KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

RAJESH THANGARAJ

IMPROVEMENT OF THE EFFICIENCY OF SMALL WIND TURBINE

Master's Degree Final Project

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KAUNAS, 2017

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MECHANICAL ENGINERRING (621H30001)

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(Title of study programme, code)

"IMPROVEMENT OF THE EFFICIENCY OF SMALL WIND TURBINE"

Final project

DECLARATION OF ACADEMIC INTEGRITY

January 2017

Kaunas

I confirm that the final project of mine, **Rajesh Thangaraj**, on the subject, **Improvement of the Efficiency of Small Wind Turbine** is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources; all direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT

STUDY PROGRAMME MECHANICAL ENGINERING - 621H30001

Approved by the Dean's Order No. V25-11-7 of December 11th 2016 y

Assigned to the student **Rajesh Thangaraj**

(Name, Surname)

1. Title of the Project

Improvement of the Efficiency of Small Wind Turbine

2. Aim of the project

To develop a small wind turbine for the urban environment. To develop the design of new wind turbine with cowl and analyzing the result of normal and new wind turbine design by CFD flow analysis.

3. Tasks of the project

- Literature review of Wind turbine design and efficiency methods.
- Modelling of new wind turbine
- Meshing the mode in ANSYS software new wind turbine with cowl and without cowl
- Boundary conditions for flow inlet and outlet
- Analysis of velocity and pressure streamline
- Comparing both results

4. Specific Requirements

Conducting the final experimental project thesis according to KTU regulations and requirements.

5. This task assignment is an integral part of the final project.

6. Project submission deadline: 2017 JANUARY 2th.

Task Assignment received	Rajesh Thangaraj	
	(Name, Surname of the Student)	*(Signature, date)*
Supervisor	Prof. Dr. Valdas Eidukynas	
	(Position, Name, Surname)	*(Signature, date)*

RAJESH Thangaraj. “Improvement of the Efficiency of Small Wind Turbine”. Master’s Final Project / supervisor Assoc. prof. doc. dr. Eidukynas Valdas; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study field and area: Technological science, Mechanical engineering

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SUMMARY

At present the world's fastest growing renewable power source, wind energy is the transformation of the winds from kinetic force into mechanical power through a turbine. The mechanical power can be used for such tasks as pumping water or grinding grain, or converted into electricity through a generator for use by homes and businesses.

Wind turbine provides an attractive power source as an alternative to fossil fuels because it is abundant, pollution resistance, clean, and produces no harmful emissions. To extract more energy from the wind, need of increase the wind turbine size. However, the Increasing in size has begun to reach a limit in terms of material composition and structural stability. To quell the trend of increasing size in wind power systems alternative wind turbine blade designs are evaluated and investigated to increase power production and efficiency of present size machines. Wind concentrators have been proposed for the low velocity and turbulence flow region because they provide structural and aerodynamic advantages. A computational fluid dynamics (CFD) program was used to model air flow patterns through a prototype wind turbine blades and optimize its performance.

RAJESH Thangaraj "MAŽOS VĖJO JĖGAINĖS EFEKTYVUMO PADIDINIMAS" Magistro baigiamasis darbas / vadovas doc. prof. dok. Dr. Eidukynas Valdas; Mechanikos fakultetas ir dizaino, Kauno technologijos universitete.

Studijų kryptis ir plotas: technologijos mokslai, mechanikos inžinerija

Raktažodžiai: vėjo turbinų, gaubtas, Dizainas, Efektyvumas, slėgio ir greičio

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SANTRAUKA

Šiuo metu pasaulyje viena sparčiausiai augančių atsinaujinančių energijos šaltinių yra vėjo jėgainės, kurios turbinos dėka vėjo energiją verčia į mechaninę galią. Mechaninė galia gali būti naudojama tokioms reikmėms kaip vandens pumpavimas, grūdų malimui ar tiesiog generatoriaus pagalba verčiama į elektros energiją naudojamą pramoniniais tikslais ar buityje.

Vėjo jėgainėmis generuojama elektros energija yra patrauklus maitinimo šaltinis, kaip alternatyva elektros energijai išgaunamai naudojant iškastinį kurą, nes vėjo atsargos yra neišsenkamos, šis elektros energijos išgavimo būdas yra ekologiškas, tai yra nedidina aplinkos taršos, kas yra būdinga iškastiniu kuru generuojamai elektros energijai. Norint išgauti maksimaliai daugiau energijos iš vėjo tenka ženkliai didinti vėjo turbinų dydį. Tačiau vėjo jėgainių didinimas yra galimas tik iki tam tikro dydžio, kurį ribojamo medžiagų iš kurių gaminamos jos dalys mechaninės savybės. Darbe siekiant sumažinti vėjo jėgainių matmenis tiriamos konstrukcinės alternatyvos leidžiančios sumažinti vėjo jėgainių matmenis. Modifikuotai konstrukcijai atlikti aerodinaminiai skaičiavimai naudojant universalią skysčių ir dujų tėkmės modeliavimo sistemą ANSYS CFX. Darbe pasiūlyta modifikuota vėjo jėgainės konstrukcija panaudojant papildomą aerodinaminį apvalkalą, kurio dėka padidėja jėgainės naudingumo koeficientas.

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INTRODUCTION

Wind power is an important clean source of renewable energy and its conversion to usable energy is important, considering the usage, decline of fossil energy sources of earth, it can be utilized effectively for generating the electrical energy. To obtain energy from wind, more number of wind turbines is being installed. However, regions having high wind energy density are finite. Therefore, research is being conducted to optimize the behavior of wind electric generator units. Some researchers concentrated mainly on the simulation of the performance of the horizontal wind turbine using commercial software.

Air in motion is the result of wind energy. These, motion arises from a pressure gradient. On a global basis one primary forcing function causing surface winds from the poles towards the equator is convective rotation. Solar radiation heats the air near the equator, and this low density heated air is buoyed up. At the surface, it is displaced by cooler denser higher pressure air flowing from all the poles. In the upper atmosphere near the equator the air thus tend to flow back toward the poles and away from the equator. Therefore, the net result is a global convective circulation with surface wins from north to south in the northern hemisphere.

The result clear from the above over simplified model that the wind is basically caused by the solar energy irradiating the earth. Therefore, wind utilization is considered a part of solar technology. It is actuality the wind is much more multiplex. The above model ignores the earth rotation which causes a coriolis effect force resulting in an easterly wind velocity component in the northern hemisphere.

There is the further complication of boundary layer frictional effects between the running air and the earth's rough surface. Mountains, trees, buildings, and similar obstructions impair stream line air flow. Turbulence results and the wind speed in a horizontal direction markedly increase with altitude near the surface. Local winds are caused by two mechanisms. The first is differential hating of land and water. Solar isolation during the day is easily converted to utilitarian energy of the land surface but is partly absorbed in layers below the water surface and partly consume in evaporating some of that water.

Wind turbines produce rotational motion by the design; wind energy is easily converted into electrical energy by connecting the turbine to an electric generator. The combination of wind turbine and generator is mostly referred as an aero generator. A step-up transmission is usually required to match the relatively slow speed of the wind rotor to the higher speed of an electric generator.

This project is handling the improving the speed of the wind turbine rotor by increasing the pressure and velocity from the wind. The analysis of these process of wind turbine design carried out by the engineering designing software.

GOAL

The main aim is to develop a small wind turbine for the urban environment. This project design of new wind turbine and analyzing the result of wind turbine with wind collector and without wind collector by CFD flow analysis. The focus is improving efficiency of the wind turbine with collector by CFD analysis. To results of the analysis that the wind turbine with the collector more efficient than that of the normal one.

TASKS

- Literature review
- Modelling of new wind turbine
- Meshing the mode in ANSYS software both wind turbine (i.e.) with cowl and without cowl
- Boundary conditions for flow inlet and outlet
- Analysis of velocity and pressure streamline
- Comparing both results
- Conclusion

1. LITERATURE REVIEW

A wind turbines performance and rotor characteristics was the topic of investigation for several years. In 1915, Lanchester was 1st to predict the utmost potency of a perfect turbine of 59.3% figure 1. In 1920 German Betz and Russian Joukowsky both scientist, derived this most potency severally, being unaware of Lanchester's findings. However, the limit is called as Betz limit [1].

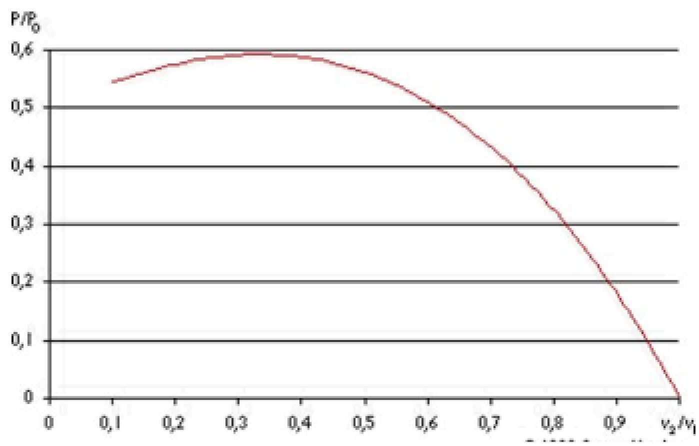

Figure 13.1 Betz Law [1]

BETZ LIMIT & POWER COEFFICIENT

Power Coefficient, Cp,

The ratio of power extract from the turbine to the total contained in the wind resource

$$Cp = \frac{Electricity\ produced\ by\ wind\ turbine}{Total\ energy\ available\ in\ the\ wind}$$

We know that kinetic energy is ½ * m * v^2

Fluid mechanics mass flow rate is density * volume flux

Is that dm/dt = ρ* A * v

Thus, the result of Wind turbine power output is Pt = ½ * ρ * A * v 3 * Cp

The Betz Limit is the maximal possible Cp = 16/27. 59% efficiency is the efficiency of best conventional of wind turbine can achieve the extracting power from the wind.

In 1935 the breakthrough in rotor prophetical ways was achieved by Glauert, who developed the technique of Blade Element Momentum (BEM). The technique based on momentum balance equations for individual ringed stream tubes passing through the rotor. In BEM, the turbine blade is split into separate blade segments and analyzed from a two-dimensional perspective. Today, industrial rotor style codes are still supported BEM. [3,4].

Aerodynamic modeling of HAWT rotors by suggests that of the standard engineering strategies has reached a degree wherever no any improvement are often expected while not a full understanding of the flow physics[6]. Extensive use of numerical studies on all HAWT aeromechanics options, performed on many various levels, starting from BEM strategies integrated by CFD calculations to full 3D Navier-Stokes models became quite well-liked thanks to predict performance and characteristics of contemporary wind turbines. Many authors have used the generalized mechanism Disk methodology that represents roughly associate extension of BEM methodology, integrated in associate mathematician or Navier-Stokes frame [7,8].

The method describes the forces that area unit distributed equally on the right direction. 3D Navier-Stokes thinker has been combined with the supposed mechanism Line Technique, within which the loading is distributed on lines representing the blade forces [4,9].

In the few past years, Sankar and colleagues developed a hybrid Navier Stokes/Full-Potential/Free Wake technique, principally for predicting 3D viscous flow over whirlybird rotors. the strategy has recently been extended to modify the HAWT flow fields. The procedure domain is split in several regions, all resolved by the correct approach: Navier-Stokes resolution close to the blades, potential flow illustration on outer field and a group of vortex ways for modeling the vorticity field [11,12,13].

Full 3D computations using the Reynolds-averaged Navier-Stokes (RANS) equations are carried out by Duque, Ekaterinaris, Sørensen and Denmark Technical University (Scandinavian nation) performed many numerical investigations on HAWT using their Navier-Stokes thinker EllipSys 2D/3D, handling overall performances and style of rotors and blade sections [14,15,16], extreme operation conditions and tip shape.

In 2008, Mandas, et al. at the University of Cagliari in Italian Republic used the industrial code Fluent to perform a close analysis of HAWT flow. The steady flow field around associate isolated rotor of a middle-sized HAWT is foreseen during a non-inertial organization, exploitation each the Spalart-Allmaras and the Menter's k-ω SST turbulence models for closure, and specifying a continuing axial wind speed at the recess. Similarly, during this thesis, the 3D behavior of the wake, the upstream and downstream flow are going to be investigated by exploitation finite – volume technique and Sir Joshua Reynolds Averaged Navier-Stokes approach [19,21]

1.1 Basic Principles of Wind Energy Conversion

1.1.1 The Nature of The Wind

The circulation of air within the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air straightaway higher than a heat space expands; it's forced upwards by cool, denser air that flows in from encompassing areas inflicting a wind. the character of the tract, the degree of bad weather and the angle of the sun within the sky area unit all factors that influence this method. In general, throughout the day the air higher than the land mass tends to heat up quicker than the air over water. In coastal regions, this manifests itself during a robust onshore wind.

The main planetary winds are caused in much the same direction: Cool surface air sweeps down from the poles forcing the warm air over the topics to rise. But the direction of these massive air movements is affected by the rotation of the earth and the total pressure areas in the countries-clockwise circulation of air around low pressure areas in the northern hemisphere, and clockwise circulation in the southern hemisphere part. The strength and direction of these planetary winds change with the seasons as the solar input varies.

Despite the wind's intermittent nature, wind patterns at any explicit web site remains remarkably constant year by year. Average wind speeds area unit larger in mountainous and coastal areas than they're well midland. The winds conjointly tend to blow a lot of systematically and with larger strength over the surface of the water wherever there’s less surface drag.

Wind speeds increase with height. they need historically been measured at a customary height of 10 meters wherever they're found to be 20-25% bigger than near the surface. At a height of sixty meter they'll be 30-60% higher due to the reduction within the drag impact of the earth’s surface. [22]

1.1.2 The Power in The Wind

Wind possesses energy by its motion. Any device capable of slow down the mass of moving air, sort of a sail or propeller, will extract a part of the energy and convert it into helpful work [3]. There are three factors verify the output from a wind energy converter:

(i) Speed of the wind;
(ii) Cross-section of the wind swept by rotor; and
(iii) Overall conversion efficiency of the rotor, transmission system and generator or pump.

No device, but simple, will extract all of the wind’s energy as a result of the wind would ought to be delivered to a halt and this might forestall the passage of a lot of air through the rotor. [22]

The possible is for the rotor to decelerate the whole horizontal column of intercepted air to about one-third of its free velocity. A 100% efficient aero generator would therefore only be able to convert up to a maximum of around 60% of the available energy in wind into mechanical energy. Well-designed blades will typically extract 70% of the theoretical maximum, but losses obtain in the gearbox, transmission system and generator or pump could decrease overall wind turbine efficiency to 35% or loss.

The power in the wind can be computed by using the concept of kinetics. The wind will work on the principle of converting the kinetic energy of wind to mechanical energy. We know that power is equal to energy per unit time. The energy is available in the kinetic energy of the wind. The kinetic energy of any particle is equal to one half its mass times the square of its velocity, or $1/2m V^2$. The amount of wind passing in unit time, over an area A, with velocity V, is AV, and the mass m is equal to its volume multiplied by its density ρ of air, or

$$m=\rho AV$$

(m is the mass of air transverse, the area A swept by the rotating blades of a wind turbine type generator).

Substituting this mass value in the expression for the kinetic energy, we obtain, kinetic energy = $1/2\ \rho AV.V^2$ watts.

Therefore, Kinetic energy $=1/2\ \rho AV^3$ watts

Above Equation tells us that the maximum wind available the actual amount will be somewhat less because all the available energy is not extractable-being proportional to the cube of the wind speed. It is thus evident that small increase in wind speed can have a marked reaction on the power in the wind.

Equation also tells us that the power available is proportional to air density 1.22 kg/m^3 at sea level. It may vary 10-15% during the year because of pressure and temperature change. It changes negligibly with water content. Equation also tells us that the power of wind is proportional to the intercept area. Thus, an aero turbine with a large swept area has higher power than a smaller area machine; but there are added implications. Since the area is normally rounded of diameter D in horizontal axis aero turbines, then $A = \prod/4\ D^2$, (sq.m), which when put in equation gives,

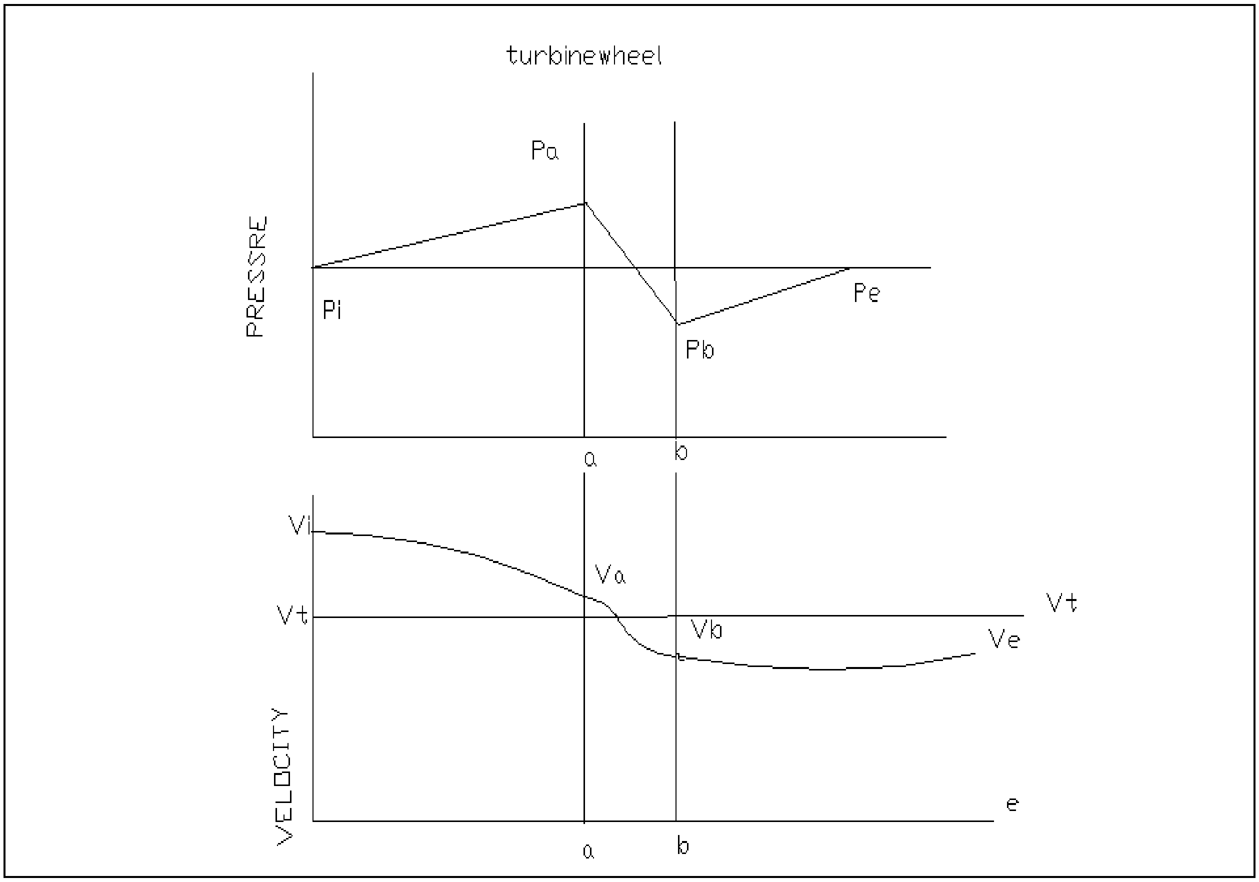

Figure 1.14 Coefficient of Turbine wheel vs pressure and velocity [3]

Available wind power $P\alpha = \frac{1}{2} \rho \, \pi/4 \, D^2V^3$ watts

Therefore, Power of wind is $1/8 \, \rho\pi \, D^2V^3$

The extracted power by the rotor is equal to the product of the wind speed as it passes through the rotor (i.e. V_r) and the pressure drop Δp [3]. In order to maximize the rotor power, it would therefore be desirable to have both speed of wind and pressure drop as large as possible. However, as V is increased for a given value of the free wind speed (and air density), increases at first, passes through a maximum, and the decreases. Hence for the specified free-wind speed, there is a maximum value of the rotor power.

The faction of the free-flow wind power that can be extracted by a rotor is called the power-coefficient; thus

$$\text{Power coefficient} = \frac{Power\ of\ wind\ rotor}{Power\ available\ in\ wind}$$

Where power available is calculated from the air density, rotor diameter, and free wind speed as shown above. The maximum theoretical power coefficient is equal to 16/27 or 0.593[1]. This value cannot be exceeded by a rotor in a free-flow wind-stream.[3]

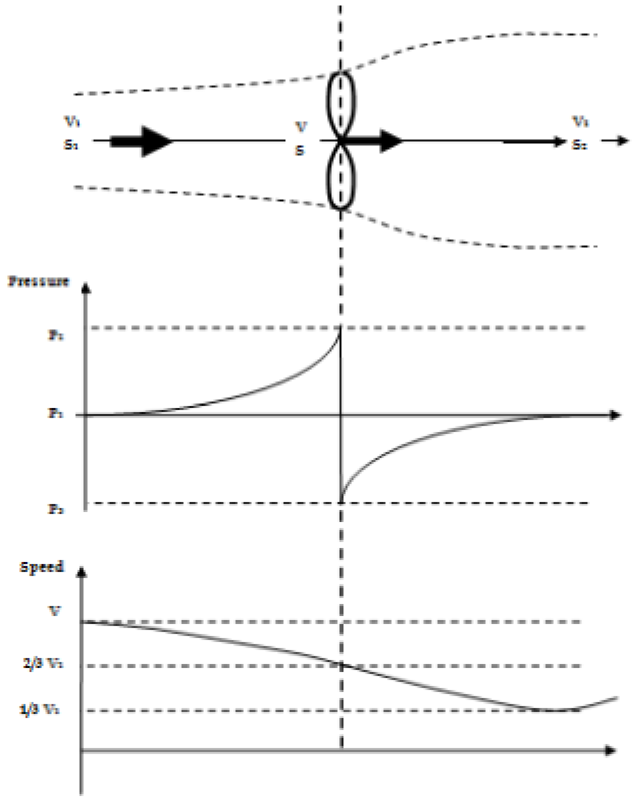

Figure 1.3 Wind Turbines Theory - The Betz Equation [3]

1.1.3 Maximum Power

The total power cannot be converted to mechanical power. Consider a horizontal-axis, propeller-type windmill, henceforth to be called a wind turbine, which is the most common type used today[7].

Assume that the wheel of such a turbine has thickness αb. Let p_i and V_i are the wind pressure and velocity at the upstream of the turbine. V_e is less than V_i because the turbine extracts kinetic energy.

Considering the incoming air between I and a as a thermodynamic system, and if the air density remains constant (since changes in pressure and temperature are very small compared to ambient), that the potential energy is zero, and no heat or work are added or removed between i and a, the general energy equation reduces to the kinetic and flow energy-terms only.

1.1.4 Wind Energy Conversion

Traditional wind turbine was used extensively in the Middle Ages to mill grain and lift water for land drainage and watering cattle. Wind energy converters are still used for these purposes now a day in some parts of the world, but the focus of attention now lies with their use to generate electricity [14]. There is also growing interest in generating heat from the wind for space, water heating and for glass-houses but the potential market is much smaller than for electricity generation.

The term “wind mill” is still widely used to describe wind energy conversion systems, however it is hardly adopt. Description any more. Modern wind energy conversion systems are more correctly referred to as ‘WECS’, aero generations’, ‘wind turbine generators’, or ‘wind turbines’.

The fact that the wind is intermittent source of energy is immaterial of some applications such as pumping water for land drainage – provided, of course, that there is a broad match between the energy required and energy supplied over any critical period. If the wind blows, the job gets done; if it does not, the job waits. However, most of the uses to which electricity is put, the interruption of supply may be highly not convenient. Operators or users of wind turbines must ensure that there is some form of back-up to cover periods when there is not sufficient (or too much) wind available. For small producers, back-up can take the form of:

(i) Battery storage,

(ii) Connection with the local electricity distribution system,

For utilities,

Responsible for public supply, the integration of medium – sized and large wind turbines into their distribution network could require some additional plant which is capable of responding quickly to meet fluctuating demand [14,11].

1.1.5 Small Producers

Private Citizens in several countries have won the right to operate wind generators and other renewable energy systems and to export power to the grid. For most small wind generators this requires that the output is 'conditioned' so that is conforms to the frequency and phase of the mains supply. Only a few small units are designed to maintain a constant rotational rate so that can be synchronized to the mains frequency and feed electricity directly into the grid. Most produce direct current (DC) or variable output alternating current (AC).

Power conditioning is readily achieved using an electronic black box called a 'synchronous' inverter', and although this is an expensive item of equipment, it does eliminate the need for batteries and for conversion of home appliances to run to DC [17].

Where there is no grid connection, electricity that is surplus to immediately requirements must be stored on site using heavy-duty batteries. It can be recovered later when the demand exceeds the supply. An alternative is to dump it (by generating an dissipating heat) or better, to convert it into heat that can be stored, for example as hot water in a well-insulated tank [17].

1.1.6 Large Producers

Large and medium-sized wind generators are designed to give a stable and constant electrical output over a wide range of wind speeds and to feed current directly into the grid. They operate primarily as fuel savers, reducing the utility's total fuel burn [17].

The choice of generator type depends on the size of the local distribution grids and its associated generating capacity. An induction generator would normally be used where there is a significant amount of other generating capacity (which could provide the necessary reactive power for excitation). Induction generators are robust and reliable and require minimal control equipment. For isolated networks where other local generating capacity is limited, and where a high degree of autonomous control is required, a synchronous generator is more appropriate. Synchronous generators are more complex and therefore more expensive than induction machines.

1.1.7 Lift and Drag

The basis for wind energy conversion is depends on turbine blade rotation and its design. The extraction of power, and hence energy, from the wind depends on creating certain forces and applying them to rotate (or to translate) a mechanism. There are two primary mechanisms for producing forces from the wind; lift and drag.

By definition lift forces act perpendicular to the airflow, while drag forces act in the direction of flow. List forces are produced by changing the velocity of the air stream flowing over either side of the lifting surface: speeding up the air flow causes the pressure to drop, while slowing the air stream down leads to increase in pressure[2].

The Reynolds number, Re, is defined by:

$$\text{Re}=\frac{inertial\ force}{viscous\ force}=\frac{UL}{V}=\frac{\rho UL}{\mu}$$

where, ρ is the fluid density, μ is fluid viscosity, V $=\mu/\rho$ is the kinematic viscosity and U and L are a velocity and length that characterize the scale of the flow. These might be the free stream velocity and the chord length on an airfoil.

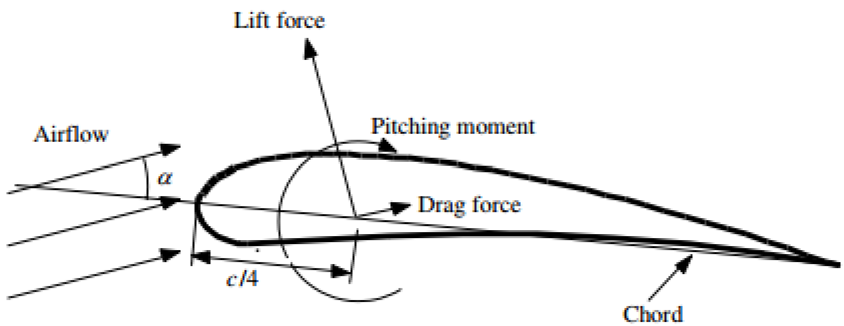

Figure 1.4 Drag and lift forces on stationary air foil, angle of attack; c, chord

- **Lift force** – The force perpendicular to direction of the oncoming airflow. The force is a consequence of the unequal pressure on the upper and lower surfaces of airfoil.

- **Drag force** – The force parallel to the direction of oncoming airflow. The drag force is due both to force of viscous friction at the surface of the airfoil and to unequal pressure on the airfoil surfaces facing toward and away from the oncoming flow.

- **Pitching moment** – The moment defined to be about an axis perpendicular to the airfoil cross-section.

Wind turbine rotor design usually uses two-dimensional coefficients, determined for a range of angles of attack and Reynolds numbers [6,11].

In other words, any change in velocity generates a pressure difference across the surface of lift. This pressure difference produces a force that begins to act on the high-pressure side of the lifting surface which is called an airfoil profile. A good airfoil has a high lift/drag ratio, in some cases it can generate lift forces perpendicular to the air stream direction that are 30 times as great as the drag force will be parallel to the flow. The lift increases as the angle formed at the junction of the airfoil and the air-stream (the angle of attack) becomes less and less actuate, up to the point where the angle of the airflow on the low-pressure side becomes excessive. [25]

When this happens, the airflow breaks away from the low pressure side. A lot of turbulence ensues, the lift decreases and the drag increases quite substantially, this phenomenon is known as stalling. For efficient operation, a wind turbine blade needs to function with as much lift and as little drag as possible because drag dissipates energy. As lift does not involve anything more complex than deflecting the airflow, it is usually an efficient process. The design of each wind turbine specifies the angle at which the airfoil should be set to achieve the maximum lift to drag ratio.

In addition to airfoils, there are two other mechanisms for creating lift. One is the so-called Magnus effect, caused by spinning a cylinder in an air stream at a high-speed of rotation. The spinning slows down the air speed on the side where the cylinder is moving into wind and increases it on the other side; the result is similar to an airfoil. This principle has been put to practical use in or two cases but is not generally employed. The second way is to blow air through narrow slots in a cylinder, so that is emerges tangentially; this is known as a Thwarts slot. This also creates a rotation (or circulation) of the air flow which in turn generates lift. Because the lift ratio of airfoils is generally much better than those of rotating or slotted cylinders, the latter techniques probably have little practical potential. [14]

1.1.8 Wind Turbine Tip Speed Ratio

The Tip Speed Ratio (known as the TSR) is of very importance in the design of wind turbine generators [15]. When a rotor blade passes through the air it leaves turbulence in its wake. If another blade on the spinning rotor arrives at this point while the air is still turbulent, it will not be able to extract power efficiently from the wind. However, if the rotor span a little slowly the air hitting each turbine blade would no longer be turbulent. Therefore, the tip speed ratio is also chosen so that the blades do not pass through too much turbulent air.[25]

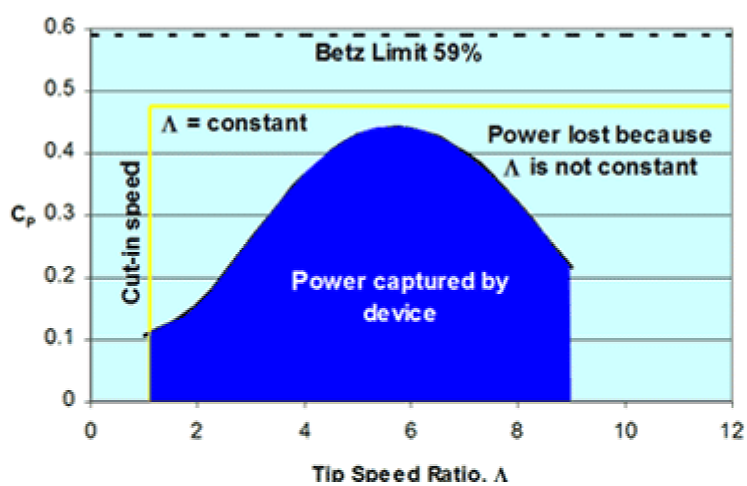

Figure 1.5 Power and TSR relation [15]

According to the research paper the tip speed ratio of depends on the number of blades in the wind turbine system [15].

Blade number VS. TSR	
Tip-speed ratio	Number of blades
1	6-20
2	4-12
3	3-8
4	3-5
5-8	2-4
8-15	1-2

Figure 1.6 Turbine blade and TSR relation [15]

1.1.9 The Characteristic Curve of The Wind Power

Based on [24] Configuration of PMSG System The variable speed wind turbine of the PMSG system direct driven by PMSM is a complex electromechanical system, which includes the mechanical components and the PMSG. The description of these components is presented as follows figure. Model of Wind Turbine. The characteristic curve of the wind power versus rotor speed for model of wind turbine at different wind speeds in steady state shown in Figure is very important for PMSG system direct-driven by PMSM. The power specification of the adopted wind turbine is the 1.5 kW in this paper[24]. Its diameter is 2 m. It is the three-blade horizontal axis type. It is capable of obtaining the working point of the wind turbine that used the intersection point of the load and the turbine characteristic curve at a designated wind speed. It is a very important characteristic curve that the shaft power of the wind turbine relates to the wind speed V1 and rotor speed $\omega r1$ to the maximum power tracking in Figure

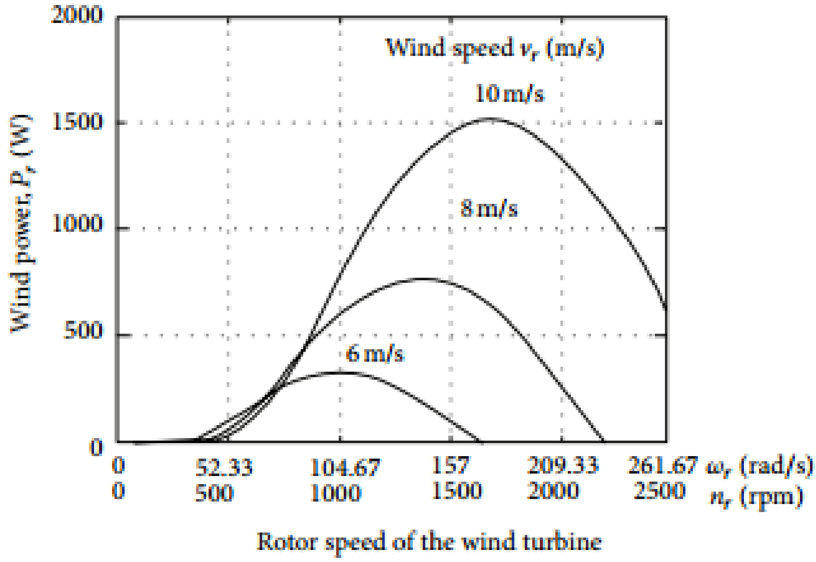

Figure 1.7 Characteristic curves of wind power [24]

For convenient usage and application, the characteristic curve shown in Figure 1.8

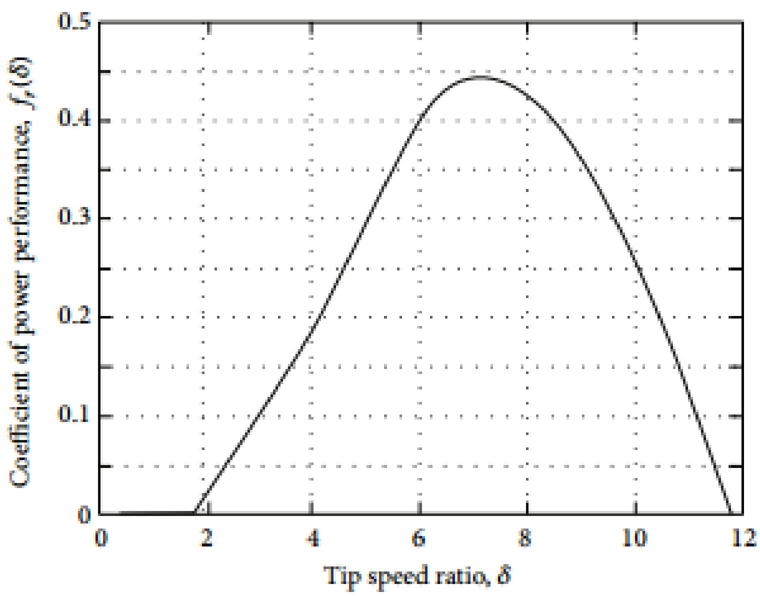

Figure 1.8 Characteristic curve of coefficient $fr(\delta)$ of power performance versus tip ratio δ for turbine[24]

2. METHODOLOGY AND DESIGN CONCEPT

Why This Design Is Important?

Now a days modern three-blade HAWT (horizontal axis wind turbine) does interact with all the air blowing through it. The blades utilize airfoils to greatly enhance the power extracted from the wind, like helicopter blades use airfoils to generate more lift than a simple screw propeller could. Thus, they can spin much faster in tip velocity than a flat-bladed windmill much faster than the wind blows over them. And by spinning faster, a lighter and thinner blade is able to interact with the same amount of air as a slow and fat blade. That saves materials and decreases cost.

The cowl (wind collector) distance is very important to design because the distance of the cowl is the only design to improving the efficiency range of turbine. Very high value of pressure and velocity may cause mechanical failure or mechanical risk from the theory of Tip speed ratio in literature survey and Betz limit of Power coefficient. [26]

2.1 Modelling

In these approaches the same basic procedure is followed.

- During preprocessing:
    - The physical bounds, geometry of the problem is defined.
    - The Space occupied by the fluid is divided into discrete cells (mesh). The mesh may be non-uniform or uniform.
    - The physical modeling is defined – for example, the equations of motion, enthalpy, radiation and species conservation.
    - Boundary conditions are defined. This involves specifying the behavior of properties of design and fluid at the boundaries of the problem. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved by steady-state or transient by iteratively.

- Finally, a postprocessor is used for the visualization and analysis of the resulting solution

Model is a Representation of an object, a system, or an idea in some form other than that of the entity itself. The process of modeling is the producing a model; a model is a representation of the construction and working of some system of interest. A model is similar but simpler than the system it represents. The model purpose is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the system and incorporate most of its salient features. On the other hand, it must not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between simplicity and realism. Simulation practitioners recommend improving the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input data conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.

2.2 Material Properties

This research wind turbine and collector was designed by using of Creo2.0 software. The material selection of both the wind turbine blades and cowl are different materials. The material which given for cowl is carbon fiber [23,22] because the material is less weight and strong as compare to other material properties and carbon fiber can withstand all the climate weather conditions. and material which given for turbine blades is steel. The part exists, define a library of the mandatory materials that compose the object (or project) being modeled. This includes thermal and mechanical properties [26]. After the material selection, the diagram imported in ANSYS for fluid analysis. Several concept design tools that provide up-front concept of Industrial design can then be used in the downstream process of engineering the product. These range from conceptual Industrial design drawing, reverse engineering with point cloud data and comprehensive free-form surface tools.

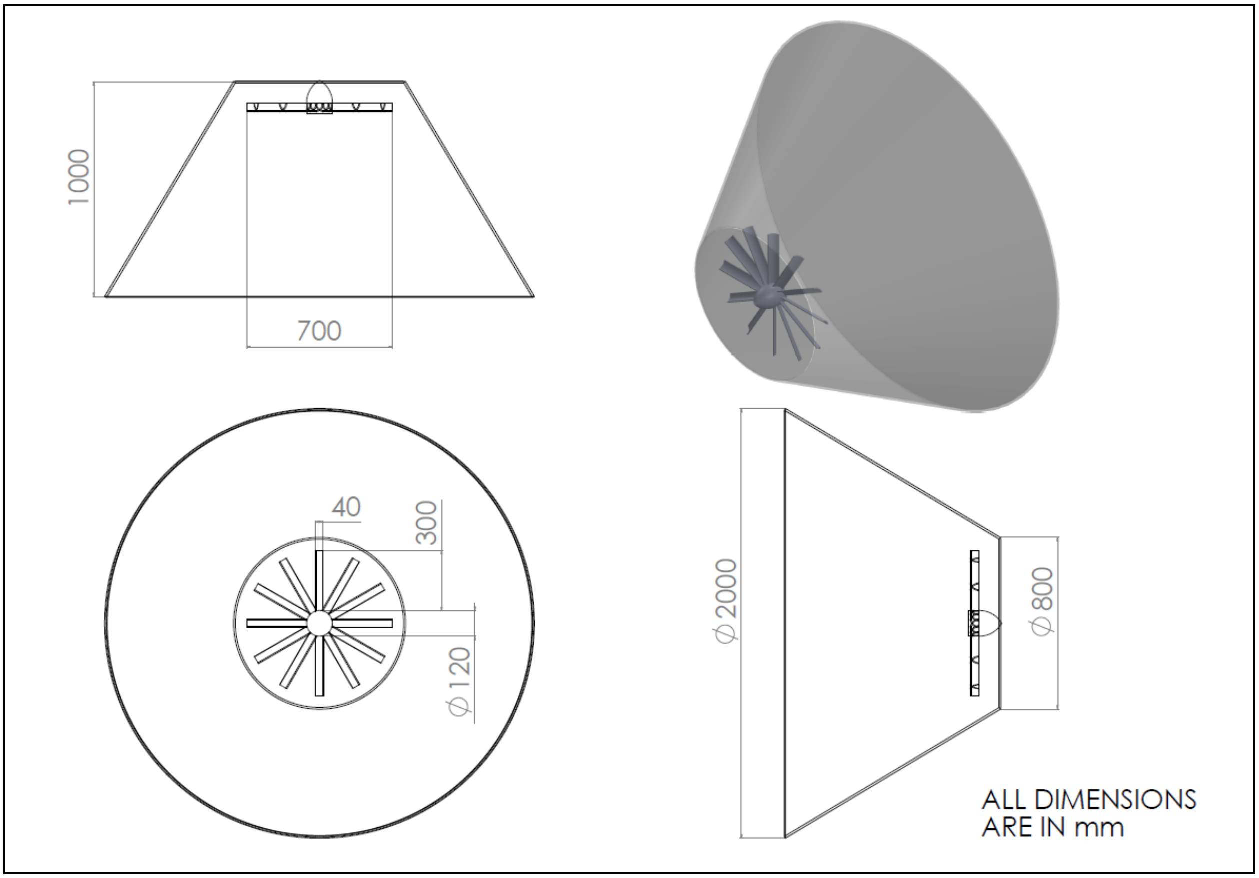

Figure 2.1 New Model of wind turbine with cowl and dimensions

Figure 2.1 is the model of this project work. The model of wind turbine and cowl is dimension are in millimetre. Sketch of model is drawn by the cero2.0 software. This design approach is use to improve the pressure and velocity of the wind turbine.

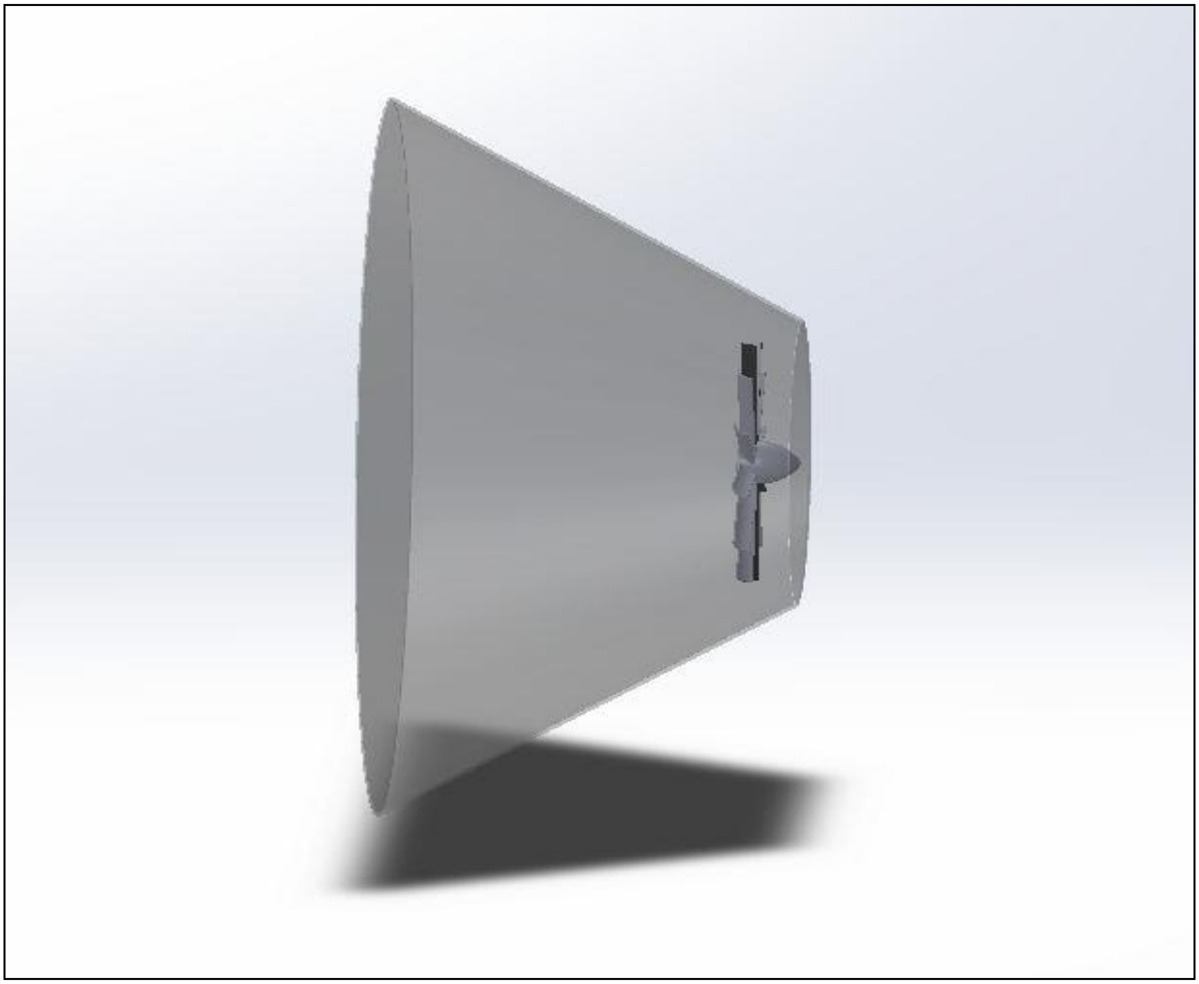

Figure 2.2 Side view of Model

The above figure 2.2 is the side view of the model left side of the cowl is the air inlet and right side is air out let. The wind turbine and generator is take place on end of the cowl. The total length of the cowl from inlet to out let of air is 1000mm.

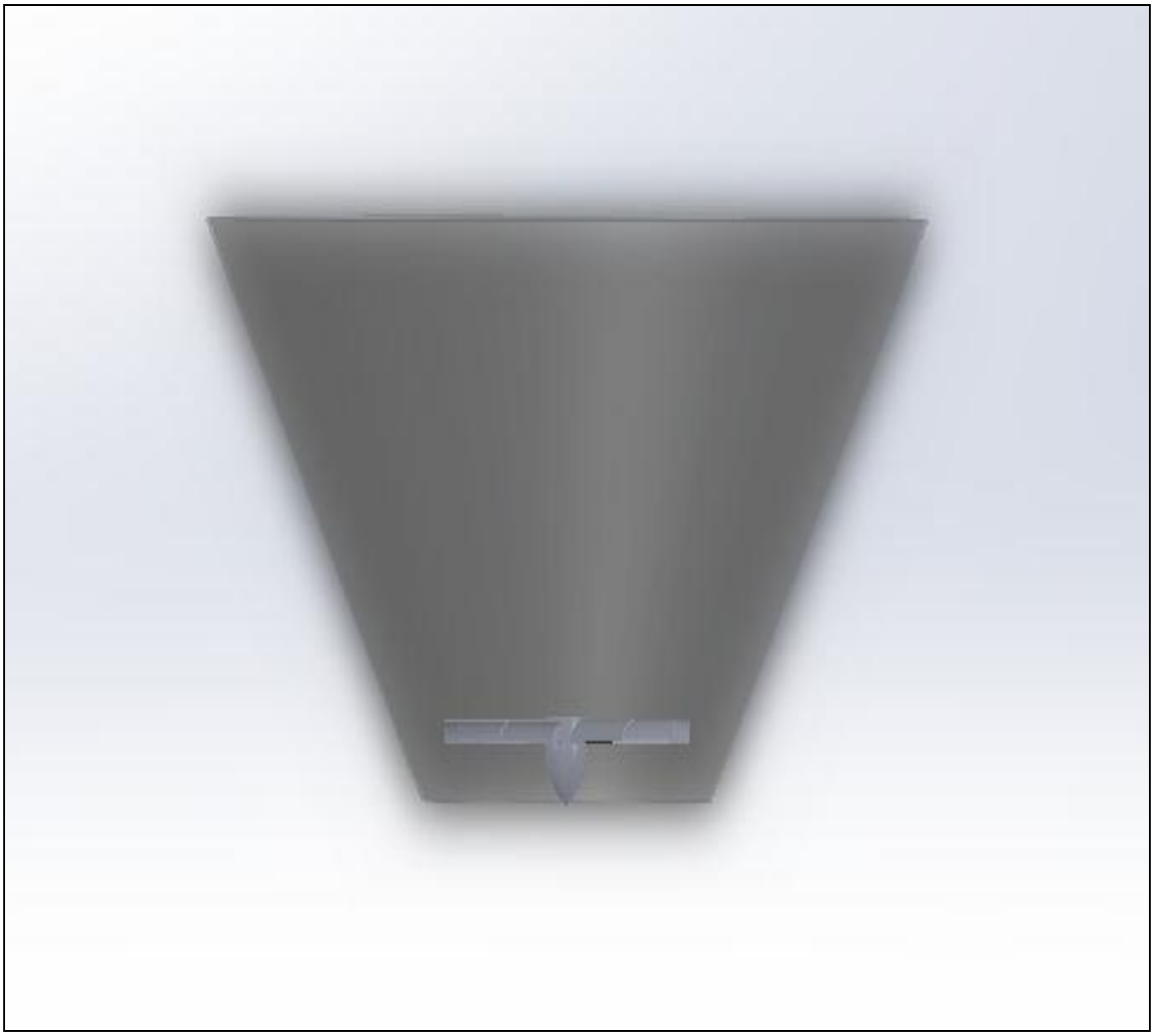

Figure 2.15 Top view of the model

Figure 2.3 is the total volume of the cowl from top viwe. The diameter of the air inlet of the cowl is 2000mm and outlet of air is 800mm

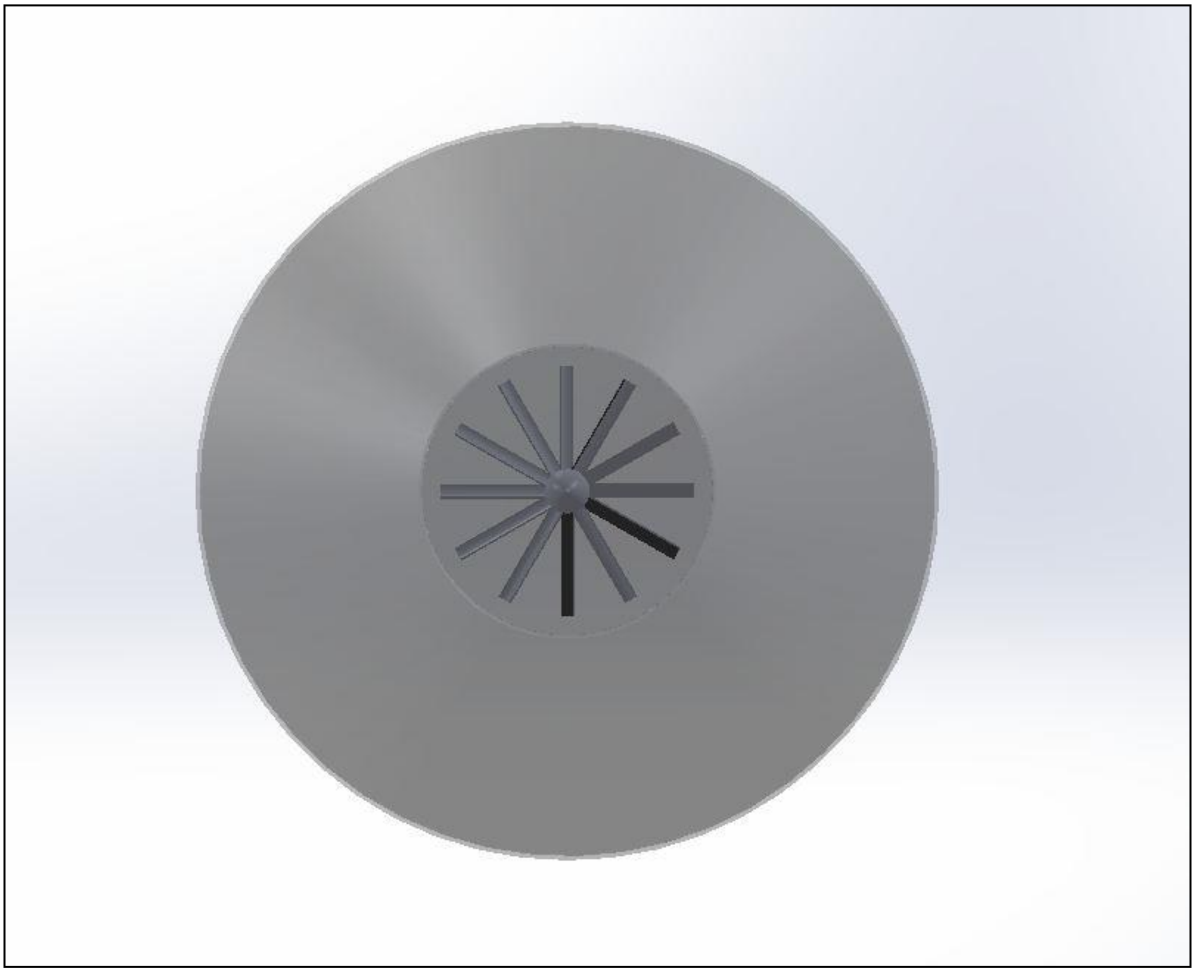

Figure 2.16 Front view of the model

The above figure is the model front. Where wind turbine blade and generator is take place on centre of the cowl. The turbine contains 12 blades because to avoid the mechanical failure and each blade are flat and the size is 40 mm and size of generator is 120mm

.

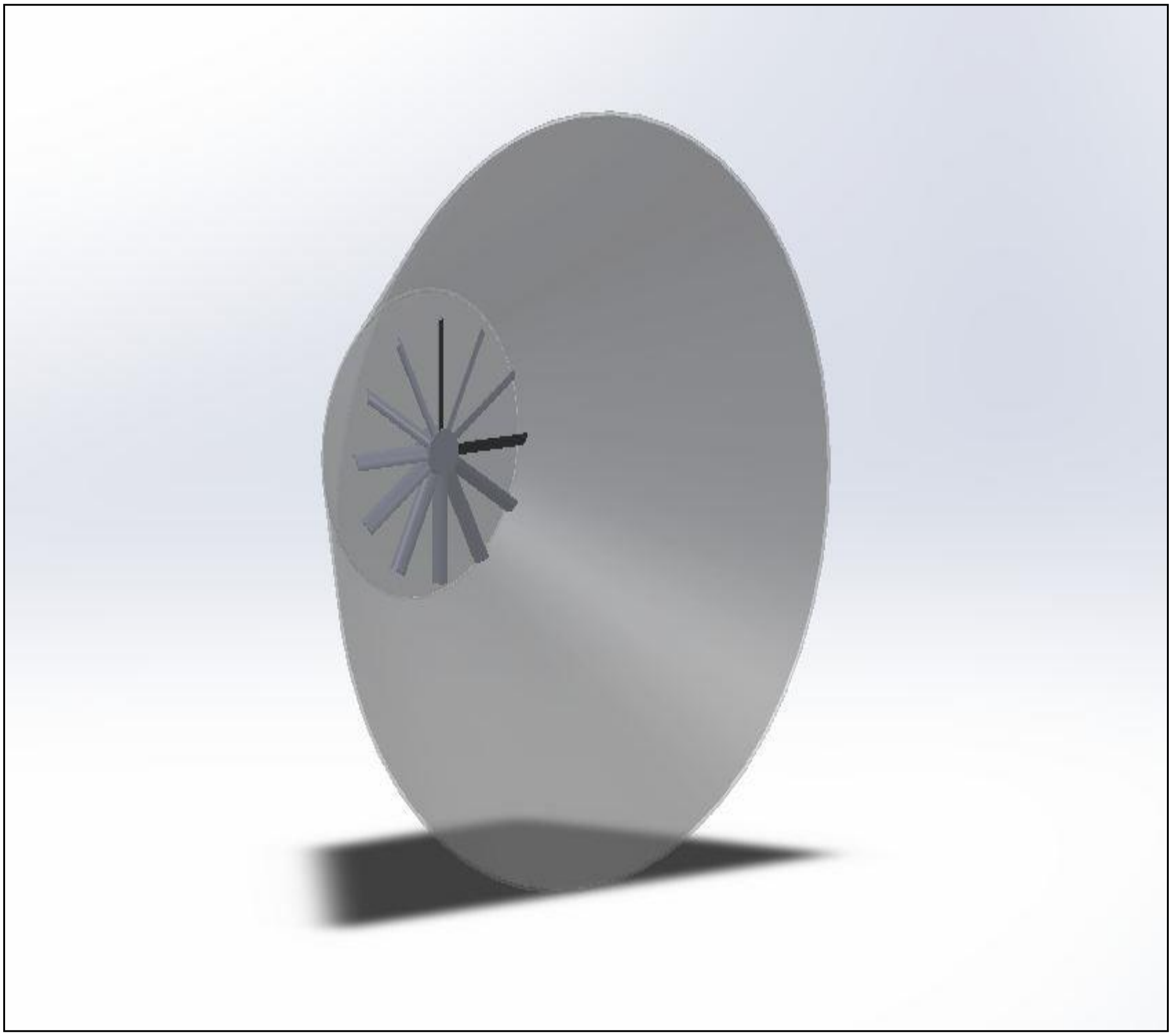

Figure 2.17 3D view of the model

The exact model is shows in figure 2.5 The wind turbine placed on end of cowl. The distance between each blades and cowl is 40mm and turbine generator fixed on 880 mm distance from the air inlet of the cowl.

2.3 Computational Fluid Dynamics

Computational fluid dynamics (CFD), is a branch of fluid mechanics to solve and analyse problems by using numerical methods and algorithms that involve fluid flows. System are used to perform the mathematical calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions in design. In high-speed supercomputers, better solutions can be achieved.

This project is analysis of flow on wind turbine by given boundary conditions. The analysis research make out the result of flow of air over the turbine. The analysis give the result of pressure and velocity of the wind turbine with cowl and without cowl. Ongoing analysis yields computer coding that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software work is using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests. Three-dimensional Unsteady Computational Analysis was performed for solving the equation of energy, momentum and continuity. The modified k-e turbulence model was used to describe turbulence transport, with the both standard wall function model for near wall treatment.

3. WIND TURBINE DESIGN ANALYSIS

3.1 MESH

Mesh generation is one of the most critical aspects of simulation in engineering. Too many cells may result in long solver runs, and too few may lead to inaccurate results. Technology of Meshing in ANSYS has provides a means to balance these requirements and obtain the right mesh for each simulation in the most automated way possible. ANSYS technology in meshing has built on the strengths of stand-alone, class-leading meshing tools. The separate tools of these strongest aspects have been brought together in a single environment to produce some of the most powerful meshing available.

Meshing of Normal Wind Turbine

The below table is the number of nodes and elements of meshing for normal wide turbine.

Table 3.2 Number of nodes and elements for normal meshing

	BLADE	DOMAIN	TOTAL
Nodes	5328	32252	37580
Elements	18085	175769	193854

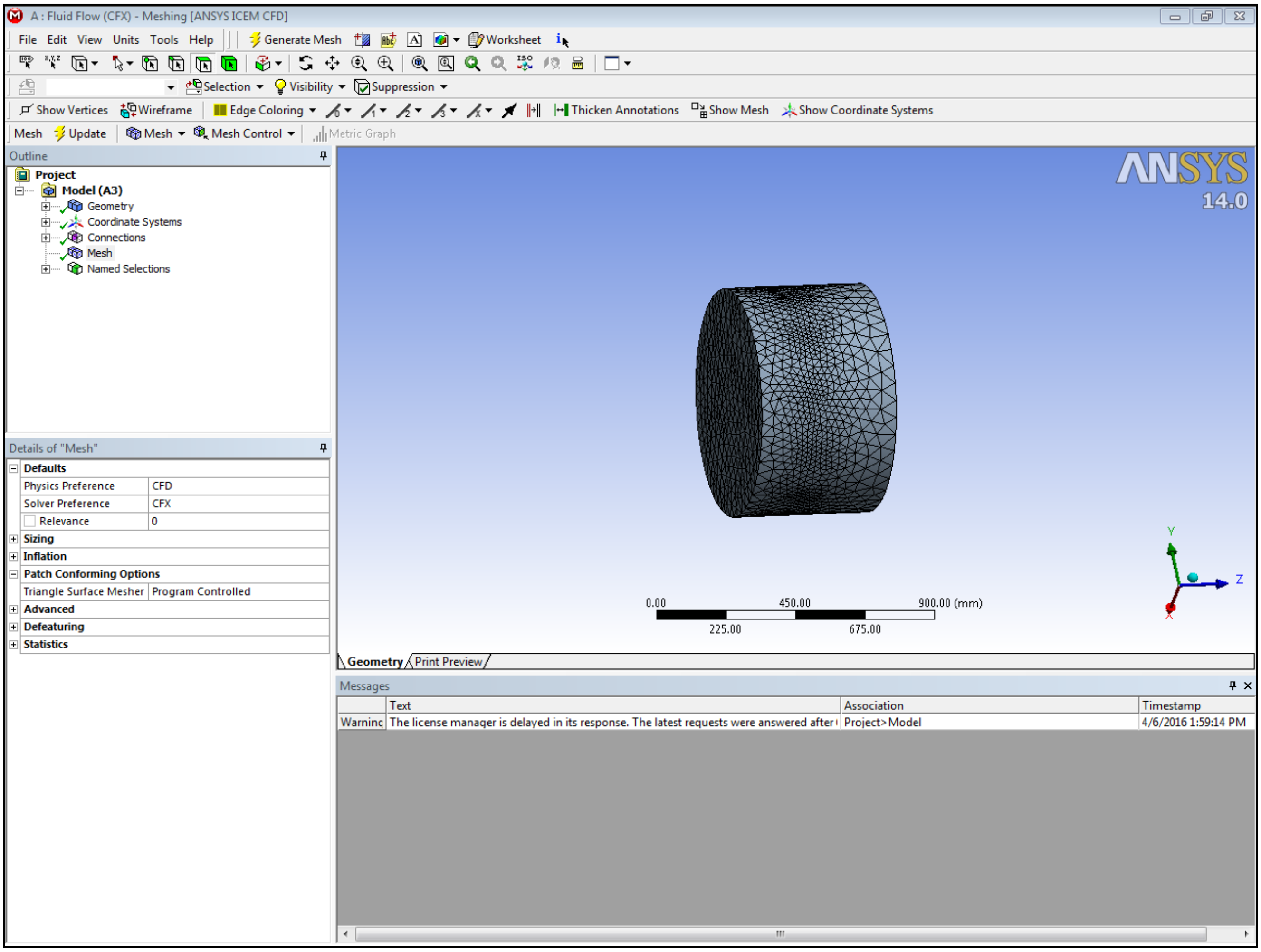

Figure 3.1 Meshing of normal wind turbine

Meshing of wind turbine with collector

The below table is the number of nodes and elements of meshing for new design of wind turbine in this project.

Table 3.2 Number of nodes and elements of meshing for new design

	BLADE	DOMAIN	TOTAL
NODES	4895	35738	40633
ELEMENTS	15795	198709	214504

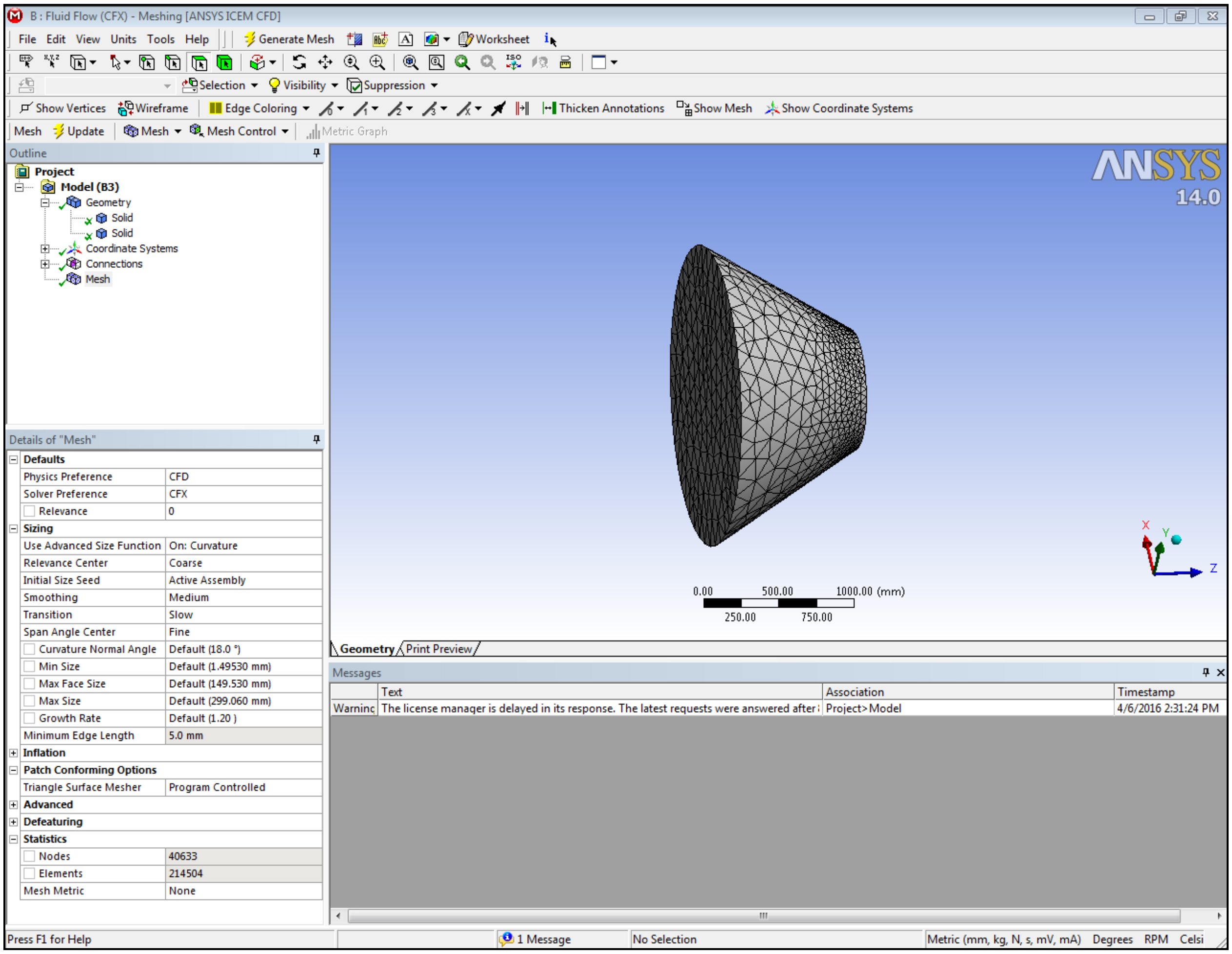

Figure 3.2 Meshing of new wing turbine

3.2 Turbulence Modelling

Turbulent flows have characteristic properties which distinct them from flow of laminar. In this study, realizable k-epsilon turbulence model has tried.

K-ε turbulence model:

The k-epsilon model has been implemented in most general purpose CFD codes and is considered the standard of industry model. It has proven to be numerically robust and stable and has a well-established regime of predictive capability. The simulation of general purpose, the model offers a good compromise in term of accuracy and robustness.

Realizable k - ε model:

This model differs from the standard k – ε model in that it features a reliability constraint on the predicted stress tensor, by that giving the name of realizable k - ε model. The normal stress can become negative in the standard k - ε model for flows with large strain rate by the correction of difference comes in k-equation.

3.3 Boundary Condition

Mostly every computational fluid dynamics problem(CFD) is defined under the limits of initial and boundary conditions. For implementation of boundary conditions when the construct a staggered grid add an extra node across the physical boundary to get,

- The nodes outside the inlet of the system are used to assign the inlet conditions
- The physical boundaries can coincide with the scalar control volume boundaries.

This conditions will allow to introduce the boundary conditions and achieve discretion equations for nodes near boundary with small modifications.

3.3.1 BOUNDARY CONDITION FOR NORMAL WIND TURBINE

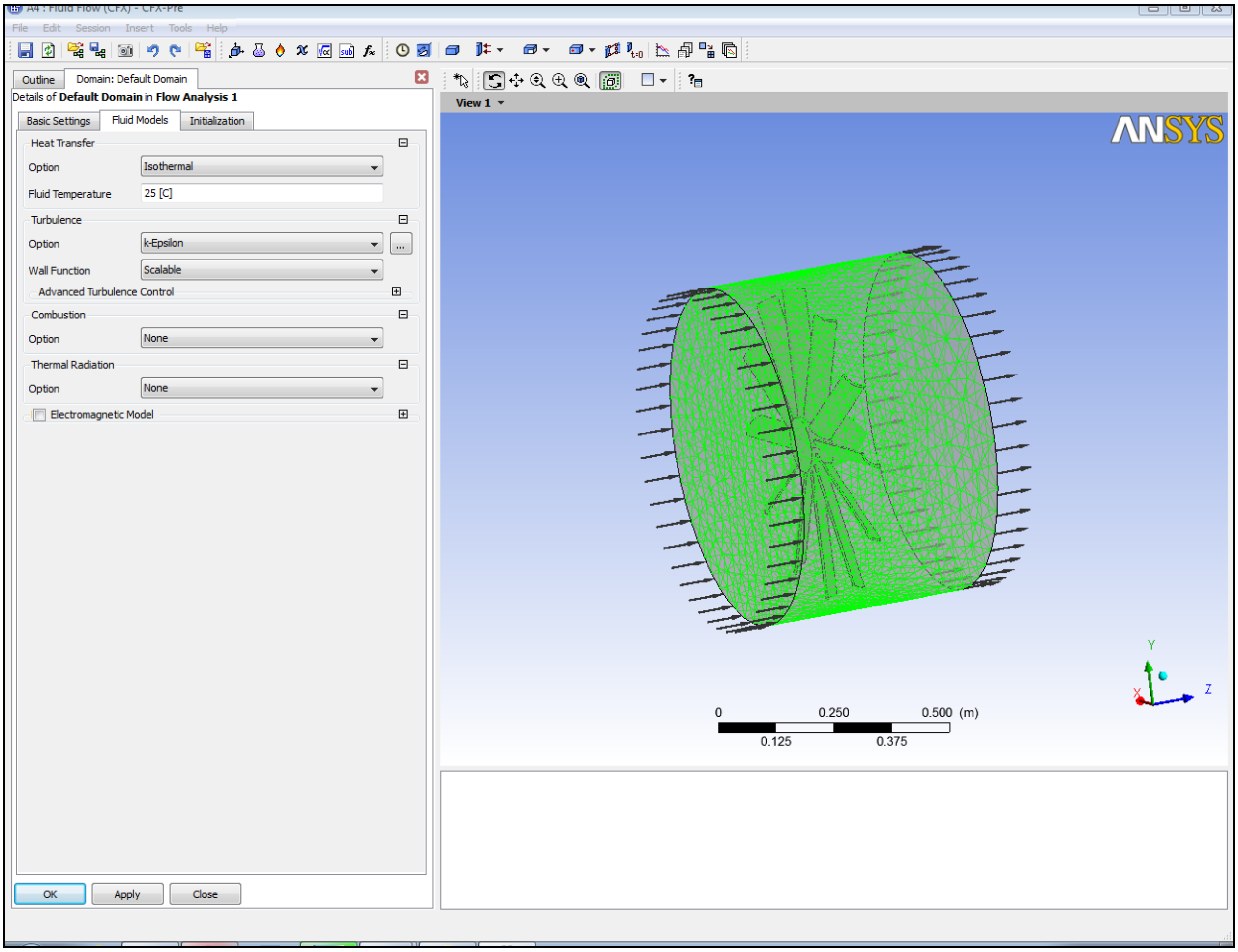

Figure 3.3 Boundary conditions for normal turbine

The figure 3.3 is the boundary conditions for turbine without cowl. The fluid temperature is 25 degree. In figure the arrow marks are clearly denoting the air inlet and air outlet over the wind turbine.

3.3.2 BOUNDARY CONDITION FOR WIND TURBINE WITH COLLECTOR

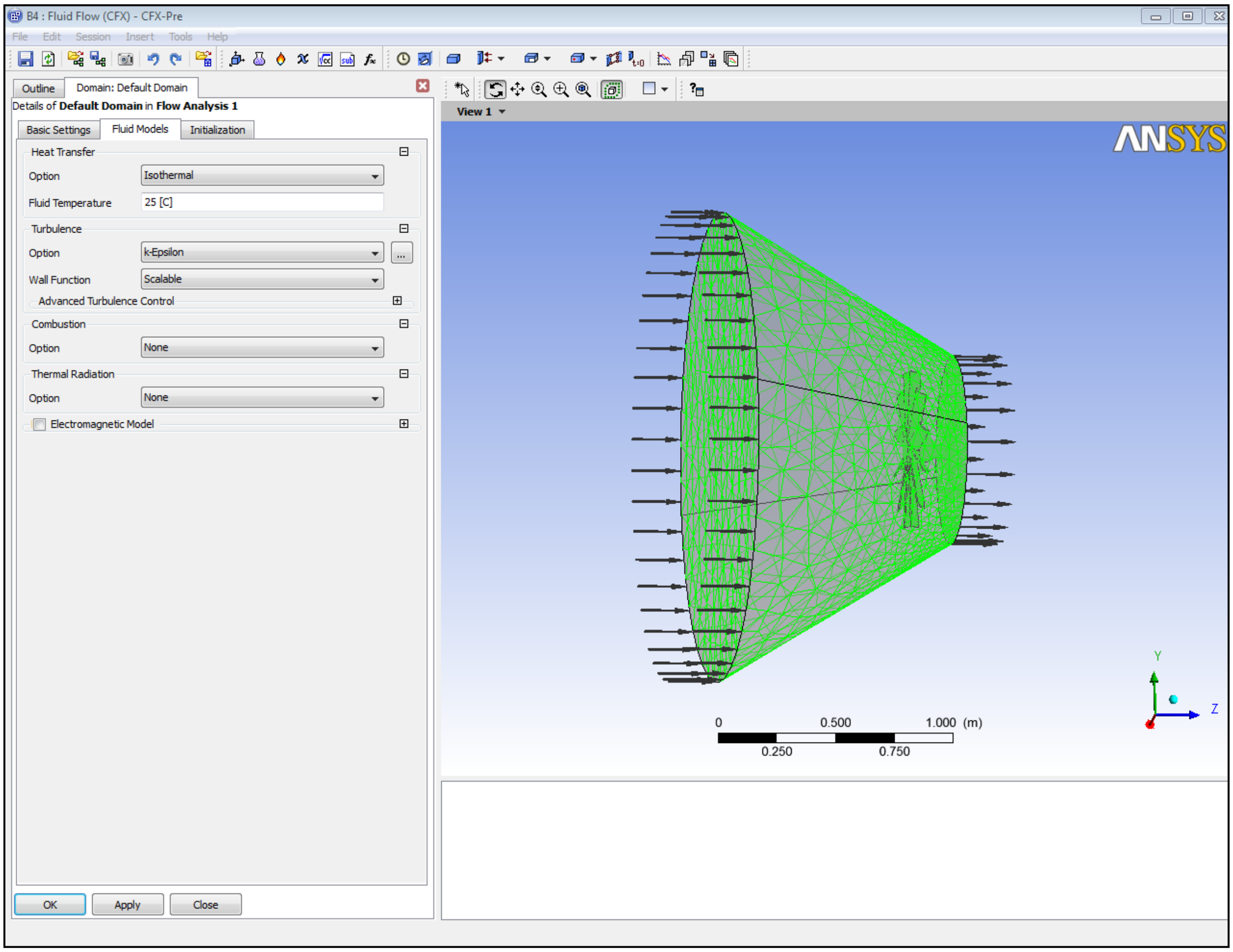

Figure 3.4 Boundary conditions for new turbine

The figure 3.4 is the boundary conditions for wind turbine cowl. Its data given like figure 3.3 to compare both the result. The fluid temperature is 25 degree. In figure the arrow marks are clearly denoting the air inlet and air outlet over the wind turbine.

3.4 Streamline of Normal Turbine

3.4.1 Result of Velocity for Normal Wind Turbine

Initial Wind Speed: 10m/s (Inlet)

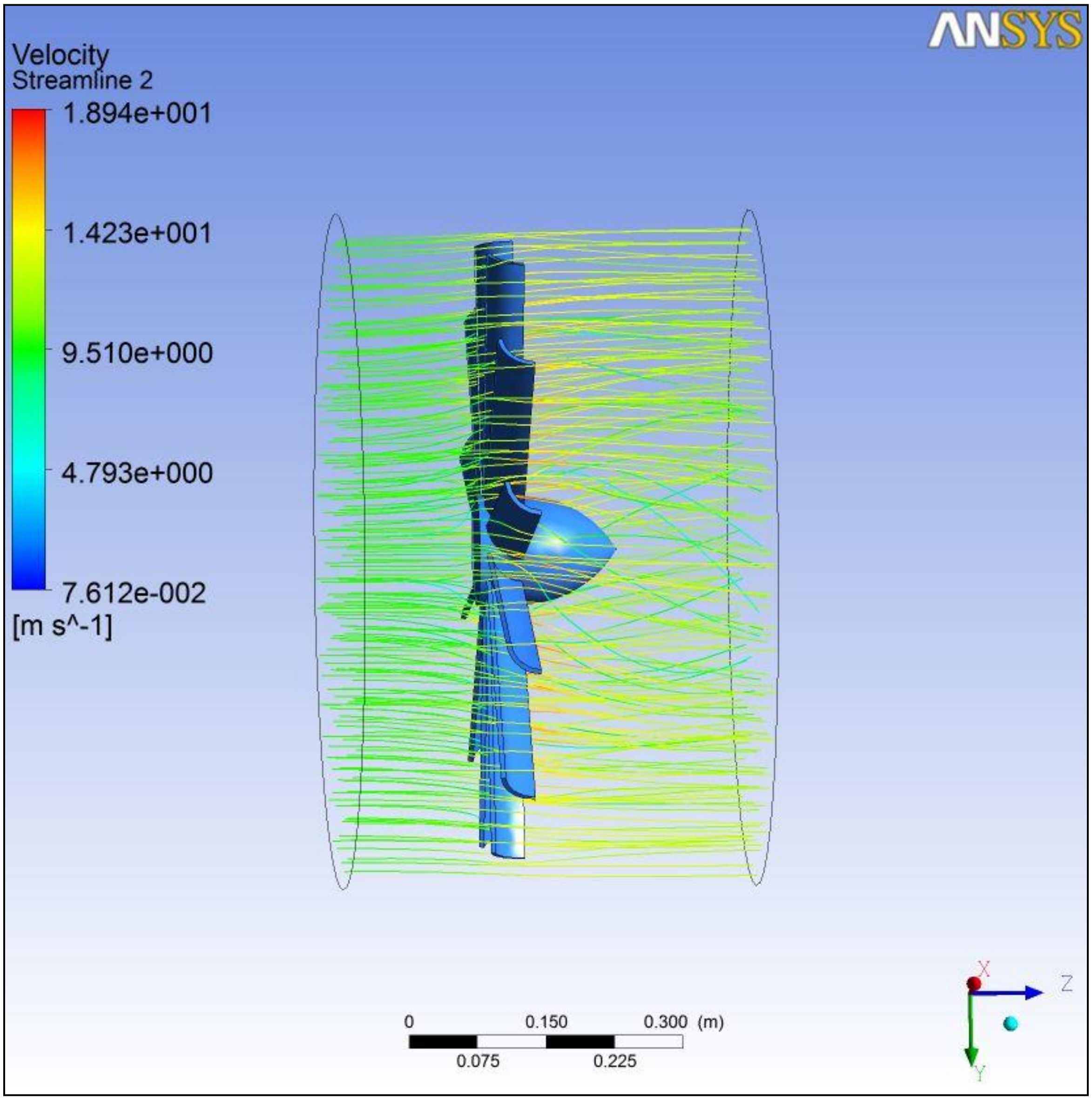

Figure 3.5 Velocity streamline of normal turbine

The rate of change of its position with respect to a reference, and is a function of time is the object of velocity. Velocity is equivalent to a specification of its direction of its motion and speed. Velocity is an important concept in kinematics, to describes the motion of the body in branch of classical mechanics.

3.4.2 Result of Pressure for Normal Wind Turbine

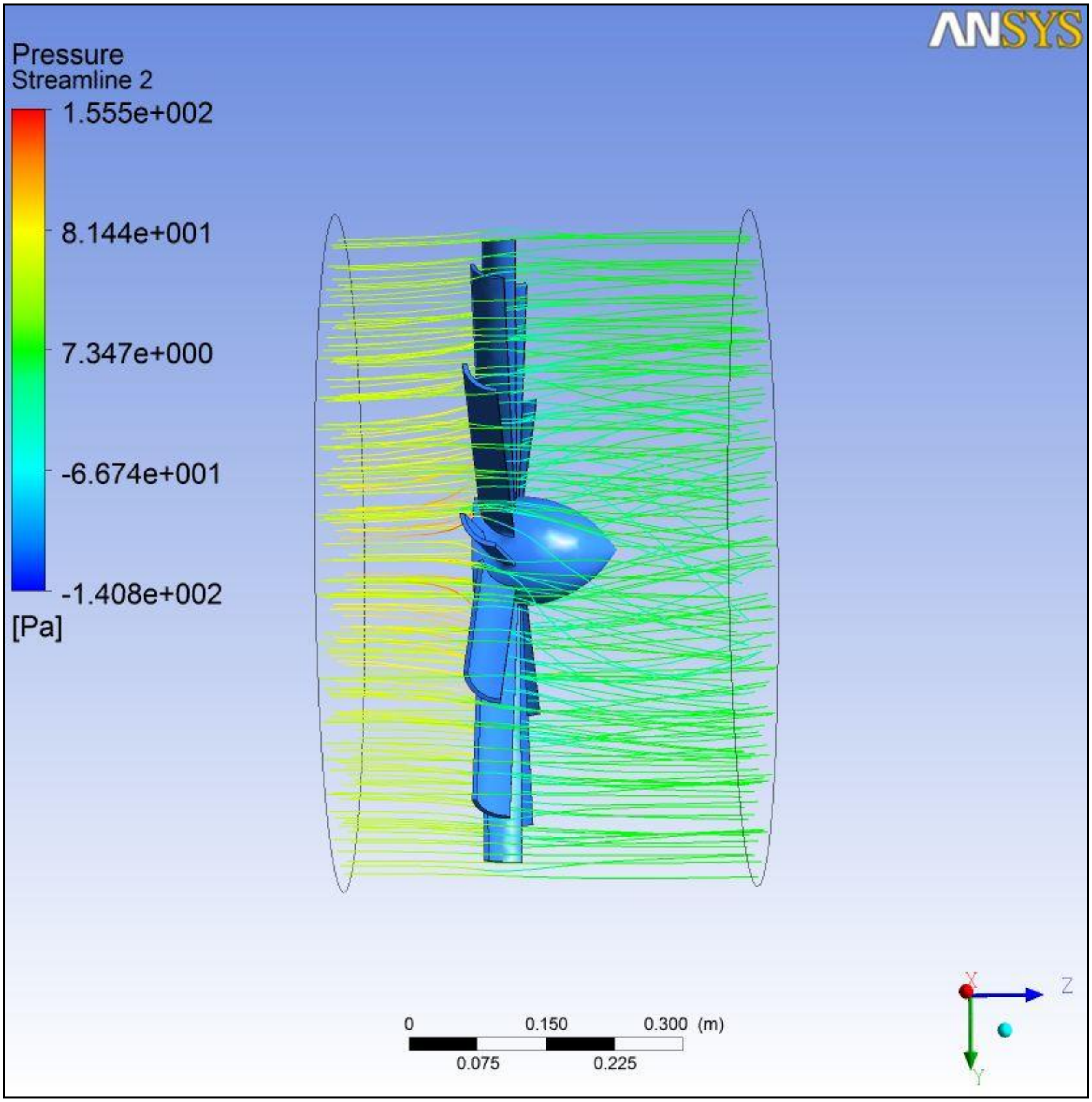

Figure 3.18 Pressure streamline of normal turbine

Pressure of fluid is the pressure at some point within a fluid, such as water or air and for more information specifically about liquid pressure, see section below

Fluid pressure occurs in one of two situations:

1. an open condition, called "open channel flow", e.g. the ocean, a swimming pool, or the atmosphere.
2. a closed condition, called "closed conduit", e.g. a water line or gas line.

3.5 Normal Wind Turbine Graph

Turbulence, Momentum and Mass Graph for Normal Wind Turbine

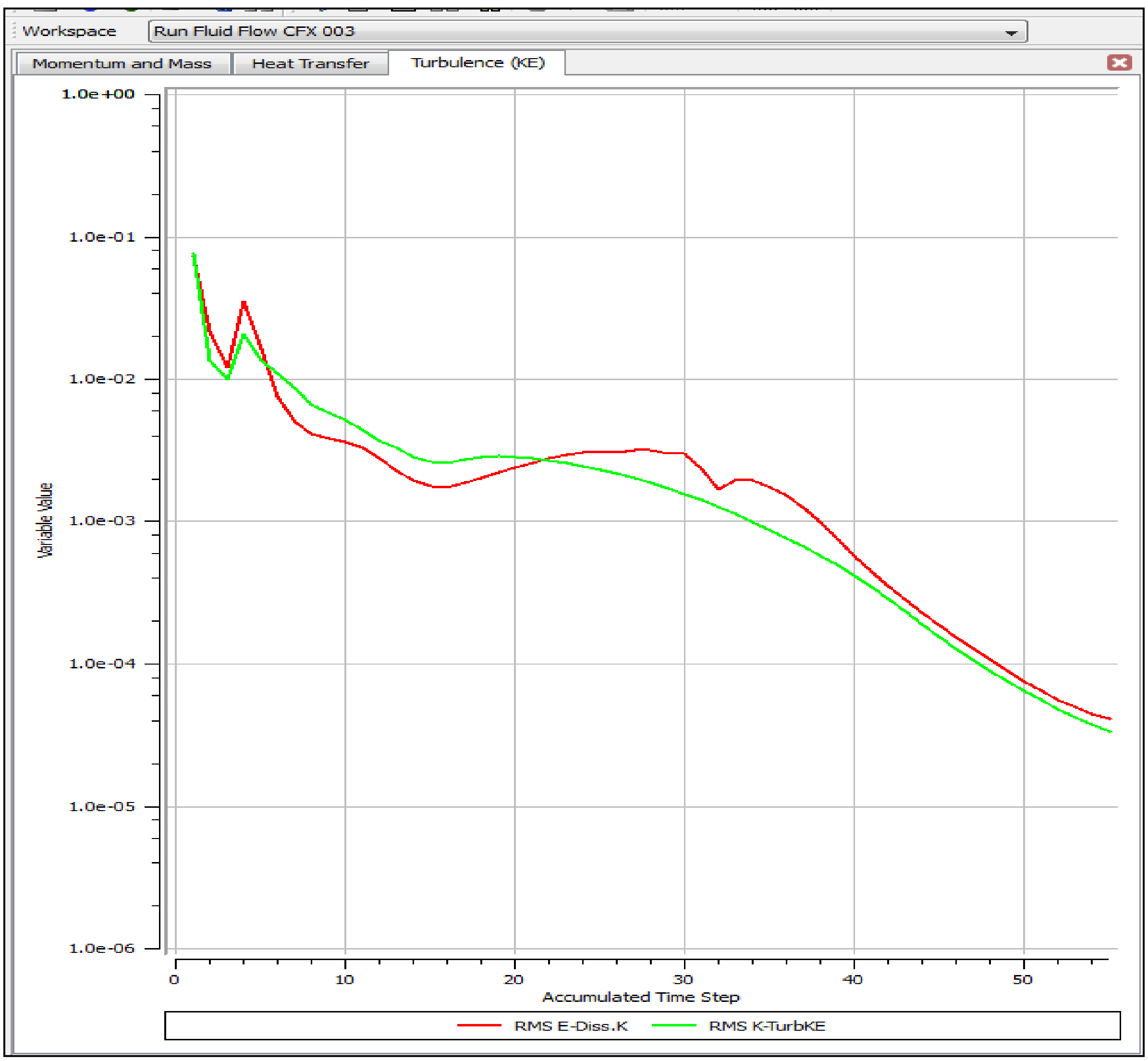

Figure 3.19 Turbulence graph

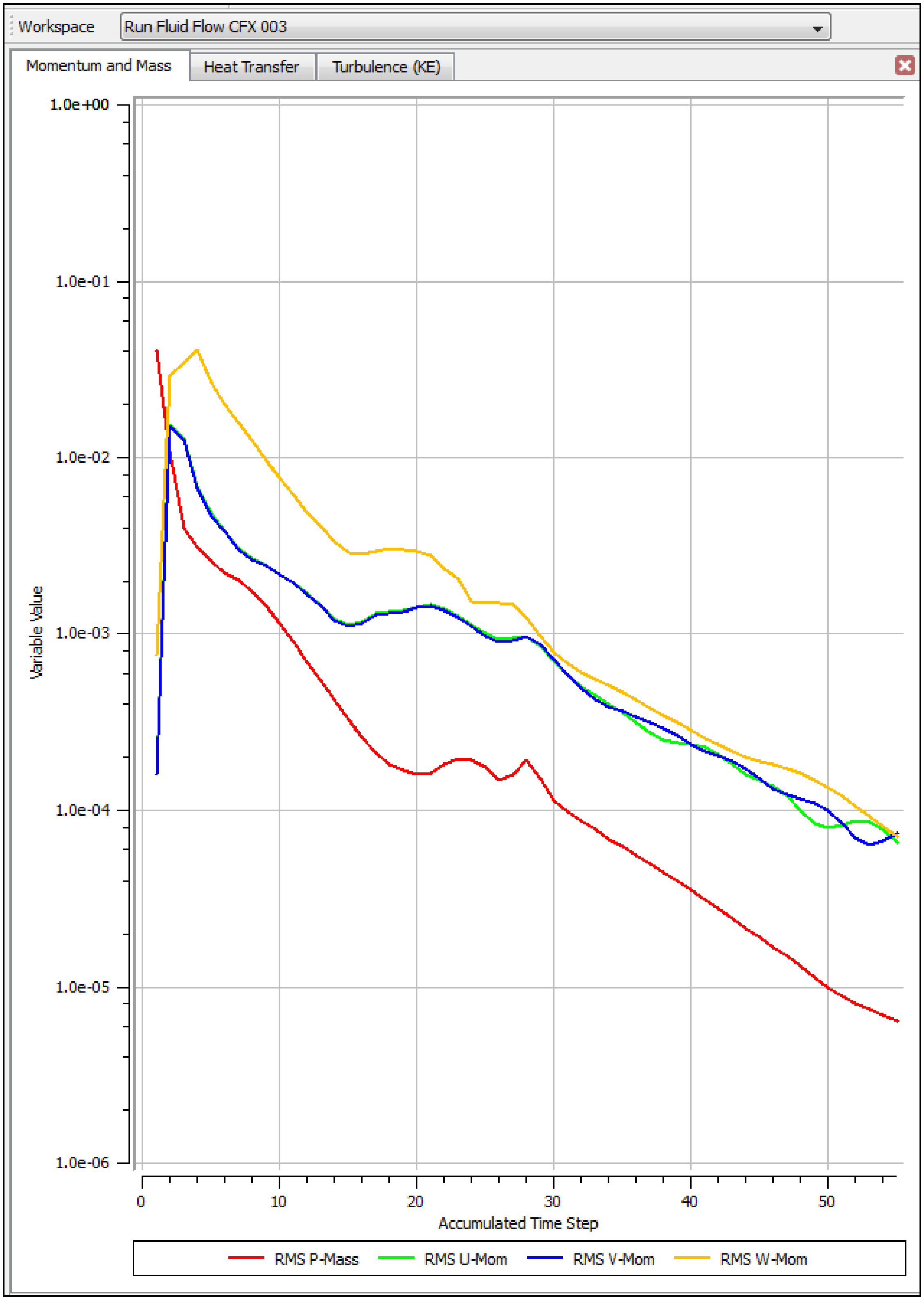

Figure 3.20 Momentum and Mass Graph

3.6 STREAMLINE OF WIND TURBINE COLLECTOR

3.6.1 RESULT OF VELOCITY WIND TURBINE WITH COLLECTOR

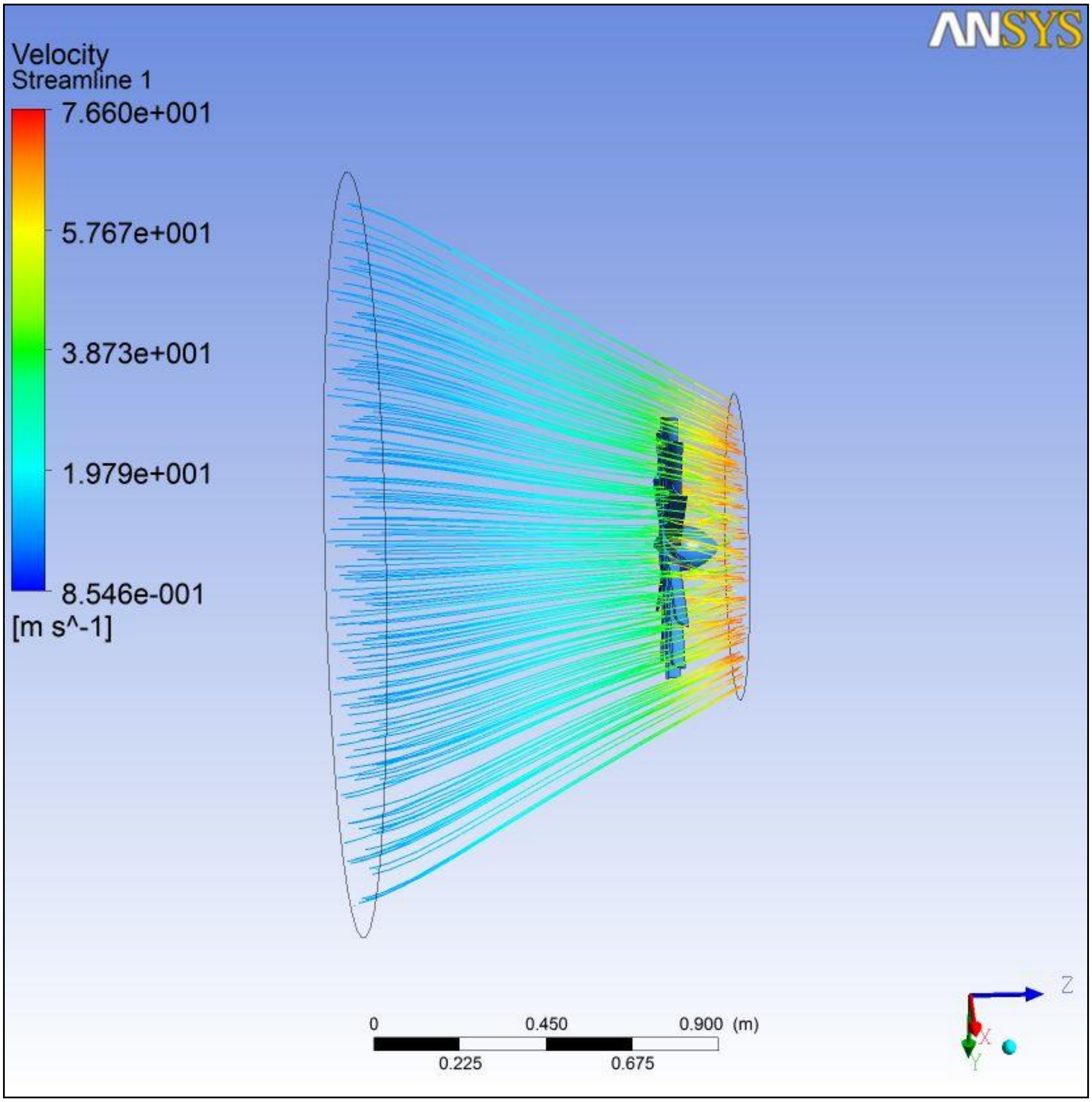

Figure 3.21 Velocity streamline for New turbine

3.6.2 RESULT OF PRESSURE WIND TURBINE WITH COLLECTOR

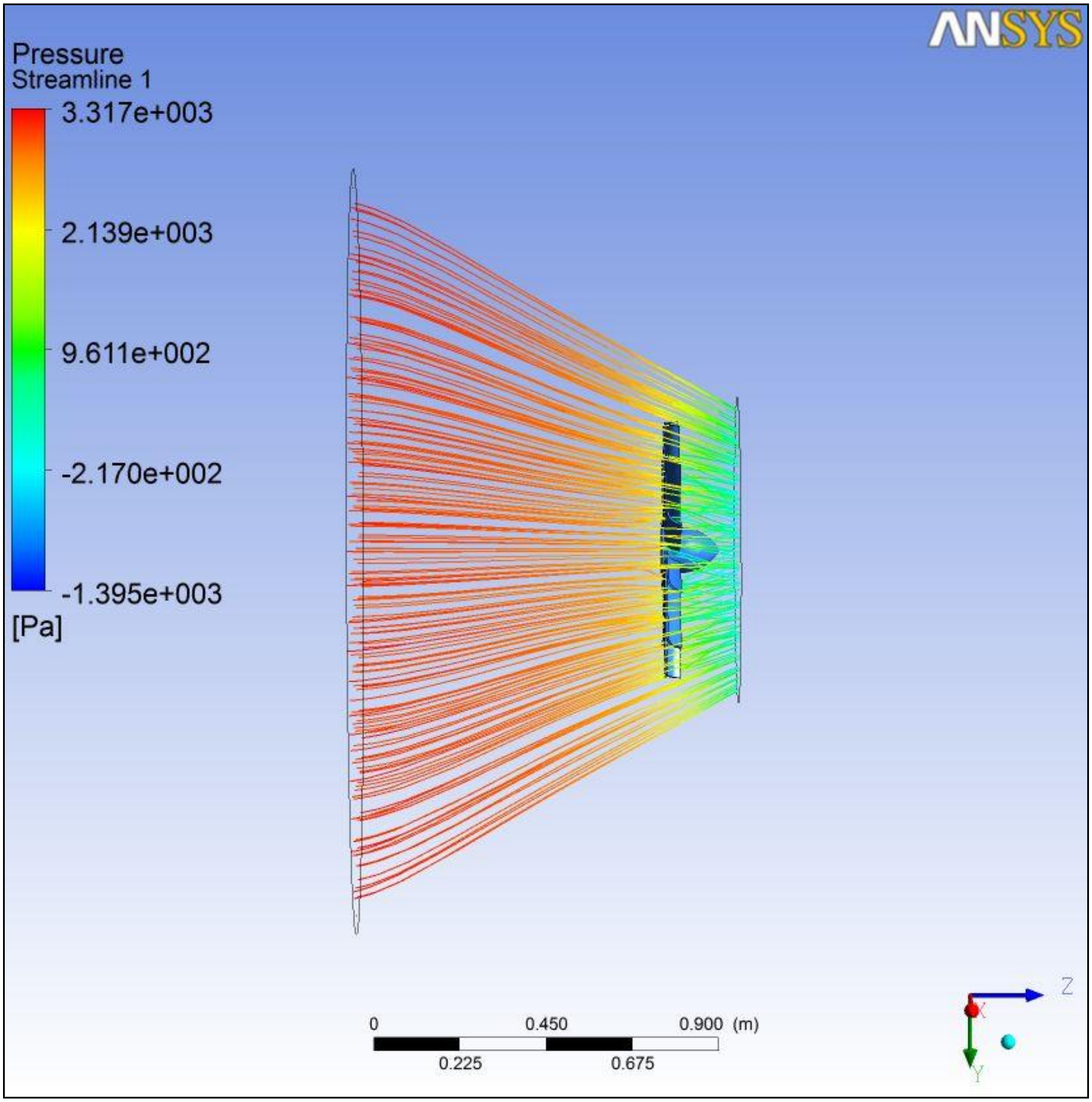

Figure 3.22 Pressure streamline for New turbine

3.7 WIND TURBINE COWL GRAPH

Wind Turbine with Cowl Graph of Turbulence, Momentum and Mass Graph for Normal Wind Turbine

In fluid dynamics, turbulence or turbulent flow may be a flow regime characterised by chaotic property changes. This includes low momentum diffusion, high momentum convection, and speedy variation of pressure and flow rate in house and time.

Flow during which the kinetic energy dies out due to the action of fluid molecular viscosity is laminar flow. whereas there's no theorem relating the non-dimensional Reynolds range (Re) to turbulence, flows at Reynolds numbers larger than 5000 are typically (but not necessarily) turbulent, whereas those at low Reynolds numbers typically stay laminal. In Poiseuille flow, for instance, turbulence will 1st be sustained if the Reynolds range is larger than a essential price of regarding 2040; what is more, the turbulence is mostly interspersed with streamline flow till a bigger Reynolds range of regarding 4000.

In flow, unsteady vortices seem on several scales and act with one another. Drag thanks to physical phenomenon skin friction will increase. The structure and placement of physical phenomenon separation typically changes, typically leading to a discount of overall drag. though laminar-turbulent transition isn't ruled by Reynolds range, an equivalent transition happens if the dimensions of the article is bit by bit redoubled, or the viscousness of the fluid is cut, or if the density of the fluid is redoubled. Nobel Laureate Richard Feynman represented turbulence as "the most vital unsolved downside of classical physics."

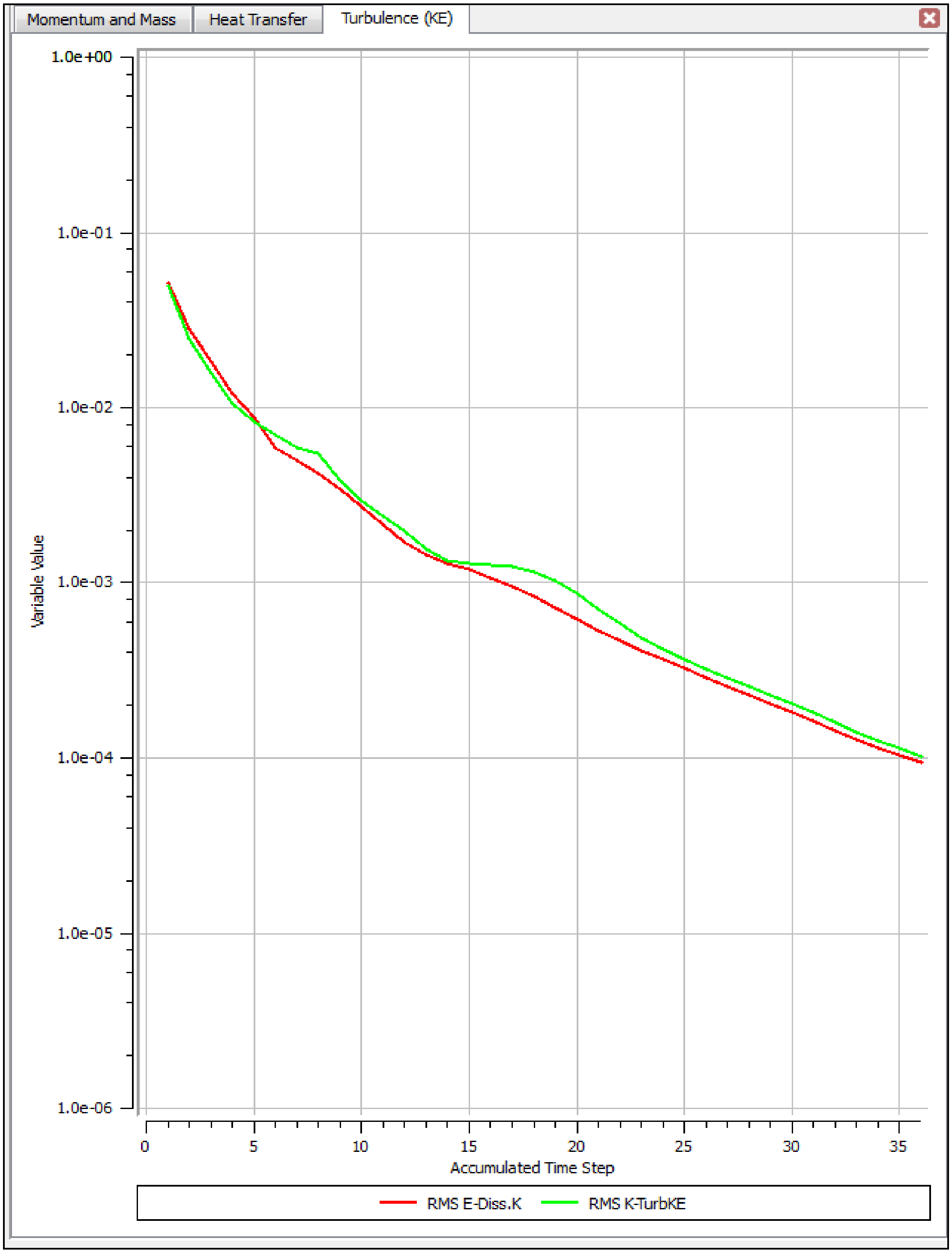

Figure 3.23 Turbulence Graph

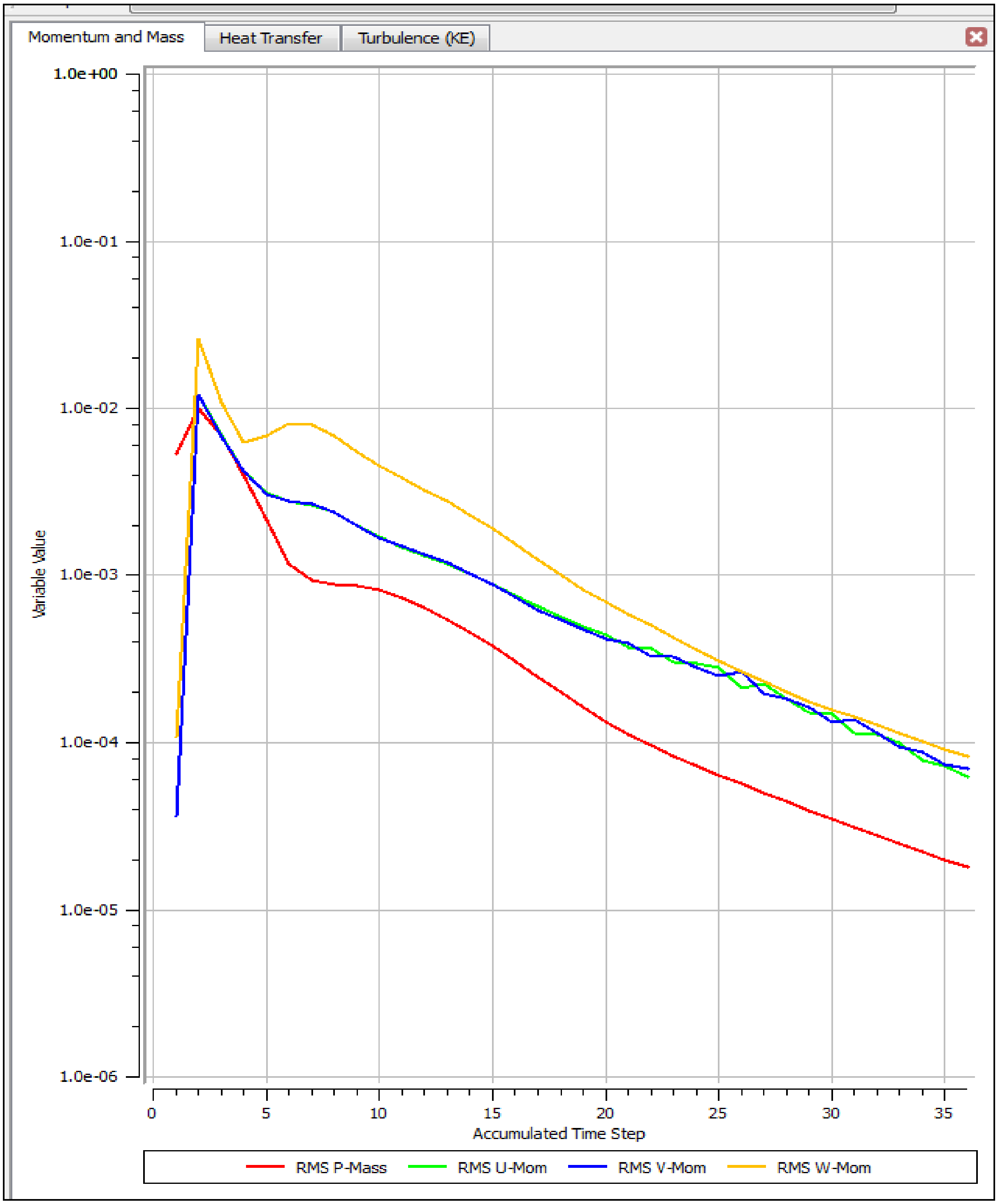

Figure 3.24 Momentum and Mass graph

Fig.21

4. RESULTS AND DISCUSSION

	NORMAL WIND TURBINE WITHOUT COLLECTOR	NEW WIND TUBINE WITH COLLECTOR
Inlet velocity(m/s)	10	10
Outlet pressure(Pa)	1.55e2	3.317e3
Outlet velocity(m/s)	1.894e1	7.66e1

The above Table is the result of outlet pressure and velocity of normal wind turbine and wind turbine with collector. Table clearly shows that turbine with collector is more efficiency then normal turbine.

ADVANTAGES OF THE PROJECT

According from the review of [23] The Wind Turbines have blades, like electric fan, but instead of using electricity to generate wind, the turbines do just the opposite work. Wind rotates the blades, which spin a shaft connected to a generator and the movement leads to the generation or production of electricity.

- Renewable Source of Energy – Wind means fast moving air, present everywhere. It is renewed for all the time as the earth heats and cools. It is a renewable source of energy not like the fossil fuels like coal dug from the core of the earth surface.

- No Air Pollution – The wind turbine is used to generate electricity, therefore there are no hazardous waste eliminated into the air. Whereas traditional power plants produce like sulfur dioxide and nitrogen oxide the oxide will cause acid rain harming forest, wild life and human health.

- No Water Pollution – Most typical power plants unleash poisonous metal wastes into the atmosphere polluting lakes, water bodies and others. These will accumulate within the tissues and square measure risky to the marine life additionally as humans. turbine farms don't unleash poisonous wastes to the atmosphere.

- No Emission of the Greenhouse Gases – It is well-known that standard power plants emitting greenhouse emission, that is that the favorite explanation for heating. greenhouse emission acts as a defend stable gear the sun rays within earth’s atmosphere and heating up the surface, like a greenhouse. This greenhouse emission is so cause for alarm and not emitted the least bit by an influence of wind plant.

- No Depletion of Natural Resources – Unlike an influence plant that needs coal to be transported and extracted victimisation Brobdingnagian amounts of natural resources like fossil fuels, water etc. within the method, wind is obtainable naturally and simply all-round the surface of the planet. Therefore, it considerably reduces the employment of natural resources, and additionally the price, time and energy concerned within the extraction method.

- Free Fuel - Unlike different styles of electrical generation wherever fuel is shipped to a process plants, wind energy generates electricity at the supply of fuel, that is free. Wind may be a native fuel that doesn't ought to be well-mined or transported, taking 2 high-ticket prices out of long-run energy expenses.

5. CONCLUSION

As a result, turbine blade is able to spin much faster in tip velocity than an flat-bladed windmill - much faster than the wind blows through them. And by spinning faster, a lighter and thinner blade can interact with the same amount of air as a slow and fat blade. That saves materials and decreases cost.

Therefore, the project design of the wind turbine collector has provided us an excellent efficiency result when compare to normal wind turbine. The CFD analysis was done over the normal wind turbine blades and the turbine with the collector. The results of the analysis prove that the wind turbine with the blades is more efficient than that of the normal one. For, Analysing the airflow is taken in ANSYS14.0 software where useful to compare the result of pressure and velocity for both wind turbine is that with collector and normal. However, this project may useful for provides an attractive power source as an alternative to fossil fuels because it is abundant. clean, and produces no harmful emissions. The project work is a good solution to bridge the gates between the institution and the industries.

REFERENCES

1. Kuik, G.A.M., the *Lanchester-Betz-Joukowsky Limit, Wind Energy* 10, 2007, 10pp. 289-291

2. Glauert, H., *Aerodynamic Theory*, Vol. 4, Berlin, Germany, Julius Springer, 1935: p. 169 – 360

3 Kathy Araujo, *Wind Power Wind Power Fundamentals*, MIT Mechanical Engineering,

4.Sørensen JN, Shen WZ. Numerical Modeling of Wind turbine Wakes; J. Fluid Engineering 2002; Vol.124; 393-399.

5. Kang S, Hirsch C. Features of the *3D flow around wind turbine blades based on numerical solutions*; Proceedings from EWEC 2001, Copenhagen.

6. Alinot C, Masson C. *Aerodynamic simulation of wind turbines operating in atmospheric boundary layer with various thermal stratifications*; AIAA Paper 2002-0042.

7. Mikkelsen R. *Actuator disc methods applied to wind turbines*; Dissertation submitted to the Technical University of Denmark in partial fulfillment of the requirements for the degree of PhD in Mechanical Engineering; Lyngby, 2003.

8. Ivanell SSA. *Numerical computations of wind turbine wakes*; Technical reports from KTH Mechanics, Royal Institute of Technology; Stockholm, Sweden; 2005.

9. Xu G, Sankar LN. *Computational study of HAWT*; AIAA Paper 1999-0042.

10. Xu G, Sankar LN. *Effects of transition, turbulence and yaw on the performance of HAWT*; AIAA Paper 2000-0048.

11.Benjanirat S, Sankar LN, Xu G. *Evaluation of turbulence models for the prediction of wind turbine aerodynamics*; AIAA Paper 2003-0517

12.Duque EPN, Van Dam CP, Hughes S. Navier-Stokes simulations of the NREL combined experiment phase II rotor. AIAA Paper 99-0037, 1999.

13.Ekaterinaris JA. *Numerical simulation of incompressible two-bladed rotor flow field.* AIAA Paper 97-0398, 1997.

14. J.F. Manwell, J.G. McGowan and A.L. Rogers *Wind Energy Explained* Page-53-57, 2011

15. *Nonconventional Energy*., Author (s): Ashok V. Desai, 1998

16. Sørensen NN, Johansen J, Conway S, Voutsinas S, Hansen MOL, Stürmer A. KNOW-BLADE Task-3.2 report. Tip Shape Study. Risø National Laboratory, Roskilde, Denmark, 2005.

17.Mandas N, Carcangiu CE, Cambuli F. The economy of large scale wind turbines; Fluent News Summer 2005; Vol. XV; 5-7

18.NASA, *Turbulence modeling resource:"The Menter Shear Stress Transport Turbulence Model*". http://turbmodels.larc.nasa.gov/sst.html

19.Spalart P. R. and Allmaras S. R. A one equation turbulence model for aerodynamic flows20. *Design and Fabrication of Wind Mill for Power Generation* G. Balasubramanian*, P. Balashanmugam

21. http://www.brighthub.com/environment/green-living/articles/68454.aspx

22. http://www.wind-works.org/cms/

23.http://www.seeker.com/top-wacky-wind-turbines-photos-1767389880.html?slide=XCJJnP

24. "*Novel Modified Elman Neural Network Control for PMSG System Based on Wind Turbine Emulator*" Research Article, Author: Chih-Hong Lin Department of Electrical Engineering, National United University, Miao Li 360, Taiwan