ABSTRACT

This project is about modeling and analysing a Vertical Axis Wind turbine, VAWT to transfer the wind speed to rotational motion using this turbine. This turbine will be attached to a manufacturing tree that will look like a modern design which can be installed in and around any public area, park, road or business Offices.

This project presents a review on the performance of savonius wind turbines. This type of turbine is not commonly used and its application for obtaining useful energy from a stream is still considered as an alternative source. Low wind speed starts up working with any wind direction and the less noise are some advantages of VAWT-savonius model. This project consists of two phases which are design and analysis.

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CHAPTER 1
INTRODUCTION

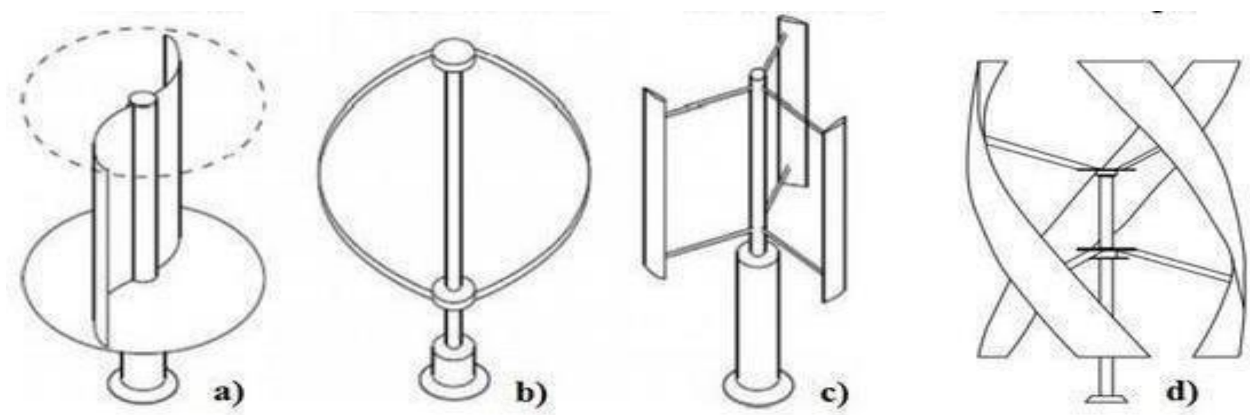
1.1 Wind energy:-

In the past few years, research and new advancement in wind turbine technology has increased for onshore and offshore wind turbine technology. Mainly wind turbines are classified into two types, horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). Out of those two, HAWTs are more efficient due to its mature technology. VAWTs are mainly classified into two types, Savonius type and Darrius wind turbine. In the past decade, many studies have been done on various VAWT. Savonius wind turbine has proven its capabilities in turbulent flow conditions. Due to simple and robust construction, it's primarily installed in remote areas where the grid connection is not available. Till now various savonius design have been developed and investigated. This technology is mainly focused on small applications, so it won't be able to give a major contribution to the total installed power of the world. A brief discussion on Savonius and other VAWTs is provided in the theory section.

1.2 Different types of VAWT :-

Mainly VAWTs are divided into two major types :-

1. Savonius – drag driven
2. Darrius – lift driven
    I. H-Type
    II. Helix Type



a) Savonius b) Darrius c) H-Type d) Helix type

Figure 1.1:- Types of VAWT

From design point of view, Savonius turbines are simple compared to Darrius turbines. Savonius turbines contains two semi-cylindrical cups attached to the vertical shaft in such a way that it can create drag forces and rotate around the vertical axis. Figure 1.1(a) shows the design of the Savonius wind turbine.

1.3 Working principle of savonius wind turbine :-

The savonius wind turbine is the simple vertical axis devices having a shape of half cylindrical parts attached to the opposite sides of a vertical shaft (for four bladed arrangement) and operate on the drag force, so it can’t rotate faster than the wind speed. This means that the tip speed ratio is equal to 1 or smaller. As the wind blows into the structure and comes contact with the opposite faced surfaces (one convex and other concave). Two different forces (lift and drag) are exerted on those two surfaces. The basics principle is based on the difference of drag force between the convex and concave part of the rotor blades when they rotate around a vertical shaft. Thus, drag force is the main driving force of the savonius rotor.

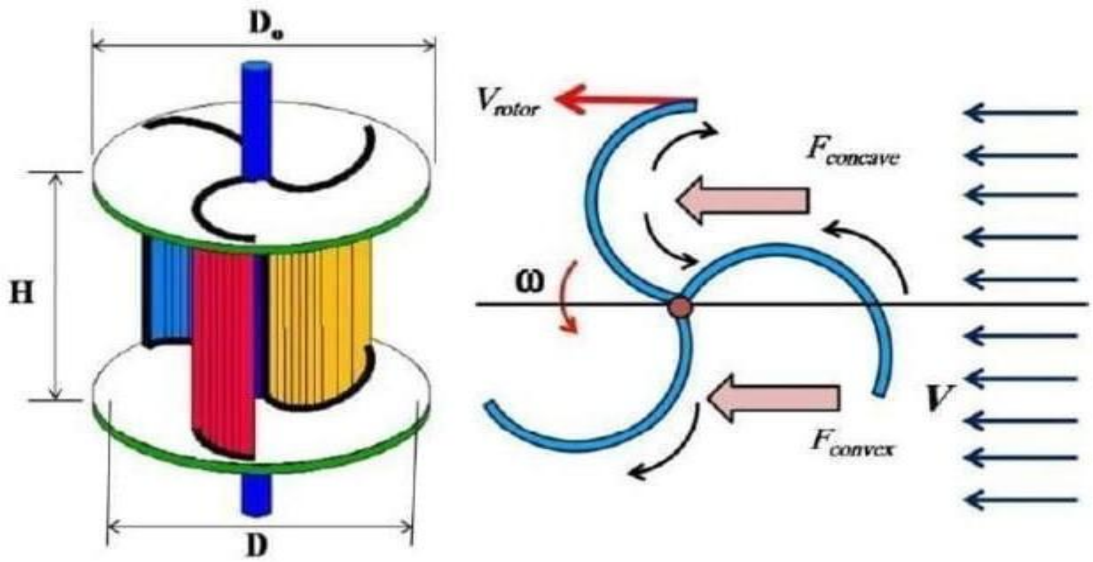


Figure 1.2 :- Savonius wind turbine

1.4 Applications for VAWT technology :-

The applications of a vertical axis wind turbine include the following.

- Used in small wind projects
- Used in residential applications
- These turbines are used to generate power even in not stable weather conditions like gusty wind & turbulence.
- Residential Wind Power: VAWTs are suitable for small-scale residential wind power generation, especially in areas with turbulent wind flows.
- Urban Wind Power: VAWTs are well-suited for urban areas due to their compact size, quiet operation, and ability to capture wind from any direction.
- Wind-Powered Water Pumping: VAWTs can be used to power water pumps for irrigation, drinking water supply, or other applications.
- VAWTs can serve as emergency power generators during natural disasters or grid outages.
- Agricultural Wind Power: VAWTs can be used to power agricultural equipment, such as irrigation systems or farm machinery.

Thus, this is all about an overview of a Vertical axis wind turbine or VAWT. In this type of wind turbine, the main rotor shaft is arranged vertically so that it captures wind from any direction. These turbines operate without needing yaw controls apart from the direction of the wind. These turbines were innovative designs and they have good features including quiet operation. These are smaller units, so we can easily locate them in commercial and residential areas.

CHAPTER 2
LITERATURE REVIEW

Several studies have been conducted on modeling and analyzing vertical axis wind turbine (VAWT) blades to optimize their performance. It is necessary to optimize the design of VAWT blades for improved performance and reliability. Ongoing research aims to further refine the modeling techniques and explore novel blade designs to make VAWTs a more viable renewable energy solution.

[1] **Niranjana s j** in his paper **"Design and Analysis of Wind Turbine Blade"** has focused on the power generation by the vertical axis wind turbine. In this the power is generated by fixing the wind mill on the road highways. When the vehicles are passed through the road at the high speed the turbine of the wind mill rotates and generates the power sources. This analysis indicates the vertical axis wind turbine can be able to attend the air from all in the direction produces the power of one kilowatt for a movement of 25 meter per second.

[2] **Borikar and Mukullambat in his paper titled "review paper on vertical axis wind turbine" has focused on -**VAWT's which can produce electricity from wind ofany direction without no cut in wind speed . this turbines are light weighted than HAWT's .this turbines are based on aerodynamic drag forces. The research efforts on this turbines are focused on increasing the aerodynamic efficiency by reducing the drag effect and increasing the lift effect. It was predicted that they could be an efficient solution for built up area where the wind is unstable.

[3] **Mohammed hadi ali in his research paper "Experimental Study for savonius Wind Turbine of Two and Four Blades at Low Wind Speed".** The experiment's procedure was carried out and tested in the wind tunnel and the required measurement were obtained to study the performance of the two blades and three blades savonius wind turbine and makes the comparison between them to see which one is better in performance than the other. The performance [the dimensionless parameters torque coefficient (Ct) and power coefficient (Cp) was evaluated as function of the dimensionless parameter the tip speed ratio (λ) at low wind speeds in terms of starting acceleration and maximum no-load speed.

[4] **Ashwin Dhote & Vaibhav Bankarin his paper titled "DESIGN, ANALYSIS AND fabrication of savonius vertical axis wind turbine (VAWT)"has focussed on –** The Savonius rotor is widely considered to be a drag driven device. This indicates that the wind drags, acting on its blades, is the only driving force. However, it has been observed that at low angle of attack the lift force also contributes to the overall torque generation. Thus, it can be concluded that the

savonius rotor is not a solely drag driven machine but a combination of a drag-driven and lift-driven device

[5] **Magedi Moh. M. Saad, a, Norzelawati Asmuin presented research paper on "Comparison of horizontal axiswind turbines and vertical axis wind turbine".** This paper gives a comparison between the horizontal axis wind turbines, or HAWTS, and the vertical axis wind turbines, or VAWTS. The two types of wind turbines are used for different purpose. Both types of turbines, whether VAWTs or HAWTs, are used for generating electrical power from the wind. This work has compared both types, and also presented the advantages and disadvantages of both types. Each type has its applications. It depends on the wind speed and place to be fixed on. Any way the horizontal axis with propeller blades is the most common one, since its efficiency is about 60%.

Summary

Wind field modelling is an important part of a structural analysis of wind turbines. In aerodynamic modelling blade element moment theory is used for calculation of aerodynamic forces acting on the rotor blade. Control system modelling is used to keep the operating parameters of the wind turbine within the specified limit. These developments and growing trends towards wind energy signal is a promising future for the wind energy industry. With this improved technology wind turbine can be designed for its optimum power production at less cost.

CHAPTER 3
METHODOLOGY

3.1 Objectives of the project:-

The Vertical Axis Wind Turbine (VAWT) project is an innovative endeavor that seeks to revolutionize the way we harness wind energy. By designing and developing a cutting-edge wind turbine that can thrive in urban and residential environments, this project aims to provide a decentralized source of renewable energy for communities worldwide. Unlike traditional wind turbines, the VAWT boasts a compact and quiet design, making it an ideal solution for areas where noise and visual impact are a concern. Through advanced materials selection and design optimization techniques, the project team is working to maximize energy production while minimizing environmental impact. Extensive wind tunnel testing and performance optimization will ensure that the VAWT operates at peak efficiency, making it a scalable and commercially viable solution for a sustainable energy future. By pushing the boundaries of wind turbine technology, the VAWT project has the potential to make a significant contribution to the global transition to renewable energy, providing clean power for generations to come.

Few steps which have been followed:-

- Design of vertical axis wind turbine.
- Modelling of vertical axis wind turbine blade.
- Analysis of the model for the given conditions.

  For the applied forces

  I. Total deformation

  II. Shear stress

3.2 Methodology:-

The methodology applied to this project can be divided into six phases. These phases are information gathering, model generation, model analysis and refinement, concept selection and verification these phases are shown in figure.

3.3 Flow Chart:-

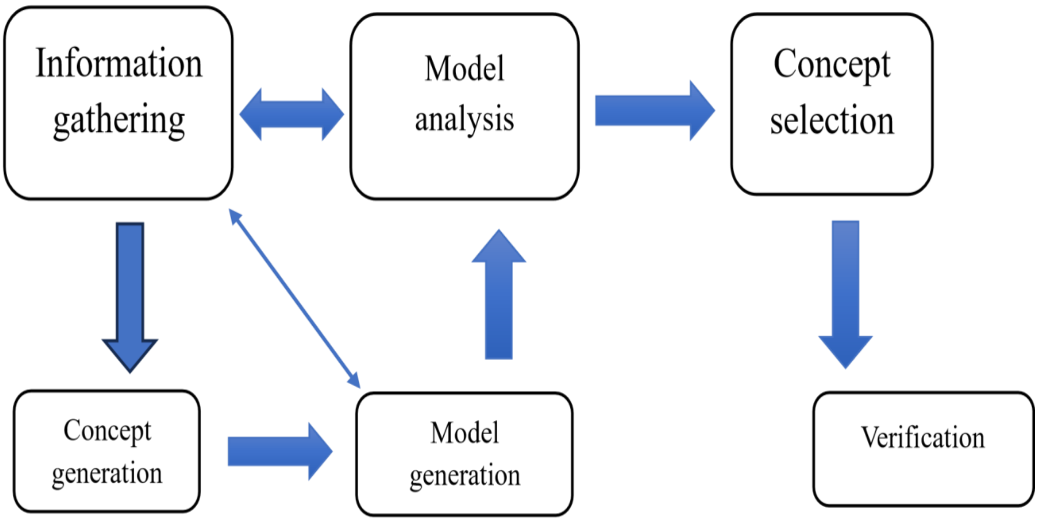


FIGURE 2.1: Methodology flow chart

Prior any appropriate solution can be developed; a thorough investigation has to be conducted in order to find out what solutions have already been proposed (information gathering). Once these solutions have been analysed and the team has an understanding of why respective solutions are not currently being implemented, a solution generation phase is taking place. Here various solutions are presented and evaluated against criteria and constraints (concept generation) solution concepts are then modelling. The result of the models are then analysed and the model, as well as solution parameters, may be tweaked (model analysis and refinement).

CHAPTER 4

MODELING OF SAVONIUS WIND TURBINE

The key feature of this rotor is its simpler design. A Finish engineer Savonius introduced the Savonius rotor in 1920s. He has reformed the design of Flattener's rotor by dividing a cylinder into half, along its central axis and relocating the two semi-cylindrical surfaces sideways. This shape is akin to "S" when viewed from top as shown in Figure. These types of rotors may be of two, three or higher bladed systems and can be used in single- or multi-staged arrangements. The working principle is based on the difference of the drag force between the convex and the concave parts of the rotor blades when they rotate around a vertical shaft. This is chosen because of its simple construction and self-starting capacity at low wind speed.

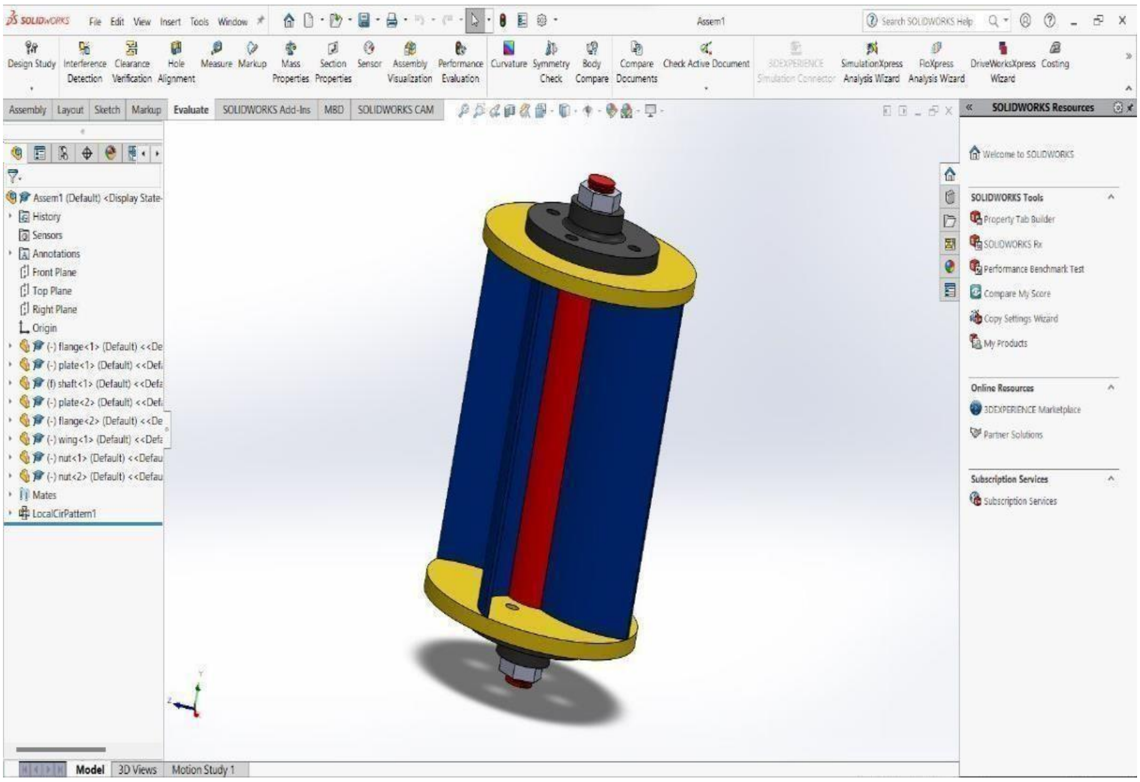


Figure 3.1:- Model of VAWT

CHAPTER 5
FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computer based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculated deflection, stress, vibration, buckling behaviour and many other phenomena. It also can be used to analyse either small or large scale deflection under loading or applied displacement. In this project finite element analysis was carried out using the FEA software ANSYS. Static, Deformation, Maximum shear stress and equivalent stress analysis was carried out. We have used aluminium alloy for this analysis.

5.1 Total Deformation :-

VAWT blades experience deformation due to aerodynamic forces, centrifugal forces, and gravity. Deformation analysis helps determine the blade's structural integrity and potential failure points. Fig 4.1 shows the total deformation of the blade is $5.782e^{-6}$.

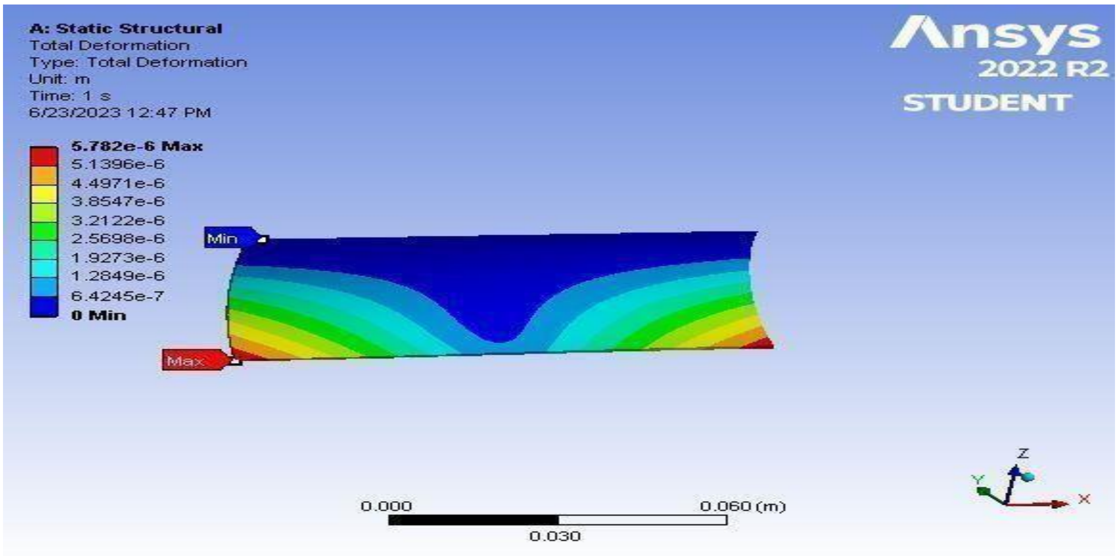


Figure 4.1:- Total deformation

5.2 Maximum Shear Stress

Shear stress analysis helps identify areas where the blade may fail due to excessive shear forces as shown in Fig 4.2 (τ)1.8593e^6.

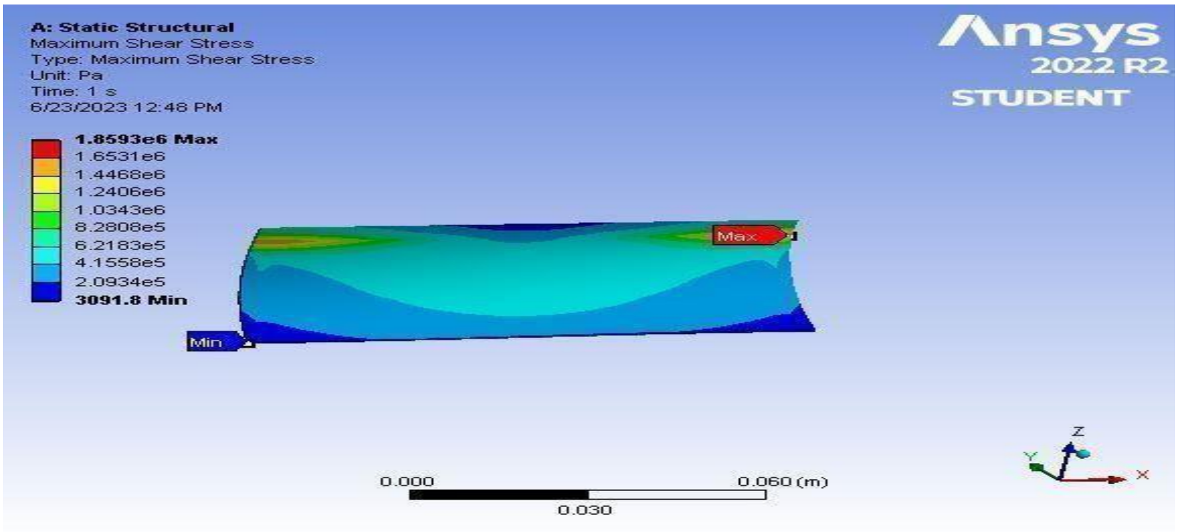


Figure 4.2:- Maximum shear stress

5.3 Equivalent stress

Equivalent stress analysis combines normal and shear stresses to evaluate the blade's overall stress state as shown in fig 4.3 Equivalent stress is typically evaluated using:

- Von Mises stress criterion
- Tresca stress criterion

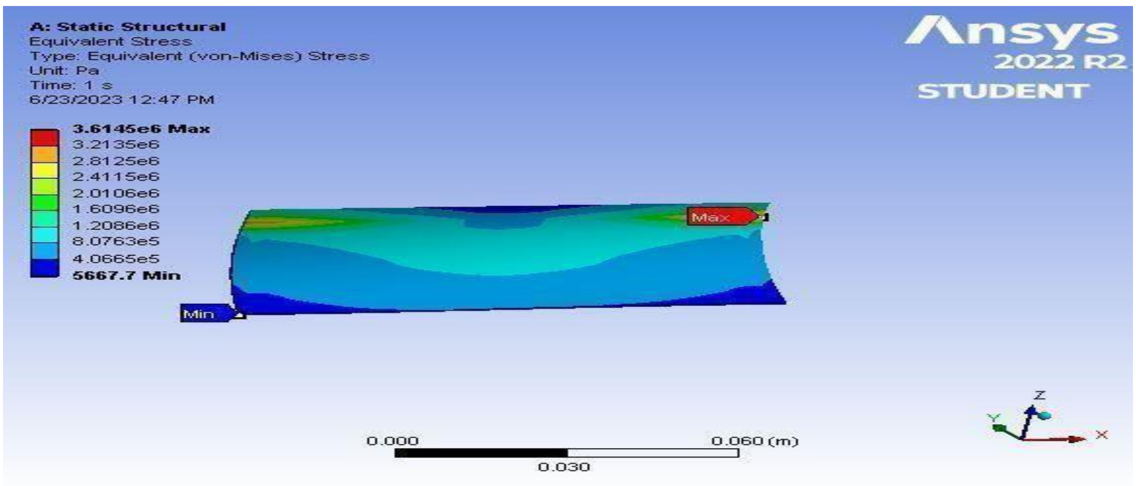


Figure 4.3:- Equivalent (von-mises) stress

CHAPTER 6
RESULT COMPARISON

6.1 List of formula:-

1. Area of blade $A = 2\pi rh \quad m^2$
2. Lift force $FL = 0.5\times\rho\times a\ v^3\times Cl \quad N$
3. Drag Force $FD = 0.5\times\rho\times a\times v^3\times Cd \quad N$
4. Resultant force $FR = (FL^2+FD^2)^{(1/2)}$
5. Deformation $\delta = w\times r^2/(24\times e\times t) \quad m$
6. Shear Stress $\tau = w\times r/(t) \quad N/m^2$

6.2 Notations in formula:-

1. A =Area of blade
2. T = thickness of blade
3. R = radius of blade
4. H = height of blade
5. V = velocity
6. ρ = Density of air
7. CL = co efficient of lift
8. FL = List force
9. CD = Co-efficient of draft
10. W = load
11. e = young's modulus
12. FD = drag force
13. FT = total force
14. δ = shear stress

6.3 Analytical Calculation :-

1. **AREA OF THE CURVED PANEL**

$$A = 2\pi rh$$
$$= 2\times3.142\times0.025\times0.1$$
$$\mathbf{A = 0.0157\ m^2}$$

Assuming velocity [v=10 m/s]

2. **LIFT FORCE**

$$FL = 0.5\times\rho\times a\ v^3\times Cl$$
$$= 0.5\times1.125\times10^3\times0.00157\times0.385$$
$$\mathbf{FL = 7.0209\ N}$$

3. **DRAG FORCE**

$$FD = 0.5\times\rho\times a\times v^3\times Cd$$
$$= 0.5\times1.125\times0.00157\times10^3\times1.5$$
$$\mathbf{FD = 20.75\ N}$$

4. **RESULTANT FORCE**

$$FR = (FL2+FD2)\ (1/2)$$
$$= (7209^2+20.75^2)^{(1/2)}$$
$$\mathbf{FR = 21.9052\ N}$$

5. **DEFORMATION**

$$\delta = w\times r^2/(24\times e\times t)$$
$$= 23.99\times (0.025)^2/ (24\times70\times10^9\times0.001)$$
$$\mathbf{\delta = 5.028\times10^{-6}\ m}$$

6. **SHEAR STRESS**

$$\tau = w\times r/(t)$$
$$= 20.99\times25\times10^{-3}/ (1\times10^{-3})$$
$$\tau = \mathbf{2600\ n/m^2}$$

6.4 Comparison Between Analytical & Ansys Results

Tables 5.1: Analytical v/s ANSYS results

METHOD	DEFORMATION	SHEAR STRESS
ANALYTICAL	5.028×10^{-6} m	2600 n/m^2
ANSYS	5.782×10^{-6} m	3091.8 n/m^2

CHAPTER 7
CONCLUSIONS

The field of wind power utilization is not fully tapped at the present time. As we are degrading our fossil fuels at high rate. It is important for us to look for alternatives and certainly the VERTICAL AXIS WIND TURBINE (VAWT) is a key process for harnessing this renewable energy. At present, HAWT technology is more mature than VAWT technology because of strong US and European research efforts, ready adaptability of certain aerodynamic and structural analysis techniques for propeller and helicopter rotors and an existing foundation of HAWT design philosophy from early nineteenth century. Nevertheless, VAWT technology can show equal or superior promise if more funding is given for further R&D activities. The two categories of wind turbines, VAWT and HAWT, represent viable embodiments of wind energy technology, each with understandable pros and cons when considered for any given applications.

VAWTs offer a distinctive set of benefits and drawbacks, making them a valuable option for specific wind energy applications. While they may not replace HAWTs entirely, VAWTs can carve out their niche in the renewable energy landscape, particularly in urban and small-scale settings. As technology advances, VAWTs may become an increasingly important part of our transition to a more sustainable energy future.

CHAPTER 8:-
REFERENCES

References should be numbered using Arabic numerals followed by a period (.) as shown below and should follow the format in the below examples.

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