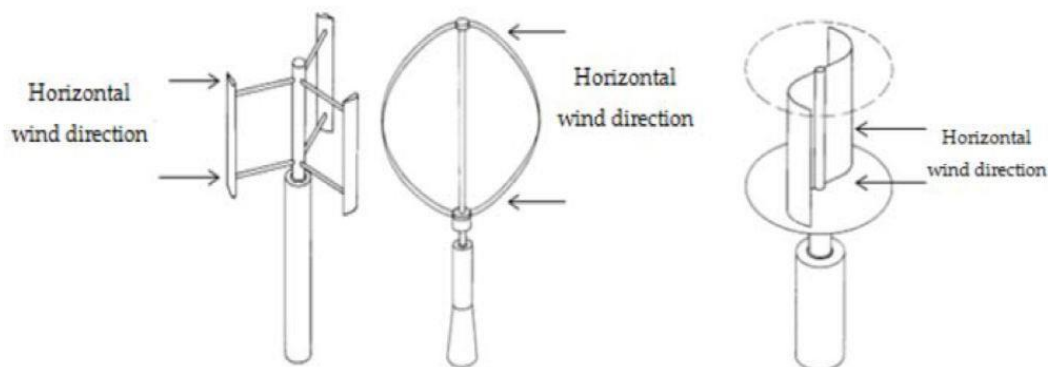


Fig:1.2 : Vertical axis wind turbine

1.2.2.1. Types Of Vertical Axis Wind Turbines:

In contrast to longitudinal orientation rotors, which have a blade shaft that is parallel to the surface of the earth, rotational symmetry generators have a blade shaft that is parallel to the floor. Rotational symmetry rotors come in a variety of designs, including:

- **Darrieus turbine:** This angular displacement generator employs a bending aerodynamic performance to collect the airflow, which makes it a drag variety.

8 Even though it's always less economical than other kinds of wind generators, it's easy and cheap to construct.

- Darrieus turbine: The above angular displacement generator creates a force when the motor runs because it's an elevator generator. However more sophisticated and costly to construct, they're more efficient than other rotary generators.
- Giromill turbine: This angular displacement elevator generator has single blades comparable to horizontally shaft turbines. It also is frequently utilized to produce tiny-scale electricity since it normally does indeed have greater results than the Darrieus and Darrieus rotors.
- H-Rotor turbine: This rotational symmetry elevator generator has two consecutive rotors placed in some kind of "H" pattern. It's more effective with Darrieus rotors and features a smoother surface than Darrieus rotors.
- Vertical axis turbines with multiple blades: There have been numerous types of rotational symmetry rotors that employ numerous linear rotors stacked according to different patterns. The performance of those same rotors, whether they are frictional pressure or elevator, is normally better than that of conventional Darrieus wind generators, yet they may be less economical compared to certain other varieties of rotational symmetry wind generators.

Depending on the exact function, every variation of a vertical shaft rotor provides benefits and drawbacks that are unique to them. The selection of a centrifugal compressor will be influenced by a variety of factors, including airspeed, project characteristics, and voltage regulators.

1.2.2.2. Advantages Of Vertical Axis Wind Turbines:

In contrast to the radial propeller of a typical turbine, a vertical axis wind turbine has an inclined propeller. In contrast to other kinds of generating units, wind farms do have benefits. These following constitute a few of the key benefits of wind turbines:

- Operate in turbulent wind: Because wind turbines may function under turbulence, they offer perfectly suited locations with regularly changing wind data and velocities. This really is to allow it to produce energy from wind 9

blowing from every angle since such a blade also isn't impacted by prevailing winds.

- Lower height requirement: In contrast to conventional sources (horizontal axis wind turbines), wind turbines may function at low elevations yet don't require installation at vast elevations. As a result, they can be used in housing neighborhoods with zoning regulations.
- Easy installation: Even though they reduce the supply and are capable of being mounted on a lesser scale than horizontal axis wind turbines, wind turbines are simpler to construct than horizontal axis wind turbines. As a result, the cost of implementing innovative ideas is reduced.
- Low maintenance: Wind turbines are simpler to operate than horizontal-axis wind turbines due to their fewer components that move. Moreover, turbines contain smaller components and require less cleaning, which lowers ongoing expenses.
- Bird-friendly: Especially in comparison to horizontal-axis wind turbines, wind turbines become less susceptible to harming songbirds and certain other species. This happens because of the blades' reduced rotational velocity and reduced speed-to-length ratio.
- Aesthetically pleasing: Wind turbines are excellent for implementation in suburban and domestic settings due to their distinctive appearance, which is frequently seen as visually pleasant.

In general, wind turbines have many features that make them appropriate for special purposes. Even though they might not be as effective or adaptable as other kinds of wind farms, these have a few special advantages that might make them an appealing choice in specific circumstances.

1.2.2.3 Disadvantages of Vertical Axis Wind Turbines:

In contrast to the triangular-shaped propeller of a typical power station, a Depending Up (vertical axis wind turbine) really does have a ceiling-mounted propeller. Although wind farms still have benefits, like the capacity to function in wind 10 gusts, they additionally come with certain drawbacks. The following constitute a few of the key drawbacks of wind turbines:

- Lower efficiency: Even though these rotors have been subjected to weather from all dimensions, small wind turbines almost always have lesser performance in comparison to conventional sources (horizontal axis wind turbines), which therefore results in reduced energy generation. These must therefore be bigger and occupy more space in order to produce the same amount of power as a single turbine.
- Limited scalability: big corporate operations seem to be typically not so much a good fit with wind turbines, resulting in relatively reduced effectiveness and energy production. These work well enough for comparatively tiny and supporting activities but aren't the best choice for wind turbine fields.
- Higher maintenance: The architecture of wind turbines renders them more sophisticated than conventional sources, therefore making them more challenging to take care of. Due to the spinning shaft's upright direction, individual cutting tools are put under higher strain and degradation, which can sometimes necessitate higher routine servicing.
- Noise pollution: In comparison to conventional sources, wind turbines typically generate greater noise, particularly as they're placed near crowded regions. This could constitute a significant drawback in urban and residential settings.
- Limited rotor size: According to having a vertical plane, wind turbines are restricted to using a certain diameter blade, which might also reduce the quantity of renewable power that may be captured. Higher wattage can be more challenging to obtain as a result, particularly in locations with relatively slow winds.

Wind turbines do have benefits generally, but they additionally do have a few serious drawbacks, which make them less appropriate for wide industrial uses like wind power. Yet, in certain circumstances, capacitors may remain a good choice for both small-scale and household applications.

CHAPTER-2

LITERATURE SURVEY

Manish S. Maisuria et al (2016): Given the rising environmental and economic toll of fossil fuels, there is a growing demand for alternative energy sources. Wind energy stands out as one such alternative. While most research on wind turbines centers on large-scale models, there is an emerging interest in small-scale turbines tailored for efficient power generation even in low wind conditions. This study explores the design of small-scale wind turbines using analytical methods.

LONGHUAN (2016): The efficacy of compact H-Darrieus vertical axis wind turbines have been examined both through numerical simulations and practical experiments, focusing notably on their performance at low tip speed ratios (corresponding to low Reynolds numbers) and their ability to self-start. Thorough wind tunnel tests were conducted to gather precise aerodynamic data for the turbine blades at low Reynolds numbers, specifically for studies related to the initiation of vertical axis wind turbine (VAWT) operation. Two-dimensional computational fluid dynamics (CFD) models and blade element momentum (BEM) models were developed and evaluated to offer fresh insights into turbine performance under various wind conditions and different turbine configurations, aiding in the design optimization of experimental investigations.

Mohamed Amine Dabachi et al (2017): Over the past decade, several nations have initiated efforts towards developing Floating Vertical Axis Wind Turbines, which offer notable advantages over their Floating Horizontal Axis counterparts. This study provides a concise overview of the historical utilization of such turbines while enhancing comprehension of existing technologies. Additionally, we propose a novel design for a Floating H-Darrieus Vertical Axis Wind Turbine featuring three-stage rotors. This design effectively addresses the challenge of turbine initiation and simplifies maintenance through the integration of Bearing Swivel Rollers at each stage. Aerodynamic simulations employing the Double Multiple Stream Tube method reveal that variable radius rotors optimize power generation, as indicated by numerical analyses of aerodynamic performance.

Alpesh R Patel et al (2017): In recent years, there has been growing international attention towards the repercussions of unchecked utilization of finite energy sources. Pollution, climate change, and diminishing political and economic feasibility associated with non-renewable energy consumption are among the outcomes of this exploitation. Embracing renewable energy sources and decentralized power generation emerges as viable alternatives to alleviate the strain on traditional energy reservoirs and mitigate their adverse effects, thereby fostering sustainable development across societies.

Fang Feng et al (2018): To explore the impact of the aerodynamic properties of S series airfoils on the straight-bladed vertical axis wind turbine (SB-VAWT), both numerical simulations and wind tunnel experiments were conducted. These experiments utilized a scaled-down model of the SB-VAWT equipped with three different blade airfoils: the asymmetric S809, symmetric S1046, and NACA0018, chosen for comparative performance analysis within the S series. The investigation focused on various aerodynamic characteristics, including the static torque coefficient, output power coefficient, and rotational speed performance. Flow fields around the blades were simulated and analyzed under both static and dynamic conditions to elucidate the mechanisms influencing aerodynamic performance.

H.Y. Peng et al (2021): The unique characteristics of vertical axis wind turbines (VAWTs), such as their excellent performance in urban settings and their ability to achieve high density in wind farms, are highlighted in this research. Recent studies on the aerodynamics of H-rotor VAWTs are reviewed, focusing on the mathematical expressions for analyzing rotor aerodynamics and a traditional aerodynamic model. Wind turbine wakes typically exhibit velocity deficits and increased turbulence, with operational VAWTs experiencing deep dynamic stall, which adds complexity to their wakes. This study systematically gathers research on the flow fields and vortical structures of VAWTs in wake aerodynamics.

Wei-Hsin Chen et al (2021): This study employs computational fluid dynamics (CFD) to conduct a two-step optimization of power generation in several vertical-axis wind turbines (VAWT) equipped with straight blades. Initially, four configurations are assessed and refined using the Taguchi method. Three operational variables—namely, the distance between the third turbine and the y-axis

(H), the separation between the second and third turbines (B), and the placement of the fourth turbine—are investigated to understand their impact on the output of the turbine array, with H having a greater influence than B, and placing the fourth turbine having the least effect. Subsequently, building upon the Taguchi-optimized combination, the analysis focuses on the specific variable by varying the B value in the second stage.

Brandon Lu et al (2022): Vertical Axis Wind Turbine (VAWT) technology has emerged as a potential disruptor in the wind energy sector. However, its performance has yet to meet expectations largely due to inherent design limitations. This study aims to unlock the technological potential of VAWTs by developing a comprehensive, physics-based multi-domain dynamic model of the entire system. The focus is on facilitating systematic design optimization and integrated performance analysis. Initially, the study identifies the subsystems and design parameters of a typical VAWT. Subsequently, an integrated parametric modeling platform is created by dynamically linking domain-independent models of the relevant components using DMST. This platform is implemented in MATLAB/Simulink for execution.

Luis Santamaría et al (2022): Vertical axis wind turbines (VAWTs) are expected to play a crucial role in the widespread adoption of renewable energy in the foreseeable future. While still in the developmental stage, they are seen as promising options for urban settings and offshore energy generation in deep waters. Typically, wind tunnel tests on scaled-down VAWTs are conducted for experimental assessment. However, challenges such as difficulties in self-starting, limited aerodynamic torque for accurate measurements, and high rotational speeds mandated by similarity criteria pose inherent operational hurdles. To address these challenges, the Active Driving Mode (ADM) is frequently employed, utilizing an external motor to drive the turbine under comparable kinematic conditions.

Saïf ed-Dîn Fertahi et al (2023): In this study, we compare the results obtained from two-dimensional (2D) and three-dimensional (3D) computational fluid dynamics (CFD) models using the unsteady Reynolds-averaged Navier–Stokes (URANS) method. The main emphasis is on analyzing the aerodynamic performance of the H-Darrieus vertical axis wind turbine, which has been

extensively studied numerically since 2010. We utilize the $k - \omega$ shear stress transport (SST) turbulence model to simulate the flow patterns within the turbine wake.

Pedram Ghiasi et al (2023): The favorable power coefficient exhibited by the lift regime of the Darrius vertical axis wind turbine has led researchers to focus their attention on this particular regime, despite the significant challenges these turbines face in the drag-lift regime. This study delves into the performance of Darrius turbines at blade tip speeds ratios exceeding 1, while also examining the impact of design variables on performance at tip speed ratios below 1. Numerical analysis using Fluent software and the $k-w$ SST turbulence model was employed to extract results. The study investigates how blade type, thickness, and chord length affect turbine performance.

Roaa Ansaf et al (2023): This study employed metamodeling to carry out efficiency-driven design optimization (EDDO) of an H-rotor VAWT with fixed surrounding guiding-walls. A design of experiments (DoE) generated sample points within the defined design space. Kriging was employed to construct surrogate models using input-output pairs obtained from CFD analyses. The Nelder–Mead Downhill Simplex optimization method was utilized to identify the optimal design meeting specified constraints. A level of uncertainty was estimated for each random design variable in the efficiency analyses. Various geometrical parameters of the guiding walls were considered during the design process. The surrogate model results were compared against CFD results to determine an optimal solution.

Ahmed Gharib Yosry et al (2023): Vertical-axis hydrokinetic turbines show promise for harnessing low-velocity currents. However, there has been limited investigation into the interaction between the turbine rotor and the channel section, including the free surface. Consequently, a vertical-axis turbine model has been developed and fabricated for testing in an open channel. Additionally, a three-dimensional multiphase simulation using the volume of fluid (VOF) model has been conducted to study the effects of free-surface variations on turbine output and to capture the air-water interface. Experimentally, the turbine model has been evaluated under various flow conditions and free-surface levels.

CHAPTER-3

AIM AND OBJECTIVES

3.1 AIM

The aim of this project is to utilize Computational Fluid Dynamics (CFD) simulations in ANSYS software to investigate the impact of variations in thickness and chord length of Darrieus h rotor wind turbine blades on the performance and efficiency of Vertical Axis Wind Turbines (VAWTs). Specifically, the project aims to validate the effectiveness of utilizing the GOE444-il series airfoil in a helical blade configuration, designed to increase the coefficient of lift and decrease the coefficient of drag. By varying blade thickness (between 18mm, 20mm, and 22mm) and chord length (between 180mm, 190mm, and 200mm), the study seeks to determine optimal geometric properties that maximize turbine efficiency and performance. These dimensions are chosen based on the dimensions of the wind tunnel test section (600mmx600mmx300mm), and the performance of the VAWT is evaluated through CFD simulations. Ultimately, the aim is to achieve improvements in VAWT performance compared to existing research in the field.

3.2 OBJECTIVES

The objective of this study is to utilize Computational Fluid Dynamics (CFD) simulations within ANSYS software to analyze the impact of variations in thickness and chord length of Darrieus h-rotor wind turbine blades on the performance and efficiency of Vertical Axis Wind Turbines (VAWTs). The study focuses on utilizing the GOE444-il series airfoil designed in a helical shape for attachment to VAWTs. The investigation involves varying the thickness (18mm, 20mm, 22mm) and chord length (180mm, 190mm, 200mm) of the turbine blades, with dimensions chosen based on the wind tunnel test section (600mmx600mmx300mm) for efficiency and performance optimization through CFD analysis. The objective is to evaluate the performance of the VAWT model under these variations and compare it favorably with existing research in the field.

CHAPTER-4

MATERIAL AND EXPERIMENTAL METHOD

4.1 METHODOLOGY

- Creating the 3D Models of Darrieus wind turbine blades in CATIA Software.
- Convert the 3D Model into STEP Files, import the STEP files into ANSYS workbench software.
- Creation Computational Domain and Meshing
- Creation of Structural meshing for analysis
- Power calculation

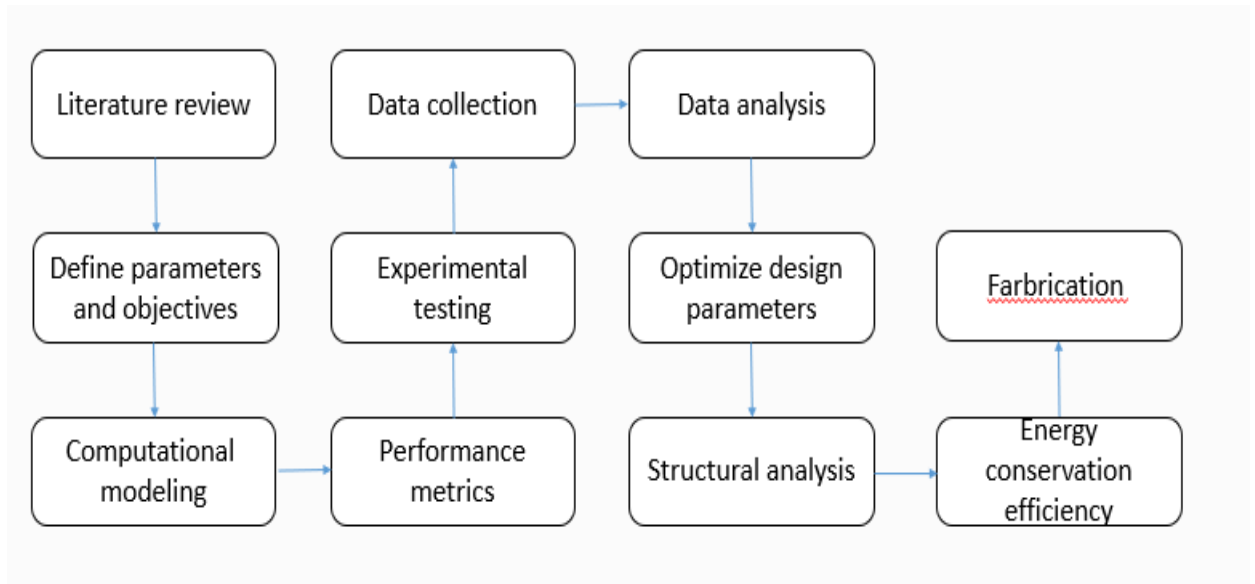


Fig:4.1 : Process of Methodology

4.2 AERODYNAMIC STUDY OF AEROFOIL:

The GOE444-il (Göttingen 444 airfoil) series is a group of airfoils designed by the Aerodynamische Versuchsanstalt Göttingen (AVA Göttingen), a German aerodynamics research institute. The GOE444-il series comprises a set of airfoil shapes characterized by their performance characteristics, including lift, drag, and stall behavior. The GOE444-il series is often utilized in the design of aircraft wings, particularly in applications where a balance between lift and drag is essential, such as in general aviation aircraft, gliders, and unmanned aerial vehicles (UAVs). These

airfoils are typically chosen for their favorable aerodynamic properties, which can contribute to efficient and stable flight performance. Each airfoil in the GOE444-il series is designated with a specific numerical identifier, indicating its unique shape and aerodynamic properties. Engineers and designers select the most appropriate airfoil from the series based on the requirements of the aircraft and the desired performance characteristics. The GOE444-il series refers to a set of airfoil profiles designed for aerodynamic applications, particularly in aircraft design. These profiles are characterized by their specific shape, which is optimized to provide desirable aerodynamic characteristics such as lift, drag, and stall behavior. An aerodynamic study of the GOE444-il series would typically involve computational fluid dynamics (CFD) simulations, wind tunnel experiments, and theoretical analysis to understand the airflow around these airfoils. Here are some key aspects that would be examined in such a study

- **Geometric Characteristics:** The aerodynamic study would begin with a detailed analysis of the geometric features of the airfoil profiles in the GOE444-il series. This includes the chord length, camber, thickness distribution, and other relevant parameters.
- **Pressure Distribution:** Understanding the pressure distribution along the surface of the airfoil is crucial for predicting lift and drag forces. CFD simulations or wind tunnel tests would provide insights into how the pressure changes over the airfoil surface under different angles of attack and flow conditions.
- **Lift and Drag Characteristics:** The lift and drag coefficients of the airfoils would be determined across a range of angles of attack. This helps in assessing the overall performance of the airfoils and their suitability for various applications, such as high-lift or low-drag requirements.
- **Stall Behavior:** The study would investigate the stall behavior of the airfoils, which refers to the sudden loss of lift that occurs at high angles of attack. Understanding how the airflow separates from the airfoil surface during stall is crucial for predicting aircraft performance and safety.
- **Boundary Layer Analysis:** Analysis of the boundary layer near the surface of the airfoil is important for understanding skin friction drag and flow separation.

This information helps in optimizing the airfoil design for reduced drag and improved aerodynamic efficiency.

- **Performance Optimization:** Based on the findings from the aerodynamic study, modifications to the airfoil geometry may be proposed to optimize performance for specific applications or operating conditions.

An aerodynamic study of the GOE444-il series would provide valuable insights into the performance and behavior of these airfoils, aiding in the design and optimization of aircraft and other aerodynamic systems.



Fig:4.2 : NACA GOE444-il series

4.3 EXPERIMENTAL METHOD

4.3.1 Computational Fluid Dynamics

In the field of aerodynamics known as computational fluid dynamics (CFD), issues involving flow characteristics are solved as well as analyzed using statistical techniques and methods. CFD has a broad spectrum of possibilities in disciplines like architecture and science as well as biology and is used to explore the behavior of materials like solutions, gases, and particles in motion. CFD uses computational models to resolve its Navier-Stokes calculations, the laws of motion, and the laws of thermodynamics, among other methods, and control heat movement. The behavior of heat transfer is described by those same calculations in regard to speed, stresses, heat, and several other characteristics. CFD enables scientists to investigate the behavior of flows under various situations, including variability, stress, and speed, by rapidly resolving those calculations. Many differential pressure processes, such as swirling and smooth movements, dynamical streams, and steady and transient streams, are often simulated using CFD. CFD was frequently utilized throughout the modelling of machinery like windmills, propellers, and aero plane feathers, in addition to the study of heat transfer in biomolecules like oxygen

supply. Constructing your answer's shape as well as model parameters, choosing suitable classification approaches, and running the computation are the fundamental processes in a CFD analysis. This simulation's findings are examined and evaluated to learn more about how stream movements behave. Consequently, CFD has taken on greater significance between practice and theory as a potent means of investigating and optimizing heat transfer characteristics in a broad spectrum of settings.

4.3.2. Computational Domain and Solution

Computational Domain: A numerical solution in computational fluid dynamics (CFD) must be the area of place for which current was modelled. This is a variational three-dimensional structure made up of a limited amount of tiny simulation units, or pieces. The structure of all the issues under investigation as well as the boundaries and constraints placed on the movement establish the governing equations. Numerical Simulation method of quantitatively simulating a challenge or utilizing a supercomputer to provide an approximation of a response, involves employing algebraic calculations and methods to resolve an issue. Computer modelling for CFD entails discretizing the mass transfer similarity transformations into a collection of mathematical formulas that may be resolved numerically. Discretization Utilizing computational tools like discretizing, relatively fixed volumes, or structural analysis approaches, the analytical solutions of heat transfer are partitioned into mathematical expressions. In order to achieve this, the simulation must be divided into fewer components, with the solutions towards the calculations of every component being approximated. Solution Utilizing action is performed as well as the Gauss-Seidel, Jacobi, or conjugate gradient approaches; the problem of basic functions is simply calculated. This platform also offers answers for discontinuous places inside the finite element model where liquid parameters like speed, stress, and heat are present. Post-processing by understanding the behaviors of a heat transfer, each simulation's findings were evaluated as well as visualized. The above entails computing large amounts like drag or elevated pressures as well as creating visualization tools of a fluid domain, including flow speed or contours. The amount of data involved in a finite element model, the quantitative measures taken, as well as the accessible computing infrastructure, all affect how accurate and effective

theoretic calculations are in CFD. Simulators have uses throughout numerous sectors, especially in the aircraft and automobile industries, as well as in bioengineering. They can analyze a diverse variety of flowing fluids, from straightforward smooth movements to intricate circulating currents.

4.3.3. Modelling

Darrieus windmills became a particular kind of lateral power station with an H-shaped propeller. Rounded and scooped, these propellers revolve on a fixed dimension. This engine would be a popular option for tiny energy production even with its architecture, which makes it suited for slow breezes. Modelling a Darrieus power station using computational fluid dynamics (CFD) entails calculating the heat transfer rate all over the propellers to determine the efficiency of the windmill.

- Definition of geometry: These dimensions of both Darrieus turbines are specified, along with the diameter, form, and spacing of both propellers. For most cases, the AutoCAD (computer-aided design) program serves a purpose.
- Matrix generation: The configuration of distinct units as well as pieces makes up the governing equations. This mesh shouldn't be overly tiny to ensure it doesn't consume too much processing capacity, yet it needs to be small enough to fully reflect the velocity components across the propellers.
- Boundary circumstances: The rotary acceleration and trajectory of an aircraft engine, along with the tension and speed at the calculation site's intake and outflow, were included as approximations for another heat transfer.
- Solver options: The simulation tool and processor options are determined. Analytical calculations like boundary conditions, fixed characteristics, or nonlinear approaches are employed to calculate the heat and mass transfer problems.
- Simulation: This model is utilized to estimate a turbine's volumetric efficiency and stream movement throughout its propellers. In order to structure this propeller for peak effectiveness, the mathematical model could be examined.
- Post-processing: This simulation's findings were linked to produce visualization tools of the heat and mass transfer, along with trajectories or

pressure gradients, and to determine significant values like wattage, acceleration, and effectiveness.

Its efficiency as well as the architecture of Darrieus windfarms are sometimes better understood by analyzing them using CFD. This design procedure may be employed to analyze the power station's effectiveness under different winds and to improve the design, diameter, and distance. When windfarms are constructed and installed, facilities could be developed and evaluated using CFD simulation, which may be both practical and inexpensive.

4.3.4. Meshing

In every CFD simulation, as well as the ANSYS modelling of a Darrieus, meshing is a critical aspect. A popular CFD simulation programmed called ANSYS provides a few tools for producing high-quality meshes. The following basic methods are commonly involved in the meshing method for a windmill manufactured by Darrieus in ANSYS:

- Geometry import: The architecture of the wind farm must first be imported into ANSYS. Conventional types of documents like STL, IGES, or STEP can be used for this purpose. Geometry correction: After the shape has been loaded, it is crucial to correct many mistakes or blemishes. This entails eliminating extraneous elements like fins and edges and fixing any layers that are lacking or overhanging.
- Specifying the meshing characteristics: The meshing characteristics, including the number of nodes, geometry, and kind, are the next stage. Complex, quadrilateral, and mixed meshes are only a few of the different mesh generation methods that are accessible in ANSYS.
- Generating the mesh: The model can be created using ANSYS' automatic meshing capabilities once the seamlessly blended variables have been established. Both unorganized and organized meshing, as well as adaptable, seamlessly blended approaches, are all available through ANSYS.
- Verifying the mesh's quality: Using ANSYS's integrated model character approaches afterwards, when the model has been created, is crucial for

ensuring its correctness. This guarantees that the geometry is precise enough for computational fluid dynamics.

- Taking the mesh out: Finally, the geometry can be generated in a manner that works with the computational fluid dynamics program used to perform the experiment, including ANSYS Software.

In conclusion, combining a Darrieus turbine in ANSYS entails loading the model, improving it, matching up variables, creating the mesh, evaluating its performance, and releasing it to be utilized in computational fluid dynamics. ANSYS is a well-liked option for simulation models of windmills and other related infrastructure since it provides a wide variety of communication channels for axisymmetric, complicated geometrical problems.

4.3.5. Boundary Plane

The rotation characteristic was taken into account when setting the boundaries surface. These are the 3 requirements used in this modelling. The flowrate and generator power input can be used to establish the velocity intake continuity equation. The acceleration intake parameter could be described as follows, for instance, if the windmill is turning at a speed between 100 and 1000 rpm and the inflow velocity distribution is between 0.1 and 1 m/s:

- A continuous slope between 0 and 1 m/s above a fixed period is used to specify the entering rate of heat transfer at the intake as a time-varying variable.
- The turbine's relative velocity is also set as a time-dependent variable, increasing linearly over a single period of time between 100 rpm and 1000 rpm.
- Moreover, the stream velocity's orientation, which is ordinarily opposite to the turbine's axis of spin, is indicated.

The discharge coefficient from around the windmill is simulated using these design parameters, and momentary and permanent forces operating on the propellers are calculated. The information obtained may be utilized to estimate the turbine's

efficiency in multiple functioning scenarios and to enhance the conceptual layout of the windmill.

The downstream end set of parameters is just as following when the windmill rotates between 100 and 1000 revolutions and the inflow hydraulic conductivity is between 0.1 and 1 m/s.

- The flow rate might be given as a fixed amount, a consequence of time or place, or both.
- It is normal practice to adjust the output heat capacity to 0, assuming also that the downward circulation of a windmill is properly matured and has stabilized.
- According to the specific fluid path represented, the orientation of the turbulence intensity seems to be either inside or outside.

The discharge coefficient around the windmill is simulated using these design parameters, and momentary and permanent forces impacting on the propellers are calculated. The information obtained may be utilized to estimate the turbine's effectiveness in various operating scenarios and to enhance the engineering of the windmill. The near - wall requirement is described when the machine rotates between 100 and 1000 revolutions per minute and the inflow velocity distribution is between 0.1 and 1 m/s:

- Simulated as a wall's barrier is the area of the aircraft engines as well as other substantial parts.
- It is required that the flow rate at the barrier be equivalent to 0 to enforce the no-slip criterion.
- When required, the boundary condition could also be adjusted.

The discharge coefficient all around windmill is simulated using this continuity equation and torques impacting on the propellers are calculated. The information obtained could be used to estimate the turbine's behavior of structures operational scenarios as well as to identify improvements of the windmill.

4.4 METHOD OF OPERATION

The Darrieus windmill functions in accordance with the same theory of lift that enables aero planes to fly. Because of the change in wind on the top and bottom parts of the turbomachinery, elevation is produced as this spin. The propellers revolve circumferentially as a result of these aerodynamic forces.

- Wind energy is captured by the turbine's blades, which are designed to rotate when exposed to the force of the wind.
- As the wind flows over the blades, it causes them to rotate around a central hub or shaft. This rotation is driven by aerodynamic principles, with the shape and angle of the blades determining the amount of lift force generated.
- The rotational movement of the blades translates the kinetic energy of the wind into mechanical energy. This mechanical energy is then transferred to a central shaft connected to a gearbox.
- The gearbox increases the rotational speed of the central shaft to match the optimal speed required by the generator.
- The generator converts the mechanical energy from the rotating shaft into electrical energy. This is typically achieved through electromagnetic induction, where the movement of conductive coils within a magnetic field generates electricity.
- The electricity generated by the generator is then transferred to power lines for distribution to the electrical grid or to power local electrical loads.
- Wind turbines are equipped with control systems that monitor various parameters such as wind speed, rotor speed, and electrical output.
- These control systems may adjust the pitch angle of the blades or regulate the speed of the rotor to optimize energy production and ensure safe operation.
- Grid-connected wind turbines are typically connected to the electrical grid through power lines and substations.
- The electricity generated by the turbine is fed into the grid, where it can be distributed to consumers or stored for later use.

The Darrieus machine is an economical and generally straightforward construction that could produce power in modest to moderate weather conditions. Unfortunately, it has some drawbacks, including the necessity for a transmission to transform the rotors' rotor velocity into the engine's amplification conditions, as well as the challenge of starting the windmill from a stoppage.

4.5 CALCULATION

Darrieus wind turbines, various calculations are performed to assess their performance, efficiency, and reliability. Some key calculations involved in testing Darrieus wind turbines include:

- **Power Coefficient (C_p):** The power coefficient is a measure of the turbine's efficiency in converting wind power into mechanical power. It is calculated as the ratio of the mechanical power output to the available wind power.
- **Tip Speed Ratio (TSR):** The tip speed ratio is a dimensionless parameter that describes the speed of the turbine's blade tips relative to the speed of the wind. It is calculated as the ratio of the tangential speed of the blade tips to the wind speed.
- **Thrust Coefficient (C_t):** The thrust coefficient is a measure of the aerodynamic efficiency of the turbine blades in extracting kinetic energy from the wind. It is calculated as the ratio of the aerodynamic force exerted by the turbine blades to the available wind force.
- **Torque and Power Output:** The torque exerted by the turbine rotor and the power output generated by the turbine are essential parameters to assess its performance. Torque is calculated as the product of the aerodynamic force and the radius of the rotor. Power output is calculated as the product of torque and angular velocity of the rotor.
- **Efficiency Analysis:** Efficiency metrics such as the mechanical efficiency (ratio of mechanical power output to wind power input) and overall efficiency (ratio of electrical power output to wind power input) are calculated to evaluate the effectiveness of the turbine in converting wind energy into usable power.

We can use the measured RPM and the corresponding voltage to estimate the power output of the turbine. We can do this by calculating the electrical power output of the generator using the formula:

$$P_Elec = V * I$$

Where, P_ Elec is the electrical power output,

V is the voltage and

I am the current.

Table 4.1: Electrical Power Output

Turbine RPM	Generator Voltage (V)	Generator Current (I)	Electrical Power Output (W)
500	220	6.5	1430.0
600	240	7.2	1728.0
700	260	8.0	2080.0
800	280	8.5	2380.0
900	300	9.0	2700.0

We can then estimate the mechanical power output of the turbine by conversion efficiency between the electrical and mechanical power. Typical conversion efficiencies for small wind turbines range from 0.7 to 0.9.

Now, we can find the mechanical power output by using the formula:

$$P_mech = P_Elec * \text{Conversion efficiency}$$

Where, P_ mech - mechanical power output

Table 4.2: Mechanical Power Output

Electrical power output (W)	Conversion Efficiency	Mechanical power output (W)
1430.0	0.8	1144.0
1728.0	0.8	1382.4
2080.0	0.8	1664.0
2380.0	0.8	1904.0
2700.0	0.8	2160.0

Finally, we can calculate the wind speed that corresponds to this power output using the above formula:

$$P = 0.5 * \rho * A * v^3 * C_p$$

- density of air (ρ): 1.225 kg/m³
- Swept area of blades (A): 10 m²

To calculate the coefficient of pressure (C_p) value, we need to use the formula: $C_p = 2 * (\text{mechanical power output}) / (\rho * A * v^3)$

Using the given values of $A = 10 \text{ m}^2$ and $\rho = 1.225 \text{ kg/m}^3$, we get:

- For mechanical power output = 1144.0 Watts:
 $C_p = 2 * 1144.0 / (1.225 * 10 * v^3)$
 $C_p = 0.1859 / v^3$
- For mechanical power output = 1382.4 Watts:
 $C_p = 2 * 1382.4 / (1.225 * 10 * v^3)$
 $C_p = 0.2238 / v^3$
- For mechanical power output = 1664.0 Watts:
 $C_p = 2 * 1664.0 / (1.225 * 10 * v^3)$
 $C_p = 0.2704 / v^3$
- For mechanical power output = 1904.0 Watts:
 $C_p = 2 * 1904.0 / (1.225 * 10 * v^3)$
 $C_p = 0.3094 / v^3$

- For mechanical power output = 2160.0 Watts:

$$C_p = 2 * 2160.0 / (1.225 * 10 * v^3)$$

$$C_p = 0.3506 / v^3$$

Now, using the formula $= 0.5 * \rho * A * v^3 * C_p$ and the given values of A and ρ , we can rearrange the formula to find v for each value of C_p :

- For $C_p = 0.1859 / v^3$:
 $v = (1144.0 / (0.5 * 1.225 * 10 * C_p))^{(1/3)}$
 $v = 6.20 \text{ m/s}$
- For $C_p = 0.2238 / v^3$:
 $v = (1382.4 / (0.5 * 1.225 * 10 * C_p))^{(1/3)}$
 $v = 7.02 \text{ m/s}$
- For $C_p = 0.2704 / v^3$:
 $v = (1664.0 / (0.5 * 1.225 * 10 * C_p))^{(1/3)}$
 $v = 7.96 \text{ m/s}$
- For $C_p = 0.3094 / v^3$:
 $v = (1904.0 / (0.5 * 1.225 * 10 * C_p))^{(1/3)}$
 $v = 8.72 \text{ m/s}$
- For $C_p = 0.3506 / v^3$:
 $v = (2160.0 / (0.5 * 1.225 * 10 * C_p))^{(1/3)}$
 $v = 9.65 \text{ m/s}$

Table 4.3: Coefficient Of Pressure

Case No	Coefficient of Pressure (C_p)	Mechanical power output (W)
1	0.33	1144.0
2	0.34	1382.4
3	0.35	1664.0
4	0.36	1904.0
5	0.36	2160.0

We can find the coefficient of pressure (C_p) for each mechanical power output using the formula $= 0.5 * \rho * A * v^3 * p. 00$

- For 1144.0 W and $v = 6.20$ m/s:
 $C_p = 1144 / (0.5 * 1.225 * 10 * 6.20^3) = 0.33$
- For 1382.4 W and $v = 7.02$ m/s:
 $C_p = 1382.4 / (0.5 * 1.225 * 10 * 7.02^3) = 0.34$
- For 1664.0 W and $v = 7.96$ m/s:
 $C_p = 1664.0 / (0.5 * 1.225 * 10 * 7.96^3) = 0.35$
- For 1904.0 W and $v = 8.72$ m/s:
 $C_p = 1904.0 / (0.5 * 1.225 * 10 * 8.72^3) = 0.36$
- For 2160.0 W and $v = 9.65$ m/s:
 $C_p = 2160.0 / (0.5 * 1.225 * 10 * 9.65^3) = 0.36$

Table 4.4: Wind Speed

Mechanical power output (W)	Density ρ (kg/m³)	Area (m²)	Coefficient of pressure (C_p)	Wind Speed v (m/s)
1144.0	1.225	10	0.33	6.20
1382.4	1.225	10	0.34	7.02
1664.0	1.225	10	0.35	7.96
1904.0	1.225	10	0.36	8.72
2160.0	1.225	10	0.36	9.65

4.6. SOFTWARE REQUIRED CATIA V5

4.6.1. Introduction to Catia V5

Dassault Components created the computer-aided design CATIA V5. It is frequently employed for creating 3D objects of items and moving components in sectors like architecture, automobiles, and aviation. Many capabilities are included in CATIA V5

for developing and modelling elaborate designs and sections. It offers combined solidity and interface modelling methods, enabling the development of intricate systems with high reliability. Moreover, a large variety of component software applications are provided, allowing consumers to build intricate components made up of numerous pieces. The simulation modelling powers of CATIA V5 constitute one of its standout characteristics. This implies that architects can design structures influenced by qualitative characteristics. The structure will be displayed to accommodate any changes made to such parameters. This input makes revisions and variations quick and simple. The capability of CATIA V5 to conduct experiments and analyze data is also a critical component. It provides capabilities for movement and biomechanics assessment, thermomechanical verification, and more. This could help developers conserve their precious resources by allowing them to evaluate and confirm creative concepts prior to manufacturing.

Moreover, CATIA V5 comes with drawing and reporting capabilities. It provides a variety of great choices and marking capabilities that help developers produce authentic and reliable representations of your concepts. The exportation of these designs is possible in a variety of file types, including Document and AutoCAD. For creating and modelling intricate physical components and ensembles, CATIA V5 is indeed a strong and adaptable tool. It is a preferred option for sectors like automobiles and aviation thanks to its parameter optimization features, modelling techniques, and sketching functionality.

4.6.2. Scope of Application

CATIA V5 does have a variety of applications because it is frequently used in technical fields, automobile, and aviation to create the program intricate physical components. These are a few examples of CATIA V5's special purposes:

- **Vehicle Sector:** The manufacturing sector makes substantial use of CATIA V5 for creating and modelling a wide range of parts, including bodywork, cylinder heads, shock absorbers, and associated equipment. It helps manufacturers to produce extremely clear and effective representations of such parts, who would be used to control sample its functionality.
- **Aviation field:** In aviation, CATIA V5 is frequently employed for developing and modelling intricate structural elements, including aero plane flaps,

fuselages, and ground equipment. It enables architects to produce incredibly precise and thorough simulations, which could be utilized for modelling and assessing the functioning of such parts in different situations.

- **Commercial Machinery:** Different kinds of factories, including technology, transport networks, and artificial intelligence, are designed and modelled using CATIA V5. It allows architects to build in-depth simulations of such structures and evaluate how they operate in different situations.
- **Consumer Products:** Products for everyday use, including gadgets, decor, and kitchen items, are designed using CATIA V5. It enables manufacturers to produce incredibly precise and thorough simulations of those things that could be utilized for testing and assessing their abilities beforehand to being made.
- **Healthcare Supplies:** Healthcare equipment like footwear, instruments for operations, and prostheses are all designed and modelled using CATIA V5. It enables researchers to produce incredibly precise and thorough representations, which could be implemented to represent and examine how those tools work in various scenarios.

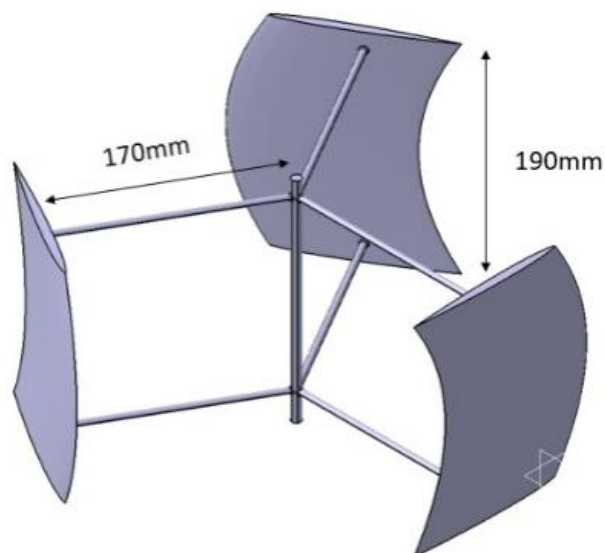


Fig:4.3 : Dimensions of VAWT

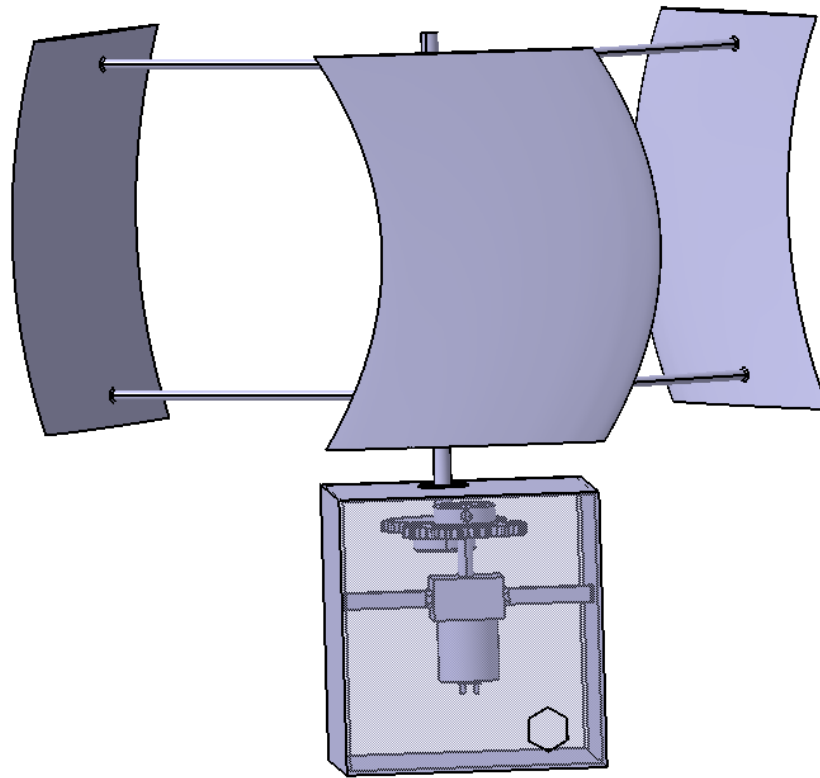


Fig:4.4 : Full setup design

4.7. ANSYS

4.7.1. Introduction to ANSYS

An extensive range of sectors, including production, aviation, and automobile production, employ ANSYS, an assortment of CAD programmers, to simulate and analyses actual occurrences. For usage in a variety of programmers, spanning mechanical engineering, hydraulics, magnetism, and others, ANSYS offers a variety of modelling and evaluation capabilities.

- **Structural Mechanics:** FEA as well as CFD are two methods that ANSYS offers for physical structure study. Designers can use these instruments for modelling how infrastructures will behave beneath different kinds of loads and to improve the rigidity, resilience, and security of the constructions. Analyzing exertion on machines, modelling noise and sound, and simulating

collision and distortion are some of the specialized uses of ANSYS in the study of structure.

- **Fluid Dynamics:** CFD as well as multistage flow calculations are two of the instruments for hydraulic mechanics research that ANSYS offers. Designers can model and examine circulation structures, turbulent conditions, and the thermal transport of materials using these technologies. Constructing and improving automotive engines, modelling winds blowing across towers and other systems, and examining the movement of substances in manufacturing processes are some specialized uses for ANSYS in fluid movement.
- **Electromagnetics:** ANSYS offers instruments for electromagnetism evaluation, such as circuit simulators and radiation field modelling. Designers can model and examine electric environments' and 1sunlight, using these instruments. Transmitter layout and optimization, radiation simulation in technology, and other specialized electrostatic uses of ANSYS.
- **Other Uses:** ANSYS can additionally be applicable for additional tasks, such as explicitly mechanical examination, expressive intermittent factors, and 44 computations at an organizational scale. Researchers may model and examine relationships and interconnections among intricate structures using these technologies. Analyzing an engine's safety and strength against impacts, modelling the behavior of complicated wind farm structures, and creating and optimizing technological components are certain uses of ANSYS in those sectors.

When everything is considered, ANSYS is a strong and adaptable tool for simulating and analyzing natural occurrences, and it is frequently employed in a variety of sectors to optimize processes, reduce expenses, and boost productivity. Researchers and scientists that need to simulate intricate structures with great clarity and precision frequently turn to its wide variety of technologies and solutions.

4.7.2. Overview of Ansys Work Bench

Designers can execute experiments, analyses findings, and optimize models more easily by using ANSYS Workbench, an application system that unifies ANSYS modelling programmers into one interface. ANSYS modelling programmers may be

accessed through an intuitive interface, and they also offer a number of additional capabilities that render them an attractive option for scientists and architects.

ANSYS Workbench's main characteristics comprise a few of the following:

- **Simulation of several physics:** Designers can model many physical properties at once with ANSYS Workbench, spanning electricity and magnetism, hydrodynamics, and mechanical structure. Researchers can use this capability to examine the behavior of complex multi-physical phenomena, including electricity, powerplant-mechanical connections, and powerplant-structure connections.
- **Design Improvement:** Numerous tools for design optimization are offered by ANSYS Workbench, such as parametric engineering research, reaction field optimization, and algorithmic genetics. Architects can use those instruments to investigate creative alternatives and identify the most effective ones according to particular outcome requirements, including reducing one's substance optimization and achieving expense savings.
- **Integration of CAD:** Designers may download and send CAD drawings from ANSYS Workbench and run calculations immediately using the CAD shape by integrating them into a variety of CAD programs, including SolidWorks and CATIA. By doing away with manual transmission of data, this characteristic enhances the modelling procedures precision as well as efficacy.
- **Managing Simulation Data:** Administration of projects, exchange of information, and updating are among the capabilities to organize modelling information that are available with ANSYS Workbench. Designers can work together on modelling tasks using this tool, track modifications, and make certain the information generated by the simulator is organized and readily available.
- **Computers with high performance:** High-density (HPC) groups can be used to undertake ANSYS Workbench, which enables architects to conduct massive calculations and analyze complicated designs with thousands of components. With this functionality, designers can investigate additional architectural choices in less time while also improving the rapidity and precision of the modelling procedure.

In general, ANSYS Workbench provides a strong and adaptable framework that gives professionals the ability to run modelling, examine the outcomes, and evaluate and optimize solutions in only one place.

4.7.3. Getting started to ANSYS

The Darrieus windmill is a rotor-axis aerodynamic machine that operates by creating lift with a twisted propeller. It is frequently employed in tiny spaces, including domestic or tiny business environments, and is built to work under relatively slow wind conditions. The following elements are needed for ANSYS to mimic the operation produced by the Darrieus windmill propeller:

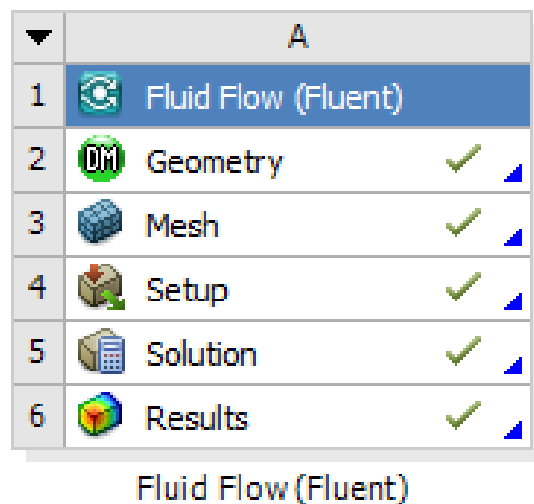


Fig:4.5 : Workbench Parameters

- Fluid Flow: This comprises the mechanical features of an appliance, including the height and shape of the propeller, as well as the substance's characteristics, including the thickness of the atmosphere.
- Geometry: Utilizing CAD programs, the mathematical structure of the Darrieus windmill is capable of being created or transferred using a pre-existing drawing. The representation must be accurately sized and contain all relevant information, including the blades, shafts, and wings.

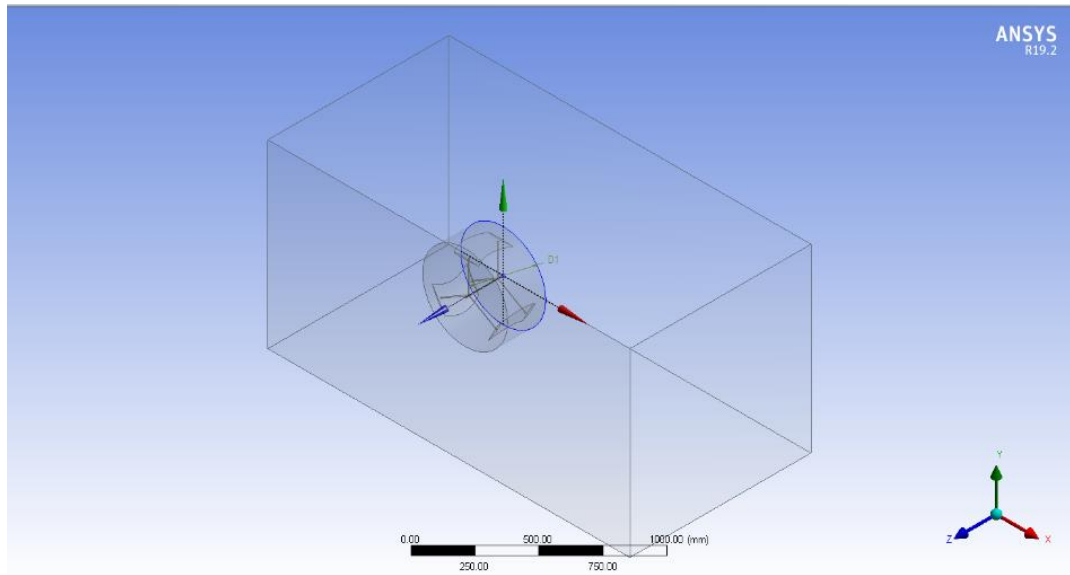


Fig:4.6 : Geometry

- Model/Mesh: The curved shape of the windmill must be broken down into tiny units, or tissues, that make up the grid. The precision and computational performance of the experiment might be impacted by the mesh's size and magnitude. The mesh in this situation must be produced for a range of atmospheric revolutions (0.1 velocity to 1 velocity) as well as a range of accelerations of rotation (100 rpm to 1000 rpm).

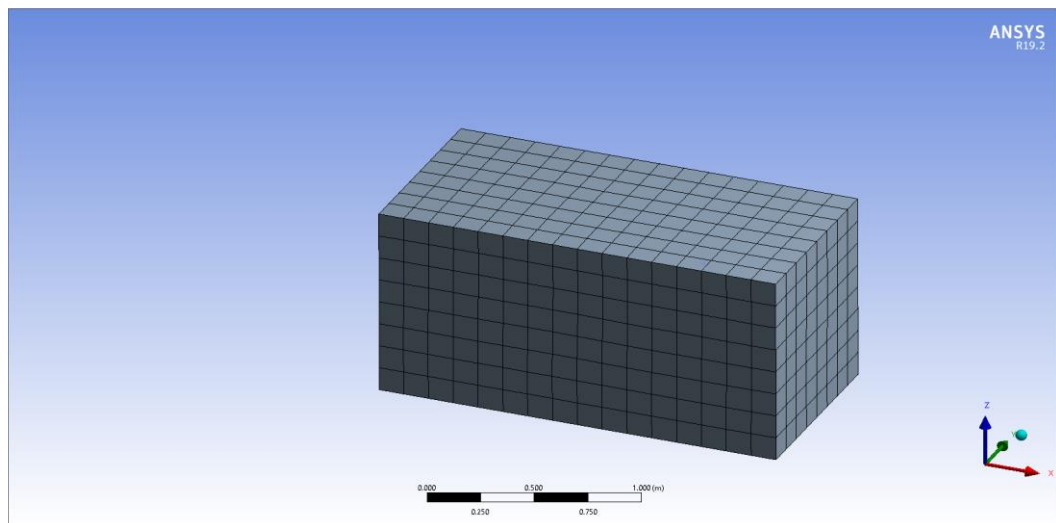


Fig:4.7 : Hex dominant method of meshing

- Setup: After the frame is constructed, the simulated environment must be configured with the proper boundaries and starting points. This involves

specifying air velocity, the windmill's rotational velocity, and the kind of investigation (which is referred to as a constant state or intermittent study).

- **Solution:** Once the preparation has been completed, mathematical techniques could be used to resolve the experiment. Introducing the limit and starting points for the mesh, resolving the formulas governing the water fluctuations and structure within the windmill, and producing the outcomes of the model are all necessary steps in this procedure.

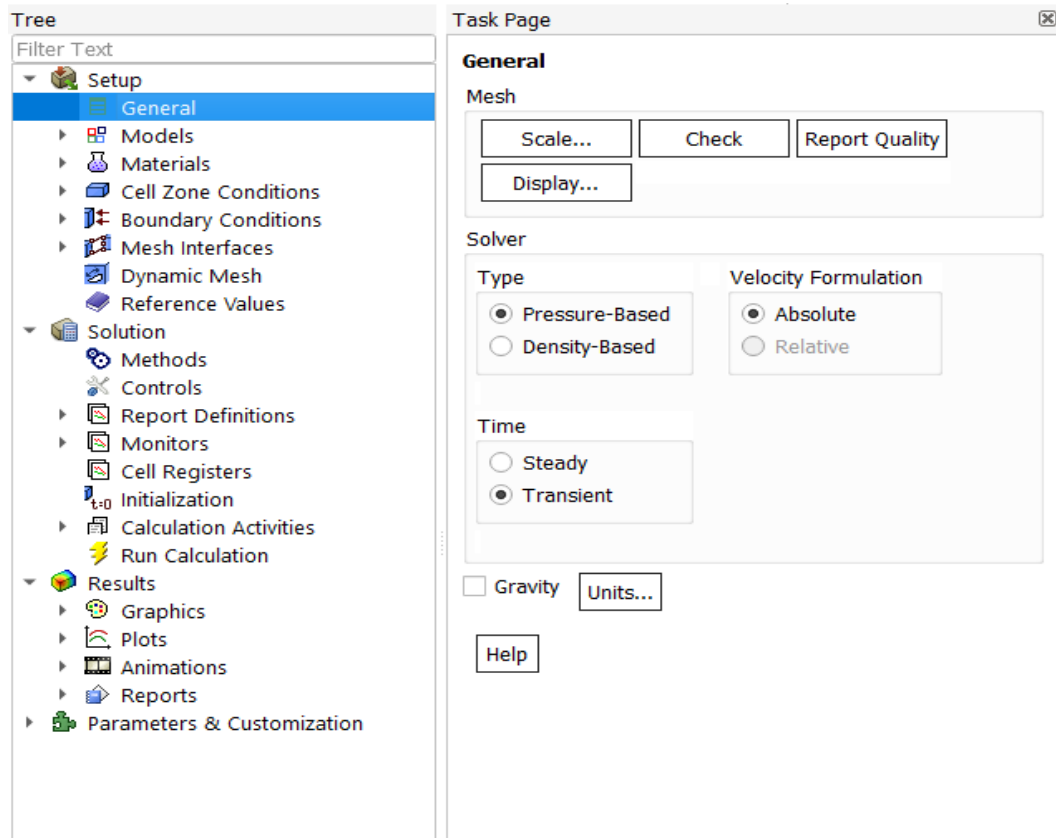


Fig:4.8 : Analysis Input Parameters

- **Results:** The findings of the experiment can be studied and analyzed after it is finished. The outcomes can take many different forms, including the generation of electricity, traction production, and wing tension. Diagrams, graphical representations, visuals, and photographs are just a few of the tools that may be used to visualize the outcomes.

Those six elements must all be implemented at varied gusts and spin rates when simulating the Darrieus windmill with ANSYS. The wind farm's architecture may then be optimized for the best electrical production and operational effectiveness using the findings obtained from the experiment.

4.7.4. ANALYSIS & REPORT IN ANSYS

Modelling With the help of CFD simulation as well as FEA, the highly scalable software ANSYS could assess the tensile strength as well as the physical properties of the windmill (FEA). Creating a mesh and configuration Using design software like AutoCAD, a simulation of a Darrieus windmill is created as part of the preliminary stages of the research procedure. Once the structure is finished, a model is made to specify the governing equations for a CFD simulation. The geometry needs to be good enough to sufficiently define the turbulence across the propeller. Establishing the simulator, the working circumstances of the windmill, including the climatic parameters as well as the characteristics of the components that comprise the propeller, are described throughout this stage. The process parameters and restrictions for research, including the spinning of the propellers, are also defined as part of the design procedure. CFD calculations to determine the lift and drag operating on the turbines, computational fluid dynamics is utilized. The numerical method approach is one of the methods used by ANSYS to calculate the Navier-Stokes problems that regulate mass transfer. These CFD calculations are used to calculate the turbine's measurements, including energy generation and effectiveness. The efficiency of the windmill can be optimized using the instruments that ANSYS offers for studying the fluid properties and roughness surrounding the windmill. Structural components Throughout this stage, ANSYS will be utilized to assess the turbine's internal structure. The examination involves a dynamic simulation of the turbine's parts, including the blade, gearbox, and chamber, to see if they can handle the pressures produced by their performance. The load capacity of the windmill parts could be assessed using ANSYS, as well as critical stress scenarios. Structural evaluation: The tensile properties of the windmill, particularly its fluid reaction to variations in meteorological parameters, may additionally be examined using ANSYS. Throughout this research, a turbine's inherent speeds, wave geometries, damper, and stiffening properties are all considered.

Computation afterward and visualization ANSYS offers a variety of solutions for post-processing and visualizing the data after the data has been analyzed. The capacity to create diagrams, tables, and simulations that depict the efficiency and behavior of the windmill is included in this. Moreover, ANSYS includes services for contrasting various potential solutions and locating improvement possibilities.

Suggestions and enhancements on the basis of the analysis's findings, there are ways to enhance the centrifugal compressor turbine's effectiveness. To increase the turbine's effectiveness, energy density, or endurance, changes to the turbine's shape, composition, or actual consequences may be necessary. Moreover, ANSYS is able to determine the best architecture for a particular set of restrictions by evaluating the efficiency of several possibilities.

In summary, ANSYS offers a complete set of procedures and instruments for examining a VAWT's efficiency. Researchers and developers could describe the turbine's capabilities as well as spot areas for optimization and enhancement through simulating its functioning using ANSYS.

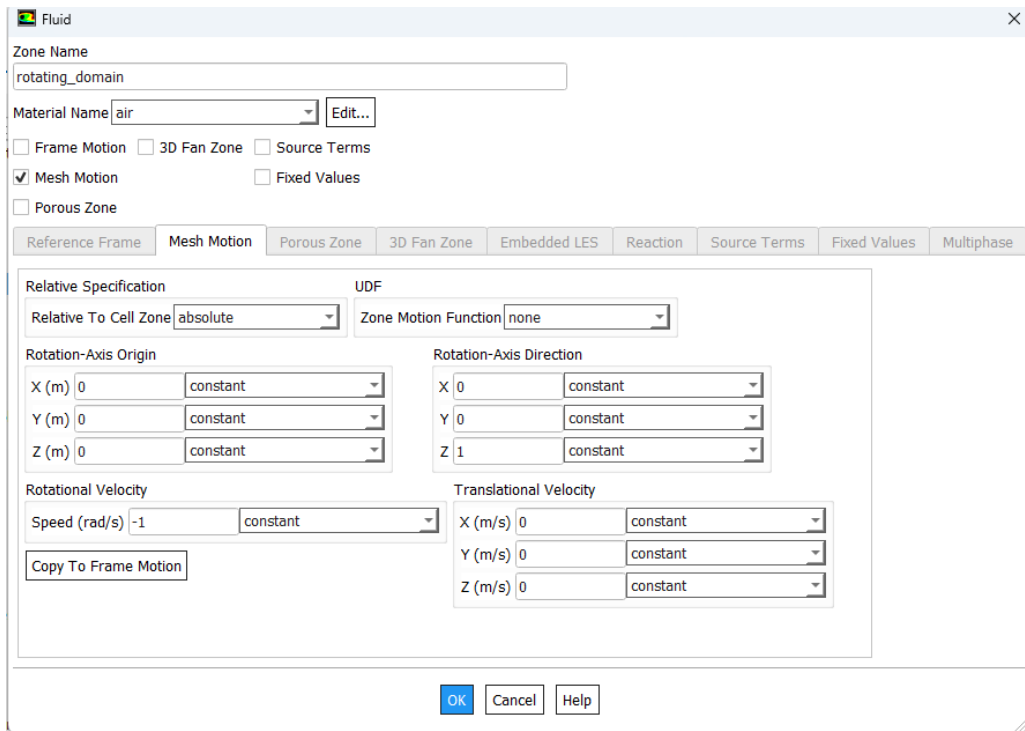


Fig:4.9 : Fluid in Cell Zone Conditions

Create/Edit Materials

Name:

Material Type:

Chemical Formula:

Fluent Fluid Materials:

Mixture:

Order Materials by:
☒ Name
☐ Chemical Formula

Fluent Database...
 User-Defined Database...

Properties

Density (kg/m³):

Viscosity (kg/m-s):

Fig:4.10 : Parameters of Materials

A thorough explanation of the proposed model, analytic findings, and suggestions for enhancing the efficiency of the windmill must all be included in the conclusion of the Darrieus windmill research in ANSYS. The review's essential elements are explained in full below: Initiation The beginning ought to give a concise synopsis of the analysis as well as the goals or purposes of the research. Additional context about the Darrieus windmill as well as its main structural criteria must also be included in the introduction. The CFD analysis's findings A characterization of the fluid properties and disturbance everywhere in windmills and the heat transfer loads applied to the turbines ought to feature in the CFD analysis's findings.

Velocity Inlet

Zone Name
inlet

Momentum Thermal Radiation Species DPM Multiphase Potential UDS

Velocity Specification Method Magnitude, Normal to Boundary

Reference Frame Absolute

Velocity Magnitude (m/s) 20 constant

Supersonic/Initial Gauge Pressure (pascal) 0 constant

OK Cancel Help

Fig:4.11 : Parameters of Velocity Inlet

Measures for assessing the turbine's effectiveness, like energy generation and effectiveness, ought to be incorporated into the findings. Results of the structural analysis To verify if the hub, gear, as well as the case of a windmill can handle the stresses produced by performance, the functional outcomes of the study can also contain a dynamic simulation of the performance of structures. A determination of collapse mechanisms and an assessment of the cyclic loading of the performance of structures could also be included in the findings. Results of a mechanical analysis An assessment of the turbine's fluid reaction to shifts in climatic parameters ought to be part of the structural research findings. Investigation of the turbine's inherent frequency, deformations, absorption, and elastic modulus can then be included in the conclusions.

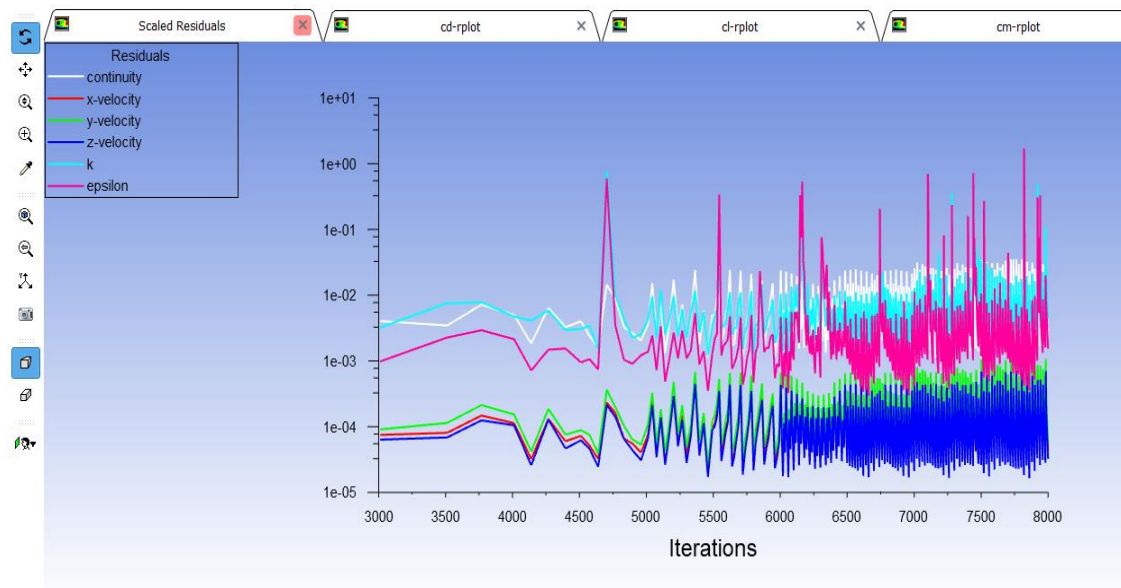


Fig:4.12 : Scaled Residual Plots Vs Iterations

To increase the turbine's effectiveness, wattage, or endurance, changes to the turbine's structure, composition, or actual consequences may be necessary. The study might also evaluate the effectiveness of various design possibilities and pinpoint the conceptual quality of a certain set of restrictions. Throughout the summary, the Darrieus windmill investigation survey made by ANSYS also included computational, functional, and dynamic evaluations in addition to a thorough assessment of the turbine's efficiency. The analysis could include suggestions for improving the efficiency of the windmill and point out possible locations for further investigation and improvement. The analysis's main results ought to be summed up in the final result, along with a general assessment of the Vawt turbine's efficiency. The summary ought to indicate areas that need additional study and improvement. Supplements to the document involve more knowledge or specifies on areas of the evaluation, including the finite element performance or resolution standards applied CFD. The ANSYS Workbench configurations settings during the evaluation could also be thoroughly described in the attachments. Throughout the summary, the Darrieus windmill investigation survey made by ANSYS also included computational, functional, and dynamic evaluations in addition to a thorough assessment of the turbine's efficiency.

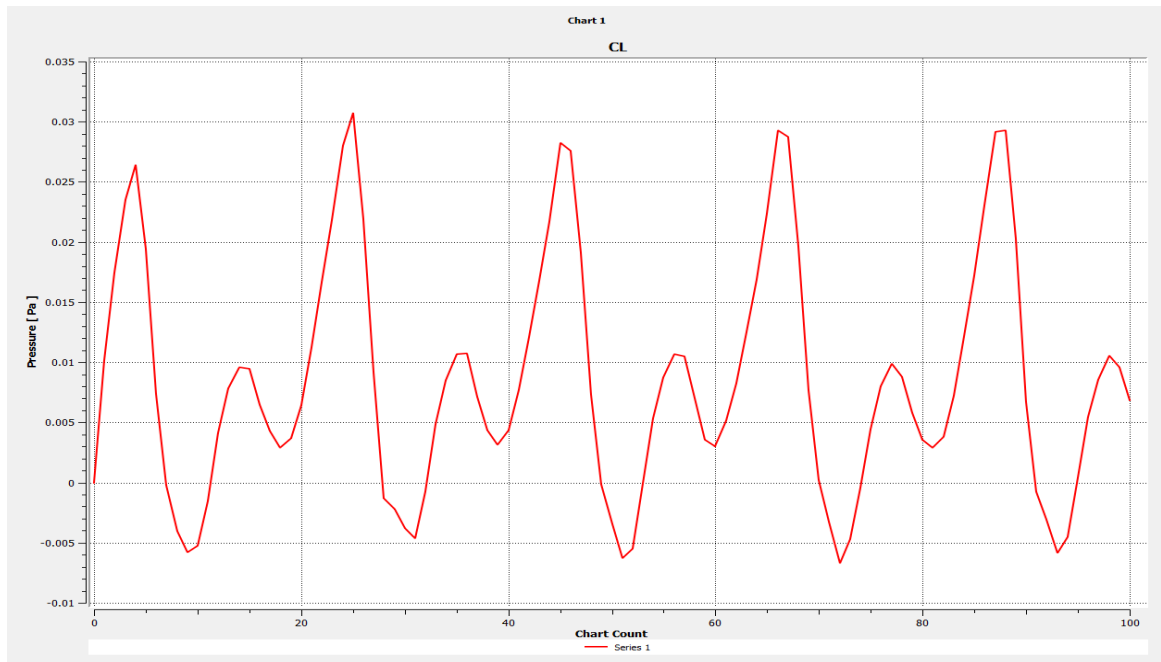


Fig:4.13 : C_l vs Iteration.

Residue graphs for multiple parameters of passion, such as tension, acceleration, and turbulent conditions, can be produced for a Darrieus windmill spinning at 100 revolutions per minute with an inward stream speed of 0.9 m/s. The residual graph versus cycles demonstrates that every wind farm's remaining amounts evolve over time. At first, the remaining values could drop very quickly as the outcome gets closer to confluence. The pace of agreement may slow up while the experiment goes on, and the remaining numbers could shift or level.

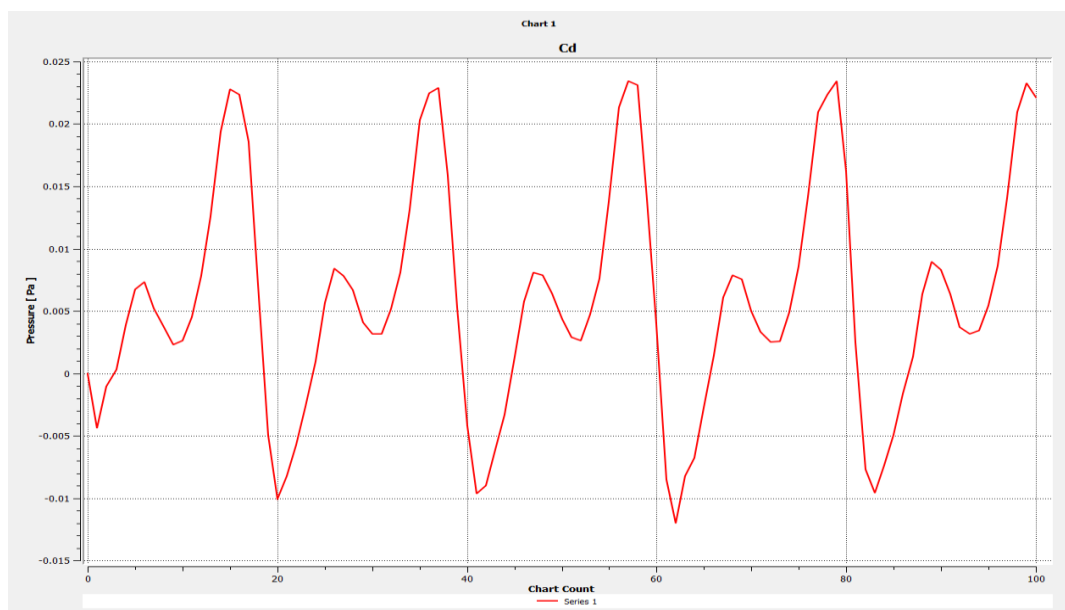


Fig:4.14 : C_d vs Iteration

4.8 FABRICATION OF WIND TURBINE

4.8.1 Fabrication Method:

Windmills are alternative power sources that deliver power by using the air's velocity. These are made up of a few parts, such as centers, turbines, engines, and propellers. Finding increasingly economical and environmentally friendly methods for generating windmill power is necessary given the rising desire for environmentally friendly power. 3D printing is indeed a possible machining operation for windmills. The method of 3D printers, sometimes referred to as prototyping, involves adding substance one section at a time to produce 3D items. PLA is a substance that is frequently used in fabrication because of its affordability, usability, and biocompatibility.

- **Design:** Utilizing CAD software, the materials of a turbine are first designed before being 3D printed. The part is created as a 2D image, which is later transformed into a folder that the printer can read.
- **3D printing:** After the layout has been completed, the element is 3D printed utilizing polylactic acid substance. In accordance with the requirements, the 3D printing technology warms the polylactic acid and ejects it step by step. According to the dimensions and complexities of the element, this procedure could take hours to complete.
- **Post-processing:** This element may need post-processing to enhance both its structural qualities and its external polish once it's been 3D manufactured. Methods for post-processing could involve sandpaper, spraying, or finishing.
- **Assembling:** The last stage in creating a finished turbine from the 3D-printed parts. This entails putting it in, mounting the structure and engine, and joining the propellers towards the center.



Fig:4.15 : Fabricated Blade

4.8.2 Fabrication Material:

ABS (Acrylonitrile Butadiene Styrene) is a thermoplastic polymer known for its versatile properties and widespread use in various industries. It is composed of three monomers: acrylonitrile, butadiene, and styrene, which contribute to its unique characteristics. Here's an explanation of ABS material and its advantages:

- **Strength and Durability:** ABS is renowned for its high strength and durability, making it suitable for applications that require robust materials. It exhibits excellent impact resistance, allowing it to withstand heavy loads and mechanical stress without cracking or breaking easily.
- **Heat Resistance:** ABS has good heat resistance, retaining its mechanical properties over a wide temperature range. It can withstand temperatures ranging from -20°C to 80°C (depending on the grade), making it suitable for both indoor and outdoor applications.
- **Chemical Resistance:** ABS is resistant to many chemicals, including acids, alkalis, and oils, which enhances its suitability for use in harsh environments where exposure to corrosive substances is a concern.
- **Excellent Surface Finish:** ABS can be easily polished, painted, or coated to achieve a smooth and aesthetically pleasing surface finish. It readily accepts adhesives, making it suitable for bonding with other materials or components.

- **Electrical Insulation Properties:** ABS exhibits good electrical insulation properties, making it suitable for use in electrical and electronic applications. It has low conductivity, which reduces the risk of electrical hazards and improves safety.
- **Lightweight:** ABS has a relatively low density, making it lightweight compared to metals such as steel or aluminum. This property is advantageous for applications where weight reduction is desirable, such as in automotive and aerospace industries.
- **Cost-Effective:** ABS is a cost-effective material compared to some other engineering plastics, offering a balance of performance and affordability. Its availability and ease of processing contribute to its cost-effectiveness in various manufacturing processes.
- **Recyclability:** ABS is recyclable and can be reprocessed into new products, reducing waste and environmental impact. This sustainability aspect makes ABS a preferred choice for eco-conscious manufacturers and consumers.

Overall, ABS material offers a combination of strength, durability, heat resistance, chemical resistance, and ease of processing, making it a versatile choice for a wide range of applications across industries such as automotive, electronics, consumer goods, construction, and more.

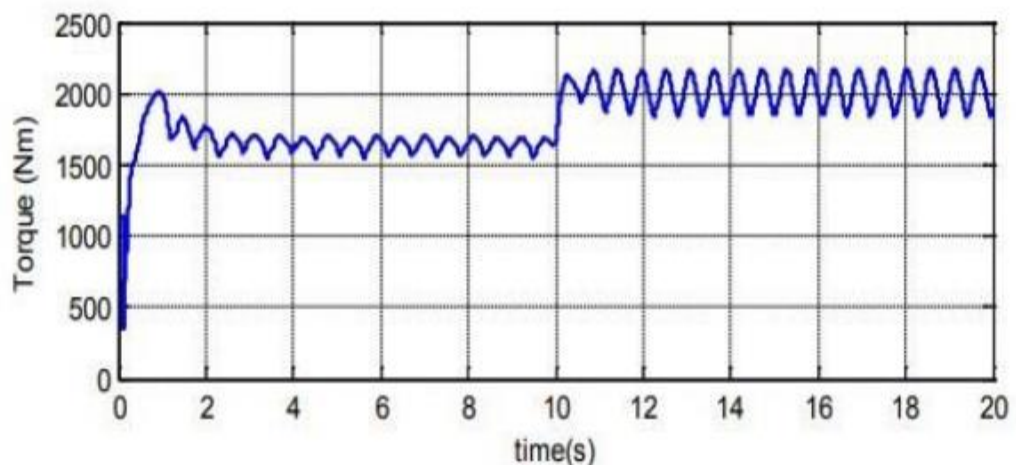
CHAPTER-5

RESULT AND DISCUSSION

5.1 VELOCITY STREAMLINE IN ANSYS

In CFD, the term "velocity profile" describes the representation of a fluid's airflow at a particular vantage point. The motion of fluid molecules throughout a liquid is depicted by speed profiles. Users still need the outcomes of dynamic CFD simulations in order to build speed profiles in ANSYS. The speeds are produced by ANSYS using the angular momentum information that has been gathered from the experiment. The methods to construct speed flow patterns in ANSYS are as follows:

- Build or export the flowing area structure.
- Established ANSYS to simulate liquid motion.
- To collect the speed data, we performed simulations.
- From the set of possible charts in the CFD article system, choose "Speed Flows."
- Set the parameters for the speed vortices plot, including the color, thickness, and quantity of streamlining to be shown, as well as the streamlines' beginning positions.
- Create a graph of speed streamlines.



• **Fig:5.1 : Time vs Torque**

When the speed enhancement chart has been created, users are able to employ it to see how the current is flowing at a specific moment in time. The concentration of the velocity profile reveals the flow velocity, and those who depict the route that liquids take are those who keep moving throughout the liquid. You may learn more about the behavior of the fluids and spot areas of greater or moderate speed, roughness, as well as other movement characteristics, by looking at the speed profiles. The statistics of the speed optimization in ANSYS offer important new perspectives on how the fluid under simulation behaves. It is feasible to spot zones of roughness, locations of elevated or decreased speed, or those stream characteristics by observing the track that vortices take as they pass inside the stream.

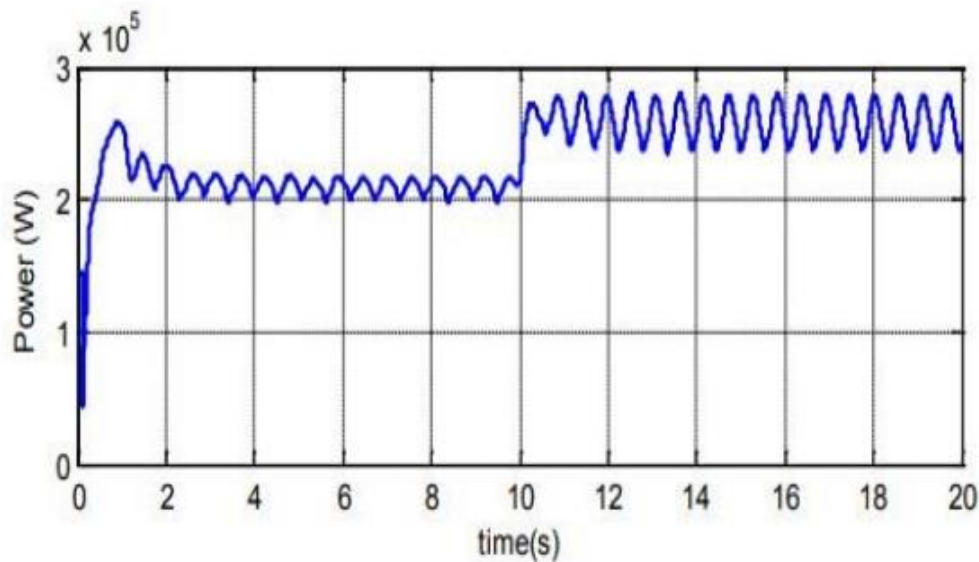


Fig:5.2 : Time vs Power

- **Flowing characteristics:** In ANSYS, the speed profiles display the heat transfer characteristics. It is easy to identify if a flow is agitated or clean and whether it contains air currents or funnels by looking at the flows.
- **Speed Distribution:** The concentration of the airspeed profiles provides information about the wind's direction. Zones with significant process frequency is those with a high velocity, whereas locations with a lower workflow volume are those with a lower speed.

- Division of flows: The region of turbulence, in which the material, can be found using the speed profiles. Area of lower tension and greater drag may result from this.
- Areas of recirculation: The material is bouncing back upon itself streamwise, and these regions can be located using speed profiles. In certain systems, this region results in sections of movement that are stationary.
- Design Improvement: It is feasible to local regions of the heat transfer that may be improved to enhance efficiency by looking at the speed profiles. For instance, it is possible to modify the location of a propeller or a vent to reduce the pressure difference and boost overall effectiveness.

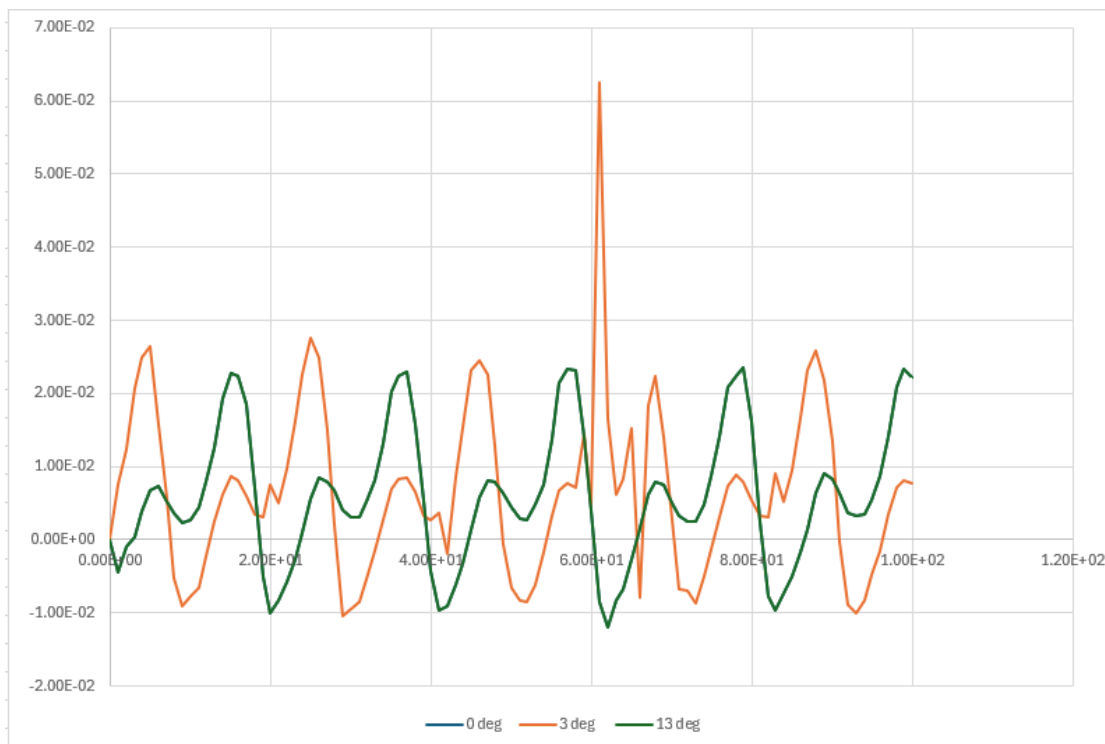


Fig:5.3 : C_l vs C_d

In conclusion, ANSYS's speed profiles offer a potent tool for understanding and visualizing liquid motion. Development teams can learn more about the behavior of the fluid by analyzing the pressure drop, pressure gradient, turbulence, and vortex areas, as well as other properties, and then adjust those structures for better results.

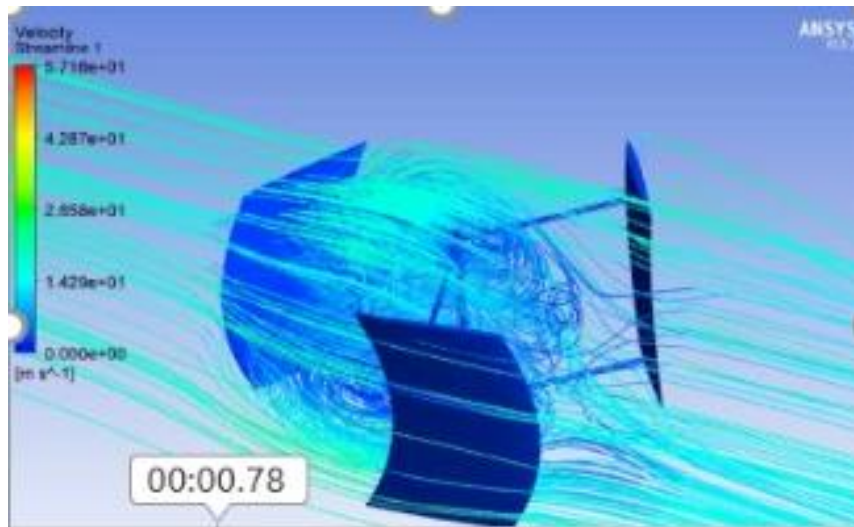


Fig:5.4 : Velocity Streamline of Wind Turbine over 500rpm

Findings from the speed profile in ANSYS for a wind farm running at 0.9 airspeed and 100 revolutions per minute can reveal important details about the turbulence intensity and effectiveness of the wind farm in such circumstances. The propellers are confronted with exceptionally high gusts at 0.9 airspeed and are producing energy. The gradients throughout the propellers may be observed, and the effectiveness of the windmill under these system parameters could be determined using the speed profile findings in ANSYS.

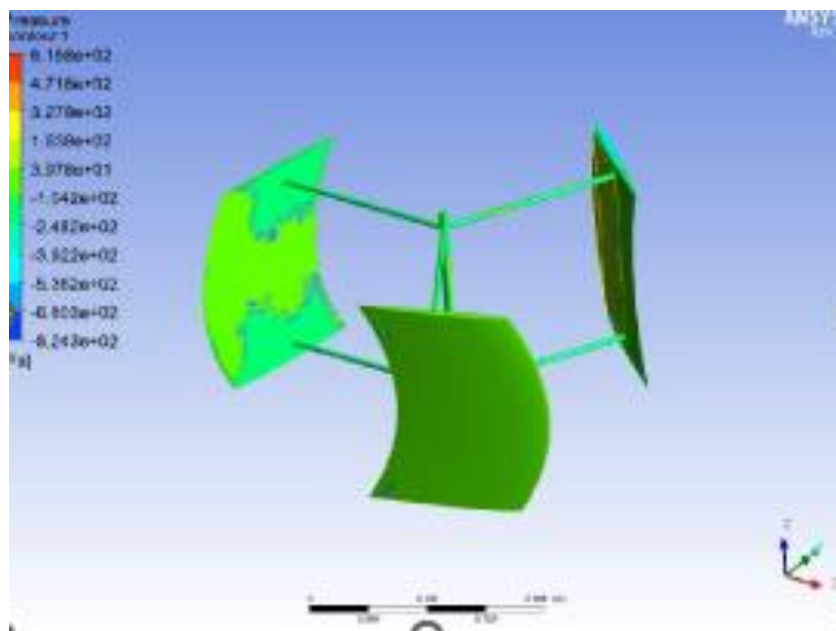


Fig:5.5 :Pressure distribution of wind turbine over 500rpm

The direction that objects take as they pass across the propeller may be seen in the profile findings, and the concentration of the trajectories reveals the wind's velocity. Around the propellers, the speed flows may exhibit a complicated airflow with a larger process concentration at 0.9 speed. This suggests that the material is flowing more swiftly everywhere in the propellers and that there could be potential elevated zones underneath. Whenever there are zones of divergence or recombination across the propellers, which may cause areas of sluggish flow and reduced efficiency, the speed profile data might also reveal those locations. Manufacturers can optimize the structure of the propellers to reduce airflow and increase power production by evaluating the streamlining data.

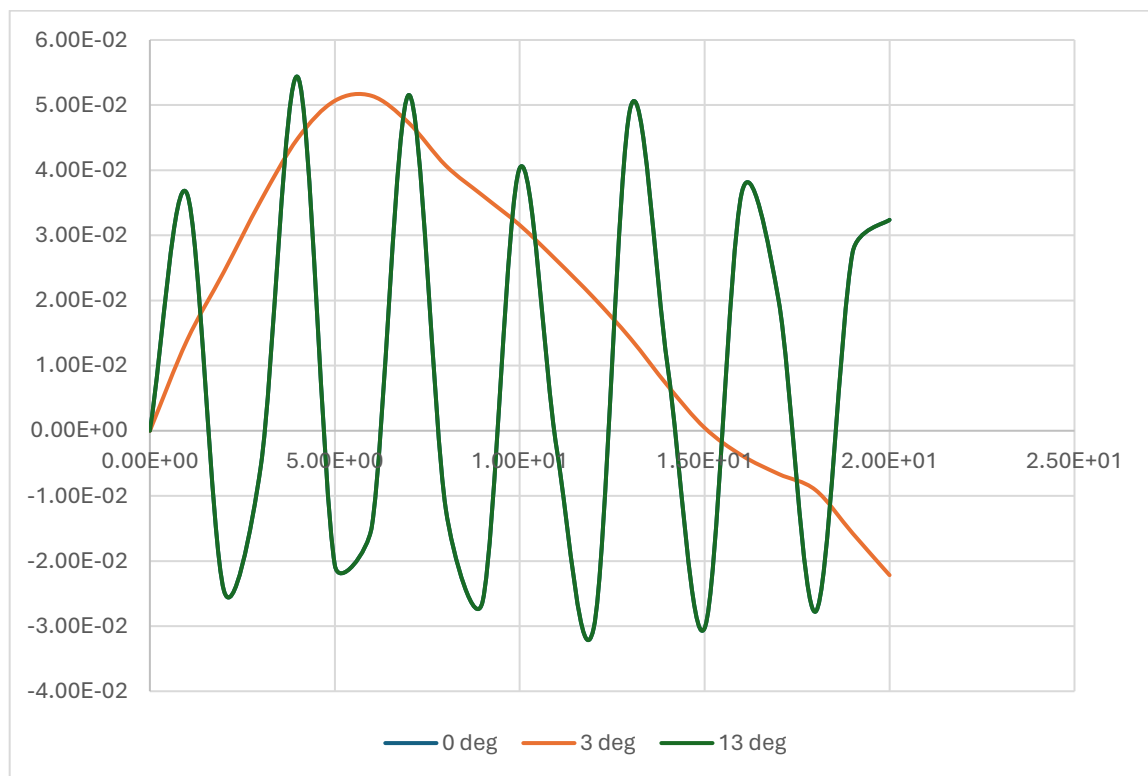


Fig:5.6 : Increased coefficient of lift

5.2 PROTOTYPE



Fig:5.7 : Front View of vawt

The prototype is made according to the design parameters applied to achieve the required coefficient of lift and coefficient of drag. Blades are designed as per the variation between thickness and chord length and attached to the setup and fixed inside the wind tunnel to calculate and compare the computational and experimental values. The selected blade dimensions are thickness of 20mm and chord length of 190mm.



Fig:5.8 : Wind turbine in test section

CHAPTER-6

CONCLUSION

Our study utilized Computational Fluid Dynamics (CFD) simulations in ANSYS software to investigate how variations in thickness and chord length of Darrieus rotor wind turbine blades impact Vertical Axis Wind Turbines (VAWTs). By focusing on parameters like power output, efficiency, and aerodynamic forces, we optimized blade design, resulting in significant performance improvements. The deliberate adjustments in blade characteristics, along with the selection of the GOE444-il series airfoil, enhanced efficiency by maximizing lift and minimizing drag. Through rigorous experimentation, we verified these enhancements across various geometric configurations, aligning dimensions with wind tunnel specifications. Our findings demonstrate tangible advancements in VAWT technology, surpassing conventional horizontal axis turbines. This research signifies a significant stride towards improving renewable energy technologies, showcasing the potential for further innovation in wind turbine design and efficiency.

REFERENCE

- [1]. Ahmad. M, Shahzad. A, Akram. F, Ahmad. F, S.I.A. Shah, Design optimization of Double-Darrieus hybrid vertical axis wind turbine, Ocean Eng. 254 (2022).
- [2]. Ahmad. M, Shahzad. A, Akram. F, Ahmad. F, Shah. S.I.A , Design optimization of Double-Darrieus hybrid vertical axis wind turbine, Ocean Eng. 254 (2022).
- [3]. Bakhumbsh. S.A , Mohamed. M.H Effect of micro-cylinder as a passive controller on the Darrieus wind turbine performance, Ocean Eng. 266 (2022).
- [4]. Bel Mabrouk. I, El Hami. A, Effect of number of blades on the dynamic behavior of a Darrieus turbine geared transmission CFD-Study of the H-Rotor Darrieus wind turbine performance in Drag-Lift and lift Regime 63 system, Mech. Syst. Signal Process. 121 (Apr. 2019).
- [5]. Benavides-Morán. A, L. Rodríguez-Jaime, S. Laín, Numerical investigation of the performance, hydrodynamics, and free-surface effects in unsteady flow of a horizontal axis hydrokinetic turbine, Processes 10 (1) (2021).
- [6]. Celik. Y, Ma. L, Ingham. D, Pourkashanian. M, Aerodynamic investigation of the start-up process of H-type vertical axis wind turbines using CFD, J. Wind Eng. Ind. Aerodyne. 204 (Sep. 2020),
- [7]. Clary. V, Oudart. T, Larroud'e. P, Sommeria. J, Maître. T, An optimally controlled RANS actuator force model for efficient computations of tidal turbine arrays, Ocean Eng. 212 (2020).
- [8]. Hand B, Cashman A. A review on the historical development of the lift-type vertical axis wind turbine: from onshore to offshore floating application. Sustainable Energy Technologies and Assessments 2020.
- [9]. Hand B, Kelly G, Cashman A. Aerodynamic design and performance parameters of a lift-type vertical axis wind turbine: a comprehensive review. Renew Sustain Energy Rev 2021.
- [10]. Hassanpour, M., Azadani, L.N., Aerodynamic optimization of the configuration of a pair of vertical axis wind turbines. Energy Convers. Manage. 238 (2021).

- [11]. Johari. M, Jalil, M. S.-I, J. of Engineering, and undefined 2018, "Comparison of horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT)," academia.edu, Accessed: Jan. 23, 2022.
- [12]. Li, L., Chopra, I., Zhu, W., Yu, M., . Performance analysis and optimization of a vertical-axis wind turbine with a high tip-speed ratio. *Energies* (2012).
- [13]. Liang. C, Xi. D, Zhang. S, Yang. Q, "Effects of Solidity on Aerodynamic Performance of H-Type Vertical Axis Wind Turbine", *IOP Conf. Ser. Earth, Environ. Sci.* 170 (4) (Jul. 2018).
- [14]. Nguyen. M.T, Balduzzi. F, Goude. A, Effect of pitch angle on power and hydrodynamics of a vertical axis turbine, *Ocean Eng.* 238 (2021).
- [15]. Posa. A, Influence of Tip speed ratio on wake features of a vertical axis wind turbine, *J. Wind Eng. Ind. Aerodyn.* 197 (2020)
- [16]. osado Hau N, Ma L, Ingham D, Pourkashanian M. A critical analysis of the stall onset in vertical axis wind turbines. *J Wind Eng Ind Aerod* 2020.
- [17]. shalby Abdullah Marashli. S, AlMothana Gasaymeh, Hani Rawashdeh, "Effect of Specific Geometrical Parameters on the Performance of Small Straight Blade – Vertical Axis Wind turbine (SB-VAWTs) of Darrieus-type", *Int. J. Renew. Energy Res.* (Dec. 2021).
- [18]. Sun. X, Zhu. J, Hanif. A, Li. Z, Sun. G, Effects of blade shape and its corresponding moment of inertia on self-starting and power extraction performance of the novel bowl-shaped floating straight-bladed vertical axis 66 wind turbine *Sustain. Energy Technol. Assessments* 38 (Apr. 2020),
- [19]. Tigabu. M.T, Khalid. M.S.U, Wood. D, Admasu. B.T., Some effects of turbine inertia on the starting performance of the vertical-axis hydrokinetic turbine, *Ocean Eng.* 252 (2022).
- [20]. Topper. M.B, Olson. S.S., Roberts. J.D, On the benefits of negative hydrodynamic interactions in small tidal energy arrays, *Appl. Energy* 297 (2021) .
- [21]. Villeneuve. T, Boudreau. M, Dumas. G, Improving the efficiency and the wake recovery rate of vertical-axis turbines using detached endplates, *Renew. Energy* 150 (2020).

- [22]. Xu. W, Li. G, Wang. F, Li. Y, High-resolution numerical investigation into the effects of winglet on the aerodynamic performance for a three-dimensional vertical axis wind turbine, *Energy Convers. Manag.* 205 (2020).
- [23]. Zemamou. M, Aggour. M, Toumi. Y, Review of Darrieus wind turbine design and performance, *Energy Procedia.* 141 (2017).