RESEARCH ARTICLE

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DESIGN AND COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF WIND LENS TURBINE

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ABSTRACT

The project aims to evaluate the performance of the variable speed horizontal axis wind turbine, through software and practical approach methods. A wind turbine is a device that converts the freely available kinetic energy in the wind to the electrical power. This project describes about the construction principles which help in improving the efficiency of the wind turbine, as they are becoming more popular in the modern renewable energy world. Primary objective is to design the wind turbine blades and the tower for the turbine which plays a major role in efficiency and further efficiency of turbine is increased by using sensors systems and their functioning, and by using wind lenses the principles of these systems are described. The design of the blade is done in software called Q-BLADE and power output is also determined from this software which uses Blade Elemental Theory. And tower for wind turbine is designed in CATIA software. Construction of the wind turbine is done and power is evaluated for the turbine and then by using practical approach methods which make changes in aerodynamic parameters on the turbine blades the obtained efficiency is increased and evaluated.

Keywords: Wind lens, HAWT, CATIA, CFD, Propeller etc.,©KY Publications

I. INTRODUCTION

Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth. Wind is the movement of air from an area of high pressure to an area of low pressure. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity. In fact, Ancient mariners used sails to capture the wind and explore the world. Farmers use windmills to grind their grains and pump water. Today, more and more people are using wind turbines to wring electricity from the breeze. Over the past decade, wind turbine use has increased at more than 25 percent a year. Many

people believe that the windmill and wind turbine are the same thing. They are actually very unique and different in many ways. The wind turbine was made to produce energy for a clean and safe environment.

Fig 1.11 Wind Turbines in ANDHRA PRADESH, INDIA

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1.2 How Does Wind Turbines Make Electricity

The terms wind energy or wind power describes the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity. A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity.

A **wind turbine** is a device that converts kinetic energy from the wind into electrical power. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.

A quantitative measure of the wind energy available at any location is called the Wind Power Density (WPD). It is a calculation of the mean annual power available per square meter of swept area of a turbine. The wind power density, measured in watts per square meter, indicates how much energy is available at the site for conversion by a wind turbine.

The major types of wind power are:

- **Utility-scale wind,** wind turbines larger than 100 kilowatts are developed with electricity delivered to the power grid and distributed to the end user by electric utilities or power system operators.

- Distributed or "small" wind, which uses turbines of 100 kilowatts or smaller to directly power a home, farm or small business as it primary use.

- Offshore wind, which are wind turbines erected in bodies of water around the world.

Most modern wind turbines have three blades. A number of variations have been tried, two blades, even one blade – but three blades works the best. Modern wind turbines rotate anti clock wise.
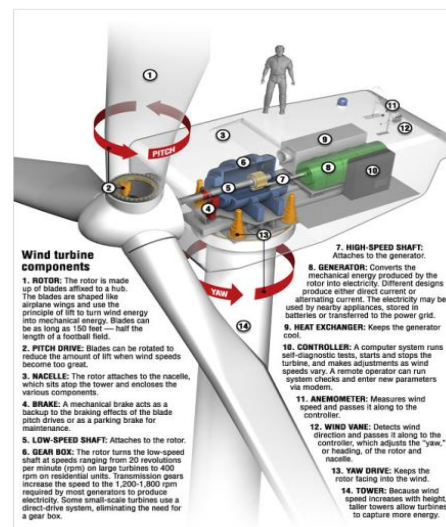

Fig 1.2.1 Parts of Wind Turbine

1.3 Advantages of Wind Turbine

- Wind is the cheapest form of renewable energy.

- Wind turbine blade rotates 15-20rpm to generate electricity.

- It spins 70-80% of the time producing power.

- A wind turbine produces power which is equal to power produce by 16000 solar panels.

- Energy is used in constructing wind turbine, but the turbine generates equivalent energy within 6 months and it keeps on generating energy.

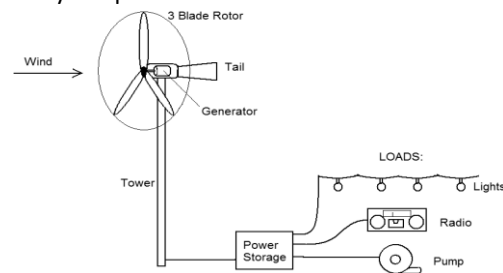- Modern wind turbines are extremely quiet and they are pollution free.

Fig 1.2.2 Functioning Of Wind Turbine

LITERATURE SURVEY

2.1 BETZ'S LAW: Betz's law calculates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. It was published in 1919, by the German physicist Albert Betz. The law is derived from the principles of conservation of mass and momentum of the air stream flowing through an idealized "actuator disk" that extracts energy from the wind stream. According to Betz's law, no turbine can

capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit.
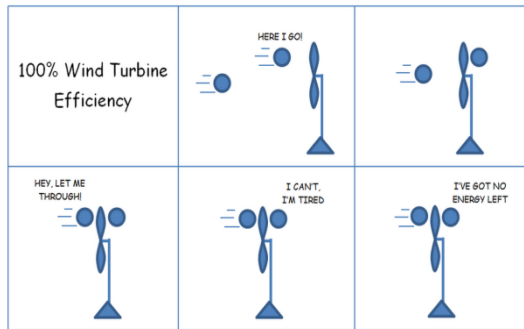

Fig 2.1.1 efficiency of wind turbine

The Betz limit is based on an open disk actuator; if a diffuser is used to collect additional wind flow and direct it through the turbine, more energy can be extracted.
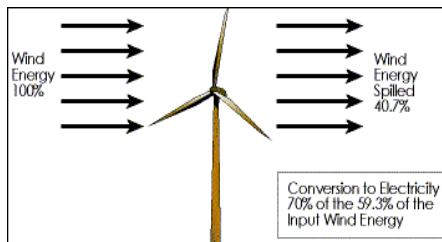

Fig 2.1.2 Betz law pictorial representation for turbine

Betz' Law applies to all Newtonian fluids, but here wind is used as an example. Consider that if all of the energy coming from wind movement through a turbine was extracted as useful energy the wind speed afterwards would drop to zero. If the wind stopped moving at the exit of the turbine, then no more fresh wind could get in - it would be blocked. In order to keeps the wind moving through the turbine there has to be some wind movement, however small, on the other side with a wind speed greater than zero. Betz' law shows that as air flows through a certain area, and when it slows from losing energy to extraction from a turbine, it must spread out to a wider area. As a result geometry limits any turbine efficiency to 59.3%.

2.2 Types Of Wind Turbines

Wind turbines can be separated into two basic types determined by which way the turbine spins. The mechanism is same for the both wind turbines but only the direction changes. Wind turbines that rotate around a horizontal axis are called as horizontal axis wind turbines(HAWT) and are more common (like a wind mill), while the wind turbines that rotate around a vertical axis are called as vertical axis wind turbines(VAWT) and are less frequent compared to HAWT.

2.3 Vertical Wind Turbine

Fig 2.3.1 Vertical Axis Wind Turbine

Vertical-axis wind turbines (VAWTs) are a type of wind turbine where the main rotor shaft is set vertically and the main components are located at the base of the turbine. The Savonius is a drag-type VAWT, so it cannot rotate faster than the wind speed. This means that the tip speed ratio is equal to 1 or smaller, making this turbine not very suitable for electricity generation. Moreover, the efficiency is very low compared to other types, so it can be employed for other uses, such as pumping water or grinding grain. Much of the swept area of near the ground, making the overall energy extraction less effective due to lower wind speed at lower heights. A VAWT does not need to be oriented into the wind and the power transition mechanisms can be mounted at ground level for easy access. The Savonius can be used where reliability is more important than efficiency: small application such as deep-water buoys , most of the anemometers are Savonius-type , used as advertising signs where the rotation helps to draw attention. The Darrieus turbine is composed of a vertical rotor and several vertically-oriented blades. A small powered motor is required to start its rotation, since it is not self-starting. When it already has enough speed, the

wind passing through the airfoils generate torque and thus, the rotor is driven around by the wind. The Darrieus turbine is then powered by the lift forces produced by the airfoils. The blades allow the turbine to reach speeds that are higher than the actual speed of the wind, thus, this makes them well-suited to electricity generation when there is a turbulent wind.

The blades of a VAWT rotate on a rotational surface whose axis is at right angle to the wind direction. The aerodynamic angle of attack of the blades varies constantly during the rotation. Moreover, one blade moves on the downwind side of the other blade in the range of 180° to 360° of rotational angle so that the wind speed in this area is already reduced due to the energy extracted by the upwind blades. Hence, power generation is less in the downwind sector of rotation. Consideration of the flow velocities and aerodynamic forces shows that, nevertheless, a torque is produced in this way which is caused by the lift forces. The breaking torque of the drag forces in much lower, by comparison.

2.4 Horizontal Wind Turbine

Fig 2.4.1 Horizontal Axis Wind Turbine

Horizontal axis wind turbines have been the standard for years which are now gaining favour with homeowners. Horizontal axis wind turbines, as the name implies turn on a horizontal axis or axel. The horizontal axis wind turbines (HAWT) need to be pointed into the wind for optimal efficiency. When the air flow acts on the blade, it generates two kind of forces, named lift and drag, which are responsible for the rotating of the blades.

The HAWT works when the wind passes over both surfaces of the airfoil shaped blade as air passes more rapidly at the upper side of the blade,

thus, creating a lower-pressure area above the airfoil. The difference in the pressures of the top and bottom surfaces results in an aerodynamic lift. The blades of the wind turbine are constrained to move in a plane with a hub at its center, thus, the lift force causes rotation about the hub. In addition to the lifting force, the drag force, which is perpendicular to the lift force, impedes rotor rotation. There are two kinds of Horizontal Axis Wind Turbines:

a. The upwind wind turbine
b. The downwind wind turbine

a) **Upwind wind turbine**:

Fig 2.4.2 Upwind Wind Turbine, HAWT

b) **Downwind wind turbine:**

Fig 2.4.3 Down Wind Turbine, HAWT

2.5 Basic Parts Of HAWT

The basic parts of a horizontal axis wind turbine (HAWT) are foundation, tower, nacelle, Generator, Rotor Blades.

TOWER:A tower that supports the nacelle and rotor hub at its top. These are made from tubular steel, concrete, or steel lattice. Height of the tower is an important in design of HWAT. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.

There are 2 types of towers:
➢ floating towers
➢ land-based towers.

Floating Wind Turbines:

A **floating wind turbine** is an offshore wind turbine mounted on a floating structure that allows the turbine to generate electricity in water depths where bottom-mounted towers are not feasible. Locating wind farms out at sea can reduce visual pollution. whilst providing better accommodation for fishing and shipping lanes. In addition, the wind is typically more consistent and stronger over the sea, due to the absence of topographic features that disrupt wind flow.

Fig 2.5.1 floating tower

Land-Based Tower:A **Land-Based Tower** is an onshore wind turbine mounted on a foundation structure that allows the turbine to generate electricity.

Fig 2.5.2 land based tower

Most wind turbines start operating at a speed of 4-5 meters per second and reach maximum power at about 15 meters per second. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind.

The structural design of a wind turbine consists of two main parts:

➤ Tower

➤ Foundation.

The tower design is based primarily on wind and ice loads, loads acting from the rotor, nacelle, blades, and additional equipment at the top of the tower in addition to wind loads acting on the tower.

The foundation is designed according to the moment and axial loads resulting from the tower design and the properties of the supporting soil.

Tower: The tower is designed to resist the loads acting on it based on the desired scale of the wind turbine and desired hub height. A taller tower translates to an exponential increase in the amount of wind that is being harvested from the wind turbine because wind speed increases as the harvest height increases. The "increase factor" of the wind speed increases exponentially as the height above a surface increases, as shown in Figure From this graph, one can see that at low heights, the wind speed increases significantly at first, but at higher elevations the rate of increase is much less.
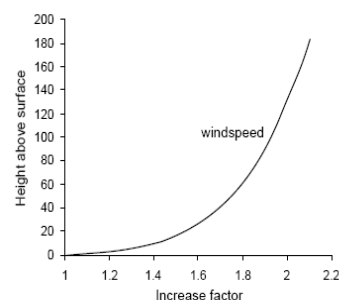

Fig 2.5.3 tower height and wind factor graph

The wind speed will also vary due to the surrounding area. The increase factor of wind speeds is higher in open areas (such as over a body of water) than in highly vegetated areas (such as wooded or built- up areas). Through years of experience, turbine manufacturers and consultants have recommended that a turbine should be at least 30 feet higher than any object within 300 feet. This rule of thumb is used to avoid rapid changes in wind velocity and direction, or turbulence. The wind speeds must be maximized and direction constant at the blades of the turbine in order to maximize the productivity of the wind turbine. A reduction in turbulent winds also reduces the wear and fatigue on the wind turbine.

The most widely used design of a wind turbine tower today is a freestanding, continuously tapered, cylindrical hollow steel monopole. The conical shape is efficient in simultaneously increasing the tower strength and saving materials as well as reducing the exposed profile for wind forces at higher elevations. The tower is constructed in sections from rolled steel at a desired thickness, and is transported on site and bolted and/or welded together to create the massive towers.

The design of a wind turbine tower is dependent on the criteria outline in Table. The codes used in conjunction with the design method are also listed. It is the responsibility of the engineer to design the wind turbine tower against local buckling, bending and combined axial and bending failures.

Tower Design Criteria

Design Factor	Design Criteria
Dead Load	Consists of the self weight of the tower, the turbine equipment at the top of the tower, and ice loads
Wind Load	Wind profile is approximated along small sections of the tower
Local Buckling	Considers a column's slenderness ration, resist failure due to high axial compressive loads
Flexural Failure	Resist failure due to high bending moments inducing tensile strength in a cross section that is greater than the yield strength
Combined Axial and Bending loads	Considers the combined failure due to combined axial and bending loads with a

	magnification factor on the bending stress

Foundation: The foundation of a wind turbine is designed for the worst-case loading. The turbine foundation has to resist great loads mainly because of the overturning moment due to wind and must simultaneously resist forces from geotechnical conditions. Reinforced concrete spread footings are most common in design because they are applicable to a wide range of soil strengths, however for some weaker soils a deeper foundation is needed to stabilize the turbine tower. The main components in designing a spread footing are its width, depth, amount of steel reinforcement, and construction requirements.

Fig 2.5.4 Foundation for tower

The essential foundation design criteria are stiffness, strength, stability, differential settlement, durability, and economy. These minimum values for foundations are usually provided by the turbine manufacturers' design specifications. Table below lists the design factor, its design criteria, and any design codes or standards that are used in conjunction with the criteria.

Foundation Design Criteria

Design Factor	Criteria
Strength	Withstand factored loads and fatigue loads
Stability	Resist excessive translational and rotational movement under extreme loads
Settlement	Considers soil criteria to ensure adequate bearing capacity
Durability	Resist environmental damage to concrete and

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	maintain serviceability for the turbine's lifetime

Nacelle:A housing which contains all the components which is essential to operate the turbine efficiently is called a nacelle. It is fitted at the top of a tower and includes the gear box, low- and high-speed shafts, generator, controller, and brakes. A wind speed anemometer and a wind vane are mounted on the nacelle.

Blades: Wind turbine blades are used to extract the kinetic energy of wind and convert to mechanical energy. These blades are made up of fiber glass-reinforced polyester or wood-epoxy. Wind turbines have one or two or three or multiple blades based up on the construction. Most of the HAWT have three blades. These are connected to rotor hub. Multiple blade concepts are used in earlier days for pumping water and grinding etc

1) **Single blade HAWT** :It reduces the cost and weight of the turbine. These are rarely used due to tower shadow effects, needs counter weights on the other side of the blade, less stability.

2) **Two blades HAWT**: It requires more complex design due to sustain of wind shocks. It is also less stable. It saves the cost and weight of one rotor blade.

Two- and one-bladed machines require a more complex design with a hinged (teetering hub) rotor, i.e. the rotor has to be able to tilt in order to avoid too heavy shocks to the turbine when a rotor blade passes the tower. The rotor is fitted onto a shaft which is perpendicular to the main shaft, and which rotates along with the main shaft. This arrangement may require additional shock absorbers to prevent the rotor blade from hitting the tower.

3) **Three blades HAWT**: Modern wind turbines use three blade concept. Because this structure have height strength to withstand heavy wind storms. Less effect due to tower shadow. Produces high output than the four bladed wind turbine.

With more number of blades, blades should be thinner to be aerodynamically efficient. But blades with thinner portion at the root may not withstand bending stress induced due to axial wind load. So generally wind turbines with 3 blades which can accommodate a thicker root cross-section are used.

Fig 2.5.5 Single blade HAWT

Fig 2.5.6 Two blades HAWT

Fig 2.5.7 Three blades HAWT

As the number of blades in the wind turbine increases aerodynamic efficiency increases, but in a diminishing manner. When we move from 2 blades to 3 blades design efficiency gain is about 3%. The more blades there are on a wind turbine, the higher will be the torque (the force that creates rotation) and the slower the rotational speed (because of the increased drag caused by wind flow resistance). But as we move from 3 blades to 4 blades design, efficiency gain is marginal. As we increase number of blades, cost of the system increases drastically. Along with that mechanical design of blades also becomes a difficult affair.

2.6 Principle Of Wind Turbine

A condition for an efficient conversion of the wind energy into mechanical energy with wind turbines is the optimal design of the rotor blades. Methods for rapid development, reliable and robust

predictions of the aerodynamics characteristics and simulation of the flow conditions around a rotor blade are essential for this design task.

The shape and dimensions of the blades of the wind turbine are determined by the aerodynamic performance required to efficiently extract energy from the wind, and by the strength required to resist the forces on the blade. The rotation of the blades is due to the different in pressure on the surface of the blade causes it to lift as the blade is attached to the hub it revolves. To design a blade different types of airfoils are used, and the twist is different at different positions.

Blades play a part in the wind turbine principle by combining with the pillar that goes down to the generator. Every time they are revolved, they impart some mechanical energy on the middle part of the structure, which is shaped like a rod with coils upon it. These turn anticlockwise to the spin of the wing-like devices above in order to impart this energy through friction to the generator below. The latter is able to convert the sent waves into power that can be stored in terms of volts.

The wind turbine principle also places special importance to the mechanical friction in order to automate the whole process and stem any undue revolution during drastic changes in climate. The central rods usually revolve anticlockwise to the spin of the blades to pass on their generated force to the next rod beyond the gear kit.

The latter, which is large and connects directly to the generator, begins faster revolution. While this is beneficial in increasing the potential power generated, in certain cases if left unchecked, especially in stormy conditions, it can break down. To check on this, the machine comes with a set of braking installations in both stages of the rods, to break on any adverse speed. The central pillar also can revolve on itself to face the whole structure towards the current instead of down its direction in order to stem on the velocity.
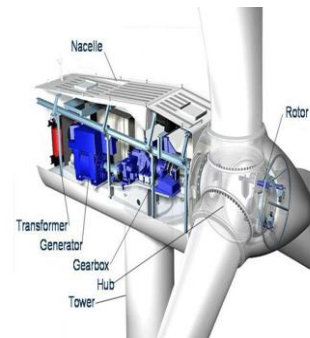
2.7 Working Of Wind Turbine

Fig 2.7.1 Working Of HAWT

Rotor blades take the energy out of the wind. They "capture" the wind and convert its motive energy into the rotation of the hub. The profile is similar to that of airplane wings. Rotor blades utilize the same "lift" principle. A wind turbine tower is not just a support structure. It raises the wind turbine so that its blades safely clear the ground and so it can reach the cleaner, stronger winds at higher elevations. The hub directs the energy from the rotor blades on to the generator. If the wind turbines have a gearbox, the hub is connected to the slowly rotating gearbox shaft, converting the energy from the wind into rotation energy. If the turbine has a direct drive, the hub passes the energy directly on to the ring generator. A gearbox is typically used in a wind turbine to increase rotational speed from a low-speed rotor to a higher speed electrical generator.

2.8 Design Of The Blade

The wind turbine blade is designed by using different airfoils, the airfoils are used according to the efficiency required and circular foil is used at the root of the blade for the structure to be fixed in the hub and for structural stability.
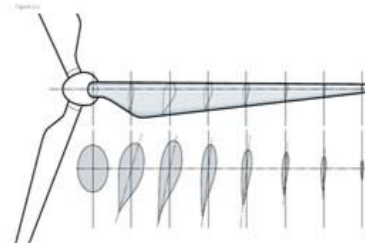

Fig 2.8.1 Internal Design Of The Blade

The blade section consists of the root, primary and tip. At the root section circular foils are used and then the airfoils are placed at a twist angle with the root and it is continued till the tip section.

The placing of different airfoils, the chord and the position of the airfoils is required for designing.

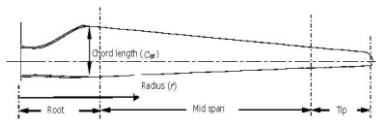The modern blade can be divided into three main areas classified by aerodynamic and structural function

Fig 2.8.2 Parts Of Blade

The blade root : The transition between the circular mount and the first aerofoil profile this section carries the highest loads. Its low relative wind velocity is due to the relatively small rotor radius.

The low wind velocity leads to reduced aerodynamic lift leading to large chord lengths. Therefore the blade profile becomes excessively large at the rotor hub. The problem of low lift is compounded by the need to use excessively thick aerofoil sections to improve structural integrity at this load intensive region. Therefore the root region of the blade will typically consist of thick aerofoil profiles with low aerodynamic efficiency.

The mid span: Aerodynamically significant the lift to drag ratio will be maximised. Therefore utilising the thinnest possible aerofoil section that structural considerations will allow.

The tip: Aerodynamically critical the lift to drag ratio will be maximised. Therefore using slender aerofoils and specially designed tip geometries to reduce noise and losses. Such tip geometries are as yet unproven in the field, in any case they are still used by some manufacturers.
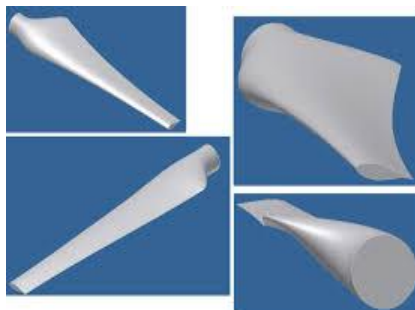
Fig 2.8.3 Different Views Of Wind Turbine Blade

The aerodynamic design principles for a modern wind turbine blade are detailed, including blade plan shape/quantity, aerofoil selection and optimal attack angles. A detailed review of design loads on wind turbine blades is offered, describing aerodynamic, gravitational, centrifugal, gyroscopic and operational conditions. The orientation of the shaft and rotational axis determines the first classification of the wind turbine. A turbine with a shaft mounted horizontally parallel to the ground is known as a horizontal axis wind turbine or (HAWT). A vertical axis wind turbine (VAWT) has its shaft normal to the ground these two configurations have instantly distinguishable rotor designs, each with its own favourable.

2.9 Aerodynamics: Aerodynamic performance is fundamental for efficient rotor design. Aerodynamic lift is the force responsible for the power yield generated by the turbine and it is therefore essential to maximise this force using appropriate design. A resistant drag force which opposes the motion of the blade is also generated by friction which must be minimised. It is then apparent that an aerofoil section with a high lift to drag ratio, be chosen for rotor blade

The co-efficient for the lift and drag of aerofoils is difficult to predict mathematically, although freely available software, such as XFOIL model results accurately with the exception of post stall, excessive angles of attack and aerofoil thickness conditions. Traditionally aerofoils are tested experimentally with tables correlating lift and drag at given angles of attack and Reynolds numbers. Historically wind turbine aerofoil designs have been borrowed from aircraft technologies with similar Reynolds numbers and section thicknesses suitable for conditions at the blade tip. However, special considerations should be made for the design of wind turbine specific aerofoil profiles due to the differences in operating conditions and mechanical loads.

Tip Speed Ratio: The tip speed ratio defined as the relationship between rotor blade velocity and relative wind velocity is the foremost design parameter around which all other optimum rotor dimensions are calculated.

Aspects such as efficiency, torque, mechanical stress, aerodynamics and noise should be considered in selecting the appropriate tip speed . The efficiency of a turbine can be increased with

higher tip speeds , although the increase is not significant when considering some penalties such as increased noise, aerodynamic and centrifugal stress an increase in centrifugal and aerodynamic forces is associated with higher tip speeds. The increased forces signify that difficulties exist with maintaining structural integrity and preventing blade failure. As the tip speed increases the aerodynamics of the blade design become increasingly critical. A blade which is designed for high relative wind speeds develops minimal torque at lower speeds. This results in a higher cut in speed and difficulty self-starting.

2.10 Blade Shape: An efficient rotor blade consists of several aerofoil profiles blended at an angle of twist terminating at a circular flange. It may also include tip geometries for reducing losses. To facilitate production, several simplifications maybe made:

- Reducing the angle of twist.
- Linearization of the chord width.
- Reducing the number of differing aerofoil profiles.

All manufacturing simplifications are detrimental to rotor efficiency and should be well justified. The introduction of new moulding techniques and materials has allowed the manufacture of increasingly complex blade shapes. Leading wind turbine suppliers now include most optimisation features such as angle of twist, variable chord length and multiple aerofoil geometries.

2.11 Airfoils: The structural requirements of turbine blades signify that aerofoils with a high thickness to chord ratio be used in the root region. Such aerofoils are rarely used in the aerospace industry. Thick aerofoil sections generally have a lower lift to drag ratio. Special consideration is therefore made for increasing the lift of thick aerofoil sections for use in wind turbine blade designs.

National Advisory Committee for Aeronautics (NACA) four and five digit designs have been used for early modern wind turbines. The classification shows the geometric profile of a NACA aerofoil where the 1st digit refers to maximum chamber to chord ratio, 2nd digit is the camber position in tenths of the chord and the 3rd & 4th

digits are the maximum thickness to chord ratio in percent.

Angle of Twist: The lift generated by an aerofoil section is a function of the angle of attack to the inflowing airstream. The inflow angle of the air stream is dependent on the rotational speed and wind speed velocity at a specified radius. The angle of twist required is dependent upon tip speed ratio and desired aerofoil angle of attack. Generally the aerofoil section at the hub is angled into the wind due to the high ratio of wind speed to blade radial velocity. In contrast the blade tip is likely to be almost normal to the wind.

The total angle of twist in a blade maybe reduced simplifying the blade shape to cut manufacturing costs. However, this may force aerofoils to operate at less than optimum angles of attack where lift to drag ratio is reduced. Such simplifications must be well justified considering the overall loss in turbine performance.

6-series: An improvement over 1-series airfoils with emphasis on maximizing laminar flow. The airfoil is described using six digits in the following sequence:

The number "6" indicating the series.

NACA 65(3)-618

NACA 65(3)-618 airfoil

Max thickness 18% at 39.8% chord.
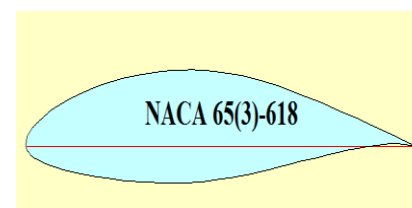
Max camber 3.3% at 50% chord

Fig 2.11.1 (a) NACA airfoil

5 is the 10 times the position of minimum pressure as a fraction of chord (0.5 chord) although it is also the position of maximum thickness.

3 is the intended span of lift coefficients that low drag occurs over in tenths (CL plus or minus 0.3).

6 is the designed lift coefficient in tenths (CL = 0.6)

18 is the maximum thickness as a percent

Maximum thickness 18% at 50% chord

NACA 64A-010 10.0%

NACA 64A010 airfoil

Max thickness 10% at 40% chord.
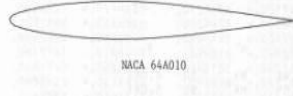
Max camber 0% at 0% chord

Fig 2.11.1 (b) NACA Airfoil

The emergence of wind turbine specific aerofoils such as the Delft University, LS, SERI-NREL and FFA and RISO now provide alternatives specifically tailored to the needs of the wind turbine industry.

S-Series:NREL's S-Series airfoils come in thin and thick families. The thin airfoil families lend themselves to stall regulated wind turbines where performance losses to airfoil soiling are significant. For variable-pitch and variable-speed turbines, airfoil soiling is not a major problem. Generally, a primary airfoil is grouped with root and tip airfoils. Most wind turbine blades have a circular section that attaches to the hub. This is especially important for pitching blades. There is then a transition from the circular section to the root airfoil section, which usually occurs around the maximum chord. Between the circular section and the root airfoil section, the transition is faired. The fairing process should avoid concavities to prevent buckling. The primary airfoil usually occurs in its pure state around the 75% radius and the tip airfoil is usually pure around the 95% location. Various interpolation methods are used to define airfoil shapes between the three pure airfoils. The tip airfoil is also usually retained out to the tip of the blade, but some allowances can be made to accommodate special tip shapes. The root airfoil usually has the greatest thickness ratio (maximum thickness to chord ratio) and the thickness ratio gets smaller as one approaches the tip. At the blade root, large airfoil thickness is needed to accommodate blade structural considerations and toward the tip thinner airfoils are needed to minimize drag and blade soiling losses.
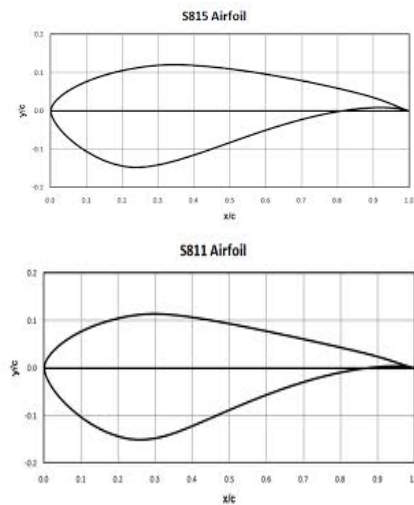
Fig 2.9.2 S-Series airfoil

The angle of attack is the angle of the oncoming flow relative to the chord line, and all figures for *CL* and *CD* are quoted relative to this angle. The use of a single aerofoil for the entire blade length would result in inefficient design. Each section of the blade has a differing relative air velocity and structural requirement and therefore should have its aerofoil section tailored accordingly. At the root, the blade sections have large minimum thickness which is essential for the intensive loads carried resulting in thick profiles. Approaching the tip blades blend into thinner sections with reduced load, higher linear velocity and increasingly critical aerodynamic performance. The differing aerofoil requirements relative to the blade region are apparent when considering airflow velocities and structural loads

An aerodynamic phenomenon known as stall should be considered carefully in turbine blade design. Stall typically occurs at large angles of attack depending on the aerofoil design. The boundary layer separates at the tip rather than further down the aerofoil causing a wake to flow over the upper surface drastically reducing lift and increasing drag forces

The sensitivity of blades to soiling, off design conditions including stall and thick cross sections for structural purposes are the main driving forces for the development of wind turbine specific aerofoil profiles. The use of modern materials with superior mechanical properties may allow for

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thinner structural sections with increased lift to drag ratios at root sections. Thinner sections also offer a chance to increase efficiency through reducing drag. Higher lift coefficients of thinner aerofoil sections will in turn lead to reduced chord lengths reducing material usage

2.12 WIND LENS:A **wind lens** is a modification made to a wind turbine to make it a more efficient way to capture wind energy. The modification is a ring structure called a "brim" or "wind lens" which surrounds the blades, diverting air away from the exhaust outflow behind the blades. The turbulence created as a result of the new configuration creates a low pressure zone behind the turbine, causing greater wind to pass through the turbine, and this, in turn, increases blade rotation and energy output.

Fig 2.12.1 wind lens structure

Wind power is proportional to the wind speed cubed. If we can increase the wind speed with some mechanism by utilizing the fluid dynamic nature around a structure, namely if we can capture and concentrate the wind energy locally, the output power of a wind turbine can be increased substantially. So a new efficient wind power turbine system has been developed. This system has a diffuser shroud at the circumference of its rotor to embody the wind energy concentration. The shroud is named as "Wind lens".

Fig 2.12.2 wind lens turbines

3. METHODOLOGY

3.1 Design Of The Blade; The design of the blade and wind lens is done using different software :

➢ Q-BLADE
➢ CATIA

The blade is created in the Q-Blade software and further modelling of wind lens is done in the CATIA and analysis of the wind lens is done in CFD fluent.

-3.2 Q-BLADE

- The designing of the blade is done in software called QBLADE. It is an open source wind turbine designing software. The software is seamlessly integrated into XFOIL, an airfoil design and analysis tool. The purpose of this software is the design and aerodynamic simulation of wind turbine blades. Extrapolations the performance data to a range of 360°Angle of attack, and directly integrate them into a wind turbine rotor simulation.

Fig 3.2.1 Qblade Logo

- The blade design method for the wind turbine, originates from the aircraft design industry and apply the same techniques. But the flow conditions that a turbine blade experiences are quite different from those affecting a plane

- The designing of the blade requires the airfoil date, coordinates of the airfoils to import, twist of the blade, positioning of the airfoils and the circular foil parameters used as root for the blade.

- The start screen of the software shows us the main tool bars and the functionalities of the tools, then by using the Foils the airfoils required for designing the blade of the turbine are imported by using a ".dat" format file, now the imported airfoils are analyzed in the X Foil tool. The analysis will only converge for a limited range of angle of attack values so they are given in the menu bar and the analysis is done.

- To simulate a wind turbine, the Angle of attack range of the polar needs to be extrapolated to 360degrees, this is done in the polar extrapolation module. Only extrapolated polar data can be used to simulate a turbine or rotor.
- By using the rotor blade design in the main tool bar the design of the blade is started the positions of the airfoils and the twist in the blades are given as the input for design. The geometric blade data (chord, radial position, twist, offset etc.) of the specified blade sections and the associated foils and 360-polars. It is defined by a name. If a blade object is deleted, all associated simulations and turbines are deleted as well.
- The blade is created by using specifications and then Blade Element Momentum Blade Element Momentum (BEM) method are used to predict the efficiency of Horizontal Axis Wind Turbines (HAWT) in the industry.

The functionality of the BEM software includes the following features:

- Extrapolation of XFOIL generated or imported polar data to 360 – Angle of attack
- Advanced blade design and optimization, including 3D visualization, using XFOIL generated or imported profiles
- Wind turbine definition (rotor blade, turbine control, generator type, losses)
- Computation of wind turbine performance over wind speed range
- export functionality for all created simulation data
- blade geometry export in .stl format

To design a blade in Q-blade we require

- ➢ The airfoil data.
- ➢ Coordinates of the airfoils to import.
- ➢ Twist of the blade.
- ➢ Positioning of the airfoils and
- ➢ The circular foil parameters used as root for the blade.

Q-blade design:

- ➢ From the setup open the Q-blade start screen.
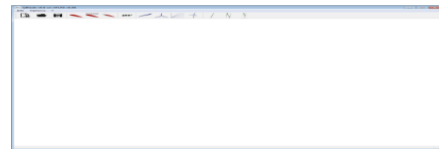
Fig 3.2.2 Start Screen Of Q blade

- ➢ From the tool menu available on the screen, press the Airfoil Design button (first red button) and then import the airfoils which are required for designing.
- ➢ NACA airfoils are inbuilt they can be used directly from the software to import other foils it can be done if the airfoil data file is in '.dat' format.
- ➢ The scale and chamber of the airfoils can also be adjusted.
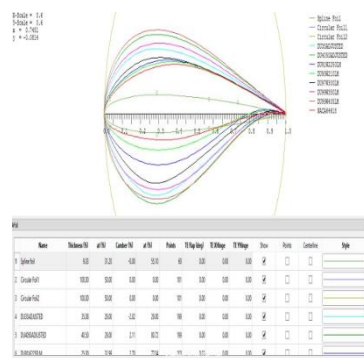
Fig 3.2.3 Airfoil Data

The S-Series airfoils are S815 and S811 are selected, as these airfoils produce more lift. NACA 64A-010 and NACA 653-618 airfoils with less thickness are also selected for the tip selection of the blade. Circular foils are also used at the tip of the blade so that the blade can be fixed in the hub.

- ➢ press the XFOIL Direct Design button (second red button)
  click Analysis > Define an Analysis such as the Reynolds number, angle of attack of the blade with the increment. Then analyse each airfoil.

X-Foil analysis is performed on the airfoils and the CL and alpha graphs are obtained.

360 EXTRA POLATION:

1. press the Polar Extrapolation to 360 button (360 button)
2. select the Montgomery radio button and press Create New 360 Polar
3. configure the initial polar via the CD90 value, the A_ and B_ sliders and press Save 360 Polar
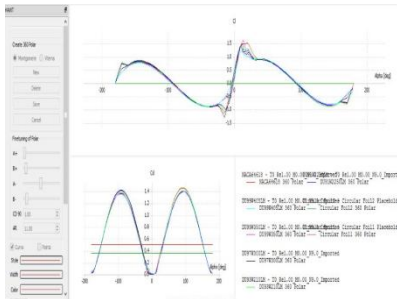4. click 360 Polar > Generate a Circular Foil

Fig 3.2.4 360 Extrapolation Graph

The blade cl and cd is calculated for all the 360 degrees of rotation of the blade and the data is obtained in a single graph. And this graph can be changed so that the design of the blade is modified with required efficiency

1. press the HAWT Rotor blade Design button (first blue button)
2. press New Blade
3. Enter the blade data using the Scale, Optimize and Advanced Design options and save

Fig 3.2.5 Design Of Blade

Design table:

Position (m)	Chord(m)	Twist	Air foil
0	3.2	13.08	Circular foil 1
1.36	3.54	13.08	Circular foil 1
4.1	3.85	13.08	Circular foil 1
6.83	4.167	13.08	Circular foil 2
10.25	4.55	13.08	DU99W405LM
14.35	4.652	11.48	DU99W350LM
18.45	4.458	10.16	DU99W350LM
22.55	4.2489	9.011	DU97W300LM
26.65	4.007	7.795	DU91W250LM
30.75	3.748	6.544	DU91W250LM
34.85	3.502	5.361	DU93W210LM
38.95	3.256	4.188	DU93W210LM
43.05	3.01	3.125	NACA64618
47.15	2.764	2.319	NACA64618
51.25	2.518	1.526	NACA64618
54.67	2.313	0.863	NACA64618
57.4	2.086	0.37	NACA64618
60.12	1.4	0.16	NACA64618
61.5	0.7	0	NACA64618

The different airfoils are used to generate various lifts at given twist. To generate the maximum power they are placed at different positions and chords. The airfoils at the tip have less twist when compared to the airfoils from the root since they have to generate more lift. It is considered by the analysis in CL vs α graph. When the air flow on the airfoil this twist is sufficient to lift the blade.

Fig 3.2.7 3D Rotor Design

As the three blades are of same design, so it is easy to create 3D blade. Then power simulation is performed on the rotor blade.

➤ Press the rotor BEM simulation and define rotor simulation. Enter the simulation parameters tip speed, and start the analysis, observe the extracted graphs.
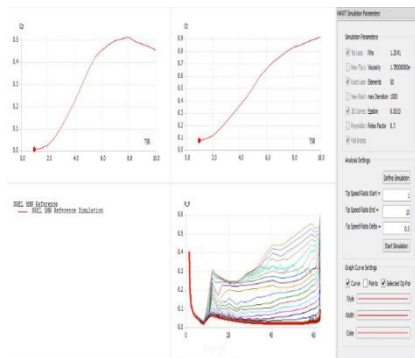
Fig 3.2.8 BEM Simulation Graphs

➢ Then define the parameters in the multi parameter BEM simulation and then analysis it.

➢ Press the turbine blade simulation and give the input wind speed and output wind speed and calculate the power generated by the wind turbine blade.
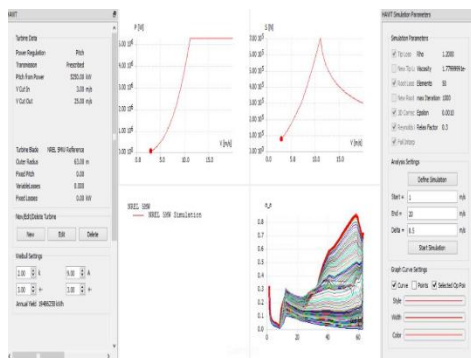
Fig 3.2.9 Turbine Blade Simulation

➢ Thus the blades are designed with different specifications and by verifying the power available the blade design is selected for further modelling.

➢ The selected blade can be exported from the Q-blade, this is an .STL file.

3.3 CATIA:CATIA (**Computer Aided Three-dimensional Interactive Application**) is the leading product development solution for all manufacturing organizations and is a multi-platform CAD/CAM/CAE commercial software
suite developed by the French company Dassault Systems.

Fig 3.3.1 Catia Logo

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing. It provides tools to complete product definition, including functional tolerances as well as kinematics definition.

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to surfacing with the ICEM surfacing technologies. CATIA is able to read and produce STEP format files and IGES format files and many other file formats.

The range of CATIA capabilities allows it to be applied in a wide variety of industries, such as aerospace, automotive, industrial machinery, electrical, electronics, shipbuilding, plant design, and consumer goods, including design for such diverse products as jewelry and clothing. Various workbenches in CATIA with surface creation tools are:

1. Wireframe and Surface Design.
2. Generative Shape Design.
3. Part design
4. Assembly design

By using Catia windlen's structure and tower is designed with the different dimensions to observe the flow properties in the structure
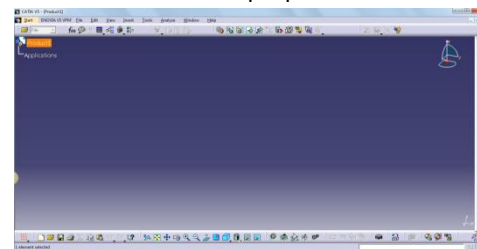
Fig 3.3.2 Catia Start Screen

3.4 DESIGN OF TOWER: The tower is the fixed support for the wind turbine which resists the loads of the nacelle, hub and the blades and also resists the moment force with the help of foundation.

The tower design is designed by using the part design in catia and the steps involved in designing are:

➢ The plane is selected for designing in sketcher.

➢ By using the circle command in the profile tool bar a circle is drawn as the base for the tower.

➢ Then the plane command is selected and offset is given to the plane in the parallel direction to a maximum length.

➢ Then the plane is selected and sketcher is used to draw the design from profile tool bar circle command is used and other circle is drawn with a diameter less than the base.

➢ Then the design is moved to part design and by using multi section solid in the selection sketch tool bar the body is joined.

➢ Thus the tower is designed and the same procedure is repeated for designing other tower designs with change in the diameters of base and other end.
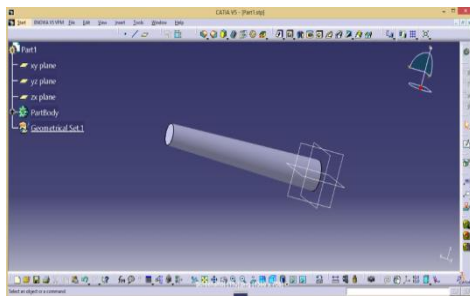
Fig 3.4.1 Tower design 1
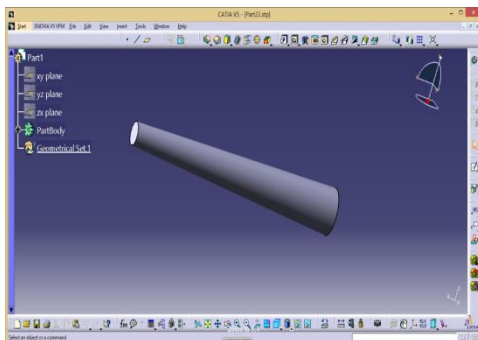
Fig 3.4.2 Tower design 2

The wind lens structure is designed by using the part design in catia the steps involved in designing are:

➢ Initially select the plane for designing in sketcher.

➢ Then by using the profile tool bar commands draw the structure of wind lens.

➢ By using the constrain tool bar the dimensions for the design is given and the dimensions are constrained.

➢ Then the body is moved to part design. The lens is a circular structure so to design it sketched based features tool bar is selected and then the shaft command is selected.

➢ The axis for revolution is given as the perpendicular line in plane and the rotation is given for 360 degree. Thus the turbine is designed

➢ The same procedure is followed for designing different wind lens structures.
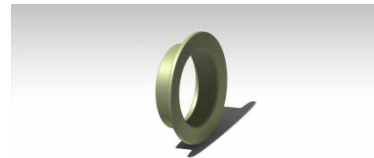
Fig 3.3.3 90 degree wind lens

Fig 3.3.4 100 degree wind lens and Fig 3.3.5 110 degree wind lens

Fig 3.3.6 120 degree wind lens

4.STATIC STRUCTURAL SETUP FOR TOWER

4.1 About structural analysis: Structural analysis is probably the most common application of the Finite Element Analysis. The term structural impels not only civil engineering structures such as bridges and

buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housing, as well as mechanical components such as pistons, machine parts and tools.

Types of structural analysis: There are seven types of structural analysis available in the ANSYS family of products. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements, other quantities ,such as strains, stress, and reaction forces, are then derived from the nodal displacement.

Structural analysis are available in the ANSYS Multi physics, ANSYS Mechanical, ANSYS Structural and ANSYS Professional programs only.

4.2 Importing The Geometry

1) Open ANSYS Workbench by going to **Start > ANSYS > Workbench**.

   As we are only doing a force loading, we will be doing a Static Structural simulation. Load the **StaticStructural** tool box by dragging and dropping it into the Project Schematic.

2) To the left of the start up window, we have analysis system. Load the *Static Structural* tool box by dragging and dropping it into the Project Schematic.

3) Save the file.

4) In the *Project Schematic* page, right click on Geometry and import the file.
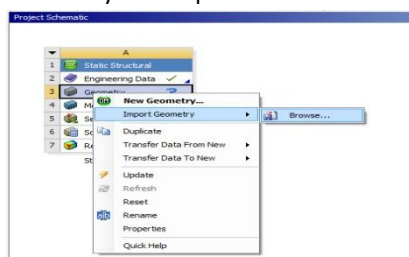
Here the structural analysis is performed on two different blade designs and comparison is done on the designs by using static analysis.

4.3 MESH GENERATION: Launch Mesher*(Double Click) Mesh*

Generate the mesh by going to **Mesh > Generate Mesh**

 Then from the mesh controls select the mapped face meshing and select the total domain and apply

on it. And generate mesh. Right click on Mesh and insert Sizing
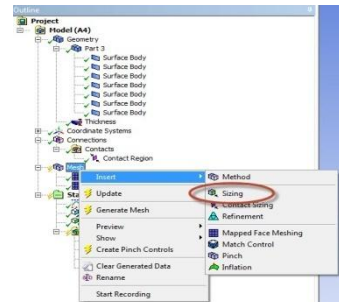
Fig 4.3.1 mesh sizing

Right click in the graphics window and click on *Select All.* Change the *Element Size.* Right click on *Mesh* and click on *Generate Mesh.* The meshed tower is shown below:
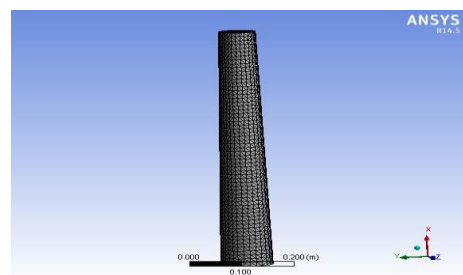
Fig 4.3.2 meshed tower 1
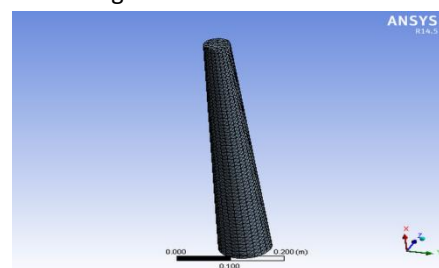
Fig 4.3.3 meshed tower 2

4.4 FIXED SUPPORT AND LOADS: To give the fixed supports and loads , right click on static structural analysis and go to insert and then select the fixed support, force and pressure and apply them on the body.

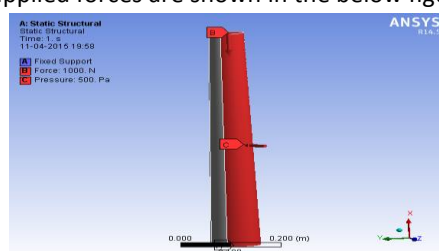The applied forces are shown in the below figure:
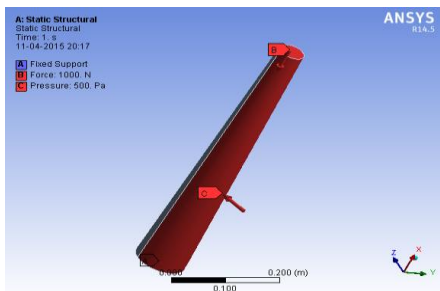

Fig 4.4.1 loadings for tower 1

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Fig 4.4.2 loadings for tower2

5.CFD SETUP

Analysis Of WIND LENS and TOWER Using Ansys Workbench:

5.1 ABOUT CFD:

Computational Fluid Dynamics (CFD) provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of

- Mathematical modelling (partial differential equations)
- Numerical methods (discretization and solution techniques)
- Software tools (solvers, pre- and post processing utilities)

CFD enables scientists and engineers to perform 'numerical experiments' (I.e. computer simulations) in a 'virtual flow laboratory.

5.2 USES OF CFD:

Numerical simulations of fluid flow (will) enable

- Architects to design comfortable and safe living environments
- Designers of vehicles to improve the aerodynamic characteristics
- Chemical engineers to maximize the yield from their equipment
- Surgeons to cure arterial diseases (computational hemodynamic)
- Meteorologists to forecast the weather and warn of natural disasters
- Safety experts to reduce health risks from radiation and other hazards
- Military organizations to develop weapons and estimate the damage
- CFD practitioners to make big bucks by selling colourful pictures
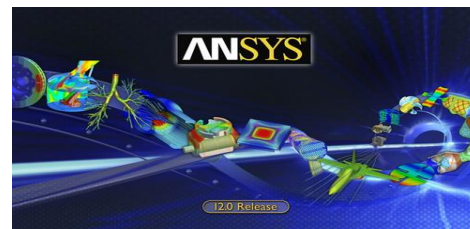
Fig 5.2.1 Ansys logo

Definition: Model : A model is a mathematical object that has the ability to predict the behaviour of a real system under a set of defined operating conditions and simplifying assumptions

The term modelling refers to the development of a mathematical representation of a physical situation

WHAT IS MODELING?

- Modelling is the process of producing a model.
- A model is a representation of the construction and working of some system of interest.
- A model is similar to but simpler than the system it represents.
- One purpose of a model is to enable the analyst to predict the effect of changes to the system. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.
- Mathematical model classifications include
- Deterministic (input and output variables are fixed values) or
- Stochastic (at least one of the input or output variables is probabilistic);
- Static (time is not taken into account) or
- Dynamic (time-varying interactions among variables are taken into account).
- Typically, simulation models are stochastic and dynamic.

Definition: Simulation

Simulation is the process of exercising a model for a particular instantiation of the system and specific set of inputs in order to predict the system response.Simulation refers to the procedure of solving the equations that resulted from model development

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WHAT IS SIMULATION?

- A simulation of a system is the operation of a model of the system.
- The operation of the model can be studied, and hence, properties concerning the behaviour of the actual system or its subsystem can be inferred.
- In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time.
- Simulation is used
- before an existing system is altered or a new system built,
- to reduce the chances of failure to meet specifications,
- to eliminate unforeseen bottlenecks,
- to prevent under or over-utilization of resources,
- to optimize system performance.

How to select the best simulation software for an application arises?

Metrics for evaluation include

- Modelling flexibility
- Ease of use
- Modelling structure (hierarchical v/s flat; object-oriented v/s nested)
- Code reusability
- Graphic user interface
- Animation, dynamic business graphics, hardware and software requirements
- Statistical capabilities
- Output reports and graphical plots
- Customer support and documentation
- Mathematical modelling - Aerospace Applications
- Using basic equations from dynamics, mathematical equations are written that describe how the vehicle will move in response to forces that are applied to the vehicle. For example, it is pretty easy to describe how a rocket will accelerate when a constant thrust is provided by the rocket's engine.

- Another type of modelling problem would be to understand and predict, in a mathematical equation, how an aircraft will respond to hitting an updraft in the atmosphere, or how the aircraft will respond to the deflection of various control surfaces at different airspeeds.
- An aerodynamic subsystem model describes how the vehicle will respond to forces caused by motion of the vehicle through the atmosphere, and predicts the effects of each different control surface (such as the flaps, rudders, ailerons, etc.) upon the motion of the vehicle.
- A propulsion subsystem model describes how any motors or engines will behave and what forces will act on the vehicle to which they are attached.
- A landing gear subsystem model is required when the vehicle is in contact with the ground in order to model how the ground reaction forces are created and how they affect the motion of the vehicle.
- An inertial properties subsystem model provides details about how the mass and inertia of the vehicle might change with time.
- any electrical, mechanical, or electronic system that assists the pilot in moving the control surfaces has to be described mathematically

The steps involved in developing a simulation model, designing a simulation experiment, and performing simulation analysis are:

Step1. Identify the problem.

Step2. Formulate the problem.

Step3. Collect and process real system data.

Step4. Formulate and develop a model.

Step5. Validate the model.

Step6. Document model for future use.

Step7. Select appropriate experimental design.

Step8. Establish experimental conditions for runs.

Step9. Perform simulation runs.

Step10. Interpret and present results.

Step11. Recommend further course of action.

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5.3 Importing The Geometry

5) Open ANSYS Workbench by going to **Start > ANSYS > Workbench**.

As we are only doing a fluent analysis, we will be doing a cfd fluent simulation. Load the **cfd fluent** tool box by dragging and dropping it into the Project Schematic.
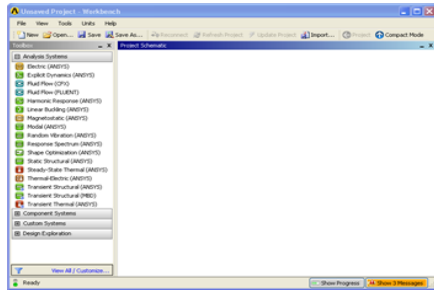

Fig 5.3.1 ANSYS Workbench Start Screen

6) To the left of the start up window, we have analysis system. Load the *Static Structural* tool box by dragging and dropping it into the Project Schematic.

7) Save the file.

8) In the *Project Schematic* page, right click on Geometry and import the file.
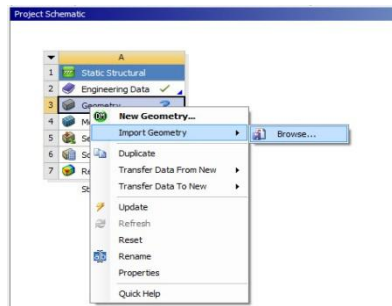
Fig 5.3.2 Importing Geometry

After importing and generating the geometry then the enclosure is given for the body as a domain, and Boolean operation is performed

Carry Out Boolean Operation: Subtraction

Create > Boolean. First,

set *Operation* to *Subtract*.

Select outer square domain as the *Target Body* and the inner airfoil surface as the *Tool Body*.

Lastly, click *Generate*
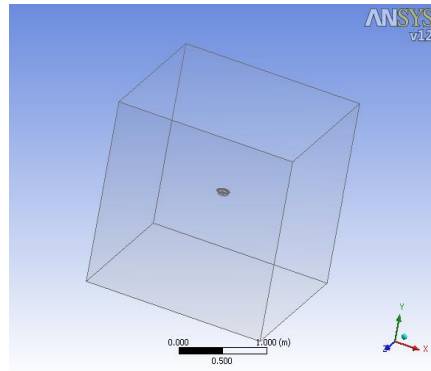
Fig 5.3.3 Geometry and domain in cfd

5.4 MESH GENERATION: Launch Mesher*(Double Click) Mesh*

Generate the mesh by going to **Mesh > Generate Mesh**

Then from the mesh controls select the mapped face meshing and select the total domain and apply on it. The sizing is also given to the domain as 0.1 from the mesh controls and mesh is generated to the domain.
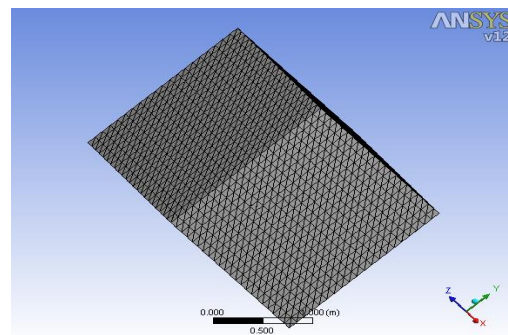
Fig 5.4.1 meshed domain

Named Selections

To create named selections right click on the surface and select *Create Named Selection*.

A dialogue box will appear where you will enter the desired name of the boundary.

  ➤ Inlet
  ➤ Outlet
  ➤ Walls
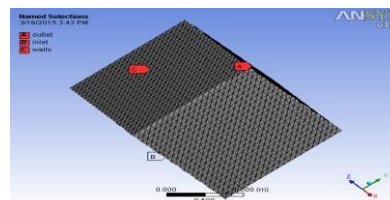
Fig 5.4.2 Named selections of domain

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6. SOFTWARE RESULTS AND DISCUSSION

Solution in Structural Analysis:

6.1 Deformation

To add deformation to the solution, first click ⊟·····🔲 **Solution (B5)** to add the solution sub menu to menu bar. Now in the solution sub menu click *Deformation > Total* to add the total deformation to the solution. It should appear in the outline tree.
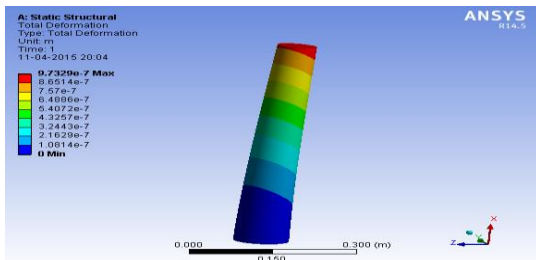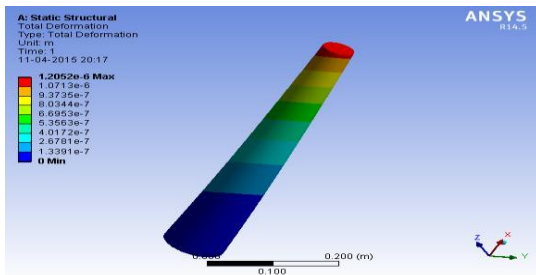

Fig6.1.1 Tower 1 deformation

Fig6.1.2 Tower2 deformation

In the solution sub menu, select*Stress > Equivalent (von-Mises).*In the details pane, ensure*Geometry*is set to*All Bodies*
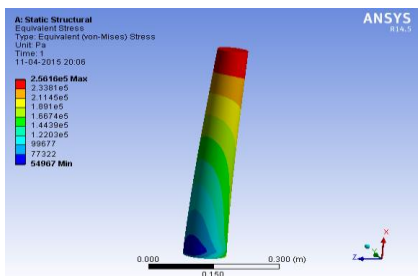
Fig 6.1.3 von-mises stress for tower 1
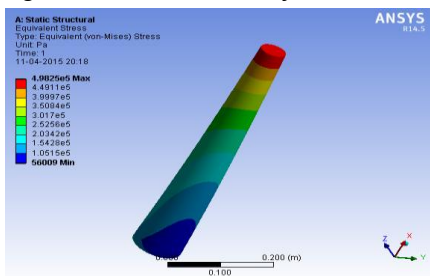
Fig 6.1.4 von-mises for tower2

In the solution sub menu, select *Stain > normal.* And solve the geometry
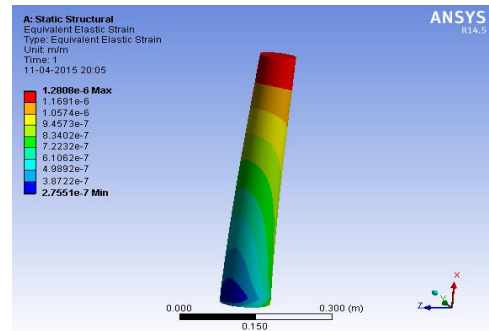
Fig 6.1.5 Equivalent elastic strain for tower 1
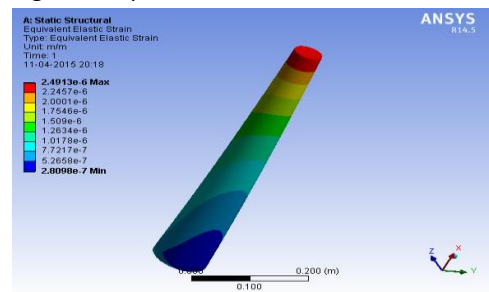
Fig 6.1.6 Equivalent elastic strain for tower 2

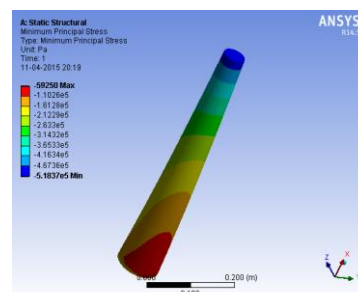In the solution sub menu, select stress > maximum shear stress

Fig minimum principal stress for tower 2

6.2 Setup and Solution in FLUENT:

In Ansys workbench double click Setup to open FLUENT.

Before FLUENT launches, In *Options* check the box next to **Double Precision**

Now the Fluent window is open and the mesh has imported into the fluent solver.

Problem setup:

➢ General→Type as: **Pressure based**
➢ Models→Energy OFF→ Select **Viscous-laminar**
➢ Materials→Air→Create/Edit→Set
➢ Boundary conditions→Select inlet→Give type a**s:*velocity-inlet*→Edit→ Set *20 m/s*→ok

➤ *Problem Setup*→Reference Value→Compute from : Inlet

Solution:

➤ Select the monitors and change convergence criteria to 10^-6.
➤ Solution initialization→Compute from: inlet→Initialize
➤ Run calculations→Enter the no. of iterations as: 1000→Calculate

By using the cfd post results are noted, in cfd post the stream lines are taken and a plane is set perpendicular to the body for easy flow from the body and the results are obtained as.
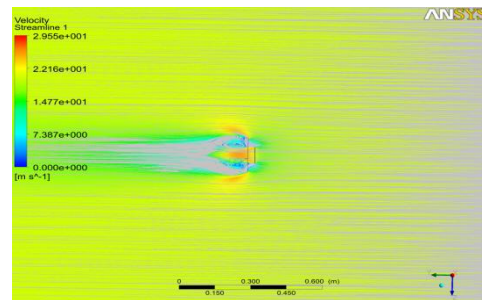

fig 6.2.1 90 degree wind lens

Fig 6.2.2 100 degree wind lens

Fig 6.2.3 110 degree wind lens

Fig 6.2.4 120 degree wind lens

The results are compared for all the wind lens and it is observed that in between the 90 – 100 degree the velocity is increased, so a wind lens for 96 degree is created and flow analysis is performed on it and the results are
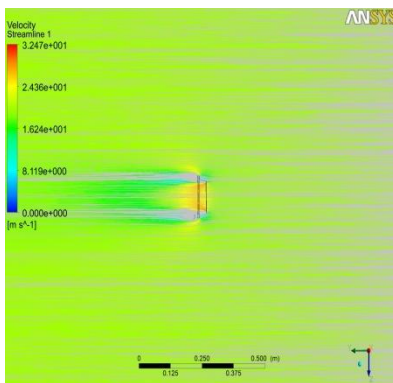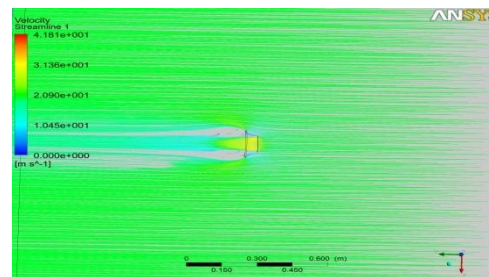

fig 6.2.5 96 degree wind lens

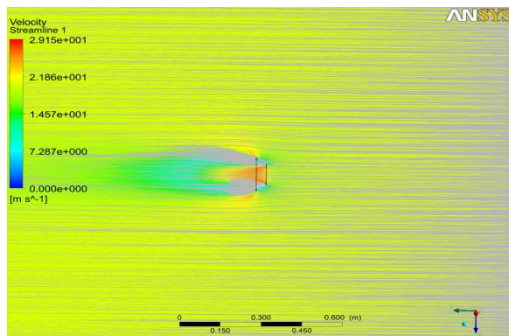So the results are concluded as the 96 degree wind lens gives better result.
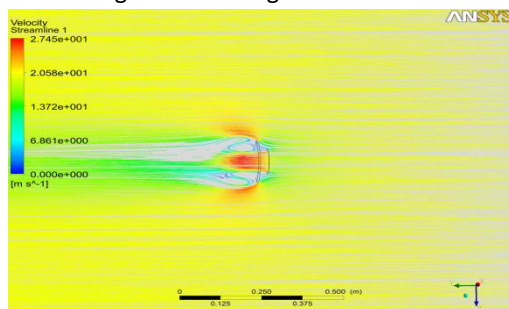
7. EXPERIMENTAL SETUP AND RESULTS

To run the experimental setup primarily the things required are:

➤ Wind turbine blades
➤ Generator (dynamo)
➤ Tower
➤ Wind lens

The power available by running the dynamo helps us in finding the efficiency of the design , the dynamo is connected to the propeller so that when the propeller rotates the shaft of the dynamo rotates to generate power.

7.1 Wind turbine blades and Dynamo:

The turbine blades are designed in the designing procedure, the manufacturing of the blades is observed to be a difficult task so the blades which are similar to the designed blades with a scaled size is bought and used for experiment purpose.

The dynamo which helps in converting the mechanical energy in to electric current is used in

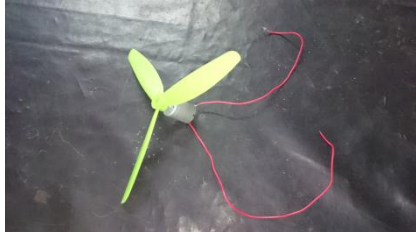the experimental procedure which has a maximum output of 12v

Fig 7.1.1 propeller and dynamo

Tower is used in this experimental setup to attach the dynamo so that the fluid passing can move easily on the propeller blades.

7.2 WIND LENS: A **wind lens** is a modification made to a wind turbine to make it a more efficient way to capture wind energy. The modification is a ring structure called a "brim" or "wind lens" which surrounds the blades, diverting air away from the exhaust outflow behind the blades. The efficiency of the turbine blades is increased by increasing the velocity of flow on the blades.

7.3 Manufacturing dimensions of wind lens: The wind lens is a divergent duct section with circular cross-section, the dimensions for manufacturing are made on basing the propeller blades dimensions.

Table 3: Dimensions of wind lens

Propeller blades (diameter)	23cm
Inlet of wind lens (diameter)	24cm
Outlet of wind lens (diameter)	28cm
Width of wind lens (length)	10cm

The wind lens is manufactured by using this dimensions and a circular obstacle is made at the end of the duct for yawing and for creating low pressure purpose.

The manufacturing of wind lens is made by using the GI sheet. As it can be flexibly bended and used so for the trail procedure this material is used.

7.4 Manufacturing procedure:

➤ Primarily the dimensions are marked for the wind lens on the GI sheet. For the dimensions the circumference of the inlet and outlet are used so that when they are closed a circular section is obtained with the given circumference and the diameter.

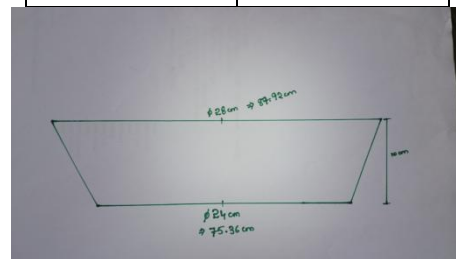|	
Circumference of inlet	75.36cm
Circumference of outlet	87.92cm

Fig 7.4.1 dimensions of wind lens

➤ The dimensions are marked on the GI sheet and the extra material is removed.

➤ Now by using the spot welding procedure the sheet is made into circular shape and joined.

➤ Now two circles are drawn on the GI sheet as shown in figure so that it can be attached at the outlet.
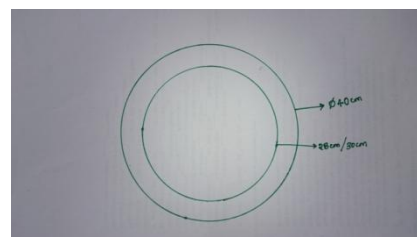

Fig 7.4.2 circular cross section diameters

➤ This circular cross section is spot welded with the convergent duct at its outlet section, thus the required wind lens is manufactured.

Fig 7.4.3 wind lens

7.5 Experiment procedure:

❖ The propeller attached to a dynamo is fitted on a tower for the height to run the experiment.


Fig 7.5.1 tower with the propeller

❖ The power is calculated when the propeller is freely rotated, then the wind lens is kept around the turbine blades so that it acts as a diffuser section and then the power is noted and the RPM (revolutions per minute) are verified.

Fig7.5.2 wind lens turbine

7.6 RESULTS

➢ The results are noted for the UPWIND and DOWN WIND turbine. It is found that the efficiency of the down wind turbine is observed to be better than up wind.
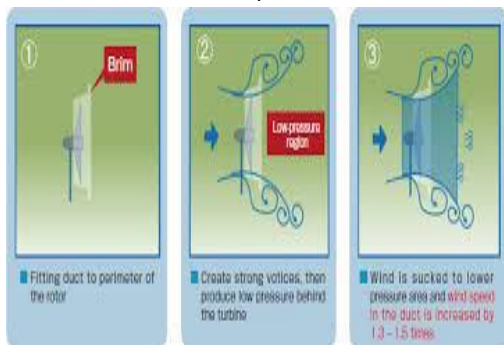

Specification	UP WIND	DOWN WIND
Without wind lens	**3volts**	**3volts**
With wind lens	**6.5 / 7 volts**	**8volts**

➢ The results may vary with the change in the velocity of the wind.

CONCLUSION

➢ Wind turbines helps in converting mechanical energy into electrical energy to improve this efficiency or the amount of obtained current the concept of wind lens is used and the results prove the increase in efficiency.

➢ Analysis on the tower is performed to know the structural changes to be used in constructing the tower.

➢ The diameters of the foundation and the tower and the varying height all play a vital role in the strength of the tower

➢ The concept of WIND LENS is used to improve the velocity of wind on the blades, it is also used to create a low pressure region in the front of the flow so that the air moves fast into the region so the turbine blades rotate with high RPM.
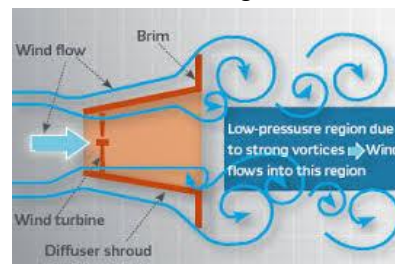
● The amount of power may change depending on the velocity of the flow, and the length of the turbine blades cause more moment so that it keeps it revolving maximum time, so the length and design of blades play a major role in power generation.

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