

DESIGN AND FABRICATION OF SEGMENTED VERTICAL AXIS WIND TURBINE BLADES FOR ENHANCING PERFORMANCE AND EFFICIENCY

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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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 **D SaiKiran (40260009)** and **MURALI KRISHNA NAIDU K(40260014)** who carried out the project entitled **"DESIGN AND FABRICATION OF SEGMENTED VERTICAL AXIS WIND TURBINE BLADES FOR ENHANCING PERFORMANCE AND EFFICIENCY"** under my supervision from November 2023 to April 2024.

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We **D SAIKIRAN (40260009)** and **MURALI KRISHNA NAIDU K (40260014)** hereby declare that the project report entitled **“DESIGN AND FABRICATION OF SEGMENTED VERTICAL AXIS WIND TURBINE BLADES FOR ENHANCING PERFORMANCE AND EFFICIENCY”** 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.

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ABSTRACT

The influence of segment configuration and airfoil selection on lift, drag, and power output is explored through wind tunnel experiments and computational analysis. The results are compared to traditional H-rotor designs, highlighting the impact of segmentation on performance and efficiency. The primary focus is on how segmentation affects variables like lift, drag, and overall turbine performance. When compared to typical H-rotor blades, segmented designs may offer advantages such as simpler blade adjustment, fewer bending moments, and improved starting torque. Computational simulations or wind tunnel measurements are used to examine the aerodynamic forces acting on the segmented blades at different wind speeds and rotation locations. The findings aim to elucidate the trade-offs between the benefits of segmentation and aerodynamic efficiency in H-rotor VAWT. design of SVWT blades involves dividing the blade into multiple segments connected by hinges or flexible joints, allowing each segment to independently align with the wind direction. This feature enables SVWTs to capture wind energy from various wind directions, enhancing efficiency and. As we have tested segmented wind turbine blades the efficiency were improved

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Segmented blades in Vertical Axis Wind Turbines (VAWTs) represent a significant innovation in wind turbine technology, offering numerous advantages and opportunities for enhancing the performance and efficiency of renewable energy systems. With their distinctive segmented design, comprising multiple airfoil-shaped segments arranged around the vertical axis of the turbine rotor, segmented blades play a pivotal role in maximizing energy capture and optimizing turbine operation. The importance of segmented blades in VAWTs lies in their ability to address key challenges and limitations associated with traditional blade designs, while also unlocking new possibilities for improving turbine performance in various wind conditions. One of the primary advantages of segmented blades is their enhanced aerodynamic efficiency and flexibility. Unlike conventional blades, which typically feature a single continuous airfoil profile, segmented blades can adjust their angle of attack independently across different segments, allowing for optimized aerodynamic performance and lift generation at varying wind speeds and angles of attack. This flexibility not only improves energy capture efficiency but also enhances the overall stability and reliability of VAWT systems, particularly in turbulent or variable wind conditions. When selecting segmented blades for Vertical Axis Wind Turbines (VAWTs), several key considerations must be taken into account to ensure optimal performance and efficiency. Firstly, the material composition of the segmented blades is crucial, as it directly affects their durability and resistance to fatigue under prolonged exposure to wind forces. High-quality materials such as carbon fiber reinforced polymers (CFRP) or fiberglass composites are commonly chosen for their lightweight yet durable properties, which contribute to minimizing blade mass and maximizing energy conversion efficiency. Secondly, the aerodynamic design of the segmented blades plays a significant role in determining their performance characteristics, including lift-to-drag ratio and stall behavior. Blades with airfoil profiles optimized for efficient energy capture

and minimal drag are preferred, as they allow the turbine to operate effectively across a wide range of wind speeds and angles of attack. Additionally, the segmentation pattern and arrangement of the blades should be carefully designed to ensure uniform load distribution and minimize aerodynamic losses due to blade interactions. Furthermore, considerations for the operating environment must be taken into account when selecting segmented blades for VAWTs. Factors such as wind speed, turbulence intensity, and environmental conditions (e.g., temperature, humidity) can impact the performance and lifespan of the blades. Therefore, blades with robust construction and resistance to corrosion and erosion are essential for ensuring long-term reliability and maintenance-free operation in challenging environments. Lastly, compatibility with the VAWT system and ease of installation and maintenance are important considerations for selecting segmented blades. Blades that are designed to fit seamlessly with the turbine rotor and hub, with provisions for efficient blade mounting and blade pitch adjustment mechanisms, facilitate smooth installation and alignment processes. Moreover, features such as self-cleaning surfaces and integrated monitoring systems can help reduce maintenance requirements and ensure optimal performance over the turbine's operational lifespan. The selection of segmented blades for VAWTs requires careful consideration of material composition, aerodynamic design, environmental factors, and compatibility with the turbine system. By prioritizing these considerations, engineers can design and select segmented blades that maximize energy capture efficiency, durability, and reliability, thereby optimizing the performance of VAWTs for renewable energy generation. A substantial amount of interest in the development and improvement of wind energy technologies has been sparked as a result of the worldwide need for renewable energy sources such as wind. Within this group, Vertical Axis Wind Turbines (VAWTs) have attracted a lot of attention due to the potential benefits they offer in urban contexts and in wind conditions that are difficult to control. It is crucial that the design and efficiency of the wind turbine blades be taken into consideration while evaluating the performance of VAWTs. In order to improve the performance of VAWT blades, this research strives to integrate advanced design software, computational fluid dynamics (CFD) simulations, and additive manufacturing technologies. The goal of this research is to enhance the state of the art. During the preliminary stage of this

investigation, the CATIA software is utilized to facilitate the development of two distinct models of VAWT blades. Because of its parametric modeling capabilities, CATIA makes it possible to investigate a wide range of design factors, which in turn makes it possible to optimize both the structural integrity and the aerodynamic efficiency of a design. Through this research, the researchers hope to come up with novel blade shapes that are capable of enhancing energy capture and withstanding a wide range of wind conditions. After that, the chosen blade models are subjected to a comprehensive flow analysis using ANSYS/CFD. During this part of the computational process, insights into the aerodynamic performance of each design are provided. These insights include a deep understanding of aspects like lift, drag, and overall efficiency. The combination of CATIA and ANSYS/CFD makes it possible to conduct a methodical investigation of the design space, which in turn makes it easier to determine which blade arrangement has the greatest potential for success. The importance of segmented blades in VAWTs cannot be overstated, as they offer a versatile and efficient solution for maximizing energy production from wind resources. With their aerodynamic advantages, structural robustness, and design flexibility, segmented blades represent a significant advancement in wind turbine technology, paving the way for increased adoption of VAWTs as a sustainable and reliable source of renewable energy. The next step in the research process is the practical phase of prototyping, which occurs once the ideal blade design has been determined through the use of CFD models. A physical prototype of the blade model that was selected is printed using additive manufacturing technology in order to create a physical prototype. The purpose of this stage is to bridge the gap between simulation and real-world performance by taking into consideration the limits of manufacturing and the qualities of the material. Rapid prototyping is made possible through the utilization of additive manufacturing, which also makes it possible to make incremental changes based on empirical data. One of the most innovative approaches in the field of VAWT blade creation is the holistic method, which involves merging modern design software, computational fluid dynamics, and additive manufacturing. This research has the potential to produce results that have the potential to greatly add to the efficiency, dependability, and manufacturability of vertical axis wind turbine blades.

The pressing demand for sustainable energy solutions, which is driven by environmental concerns and the limited nature of traditional energy sources, highlights the significance of optimizing wind turbine technology despite the fact that these solutions are desperately needed. Vertical axis wind turbines, also known as VAWTs, offer a one-of-a-kind potential for decentralized energy generation. This is particularly advantageous in urban and confined locations, where conventional horizontal axis turbines may be less feasible. Due to the fact that the aerodynamic performance of the blades of VAWTs is a vital factor in determining their efficiency, the design process has become a focal area for research and development. In order to create two separate VAWT blade models, the CATIA software, which is well-known for its adaptability and capabilities in parametric design, is utilized. Through the application of CATIA, it is possible to conduct a flexible investigation of design parameters, which in turn makes it easier to create blade geometries that are customized to maximize energy capture and structural integrity.

The later computational research into the aerodynamic properties of the proposed models, this preliminary design phase lays the groundwork for the investigation. The incorporation of ANSYS/CFD into the research framework makes it possible to conduct a comprehensive flow analysis of the VAWT blades that have been designed. In order to evaluate the effectiveness of each blade in a variety of wind situations, computational fluid dynamics (CFD) simulations offer a simulated testing ground. By utilizing this computational method, the research endeavors to determine the blade design that is both the most efficient and effective, so providing valuable information for judgments on further refining and prototype. The combination of CATIA with ANSYS/CFD helps to streamline the process of design optimization, which in turn ensures that a full examination of design options is carried out efficiently. After the ideal blade design has been chosen, the research moves into the realm of practical application by employing additive manufacturing technology for three- dimensional printing. In order to bridge the gap between simulation and real-world application, the physical prototype step is essential. This phase provides insights on the maneuverability, structural integrity, and actual performance of the product. The capability of additive manufacturing to realize sophisticated designs using a variety of materials makes it easier to create a working prototype that is in line with the conclusions of the computational analysis. This research,

in a nutshell, makes a contribution to the development of VAWT blade design by incorporating cutting-edge software tools and manufacturing procedures. The results of this research are intended to accomplish the goal of providing a comprehensive understanding of the design-performance-manufacturing continuum, which will in turn push the development of wind energy solutions that are more efficient and sustainable. The goal of this research is to play a crucial role in strengthening the feasibility of VAWTs for widespread deployment in a variety of environmental contexts. This research is being conducted in response to the intensifying global pursuit of clean energy.

CHAPTER 2

LITERATURE SURVEY

Muhammadd Mahmood Aslam Bhutta (2012) : various configurations of vertical axis wind turbines (VAWT) and design techniques employed for VAWT design. Various configurations of VAWT, coefficient of power for various configurations is different and can be optimized. 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.

Alpesh R Patel Et Al (2017): In recent years, there has been growing international attention on 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.

Palanisamy Mohan Kumar (2019) : 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.

Brian Hand (2020) : 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.

Brian Hand (2021) : 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

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.

Zhenzhou Zhao1(2022): 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.

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 deepwater. 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 - ω 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. The peak power coefficients are observed to increase with upstream velocity, a trend directly influenced by the blockage ratio and the Froude number.

CHAPTER - 3

AIM AND OBJECTIVES

3.1 Aim

The main aim of this work is to design and produce segmented VAWT blades that demonstrate superior performance and efficiency compared to traditional solid blades. By fine-tuning the aerodynamic profile of each segment and incorporating innovative materials and manufacturing methods the objective is to elevate the overall energy output and reliability of vertical axis wind turbines. the complex segmented VAWT blade design process, which includes aerodynamic analysis. also investigated the fabrication methods used to create these blades and assess their effectiveness using experimental trials and computer simulations..

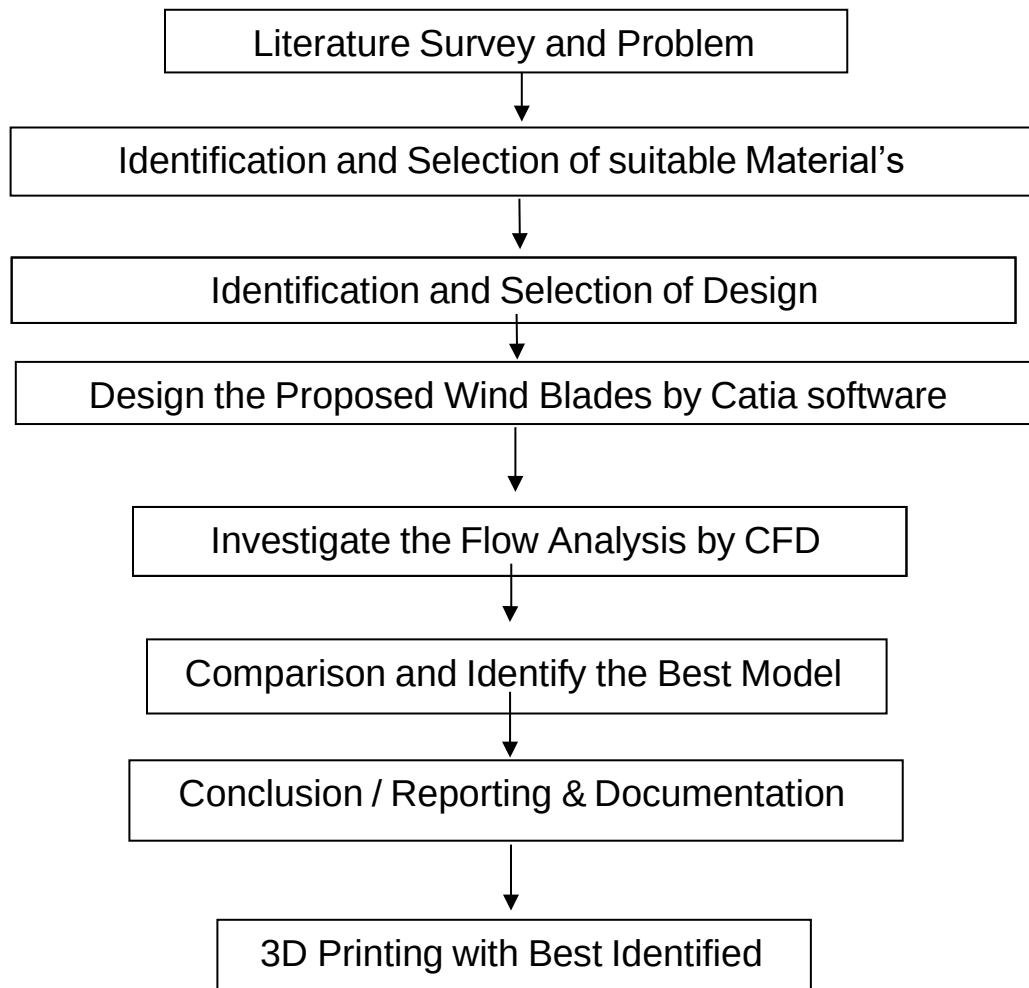
3.2 Objectives

The objective of this thorough investigation is to promote the broad use of segmented blade designs for VAWTs in a variety of applications and further the development of wind energy technology. The design and fabrication of segmented vertical axis wind turbine blades offer a promising avenue for enhancing the performance and efficiency of VAWTs. the benefits of modular design and advanced manufacturing techniques, these segmented blades present a viable solution to overcome the limitations of traditional solid blades, thereby facilitating the widespread utilization of vertical axis wind turbines as a sustainable renewable energy source. the objective is to elevate the overall energy output and reliability of vertical axis wind turbines Improving Efficiency: Enhancing the aerodynamic design, structural robustness, and control mechanisms of Darrieus wind turbines to optimize the capture and conversion of wind energy.

CHAPTER 4

METHODOLOGY

4.1 METHODOLOGY



4.2 IMPORTANCE OF VERTICAL AXIS WIND TURBINE :

The development of Vertical Axis Wind Turbines (VAWTs) for power generation holds significant importance in the broader context of renewable energy and sustainable development. Several key factors underscore the importance of advancing VAWT technology

4.2.1 Urban and Low-Wind Environments:

VAWTs are particularly suitable for urban environments where space is limited and wind directions are variable. Their compact design and ability to capture wind from any direction make them ideal for densely populated areas.

4.2.2 Turbulence Tolerance:

VAWTs exhibit better performance in turbulent wind conditions compared to Horizontal Axis Wind Turbines (HAWTs). Their inherent design allows them to effectively harness energy even in areas with inconsistent or turbulent wind patterns.

4.2.3 Aesthetic Integration:

The vertical orientation of VAWTs allows for aesthetically pleasing designs that can be integrated into various landscapes without causing visual pollution. This is crucial for gaining public acceptance and support for wind energy projects.

4.2.4 Ease of Installation and Maintenance:

VAWTs generally have simpler designs, which can result in easier installation and maintenance compared to HAWTs. The vertical axis allows for a more straightforward mechanical setup, potentially reducing overall operational costs.

4.2.5 Adaptability to Off-Grid Applications:

VAWTs can be deployed in off-grid or remote areas, providing a reliable source of renewable energy for communities without access to traditional power grids. This adaptability contributes to energy access and independence in diverse geographical locations.

4.2.6 Reduced Environmental Impact:

The development of VAWTs aligns with the global effort to reduce environmental impact and combat climate change. Wind power, in general, is a clean and sustainable energy source that significantly reduces greenhouse gas emissions compared to conventional fossil fuel-based power generation.

4.2.7 Complementing Solar Energy:

VAWTs can complement solar energy systems, providing continuous power generation during non-sunny periods. This synergy between wind and solar power enhances the overall reliability and efficiency of renewable energy installations.

4.2.8 Diversification of Energy Sources:

Investing in VAWT technology contributes to the diversification of energy sources, reducing dependence on non-renewable resources. This diversification enhances energy security and resilience in the face of potential shortages or geopolitical uncertainties.

4.2.9 Technological Innovation and Job Creation:

Research and development in VAWT technology drive technological innovation, fostering the growth of the renewable energy sector. This, in turn, leads to job creation and economic development in industries related to wind power.

4.2.10 Global Renewable Energy Targets:

Many countries have set ambitious targets for increasing the share of renewable energy in their energy mix. Advancing VAWT technology plays a vital role in achieving these targets and transitioning towards a more sustainable and environmentally friendly energy landscape. The development of Vertical Axis Wind Turbines for power generation contributes to a more sustainable, resilient, and diversified energy future,

the challenges of urbanization, climate change, and the growing demand for clean energy worldwide.

4.3 SEGMENTED VERTICAL AXIS WIND TURBINE

Segmented Vertical Axis Wind Turbine (VAWT) blades are very important in determining the efficiency and overall performance of the turbine. The design and characteristics of the blades play a significant part in this determination. In contrast to Horizontal Axis Wind Turbines (HAWTs), which have blades that revolve around a horizontal axis, Vertical Axis Wind Turbines (VAWTs) have blades that revolve around a vertical axis. There are several different aspects that are taken into consideration throughout the design process of VAWT blades. These aspects include aerodynamics, structural integrity, and materials. Listed below is an in-depth explanation of the VAWT blade design's most important components

4.3.1 The Profile Of The Aerodynamics:

One of the most important aspects that determines how effectively VAWT blades are able to capture wind energy is the aerodynamic profile of the blades. In order to ensure that the blade is able to effectively catch energy across a wide range of wind speeds, the shape of the blade has been meticulously developed to maximize lift and minimize drag. VAWT blades often have symmetric and cambered airfoil forms, which are both examples of common aerodynamic profiles. These profiles have been selected in order to achieve a balance between the characteristics of lift and drag, which will allow for the most efficient conversion of energy.

4.3.2 Control of the Twist and Pitch Modes:

When designing VAWT blades, it is common practice to incorporate a twist along the length of the blade in order to accommodate fluctuations in wind speed from the root to the tip. By ensuring that each segment functions at an angle that optimum efficiency, the twist contributes to the optimization of the angle of attack along the span of the blade.

It is also possible to add pitch control devices, which would enable modifications to be made to the angle of the blades in response to changes in the wind conditions. This improves the turbine's capacity to efficiently capture energy across a wide range of wind speeds, which was previously not possible.

4.3.3 The Selection of the Material:

It is important to strike a balance between the weight, flexibility, and strength of the materials that are utilized in the construction of VAWT blades. Some examples of materials that are commonly used are carbon fiber, fiberglass, and other composite materials. Because of the high strength-to-weight ratios and longevity offered by these materials, the blades are able to endure the dynamic forces that are experienced during rotation.

4.3.4 Aspect Ratio, Number Four:

When it comes to calculating the aerodynamic performance of VAWT blades, one of the most important parameters to consider is the aspect ratio, which is defined as the ratio of the blade length to its chord that is its width. It is often the case that blades with larger aspect ratios display lower drag and higher lift, both of which contribute to reduced drag and increased lift.

4.3.5 The Total Number Of Blades:

There are a variety of blade counts that may be found on VAWTs, with the average range being between two and numerous blades. There is a correlation between the number of blades and the beginning torque, rotational speed, and total efficiency of the turbine unit. It is necessary to strike a balance between having sufficient blades to provide adequate torque and without having an excessive number of blades, which can lead to an increase in drag and a decrease in efficiency.

4.3.6 Curvature and the Shape of a Helical Curve:

There are certain designs for VAWTs that incorporate a helical shape, which gives the blades the appearance of a corkscrew. By generating a rotating lift force as the wind blows over the curved surface, this design intends to enhance the aerodynamic

performance of the vehicle. The helical shape is designed to improve the performance of the turbine in terms of both its ability to start itself and its overall efficiency.

4.3.7 Seventh, Reinforcements For The Structure:

Internal ribs, spars, and other load-bearing elements are examples of structural reinforcements that are frequently incorporated into VAWT blades. This is because of the dynamic forces that are encountered that occur during rotation. These reinforcements contribute to the preservation of the blade structure's integrity, so reducing deformation and assuring the machine's dependability over the long run.

4.3.8 Integration With Generator, Number Eight:

The base of the VAWT blades is often attached to the generator by means of a hub or connector. In order to convert mechanical energy into electrical power, the connecting mechanism is intended to convey the rotating motion of the blades to the generator in an effective manner. To summarize, the design of VAWT blades is a complex process that entails taking into consideration an array of factors, including aerodynamics, materials, structural integrity, and overall turbine efficiency. It is essential to have a set of VAWT blades that are well- designed in order to successfully collect wind energy. This is what makes VAWTs a feasible and sustainable alternative for power generation in a variety of environmental situations.

4.3.9 The Chord Distribution and the Curvature of the Blade:

When combined with the distribution of chord length (the width of the blade), the curvature that runs along the length of VAWT blades has an effect on the aerodynamic lift and drag characteristics of the blades. It is possible to achieve a balance between lift and drag by optimizing the curvature and chord distribution of the turbine. This will allow the turbine to function at its most efficient level regardless of the wind conditions.

4.3.10 Features for the Reduction of Noise:

VAWT blades are constructed with features that reduce the amount of noise that is produced when they are in operation. When compared to HAWTs, VAWTs have a rotational axis that is distinct from that of HAWTs, which naturally results in lower noise levels. However, other design considerations, such as blade form and edge treatments, may be used in order to reduce the amount of noise produced by VAWT installations and to improve their social acceptability, particularly in residential areas.

4.3.11 Mechanisms for Variable Pitch Ranges:

Some of the most advanced designs for VAWTs contain devices that allow for changeable pitch for individual blades. Because of its variable pitch, the turbine is able to adjust to different wind speeds and maximize the amount of electricity it generates. The turbine's capacity to function effectively under a wide variety of wind situations is improved by the presence of this dynamic control system.

4.3.12 Stall Control Mechanisms, Number Twelve:

In order to effectively regulate aerodynamic forces, VAWT blade design also makes use of stall control as an additional method. Stall happens when the angle of attack is too steep, which lowers the lift and causes the aircraft to come to a stop. During high-wind circumstances, the incorporation of stall control systems, such as spoilers or slats, helps to adjust the angle of attack and prevents performance deterioration from occurring. It is possible for VAWT blade designs to add characteristics that are able to withstand the formation of ice and lessen the impacts of debris hits in places where icing or debris impact is a concern. The turbine's continuing functionality and safety are ensured by these measures, which are especially important in settings where bad weather is present.

4.4 SOFTWARE'S AN OVERVIEW

4.4.1 Ansys Software: An Overview

ANSYS is a collection of simulation software tools that are used for the design and analysis of engineering systems. It is capable of simulating and analyzing a wide variety of physical phenomena, including, but not limited to, structural mechanics, fluid dynamics, electromagnetic fields, and acoustics, amongst others. The aerospace, automotive, defence, energy, and biomedical engineering industries, amongst others, are just some of the many that make extensive use of ANSYS. The modelling and simulation capabilities of the software include a variety of tools and features, including the following. Tools for the preprocessing stage that allow for the creation and definition of geometric models, materials, and boundary conditions. Solver tools for doing numerical calculations and simulations, employing a range of methodologies such as finite element analysis (FEA), computational fluid dynamics (CFD), and electromagnetic field simulation. FEA stands for finite element analysis, and CFD and EMFS stand for computational fluid dynamics and electromagnetic field simulation, respectively. Post-processing tools, which include graphical representations and statistical analysis, are utilized for the purpose of visualizing and analyzing the findings of computer simulations. Ansys also comes with a variety of specialized modules and add-ons that can be utilized for various applications. Some examples of these applications include optimization, fatigue analysis, and non-linear material modelling. In addition, ANSYS is compatible with a wide variety of other software applications, such as computer-aided design (CAD) programmes and product lifecycle management (PLM) systems.

Analysis of Structural Components and Assemblies ANSYS Mechanical is a tool for finite element analysis (FEA), which is used for the study of structural components and assemblies. It is able to perform linear and nonlinear analyses, as well as static and dynamic analyses, analyses of fatigue, and thermal analyses.

Ansys is used for fluid dynamics. Fluent is a tool for computational fluid dynamics (CFD) that simulates fluid flow and heat transfer in a variety of applications, including aerospace and automotive engineering, as well as biomedical engineering. ANSYS Maxwell is a tool for electromagnetic field simulation that is used for analysis of electromagnetic devices and systems such as motors, transformers, and antennas. It is a part of the field of electromagnetic. ANSYS Multiphysics is a tool for the modelling and analysis of linked physical phenomena. Some examples of coupled physical phenomena are fluid-structure interaction, thermal-electric coupling, and structural-acoustic coupling. ANSYS Design Explorer is a tool that is used for optimization, namely design exploration, parameter optimization, and sensitivity analysis of complicated systems. Additive Manufacturing: ANSYS Additive Suite is a tool for the simulation of 3D printing processes, including heat analysis, stress analysis, and distortion analysis. Additive Manufacturing is also known as "additive layer manufacturing." ANSYS Simplorer is a tool for system-level simulation and analysis that is used for modelling and simulating complex systems in a variety of different sectors. In most cases, performing an analysis with ANSYS requires that one go through the following stages during this stage of the process, known as preprocessing, a geometric model of the component or system that is going to be analysed is created. Either the model can be made from scratch within ANSYS, or it can be imported from another CAD programme. In this phase, we also establish the material qualities, boundary conditions, and any other specifications that are necessary. After that, a meshing method is used to break the geometric model down into its constituent parts, each of which is a finite element. The intricacy of the model and the precision of the analysis that is required can both have an effect on the size and kind of the mesh that is used. Ansys solvers are then used to solve the set of equations that describe the physical behavior of the model when the solution has been found. Different types of solvers, such as those for structural, thermal, or fluid dynamics analysis, may be employed depending on the type of analysis being performed. After the findings of the study have been compiled, the ANSYS post processing tools are used to analyze them. These tools are able to offer visualizations of the model's behavior, including the distributions of deformation, stress, and temperature.

Validation: At this point, the accuracy of the results is checked against either experimental data or other analytical approaches. The ANSYS programme is capable of doing analyses on a broad variety of components, including the following:

2D Elements: These are the elements that are utilised for planar analysis. Some examples of these elements are beam elements, axisymmetric elements, plane stress elements, and plane strain elements. Tetrahedral, hexahedral, and wedge elements are examples of the types of 3D elements that can be used for 3D solid modelling and analysis. These elements are referred to as "3D Elements." Elements such as shell181 and shell281 are examples of shell elements, which are utilized for the modelling of thin structures such as plates and shells.

Beam components: These are used for modelling thin structures such as beams or trusses and contain components such as beam188 and beam189. Beams and trusses are both examples of these types of structures. Elements like contact174 and contact184 are examples of contact elements, which are utilized for modelling the interactions that take place between different components.

Fluid Elements: These are the elements that are utilized for the analysis of fluid dynamics. Some examples of these elements are CFD tetrahedral elements and CFD hexahedral elements. The kind of analysis that is being carried out, the geometry of the model, and the level of precision that is required all play a role in determining which element should be used. The ANSYS programme offers a diverse selection of element types in addition to a number of cutting-edge features, allowing for an accurate and effective study of difficult engineering issues. In addition to the conventional components, ANSYS provides customers with a selection of specialized elements that can be used for a variety of applications, including the following:

Composite Elements: These are the elements that are used for analyzing composite materials. Some examples of composite elements include solid46 and shell99.

Piezoelectric Elements: These are elements that are used for analyzing materials that generate an electrical charge when subjected to mechanical stress. Some examples of piezoelectric elements include solid227 and solid228, however there are many others.

Electromagnetic Elements: These are the elements that are utilized for the analysis of electromagnetic fields. Some examples of these elements are magtetor223 and magtetor224.

Elements Used to Analyze Acoustic Fields These are the elements that are used to analyze acoustic fields and include things like acoustics11 and acoustics12.

Thermodynamic Elements: These are the elements that are used to analyses heat transport and include things like convection180 and conduction.4.

Elements of Dynamism: These are the elements that are utilized in the process of analyzing dynamic systems. Some examples of dynamic elements include modal analysis and transient analysis. In addition to the various parts, the ansys programme provides a selection of material models and boundary conditions, which together enable an accurate representation of real-world engineering challenges. The adaptability and configurability of the ansys software make it an effective instrument for the analysis of a wide variety of engineering challenges encountered in a variety of business sectors. The engineering analysis software known as ansys has a variety of cutting-edge features such that ANSYS programm is capable of simulating nonlinear effects such as massive deformations, the nonlinearities of materials, and contact interactions. The ansys software has the capability to simulate dynamic systems, such as those with natural frequencies, transient responses, and random vibration.

Analysis of Multiple Phenomena The ANSYS programme is capable of simulating complicated Multiphysics situations, such as coupled thermal-mechanical or fluid-structure interaction issues.

Optimization: The ANSYS software is capable of carrying out optimization studies in order to locate the most suitable design solution according to user-specified requirements.

High-Performance Computing: The ANSYS software is able to make use of high-performance computing (HPC) resources, which helps to reduce the amount of time needed for simulations and tackle more difficult and extensive issues.

Additive Manufacturing: The ANSYS software incorporates a number of tools for additive manufacturing, which enables users to mimic the processes of 3D printing and better optimise their designs for production.

System Simulation: The ANSYS programme is capable of simulating complete systems, down to the individual electrical, hydraulic, and mechanical components, in order to anticipate the performance of the entire system.

Personalization: The ANSYS software offers a high level of personalization, enabling users to develop personalised workflows, user-defined routines, and macros.

Visualisation: The ANSYS programme offers a variety of advanced visualisation capabilities, including as 3D images, animations, and charts, to users in order to assist them in interpreting the results of simulations. The breadth and depth of functionality provided by ANSYS software makes it an effective instrument for engineering analysis in a wide variety of sectors, including the aerospace, automotive, biomedical, and energy industries, to name a few.

4.4.2 CFD : An Overview

Computational fluid dynamics, or CFD, is a subfield of fluid mechanics that makes use of computers and computer programmers to model, simulate, and otherwise study fluid flows and the phenomena they cause. Numerous phenomena, including aerodynamics, heat transfer, combustion, and multiphase flows, are amenable to investigation with CFD. The Navier-Stokes equations, which describe the motion of viscous fluids, form the basis for computational fluid dynamics (CFD) simulations. Mathematical approaches such as the finite difference, finite volume, and finite element methods are used to find numerical solutions to these equations. It is oftentimes difficult or impossible to gather

experimentally comprehensive information about the velocity, pressure, temperature, and other parameters of fluids in complex geometries, but CFD simulations can. Aerospace, automotive, chemical, energy, and biomedical engineering are just few of the numerous fields that use CFD to design and optimize products and processes. It can help engineers and scientists optimize designs, minimize costs, and mitigate hazards involved with physical investigations by providing a better understanding of how fluids behave under different conditions. Complex fluid flow issues are challenging to answer analytically or experimentally, but MORE CFD can help. Engineers and scientists can use it to examine fluid dynamics in a wide range of settings, including laminar and turbulent flow, heat transport, and chemical reactions.

CFD can be used for a variety of purposes, some of which are:

In the field of aerospace engineering, CFD is used to perfect the aerodynamics of planes, satellites, and missiles. It can also be used to mimic the combustion processes of jet engines and rocket motors. In the field of automotive engineering, CFD is used to enhance the aerodynamics of vehicles in order to lessen their impact on the environment. It can also be used to model the passage of air through mechanical parts and vents. In the field of chemical engineering, computational fluid dynamics (CFD) can be used to model and optimize process equipment including chemical reactors and mixing tanks. Fluid dynamics in pipelines and heat exchangers can also be simulated with this tool. In the field of energy engineering, CFD is used to create and improve renewable energy infrastructure like wind turbines and hydroelectric dams. Fluid flow modelling in oil and gas reservoirs is another possible application's has applications in biomedical engineering, including the analysis of blood flow, which aids in the detection and treatment of cardiovascular illness. It can be utilized as a model for tissue engineering and drug delivery systems. New methods and algorithms are constantly being developed in CFD to enhance the precision and performance of simulations. It is expected that CFD will become increasingly more essential to engineers and scientists in a wide variety of domains as computer capacity continues to increase.

4.2.3 CFD analysis methods:

In most cases, the following are what are involved in a CFD analysis:

The first step in solving any problem is to formulate it, which involves specifying the domain's shape, the fluid's properties, and the intake and outflow circumstances. A computational mesh is produced to partition the domain into cells or elements when the problem is established. The simulation's precision and performance are both heavily dependent on the quality of the mesh used.

Choosing a Solver: Whether the problem is one of steady-state or transient flow, laminar or turbulent, compressible or in-compressible, determines which solver is used. Solver settings, including time step size, convergence criterion, and turbulence model, must be specified during simulation setup. Setting the beginning and boundary conditions is a part of this process as well. The simulation is run with the specified parameters and solver. The fluid-flow equations are solved by the solver until they converge to a steady state or a solution at a specific time, at which point the process repeats. Simulated data is post-processed to obtain useful information including fluid characteristics, velocities, and temperatures. Plots and animations are generated using visualization software to help with understanding the findings. Comparison of simulation findings to either experimental data or analytical answers serves as a validation of the simulation's accuracy. If the simulation setup or mesh needs refining, the results may become more accurate. Once the simulation has been verified, it can be utilized to enhance the system's design or functionality. In order to get the best possible outcome, it may be necessary to perform several simulations with varying parameters. Steps 4–7 of the CFD analysis process can be performed as often as necessary to reach the required degree of precision. The computer resources available and the nature of the problem being addressed determine the complexity and time required for each phase.

4.5 EXPERIMENTAL CALCULATION

Calculations

$P = 0.5 * \rho * A * v^3 * C_p$ density of air (ρ): 1.225 kg/m³ Swept area of blades (A): 10m²

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

$$C_p = 0.3506 / v^3$$

- 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 $P = 0.5 * \rho * A * v^3 * C_p$ 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 4.1: Electrical Power Output

Turbine RPM	Generator	Generator	Electrical Power
	Voltage	Current	Output (W)
	(v)	(I)	
500	220	6.5	1450.0
600	240	7.2	1730.0
700	260	8.0	2075.0
800	280	8.5	2380.0
900	300	9.0	2603.0

Table 4.2: Mechanical Power Output

Electrical Power Output	Conversion Efficiency	Mechanical Power
(W)		Output (W)
1450.0	0.8	1145.0
1730.0	0.8	1380.4
2075.0	0.8	1660.0
2380.0	0.8	1904.0
2603.0	0.8	2160.0

Table 4.3: Co-efficient of Pressure

Mechanical Power Output	Density	Area	Co-efficient of	Wind Speed v
(w)	(kg/m³)	(m²)	Pressure	(m/s)
1450.0	1.225	10	0.33	6.20
1730.0	1.225	10	0.35	7.02
2075.0	1.225	10	0.36	7.90
2380.0	1.225	10	0.36	8.80
2603.0	1.225	10	0.37	9.60

CHAPTER – 5

MODEL AND ANALYSIS RESULTS

5.1 CFD ANALYSIS OF SEGMENTED VERTICAL AXIS WIND BLADE

5.1.1 Design For Model 1

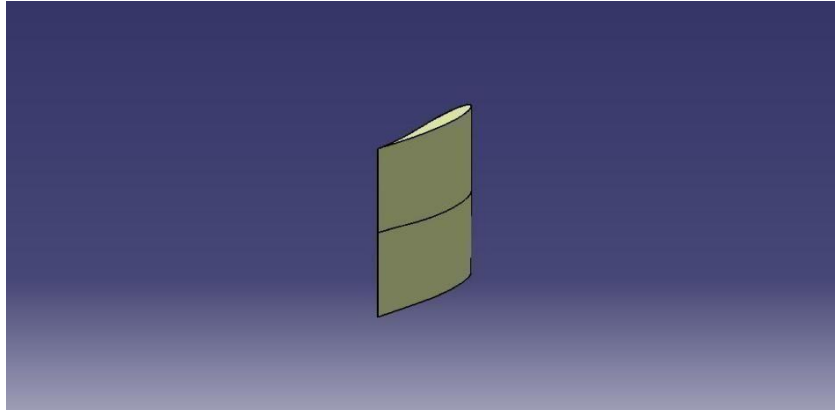


Fig:5.1 : Normal view of the Model 1

The Fig:5.1: refers to the design of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21 .

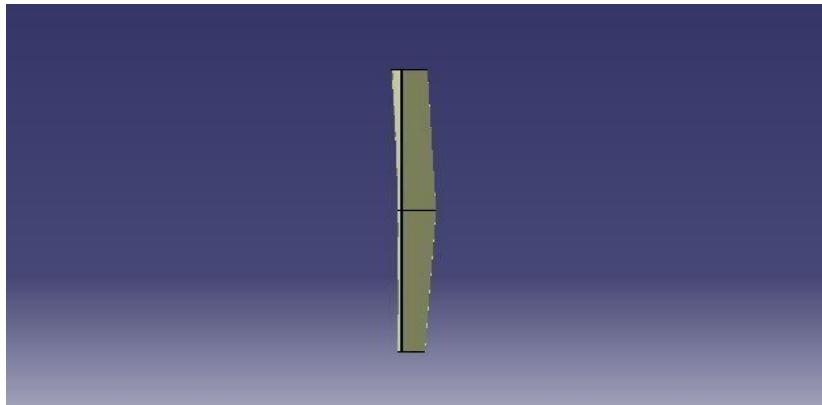


Fig:5.2 :Bottom view of the Model 1

The Fig:5.2 : refers to the bottom view of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21

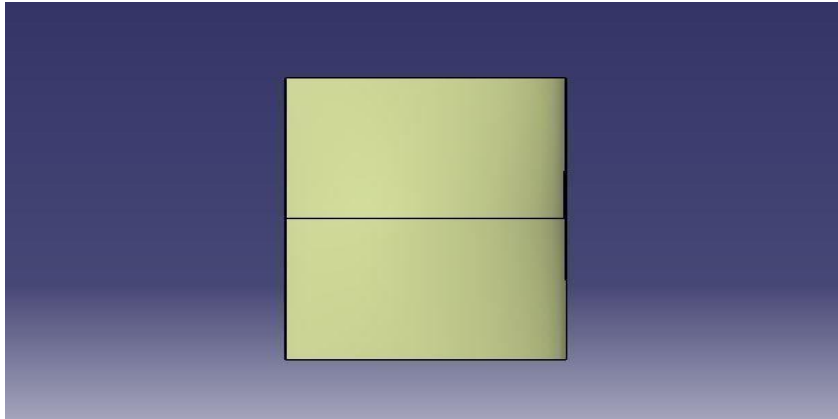


Fig:5.3 :Top view of an Blade

The Fig:5.3 : refers to the top view of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21

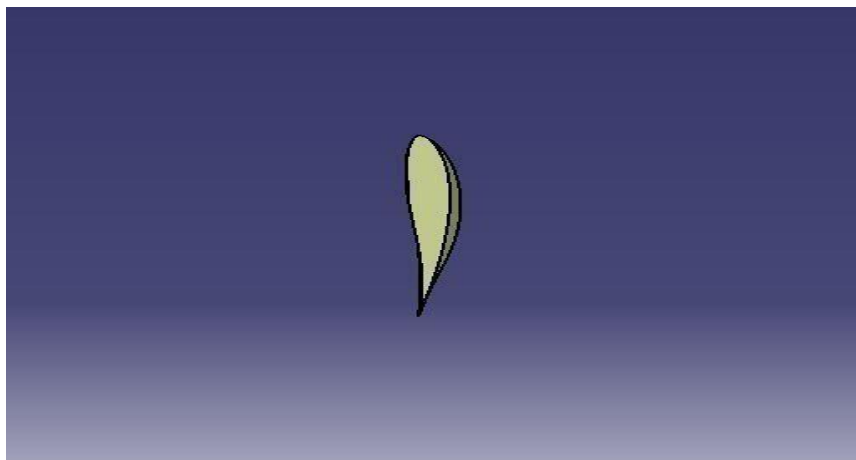


Fig:5.4 :Side view of the Model 1

The Fig:5.4 : refers to the side view of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21

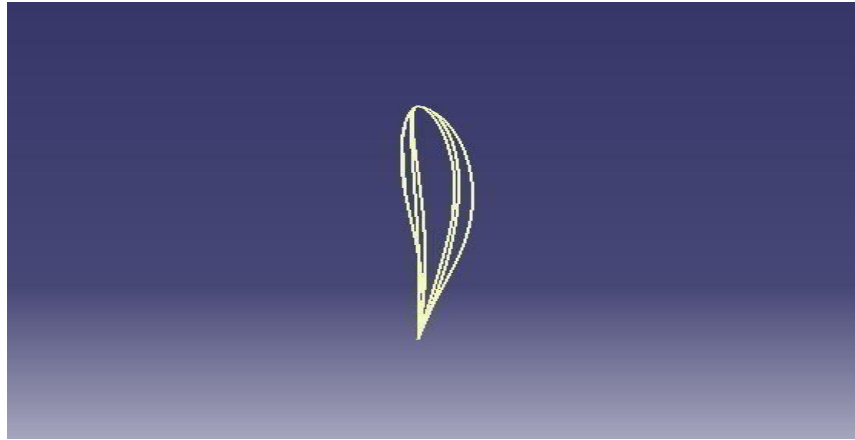


Fig :5.5: Isometric view of the Model 1

The Fig:5.5 : refers to the side view of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21.

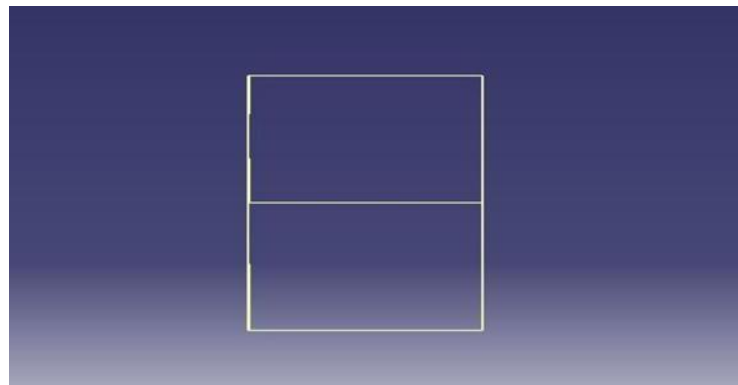


Fig :5.6: Isometric view of the Model 1

The Fig:5.6 : refers to the isometric view of Model 1 Blade designed using the Catia v5 .by using airfoil sd7062,e387,dae21.

5.1.2 Design Of Model 2 :

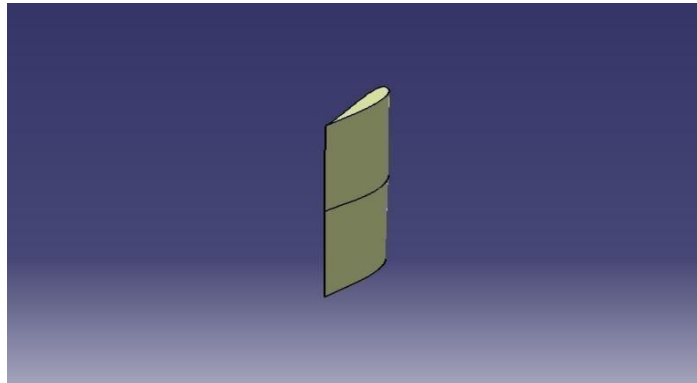


Fig:5.7 : Design of the Model 2

The ***Fig:5.7*** : refers to the Design of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.

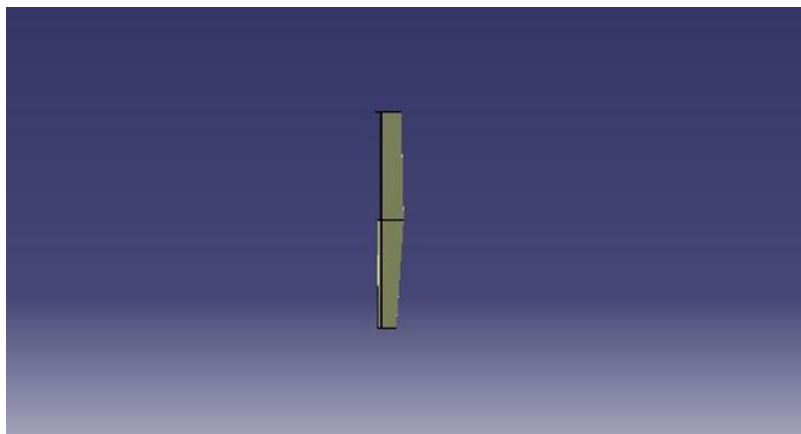


Fig:5.8: Bottom of the Model 2

The ***Fig:5.8*** : refers to the Bottom view of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.

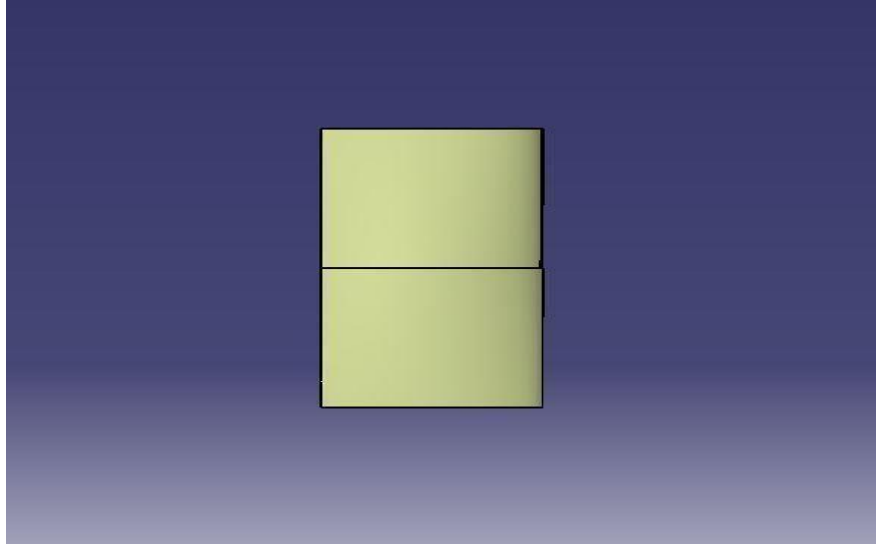


Fig:5.9 :Top view of the Model 2

*The **Fig:5.9** : refers to the Top view of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.*

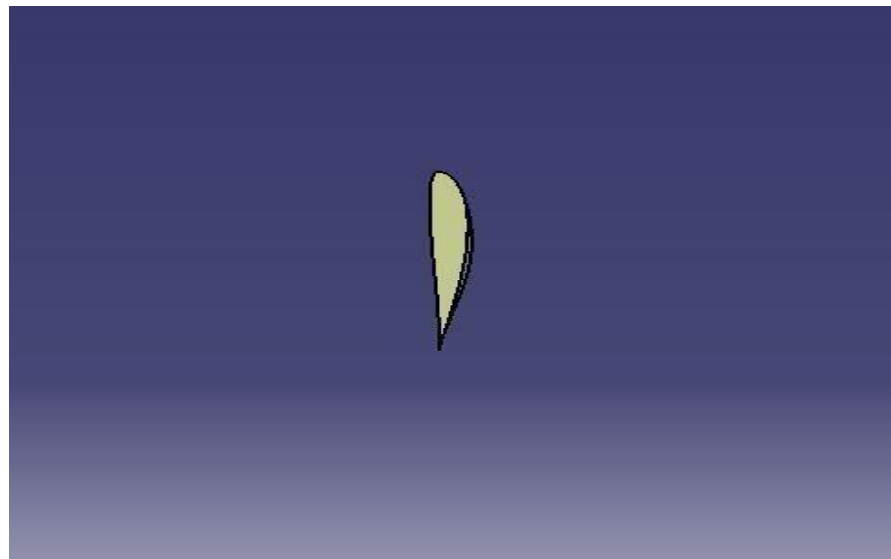


Fig:5.10 :Side view of the Model 2

*The **Fig:5.10** : refers to the Side view of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.*

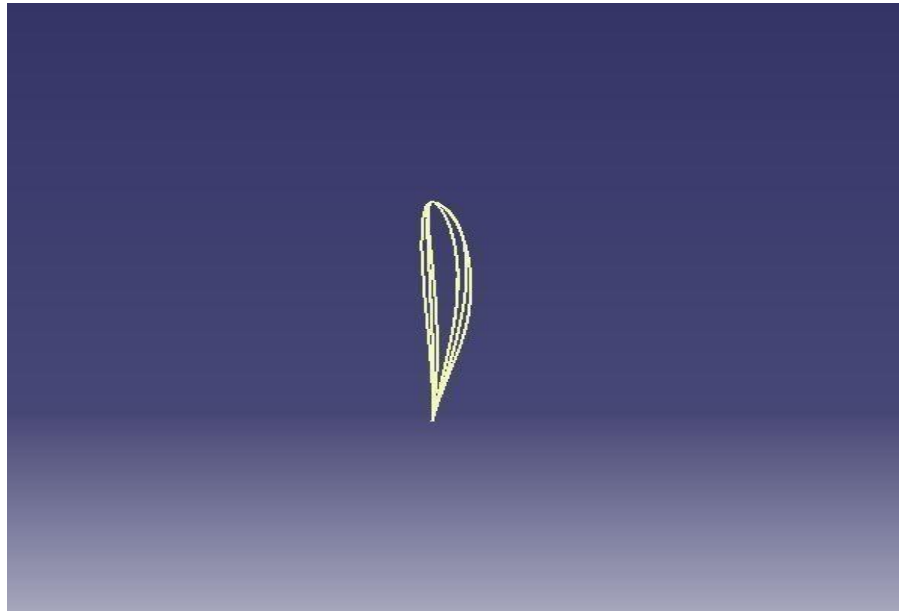


Fig:5.11 :Isometric view of the Model 2

The Fig:5.11: refers to the Isometric of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.

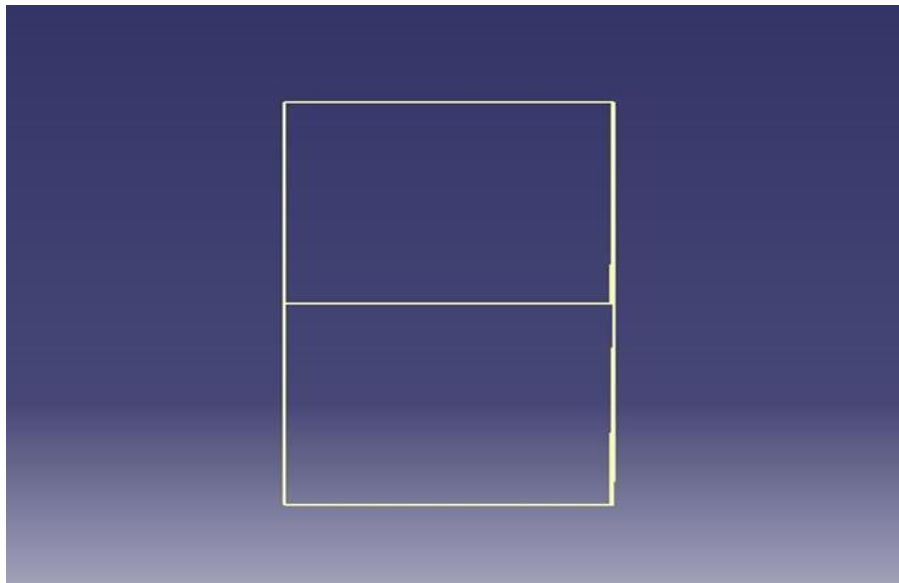


Fig:5.12 : Isometric view of the Model 2

The Fig:5.12 : refers to the Isometric view of Model 2 Blade designed using the Catia v5 .by using airfoil Fx60126,e387,dae21.

Aerodynamic design considerations :

Aerodynamic design considerations are paramount in optimizing the performance of segmented blades for Vertical Axis Wind Turbines (VAWTs), as they directly impact the efficiency and energy capture capabilities of the turbine system. The aerodynamic design of segmented blades plays a crucial role in maximizing lift, minimizing drag, and enhancing stall resistance, ultimately leading to improved overall turbine performance. Several factors influence the aerodynamic performance of segmented blades, including airfoil shape, twist distribution, and chord length. The airfoil shape, or cross-sectional profile of the blade, significantly affects its lift and drag characteristics. By carefully selecting the airfoil shape and modifying parameters such as camber and thickness distribution, engineers can tailor the blade's aerodynamic properties to optimize energy capture efficiency across a range of wind speeds and angles of attack. Additionally, the twist distribution along the length of the blade is essential for maintaining optimal aerodynamic performance along the entire span. Variations in twist angle help mitigate the effects of aerodynamic stall and ensure uniform lift distribution, particularly in regions of the blade experiencing different wind speeds or flow conditions. Furthermore, the chord length, or width of the blade, influences its lift and drag coefficients, with longer chords typically providing higher lift but also increased drag. Balancing these factors is crucial in achieving the desired trade-off between lift generation and drag reduction for optimal turbine performance. Various methods and tools are employed for aerodynamic analysis and optimization of segmented blades, ranging from computational fluid dynamics (CFD) simulations to wind tunnel testing and field measurements. CFD simulations allow engineers to model and analyze the flow behavior around segmented blades in different operating conditions, providing valuable insights into aerodynamic forces, pressure distributions, and flow patterns. Wind tunnel testing complements CFD simulations by providing experimental validation of aerodynamic performance and allowing for real-world testing of blade prototypes under controlled conditions. Additionally, field measurements on operational VAWT systems provide valuable data on actual blade performance in situ, helping refine and validate aerodynamic design parameters. In conclusion, aerodynamic design considerations are essential for optimizing the performance of segmented blades in VAWTs, with factors such as airfoil shape, twist distribution, and chord length playing key roles in determining aerodynamic efficiency and energy capture capabilities.

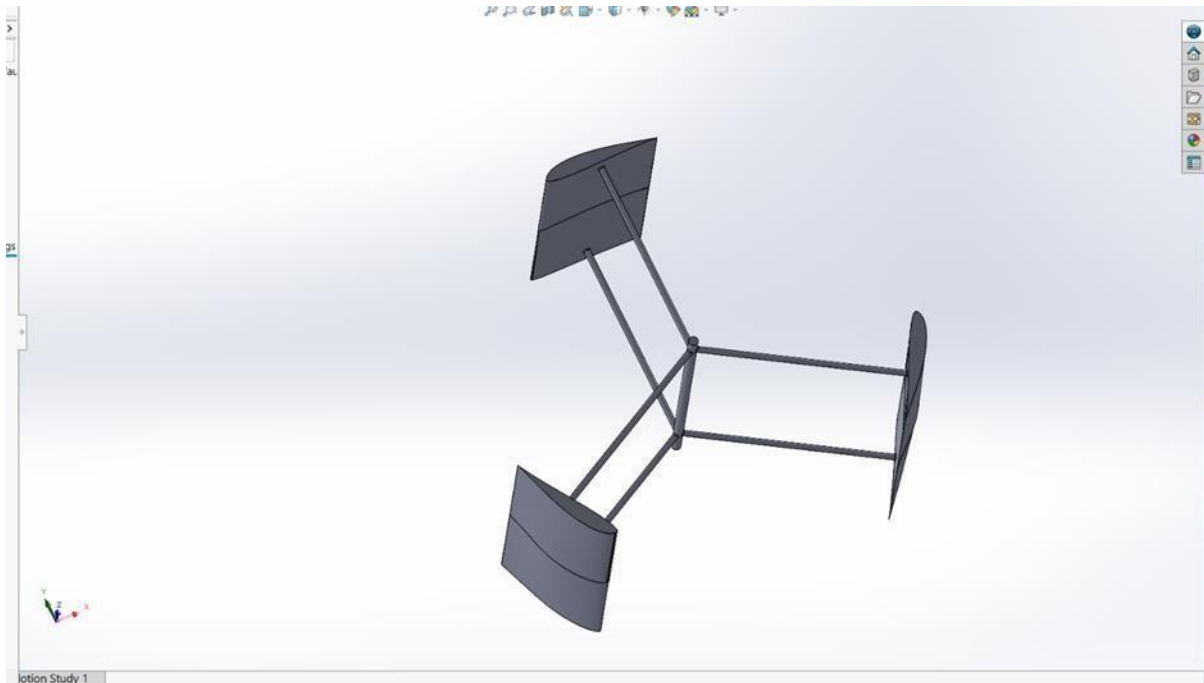


Fig 5.13: Full setup Design

A	
1	Fluid Flow (Fluent)
2	DM Geometry ✓
3	Mesh ✓
4	Setup ✓
5	Solution ✓
6	Results ✓

Fluid Flow (Fluent)

Fig: 5.14: Workbench Parameters

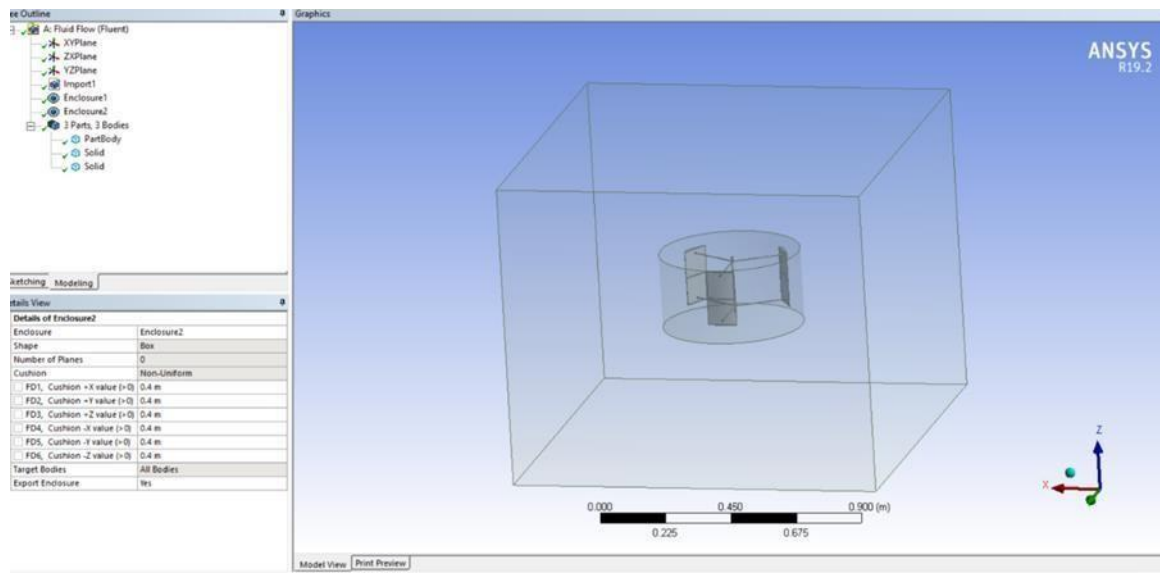


Fig 5.15: Geometry

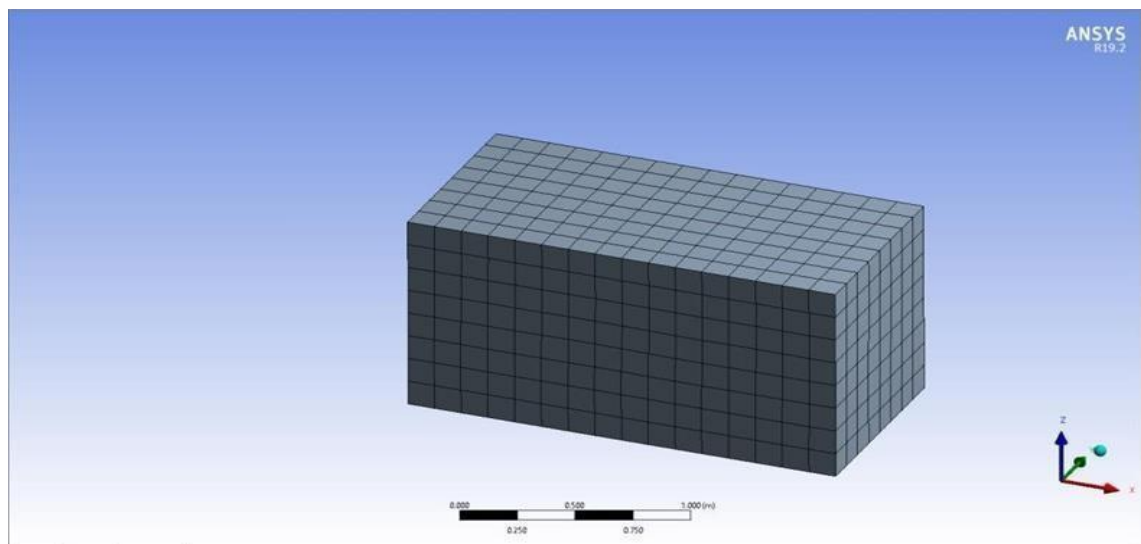


Fig 5.16 : Hex dominant method of meshing

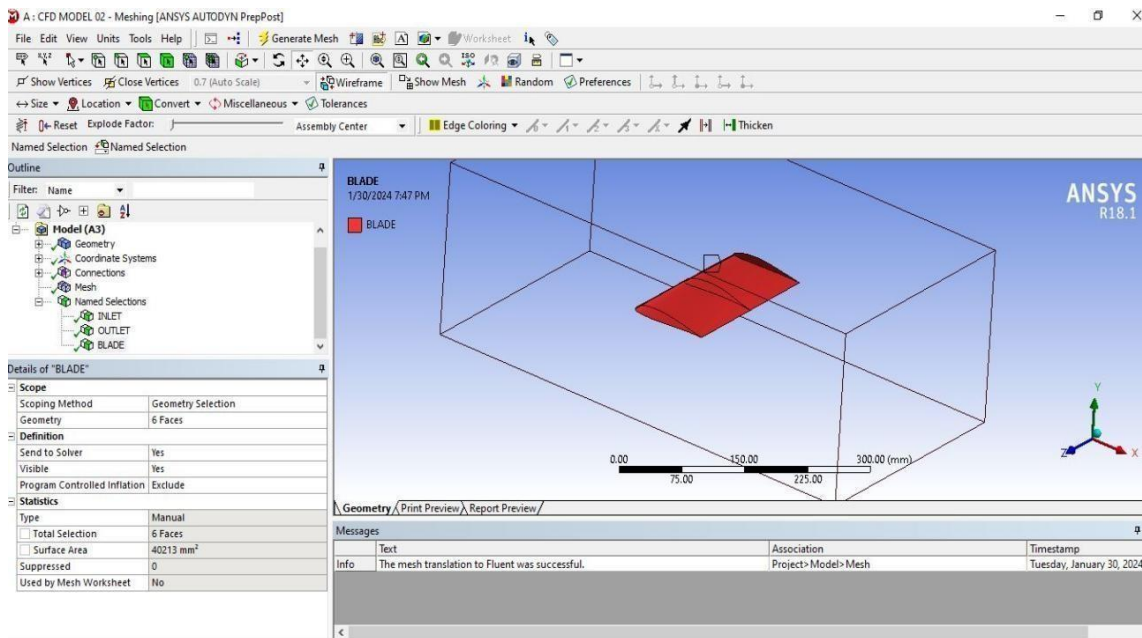


Fig:5.15 : Blade Enclosure

☐ FD1, Cushion +X value (>0)	0.25 m
☐ FD2, Cushion +Y value (>0)	0.1 m
☐ FD3, Cushion +Z value (>0)	0.05 m
☐ FD4, Cushion -X value (>0)	0.25 m
☐ FD5, Cushion -Y value (>0)	0.1 m
☐ FD6, Cushion -Z value (>0)	0.05 m

Fig:5.16: Dimensions of the Enclosure

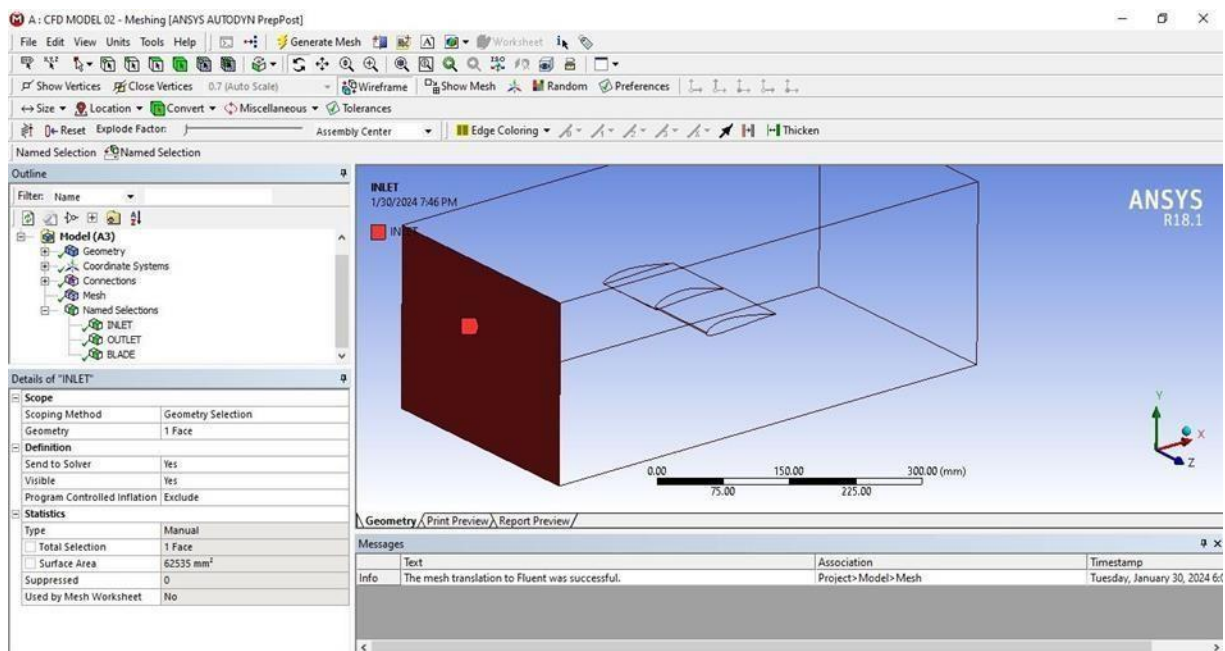


Fig.5.17: Inlet of the Enclosure

Details of "Mesh"	
Element Order	Linear
Sizing	
Size Function	Curvature
Relevance Center	Fine
Transition	Slow
Span Angle Center	Fine
☐ Curvature Normal Angle	Default (18.0 °)
☐ Min Size	Default (0.102270 mm)
☐ Max Face Size	Default (10.2270 mm)
☐ Max Tet Size	Default (20.4540 mm)
☐ Growth Rate	Default (1.20)
Automatic Mesh Based Defeaturing	On
☐ Defeature Size	Default (5.1136e-002 mm)
Minimum Edge Length	1.6771e-002 mm
Quality	
Inflation	

Fig.5. 18: Mesh Details

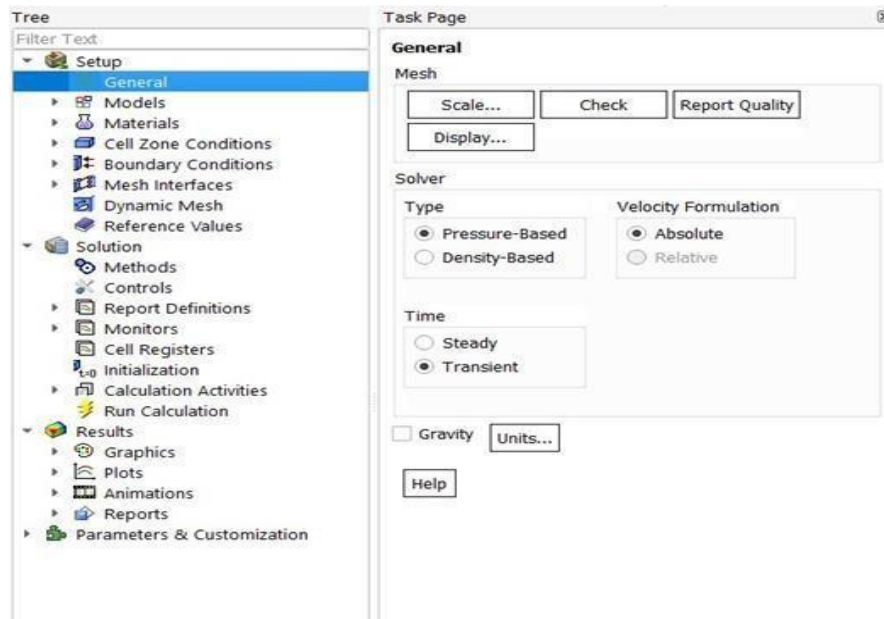


Fig:5.19: Analysis Input Parameters

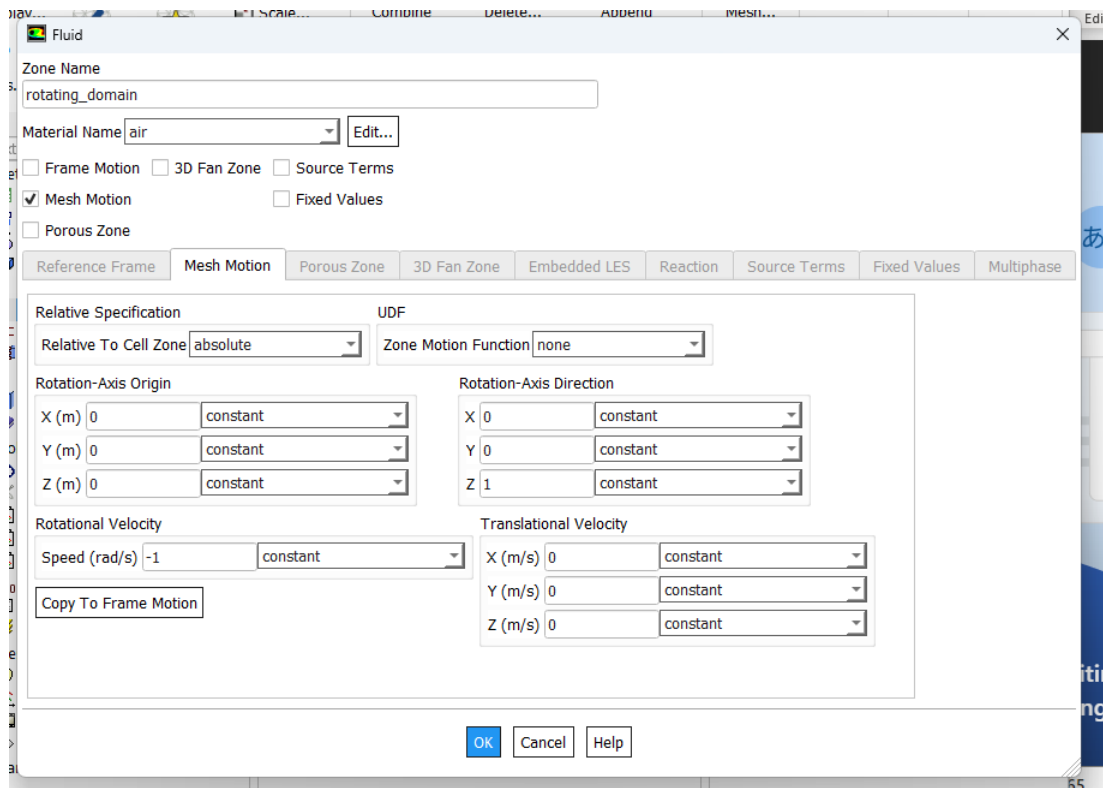


Fig:5.20: Fluid in Cell Zone Conditions

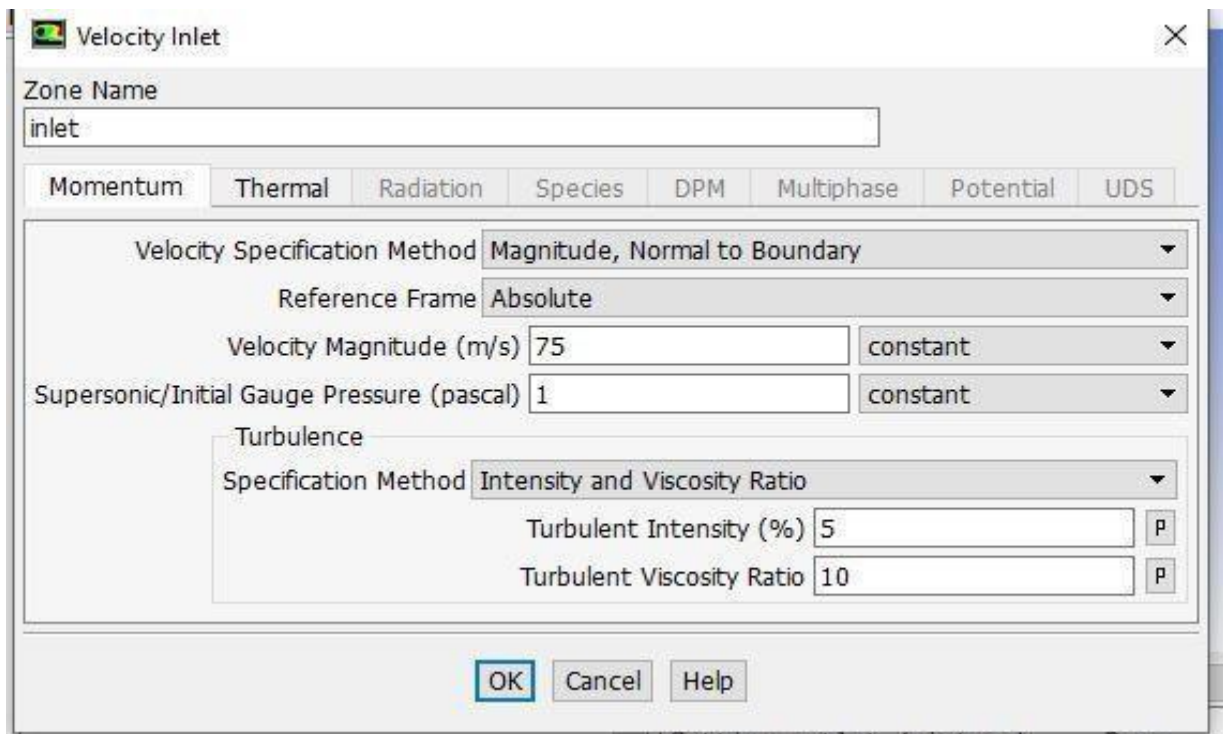


Fig:5.21 : Input Propersties of the velocity inlet

5.1.3 CFD Result For Model 1

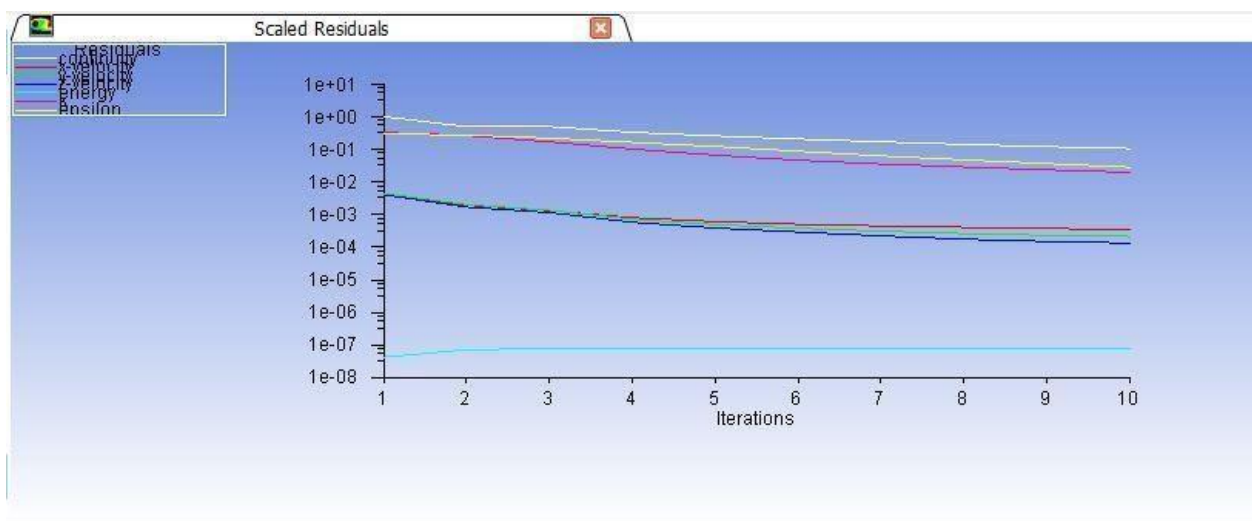


Fig:5.22 : Scaled Residuals of the Model 1

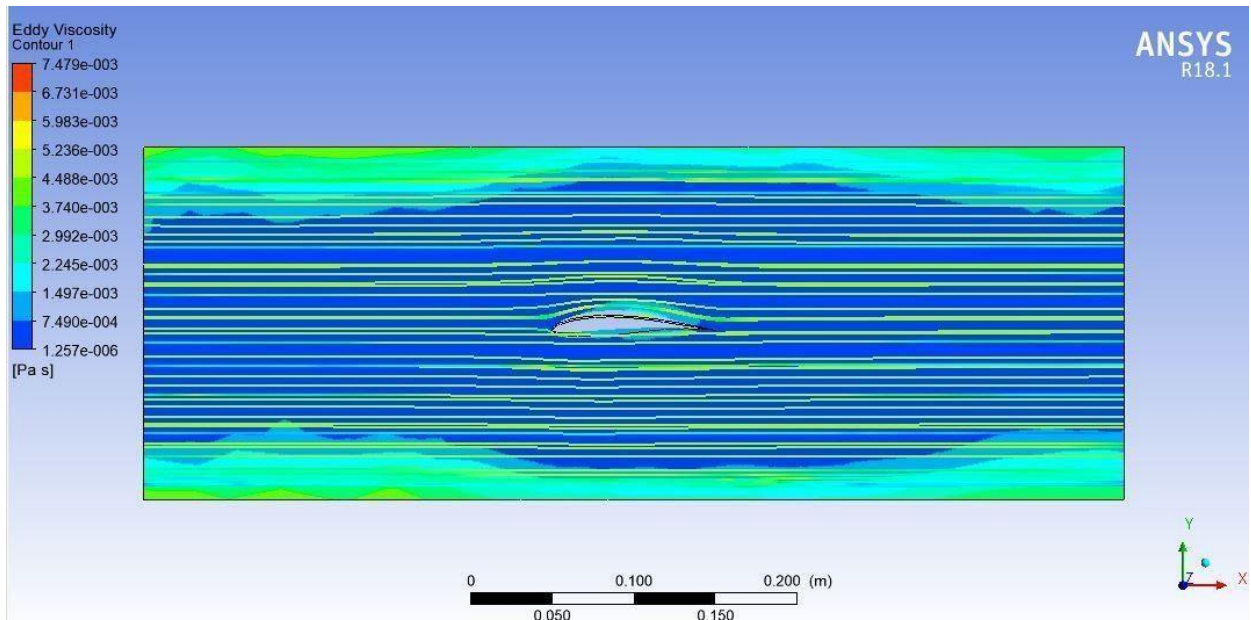


Fig:5.23 : Eddy Viscosity contour of Model 1

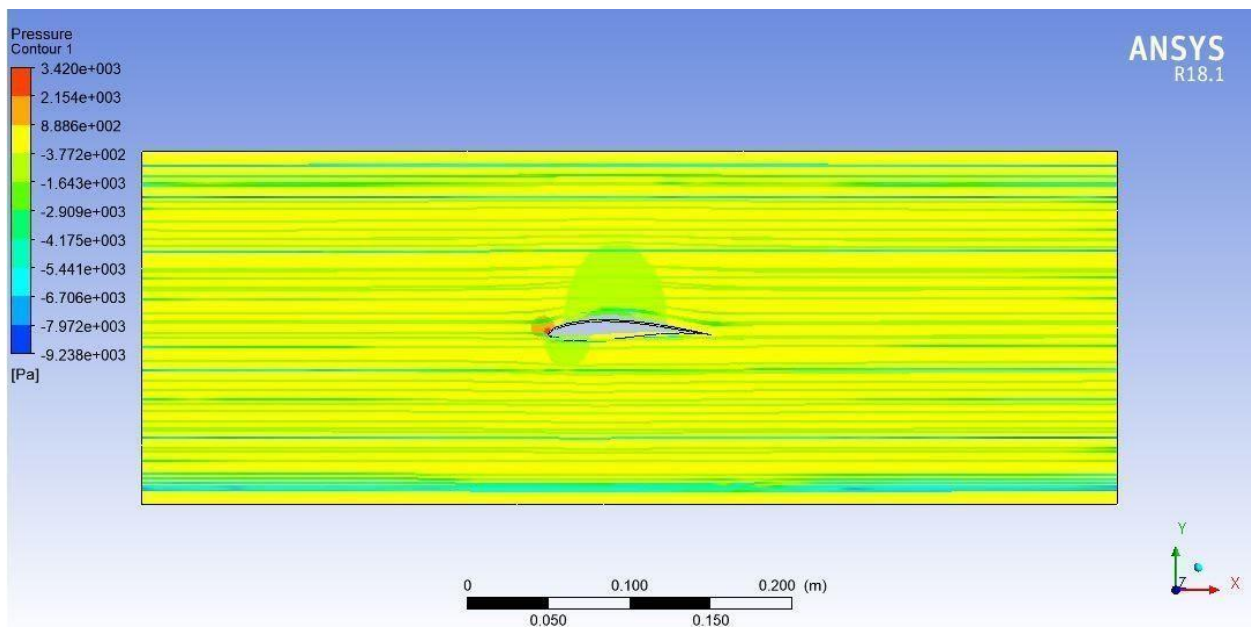


Fig:5.24 : Pressure Countour of Model 1

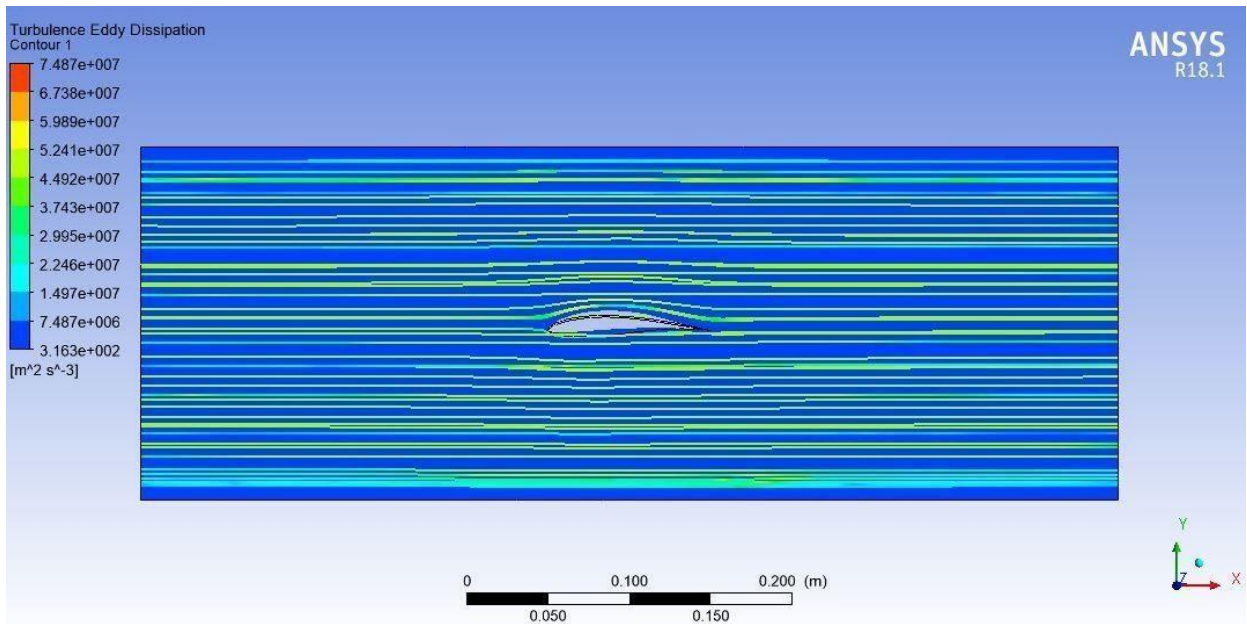


Fig:5.25 : Turbulence Eddy Dissipation Contour

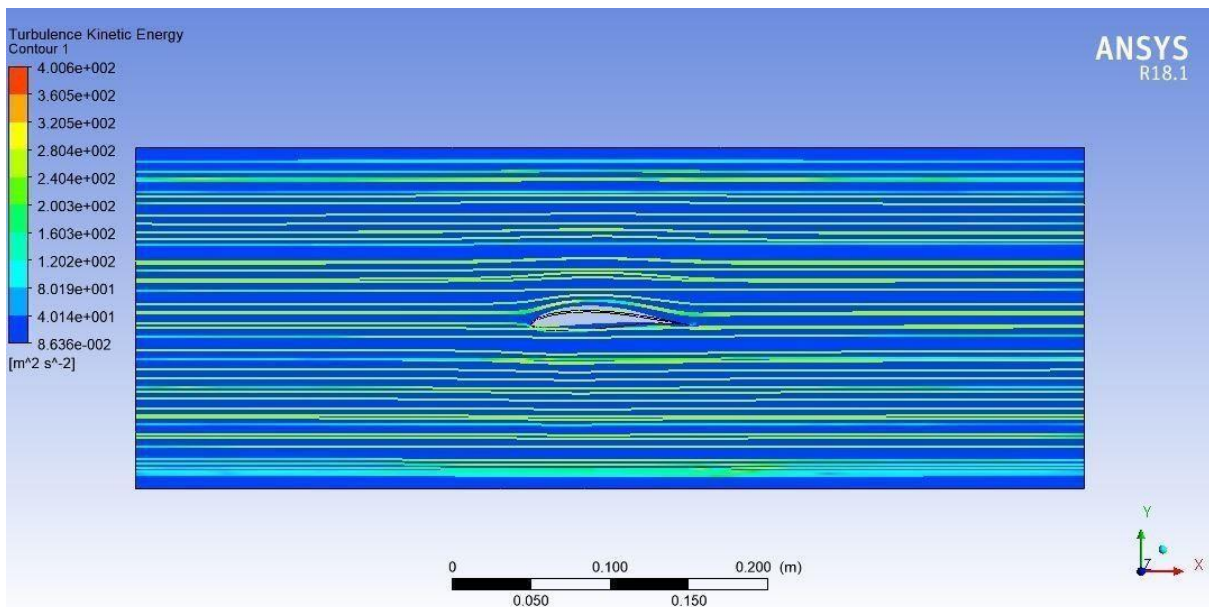


Fig:5.26 : Turbulence Kinetic Energy contour

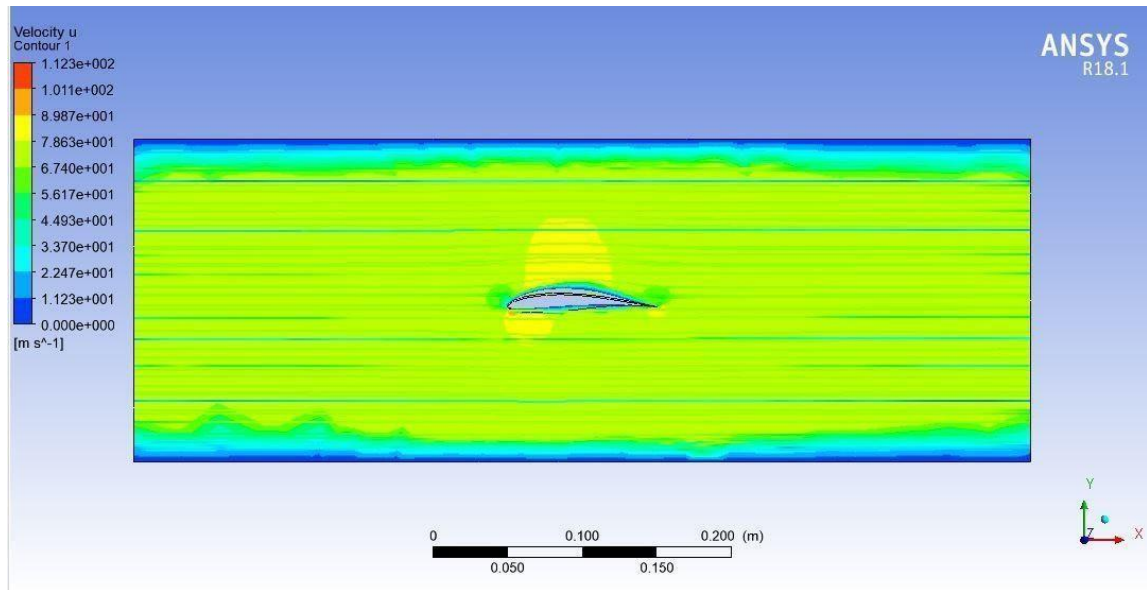


Fig:5.27 : Velocity contour of Model 1

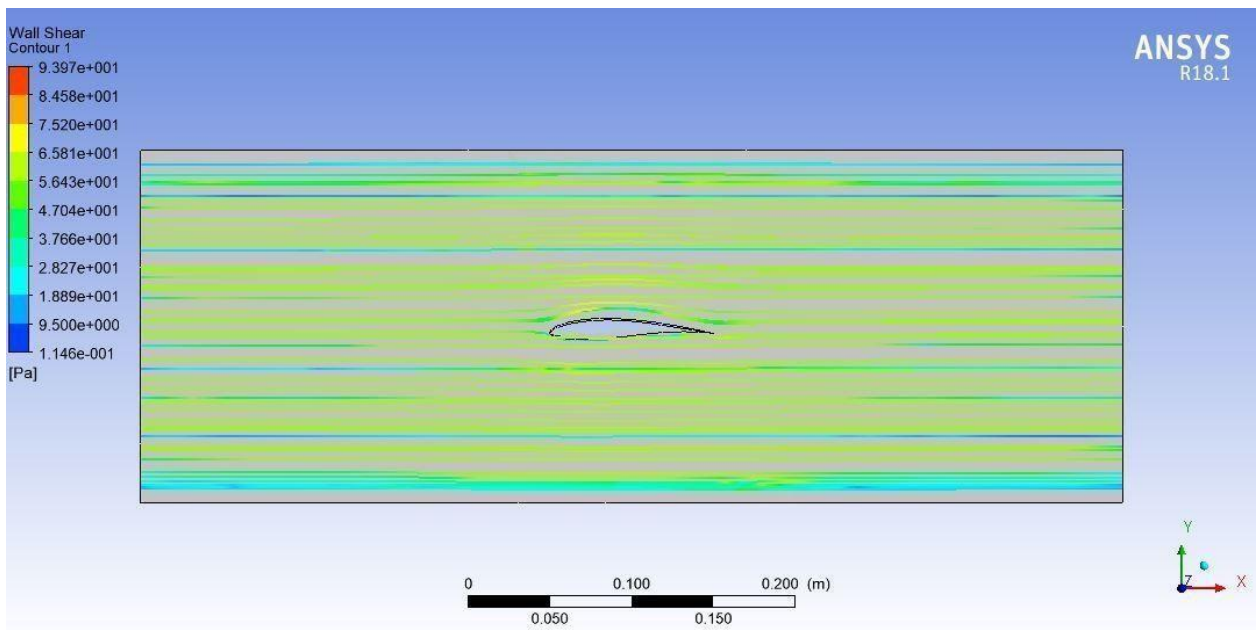


Fig:5.28 : Wall Shear contour of Model 1

CL AND CD OF AN MODEL 1

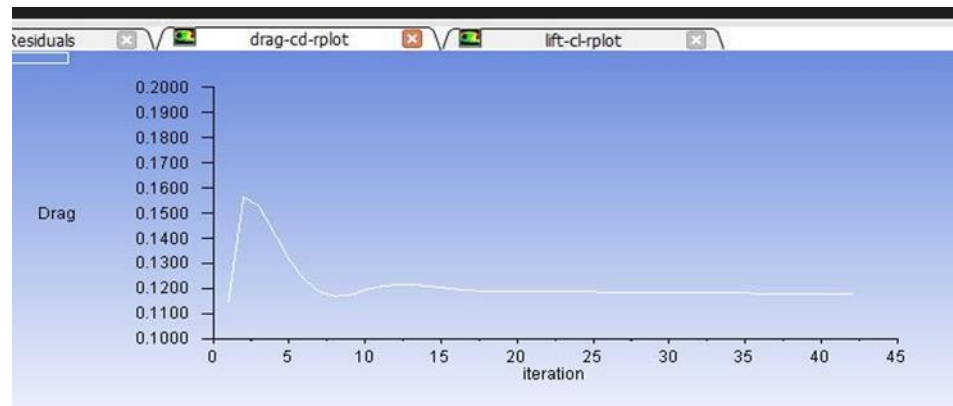


Fig:5.29: Cd graph of the Model 1

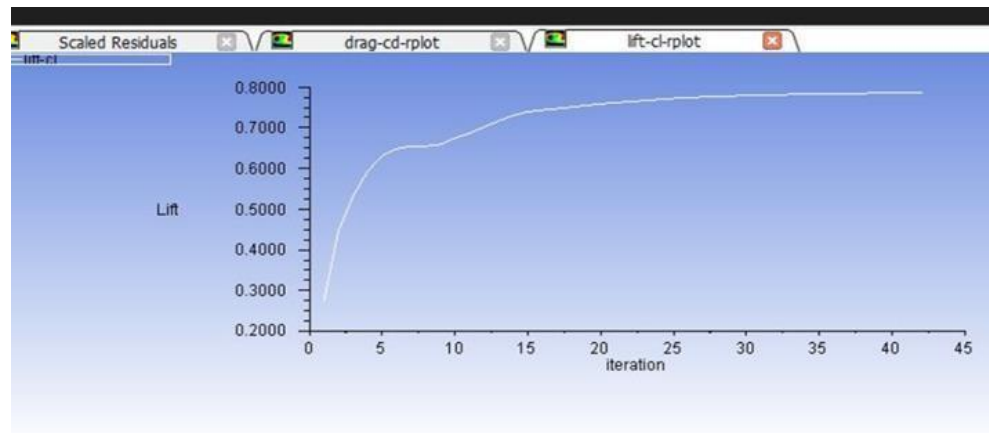


Fig:5.30: Cl graph of the model 1

model 01	
CD	CL
1.79E-02	7.86E-01

5.1.4 CFD RESULT FOR MODEL 2

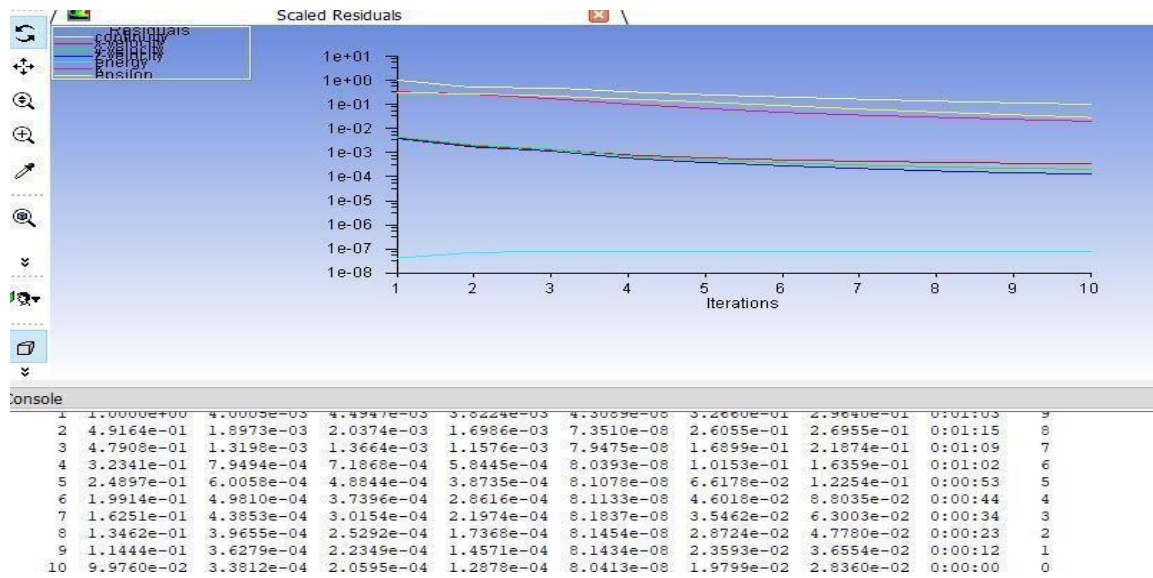


Fig:5.31 : Scaled Residuals

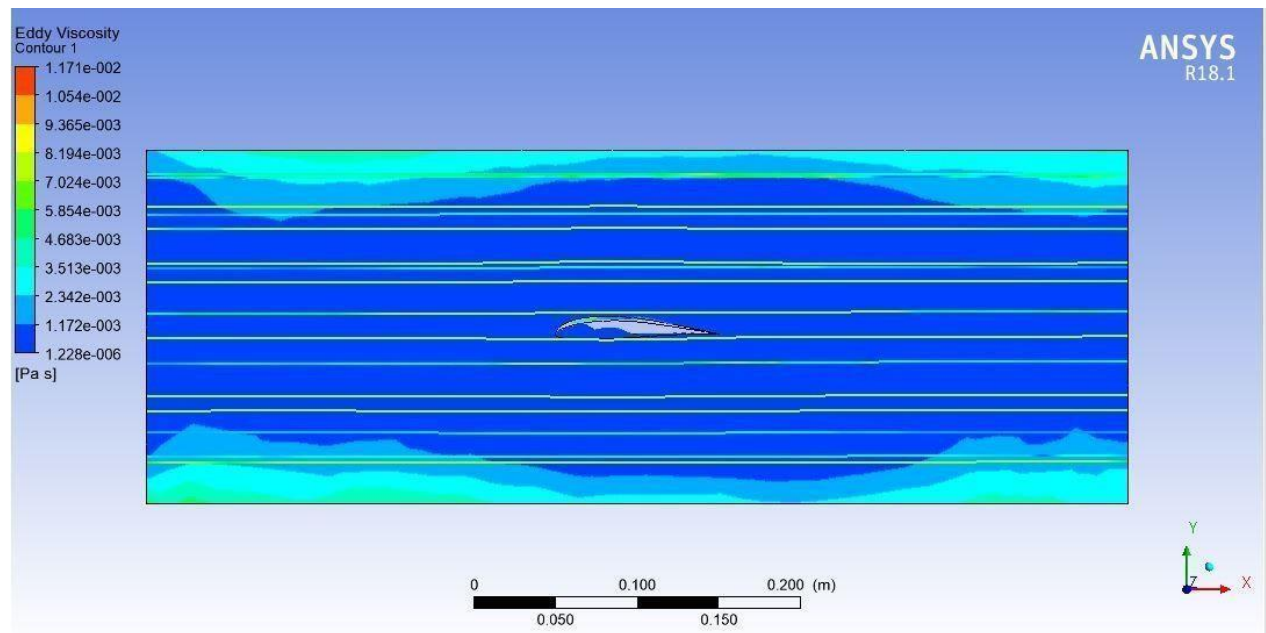


Fig:5.32 : Eddy Viscosity of the Model 2

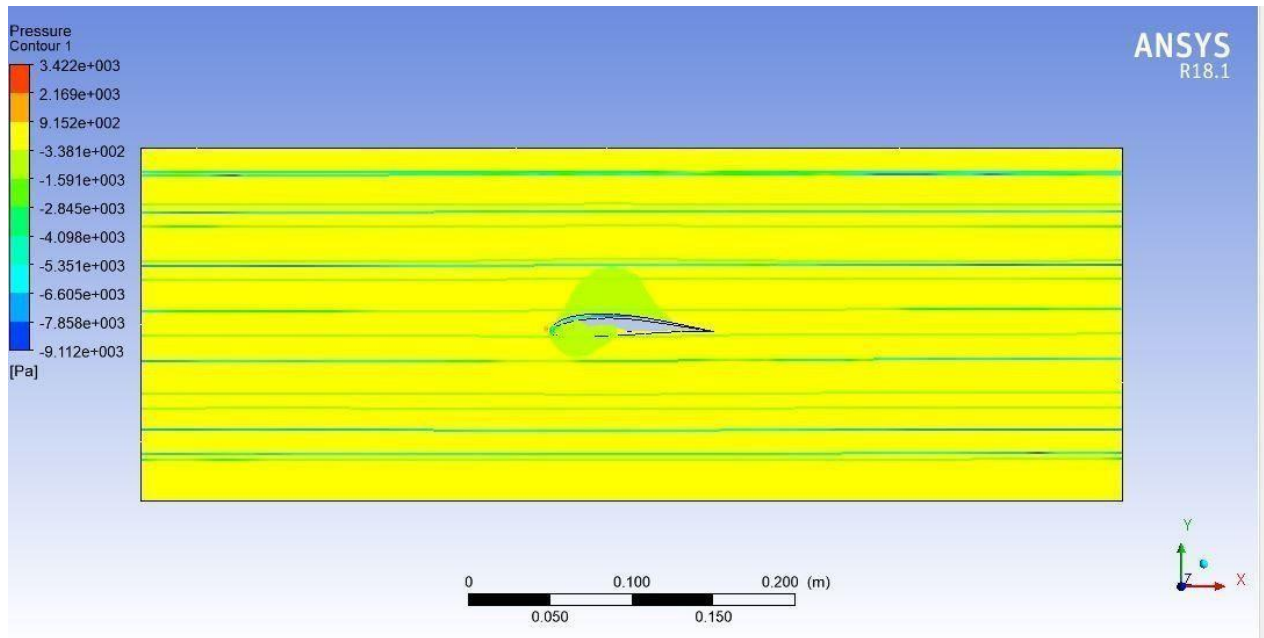


Fig:5.33 : Pressure Contour of a Model 2

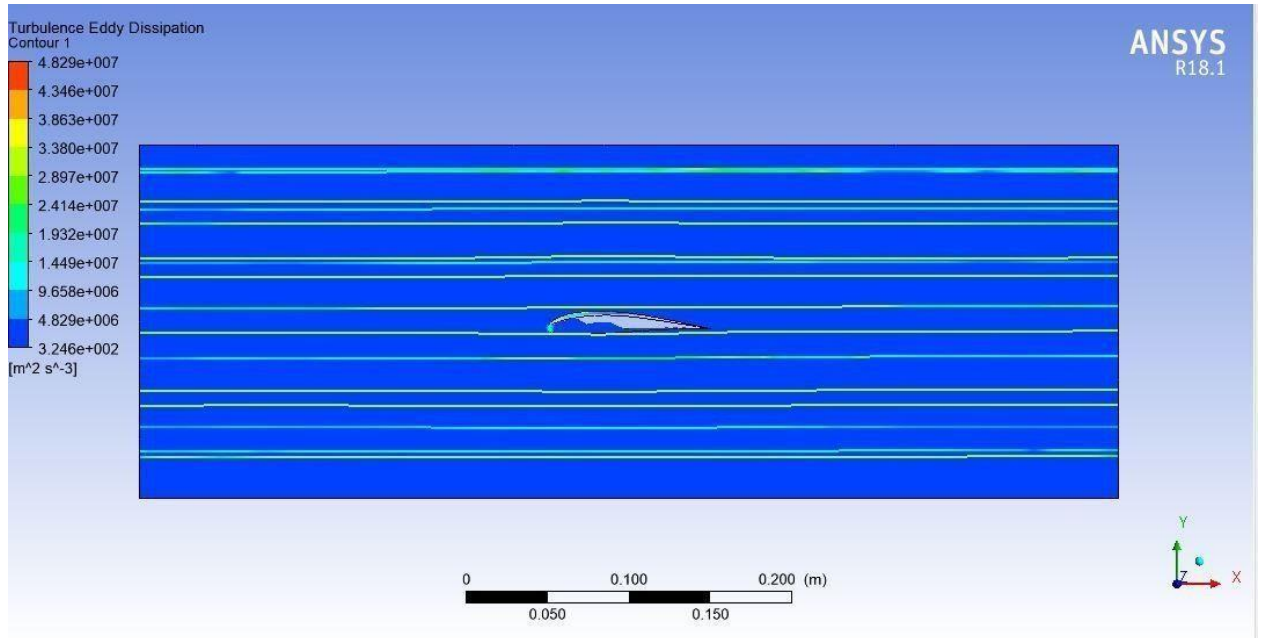


Fig:5.34 : Turbulence Eddy Dissipation contour of a Model 2

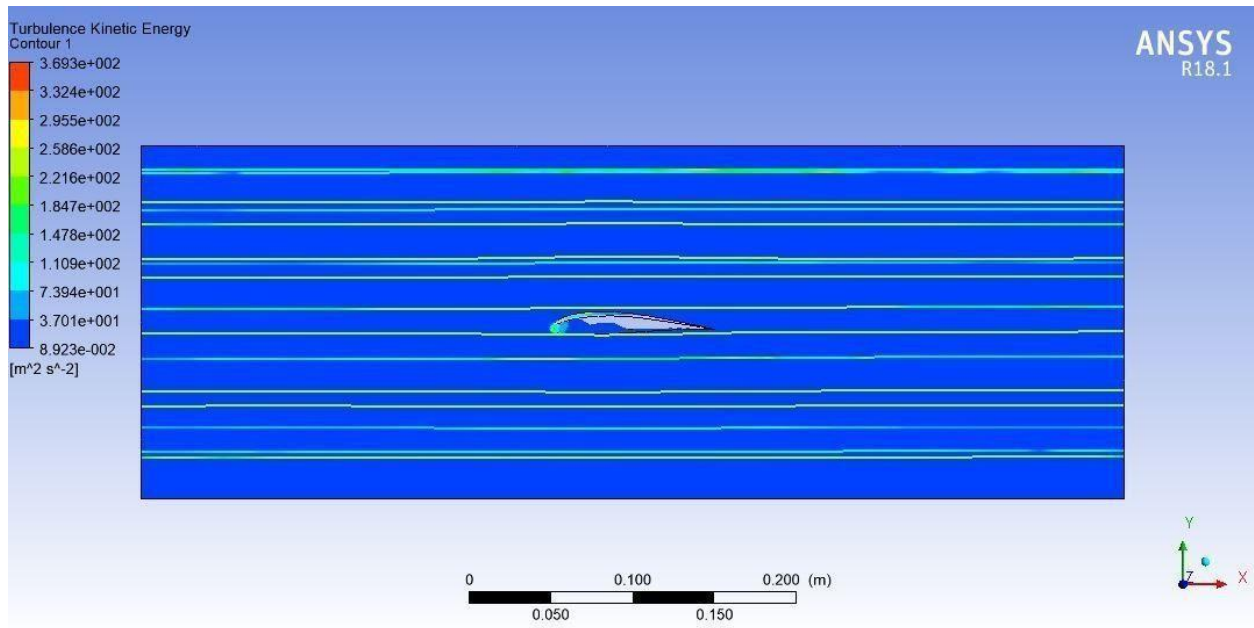


Fig:5.35 : Turbulence Kinetic Energy of a Model 2

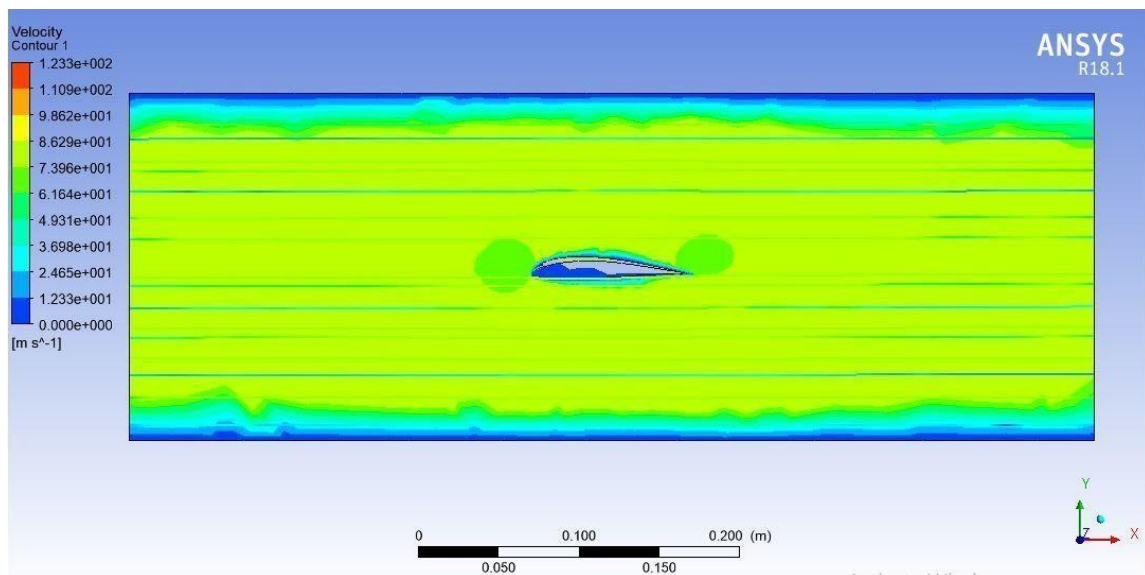


Fig:5.36 : Velocity contour Of a Model 2

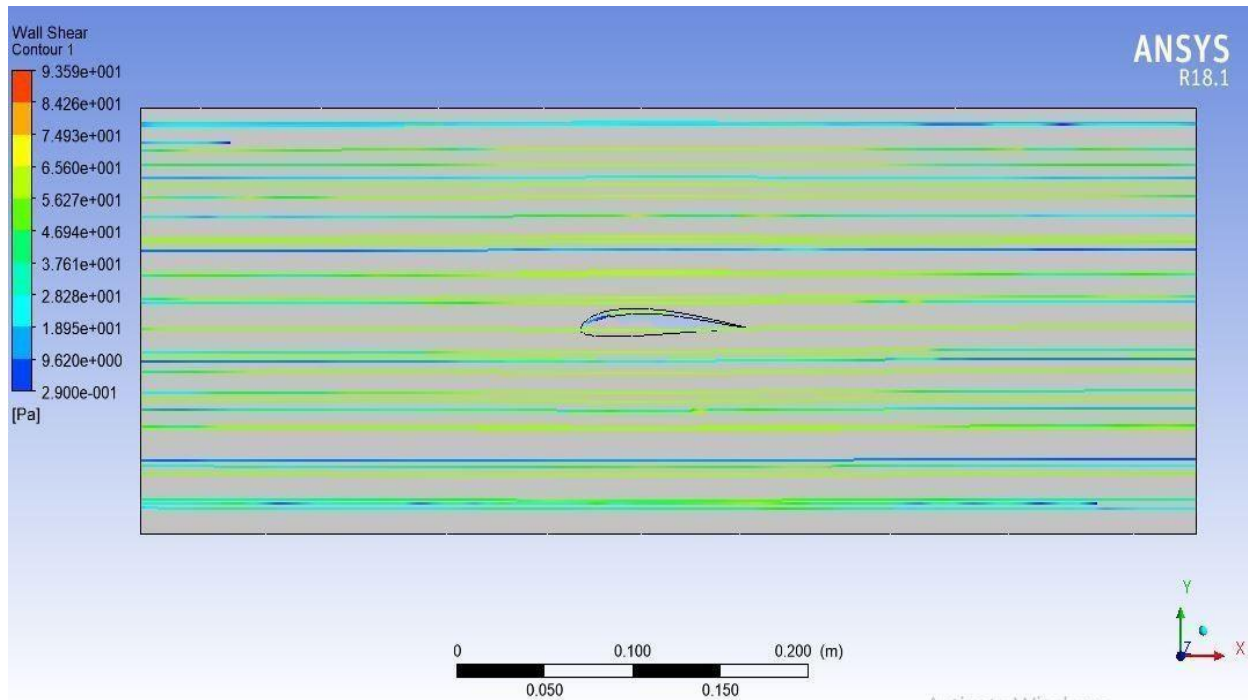


Fig:5.37 : Wall Shear of a Model 2

5.2 COMPARISON OF RESULTS

5.2.1 Eddy Viscosity

TABLE 5.1 EDDY VISCOSITY[Pa s]

TYPE	MODEL 1	MODEL 2
Eddy Viscosity[Pa s]	7.479e-003	1.171e-002

Cd and the Cl of the Model 2

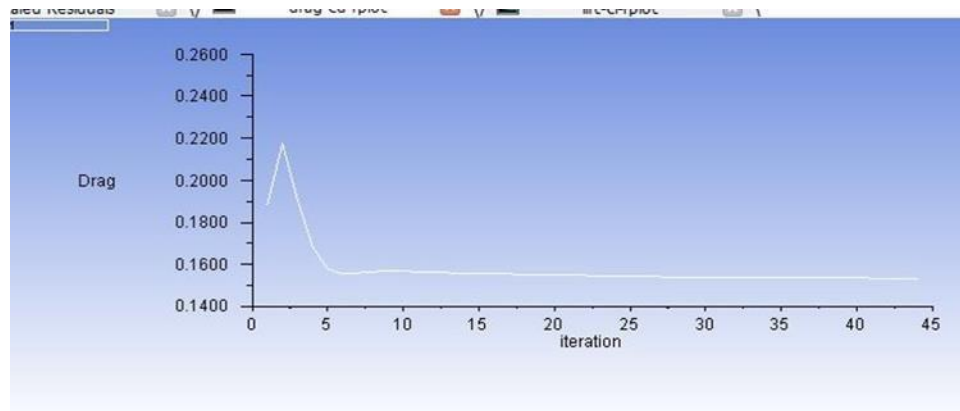


Fig:5.38 : Cd of the Model 2

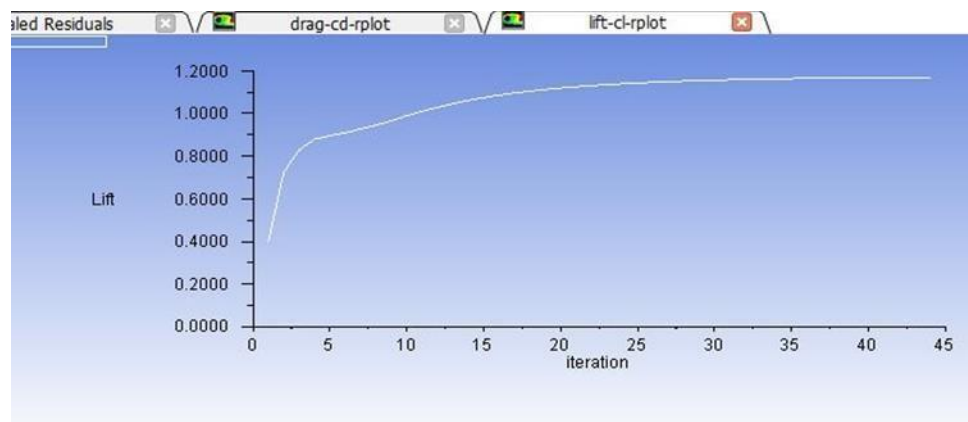


Fig:5.39: Cl of the Model 2

model 02	
CD	CL
1.54E-01	1.17E+00

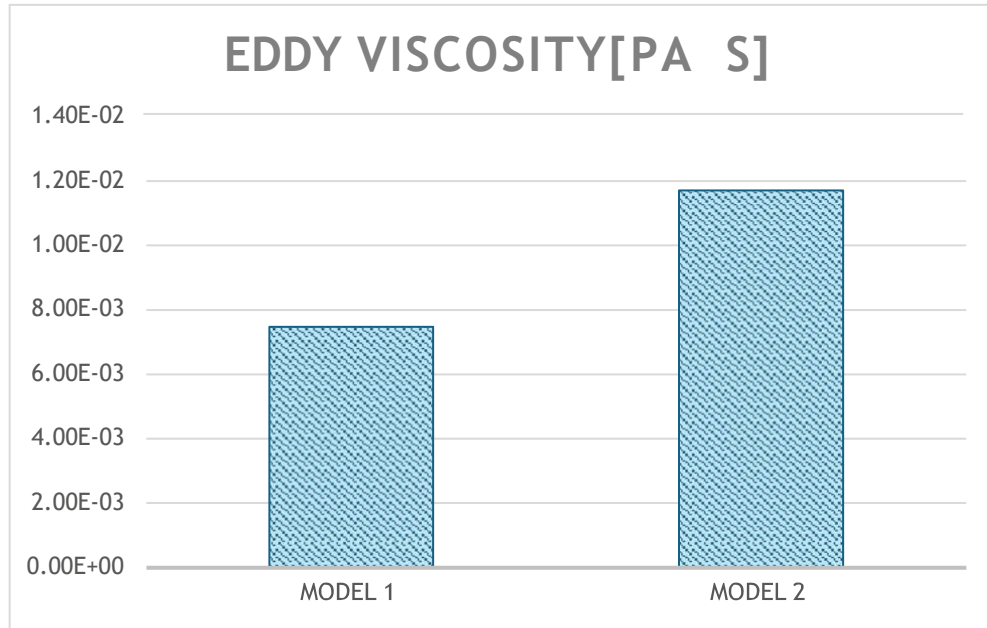


Fig:5.36 : Comparison for Eddy Viscosity

5.2.2 Pressure

TABLE 5.2 PRESSURE[Pa]

TYPE	MODEL 1	MODEL 2
Pressure[Pa]	3.420e+003	3.422e+003

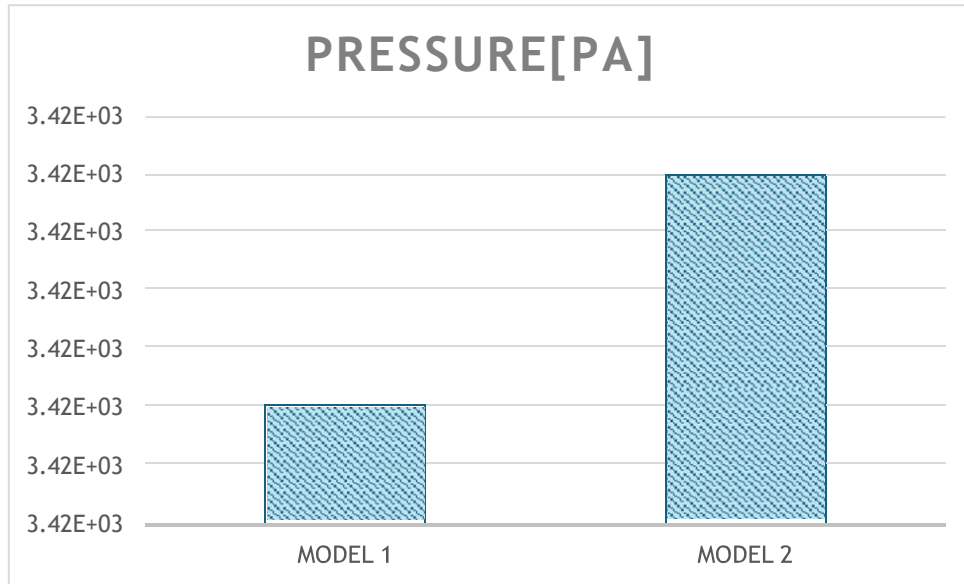


Fig:5.37 : Comparison for Pressure

5.2.3 Turbulence Eddy Dissipation

TABLE 5.3 TURBULENCE EDDY DISSIPATION[m² s⁻³]

TYPE	MODEL 1	MODEL 2
Turbulence Eddy Dissipation[m ² s ⁻³]	7.487e+007	4.829e+007

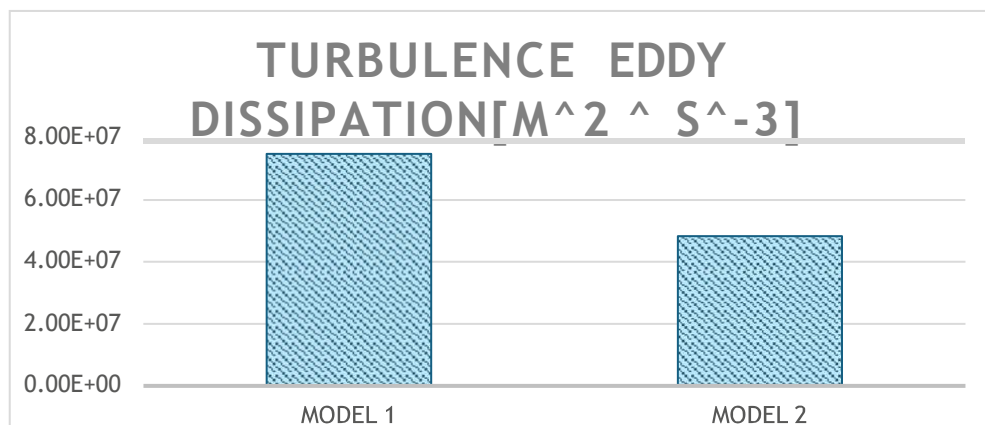


Fig.(5.38) Comparison for Turbulence Eddy Dissipation

5.2.4 Turbulence Kinetic Energy

TABLE 5.4 TURBULENCE KINETIC ENERGY[m² s⁻²]

TYPE	MODEL 1	MODEL2
Turbulence Kinetic Energy[m ² s ⁻²]	4.006e+002	3.693e+002

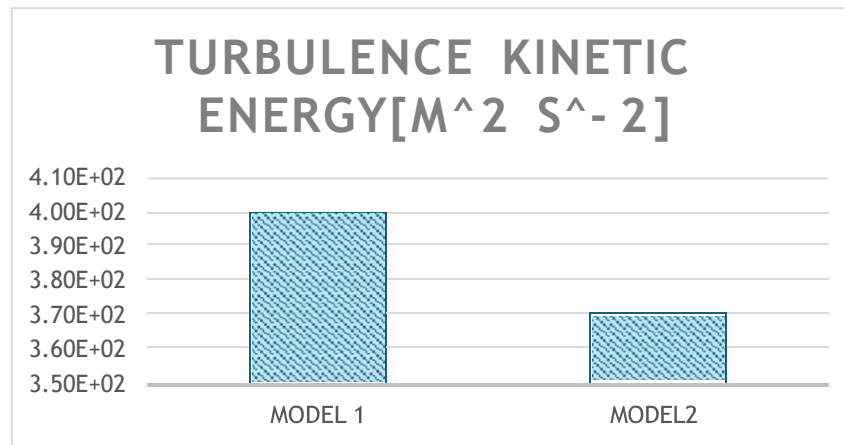


Fig.(5.39) Comparison for Turbulence Kinetic Energy

5.2.5 Velocity U

TABLE 5.5 VELOCITY U[m s⁻¹]

TYPE	MODEL 1	MODEL 2
Velocity[m s ⁻¹]	1.123e+002	1.233e+002

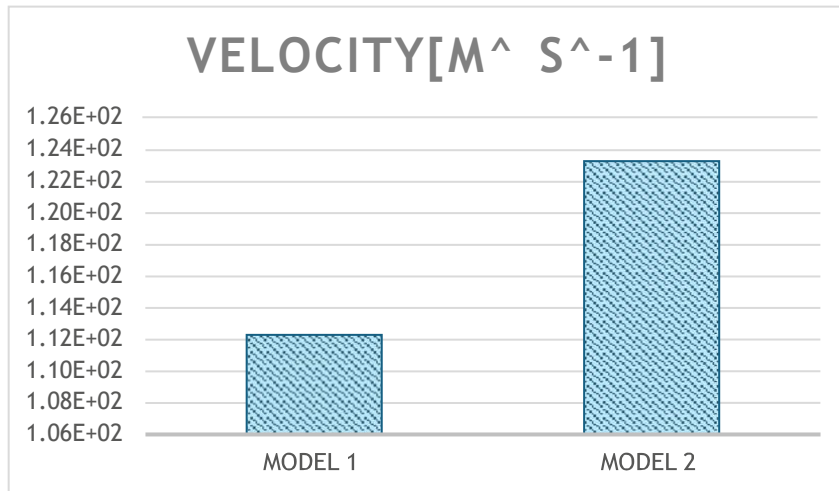


Fig:5.40 : Comparison for Velocity U

5.2.6 Wall Shear

Table 5.6 Wall Shear[Pa]

TYPE	MODEL 1	MODEL 2
Wall Shear[Pa]	9.397e+001	9.359e+001



Fig:5.41 : Prototype Wind Tunnel Testing

CHAPTER – 6

CONCLUSION

In conclusion, the comprehensive study on the design and flow characterization of Segmented Vertical Axis Wind Turbine blades, using CATIA for design and ANSYS/CFD for flow analysis, has yielded valuable insights into optimizing the performance of VAWT systems. The research involved the creation and analysis of two distinct blade models, referred to as design1 and design2, with the aim of identifying the most efficient and effective design for vertical axis wind turbines.

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