Design and Analysis of Savonius Vertical Axis Wind Turbine

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Abstract— A Savonius rotor (S-rotor) wind turbine adapted for household domestic Electricity generation. The design process and justification of the new machine will be described. The innovative technology turbine collects wind energy and converts it into electricity, which in turn produces an output which is used to charge one heavy duty battery. As a result, the home is served simultaneously by the wind turbine and the utility. In this study, a small electricity generator has been specifically designed for household installation. We are using a savonius rotor. This type of rotor (which is of the vertical axis variety) is chosen instead of a horizontal axis machine due to its simplicity and reliability. The S-rotor has been designed using an analytical method and confirmed by natural wind testing. This study was done to investigate the design and development of the vertical axis micro wind turbines. The contribution of counter rotating impellers with a freely rotating generator to produce energy was investigated. For the analysis and design, PRO-E, CAE programmes were used. Possible developments were considered.

Key words: Savonius Rotor, Savonius Vertical Axis Wind Turbine

I. INTRODUCTION

After the 19th century the demand for electricity is increased. This high demand caused development of new electric power generation facilities such as very large onshore and offshore wind energy farms, solar power plants, wave power plants and tidal power plants. Recently, there is a growing promotion of installation of micro wind turbines and solar panels in houses. The aim of this study is to investigate the design and development of micro wind turbines for integration into residential, commercial and industrial complexes.

II. WIND ENERGY SCENARIO

To better understand the current situation in India and the future of the renewable energies market, it is important to look at the trends in energy consumption, growth of the current grid, and the availability of transportation and equipment used there. More than 1/3 of energy consumed comes from renewable resources, predominantly from India is surpassed only by Germany as one of the world's fastest growing markets for wind Energy. By the mid-1990s, the subcontinent was installing more wind generating capacity than North America, Denmark, Britain, and the Netherlands. The ten machines near Okha in the province of Gujarat were some of the first wind turbines installed in India. These 15-meter Vestas wind turbines overlook the Arabian Sea. In2006, there is an installed capacity of 4,430 MW; however, ten times that potential, or 46,092MW.

III. ENERGY CONTAINED IN THE WIND

The main source of the earth's power is from the sun and it is approximately 1.484x1018 kWh/year. Only 2.5% of this energy is said to be converted into energy of motion of atmosphere. Therefore, the total kinetic energy of the air, which is related to wind, can be estimated as 2.5x1014 kWh. Most of this power is stored in very high altitudes usually 8km to 14km from the ground level. While the average wind speed is about 3 to 14 m/s around the surface of the earth, it is about 18 to 26 m/s above 8km high. However, because of turbulences in the air, the high wind speeds can also be seen in the lower layers of atmosphere.

IV. SAVONIUS MODEL VERTICAL AXIS WIND TURBINE

Vertical axis wind turbines are further subdivided into two major types namely the Darrieus model and the Savonius model. Pictured above in figure 4.2 is an example of the Darrieus Model which was named after designer and French aeronautical engineer, Georges Darrieus. This form of this design is best described as an eggbeater with the blades, two or three of them bent into a c-shape on the shaft. The Savonius model was invented by Finnish engineer Sigurd Savonius and an example is shown in Figure

Fig. 1: Savonius Model Vertical Axis Wind Turbine

The functioning of this model is dependent on drag forces from the wind. This drag force produced is a differential of the wind hitting by the inner part of the scoops and the wind blowing against the back of the scoops. Like the Darrieus model, the Savonius turbines will work with winds approaching in any direction and also work well with lower wind speeds due to their very low clearance off the ground.

V. METHODOLOGY USED FOR DESIGN

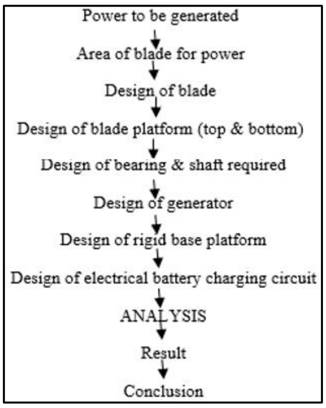

Fig. 1: Methodology

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VI. MAIN COMPONENTS OF VAWT & SELECTION CRITERIA FOR THEIR MATERIAL

A. Rigid base

We have decided to provide square shape base of better thickness to provide support at the base to the whole set up, which will very useful to stand the VAWT unit on the roof of the house. The material we are using for this is Mild steel.

B. Rigid Centre Shaft

It is that part which passes through hollow shafts of turbine and it stands on the rigid base It must be capable to absorb the radial and axial forces coming from rotor. So, the material using for shaft is SAE 1030 Steel for maintaining required strength.

C. Turbines

The number of turbine rotor we are using here is two. After comparing the available categories of shapes of blade of rotor, we have finally decided to used SAVONIUS rotor semicircular blade shape due to its large surface area for impact of wind and easier construction. The no. of blade containing in each rotor will be 6. The material for the blades of rotor will be GALVENISED STEEL sheet due to its corrosive resistive property and economical comparing to Aluminum or Plastic.

D. Generator

We are incorporating the arrangement of magnets and coils as the replacement for separate generator.

1) Magnets

There will be 24 brushless permanent magnet. 12 magnets on each disk of platform located on top of lower turbine and bottom of upper turbine. These magnets will arrange in alternate North South Pole manner on both disk.

2) Coils

The no. of coils will be 12. It will place between magnetic arrangements on both disks. 3-phase connection will be there, three phase means connect one wire with four coils at an angle 120°. It will be trapezoidal in shape and made up of Copper.

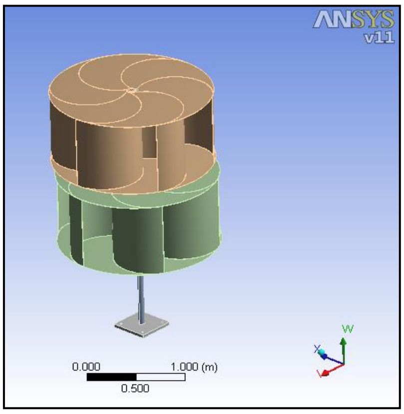

Fig. 2: VAWT

VII. DESIGN PROCEDURE

1) Step 1: Calculating the power to be generated
2) Step 2: Design of power required on blade (by impact of air)
3) Step 3: Area of blade
4) Step 4: Design of rotor (2 rotors)
   – Design of blade
   – Design of hollow shaft
   – Top and base platform
5) Step 5. Design of middle shaft and bearing
6) Step 6. Design of bearing

By using above design procedure we calculate the required parameters and data and analysis the each parts by using ANSYS software.

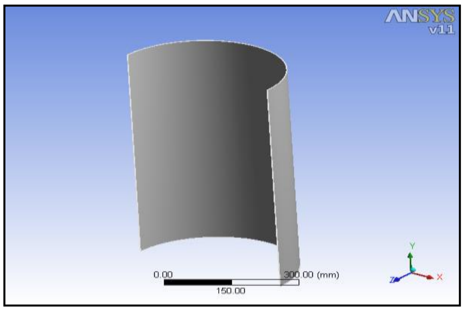

Fig. 3: Blade

The designed parameters are used to prepare 3-D model in PRO-e software and different analysis are done on it in ANSYS software. After analysis following results are obtained.

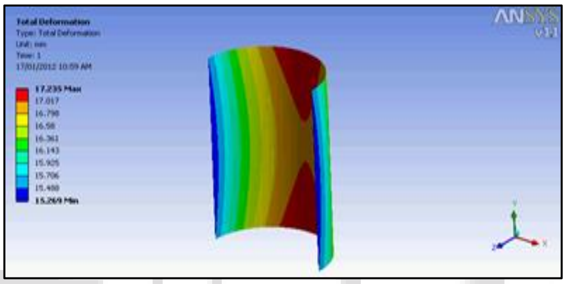

Fig. 4: Analysis of total deformation

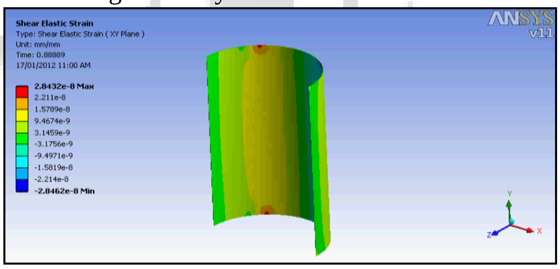

Fig. 5: Analysis of shear elastic strain

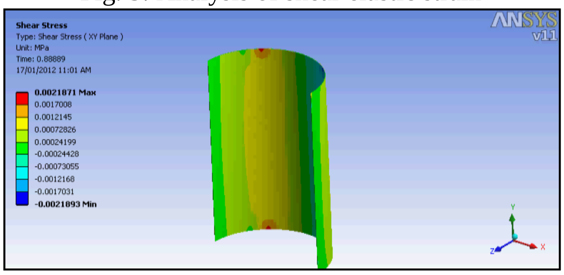

Fig. 6: Analysis of shear stress

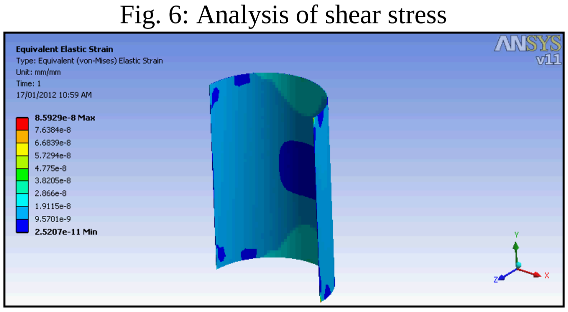

Fig. 7: Analysis of equivalent elastic strain

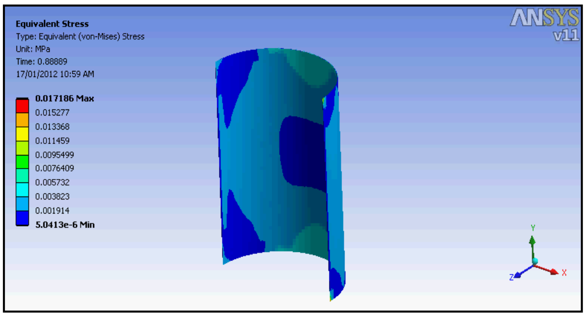

Fig. 8.Analysis of equivalent stress

Structural	
Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa
Compressive Ultimate Strength	0. MPa
Thermal Values	
Thermal Conductivity	6.05e-002 W/mm·°C
Specific Heat	434. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	1.7e-004 Ohm·mm

Table 1: Structural Steel > Constants

Table shows the structural steel constants values like young's modulus, poisson's ratio, density, thermal expansion, yield strength and ultimate strength, thermal values like thermal conductivity and specific heat electromagnetic which can be passed through pores are taken as constant of structural steel.

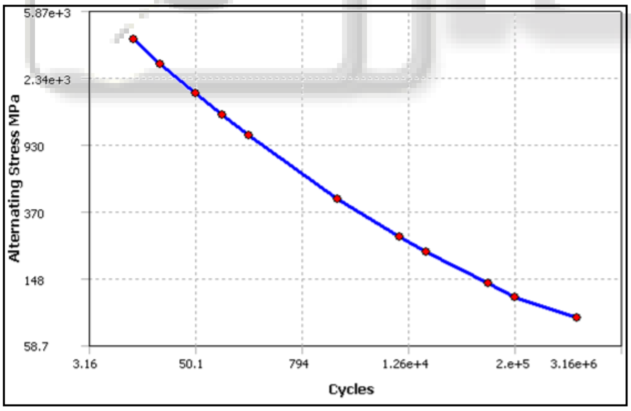

Fig. 9: Structural Steel > Alternating Stress

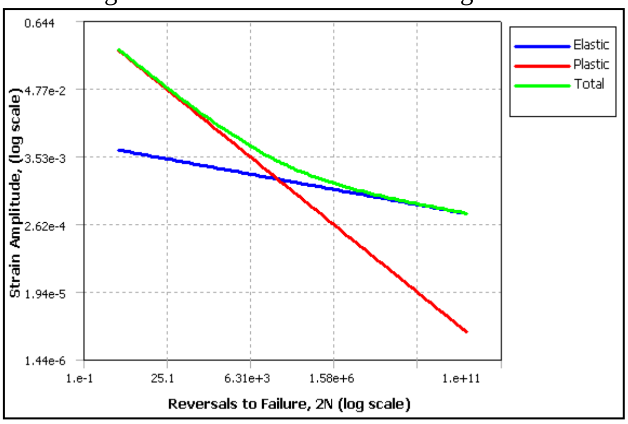

Fig. 10: Structural Steel > Strain-Life Parameters

Strength Coefficient MPa	920.
Strength Exponent	-0.106
Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cyclic Strength Coefficient MPa	1000.
Cyclic Strain Hardening Exponent	0.2

Table 2: Structural Steel > Strain-Life Parameters > Strain-Life Parameters

This table shows the structural steel strain life parameters which include strength & ductility coefficient, strength & ductility exponents, cyclic strength coefficient, cyclic strain hardening exponents.

From the above analysis it is seen that the blade type is safe for design as the values of stress, strain, and deformation are under the safety range of material properties.

VIII. Conclusion

In this study, a counter rotating vertical axis wind turbine was designed using Pro-e, ANSYS programs. The importance of using CAD software for the aim of designing a machine was experienced. The importance of tolerance in manufacture is experienced with the help of CAD software. The benefits of CR-VAMWTs over single rotating impeller wind turbines are as high as twice of the output for low efficiencies. It should also be investigated for motors and impellers which are operating in optimal speeds.

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