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Small-Scale Power Generation by Horizontal Axis Magnus Wind Turbine

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Abstract*: The present work describes a method of small-scale generation of electric power using a horizontal axis Magnus Wind Turbine (MWT). Present levels of environmental pollution from fossil fuels and the high cost of generating electricity can be solved by using Green energy extracting wind turbines. Many researchers are trying to use renewable sources of energy to solve this problem. The present work investigates the generation of electricity by using Horizontal axis Magnus wind turbine. It is observed with a small investment and proper selection of the location of the site for deployment, the wind power is a better economical solution than other methods.

***Keywords* : Magnus effect, Power generation, Turbine, Wind power.**

I. INTRODUCTION

The global warming is a major cause of concern for all. As the usage of fossil fuels is getting more and more the environmental effect is becoming very large. Fossil fuels such as coal, crude oil, and natural gas are non-renewable and unsustainable for the long term. Renewable energy is energy produced from sources that do not deplete or can be filled up in future. The energy from wind, sun, geothermal, biomass, and hydropower are common renewable sources for energy.. Renewable energy has numerous advantageous over fossil fuels. One of the major advantages is the reduction in environmental pollution to a great extent. Renewable energy is abundant, affordable, cost-effective, and easier to produce and use. By using renewable energy maintenance requirements are lower, it has numerous health and environmental benefits, lower reliance on foreign energy sources and storage capabilities. Compared with solar energy, wind energy can be harnessed at any time, day or night. Solar energy can be harnessed only during day time. Wind power is more efficient than solar power. That's why it is one of the fastest-growing energy sources in the world. The Kinetic energy of wind is converted into electrical energy by a wind turbine. Usually wind turbines are of two types horizontal axes and vertical axe with their capacities vary considerably. The power from small turbines is used in variety of applications. Large turbines are used for generating green energy power, supplying the generated power to grid. A Group of wind turbines called wind farms is already producing enough power to reduce reliance on fossil fuels. This work presents the development of a horizontal axis Magnus Wind Turbine. Design development and testing of the Magnus wind turbine of horizontal axis type, in the fields (sites) are presented in this work.

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A. Prior research work

Good Robert E. Akins et al. [1] researched on blades of Magnus wind turbine. The most important problem addressed is at low wind velocities below 6m/s the efficiency of turbine. In these periods, the power coefficient of wind turbine drops rapidly to zero at about V = 4 m/s. Whereas the Magnus wind turbines can be used from 2 to 40 m/s wind velocities. And also, environmental and operational conditions favour Magnus wind wheel because of its reduced rotation velocity that is 2 to 3 times lower than bladed turbines. N M Bychkov et al. [2] presented a research report about the Magnus force, on a rotating cylinder. In these cylinder, blades are applied a asymmetric flow. Giudice et al. [3] presented a Magnus wind turbine prototype. It uses four cylinder blades. Its main purpose is to take energy from water channels like drainage and irrigation. Ragheb et al. [4] researched using wind tunnel tests. The experiments were conducted in a wind tunnel by varying the size of the models. Jost Seifert [5] reviewed the Magnus effect, its application in devices and concepts in aeronautics and discussed future challenges. As the blade aspect ratio is an important parameter for the performance of Magnus wind turbine , Sun, X., et al. [6] conducted a 3D numerical study on it. Luka Perkovic et al. [7] presented the effect of wind power at high altitudes on rotating cylinders. It is found that wind speed and mechanical energy output have a positive correlation. The final conclusion is Magnus effect is very useful in energy production at high altitude winds. Ahmad Sedaghat [8] studied, lift and drag forces affecting rotating cylinders. Designed Magnus wind turbine cylinders by applying the methods used in aerofoil type wind turbines and analysed drag to lift ratio. A.Massaguer et al. [9] researched the impact and effect of Magnus wind turbine. The horizontal-axis blades are replaced by cylinders which are rotating. With the application of particle image velocimetry the various blade shapes are tested for their performance. Shivprakash Bhagwatrao Barve et al. [10] in his research work, found that the lesser the airspeed there will be less energy production.

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Betz's Theory states that maximum kinetic energy that can be captured by a wind turbine is 59.3%. Therefore, any rotational forces such as wake rotation, turbulence caused by drag or vortex shedding will further reduce the maximum efficiency. Ahmad Sedaghat et al. [11] examined symmetrical aerofoil for various circulating speeds and found that the aerofoil surface can be used for generating power. Omar Faruqi Marzuki et al. [12] have investigated by the surface roughness factor. Their findings highlight that, when the roughness of the surface increases the torque generation also increases around 5 times.

B. Magnus wind turbine

Magnus effect is the force produced when a rotating cylindrical component is applied a fluid force. The direction of produced force is perpendicular to applied force on the cylinder. The Magnus force effect is shown in Fig.1.

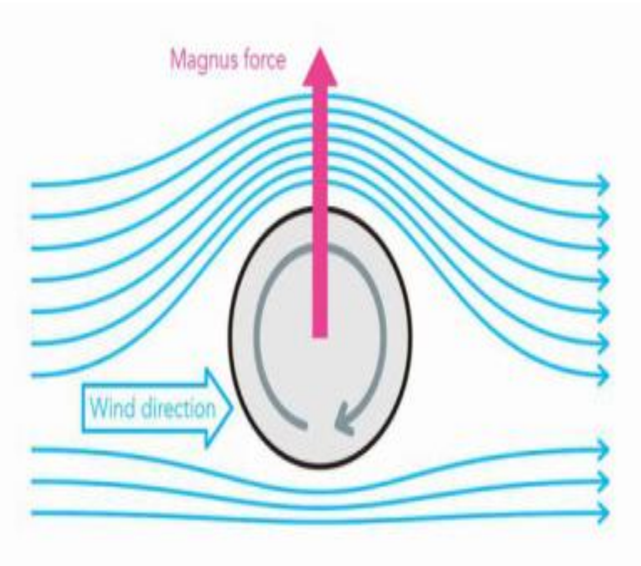

Fig. 1. The Magnus force

(reference: https://cdn.redshift.autodesk.com/2017/03/challenergy-magnus-effect-1.jpg)

As the Magnus wind turbines have rotating cylinders they rotate on their axes. This results in Magnus effect. Magnus wind turbine overcomes all major limitations of present turbines. The Magnus wind turbines are of much use in variety of wind velocities from 2 m/s to storms.

II. DESIGN OF HORIZONTAL AXIS MAGNUS WIND TURBINE

A. Design calculation

For 100 Watt power,
Assuming wind velocity, V= 5 m/s
Air Density = ρ
$\rho = 1.225$ kg/m^3
Power = P
$P = \frac{1}{2}\rho A V^3$
Area= A,
Height = H,
Diameter = D,
A = 1.5m^2
H =1.5m;
D=1m
Shaft Design:
Length = 500mm,
Diameter = 20mm,
Shear stress = 32Mpa
Torque = T,
$T = (\pi/16) \times d3 \times \zeta$
T = 50.265 KN-mm
Design of Turbine:
η = efficiency factor
R = Rotor radius
u = blade velocity
Power $= \frac{1}{2} \times \rho \times A \times u^3 \times \eta$
Power = 8W
Velocity = V
Rotational speed = N
$N = (V \times 60) / (\text{radius} \times 2\pi)$
N = 76.39 rpm
Angular Velocity = ω
$\omega = u / R = 8$ rad/s
Resultant blade velocity, VR
$VR = \sqrt{(r\,\omega \sin\theta)^2 + (r\,\omega \cos\theta + ux)^2} = 5.76$ m/s.

B. Part modeling and assembly

Modeling of cylinder shaft with spiral spins, frame and assembly of all parts were done using 3D modeling software Solidworks. The solid models of various parts and assembly of the horizontal axis Magnus wind turbine are shown in Fig. 2, Fig. 3 and Fig. 4

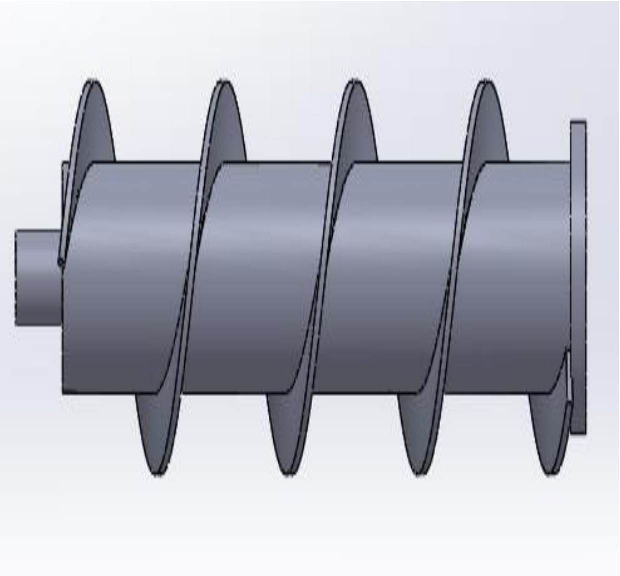

Fig. 2. Cylinder with spiral fins

Rotating cylinders are replacing aero foil type blades in this type of Magnus wind turbine. These circular rotating cylinders are coiled with spiral fins. Compared to aero foil type blades these coiled spiral type cylinders rotate even at low velocity of wind. This characteristic making it an attractive one for small-scale wind power generating applications.

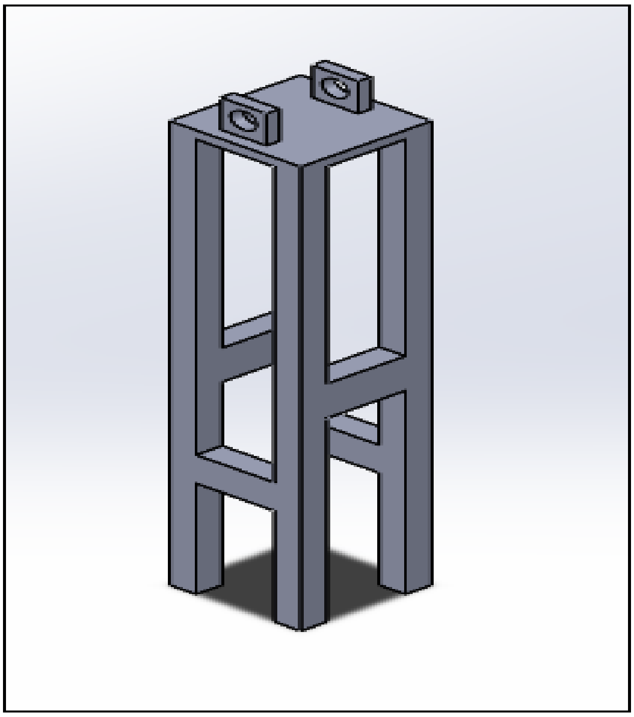

Fig. 3. Structure for mounting

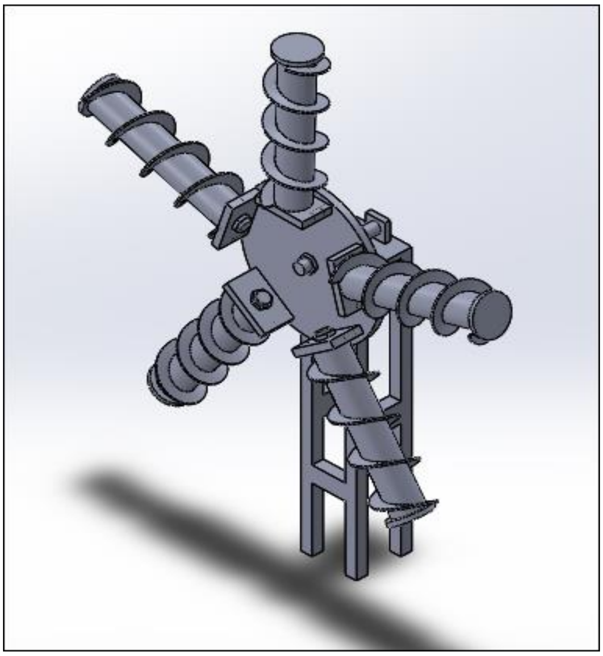

Fig. 3. Assembly of Turbine blades and frame

III. FABRICATION, ASSEMBLY AND TESTING OF HORIZONTAL AXIS MAGNUS WIND TURBINE

The parts are fabricated and assembled. The frame and rotor shaft are made of mild steel. The turbine rotor blades are made using glass fibre for lightweight. Five cylinder rotors were used for this turbine. The unique characteristic of this cylinders is it will rotate on both sides clockwise or anticlockwise and produces power. These cylinders rotate when the wind blows in any direction. These five cylinders are assembled in a hub. This assembly of cylinders with hubs is mounted on a frame and a permanent magnet generator is attached to this assembly for testing purpose.

Fig. 4. Assembled horizontal axis Magnus wind turbine

Fig. 5. Horizontal axis Magnus wind turbine at testing

IV. RESULTS AND DISCUSSION

The major finding of this experiment is even at low wind speeds the horizontal axis Magnus wind turbine can be used. Table- I shows the test results of the turbine. This turbine is made to work at wind velocity of 4 m/s, while the rotor shaft rotates at 76 rpm. The actual power output is 8W.

Table- 1

Wind velocity (m/s)	Rotor speed (rpm)	Wind turbine output (watts)
4	76	8

It can be made to use in all places where even a low wind speed as small as 4 m/s is available. The fabrication and testing of the turbine is done at very low cost with few thousand rupees and found working.

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V. CONCLUSION

The special features of Magnus wind turbine are that it needs very low wind speed to start, and cylinders rotate at any cause of rotation. The cost of fabrication of this turbine is very less. The fabricated horizontal axis Magnus wind turbine is tested at the site conditions and proved its performance. This turbine can be fabricated for higher power generation also with appropriate changes.

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