DEVELOPMENT OF A LOW COST, LOCALLY MANUFACTURED ROTOR BLADE FOR A SAVONIUS WIND PUMP

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Abstract
Studies indicate that vertical axis wind turbine provide a more reliable energy conversion technology, as compared to horizontal axis wind turbine, especially in areas of lowly rated and/or uncertain wind speeds, mostly arid and semi-arid areas. The challenge however is the development of an efficient and cheap rotor blade which is currently not manufactured in Kenya. The objective of this research was to identify local wind turbines manufactures in Kenya; design a savonius rotor blade; locally develop a Savonius vertical axis wind turbine rotor blade for wider use in Kenya and to analyze the cost of the developed Savonius rotor blade. In achieving these, a number of methodologies including: field questionnaires, empirical design calculations, prototype development and laboratory testing were used to develop such a rotor blade. Laboratory tests using a tachometer and Hygro- thermometer were able to provide a number of interesting results including: Ability to pump water of four cubic meter per day for 200 people, costing less than KES 300,000/= per unit and hydraulic power capability of less than 1 kW. Field tests for the system are to be undertaken soon but it is projected that the laboratory results will not differ significantly from the field results. In conclusion the research work has been able to develop a wind conversion technology that makes the system affordable, locally manufactured and more efficient than current existing system. A key achievement of the system has been the ability to provide the local small wind energy sector a process and material matrix to be used in developing of more efficient vertical axis wind turbine blades that are more adaptable towards Kenya's average wind speed of ≤ 4m/s.

Key words: Savonius, vertical axis wind turbine, Green energy, Energy conversion technology, non-renewable

1.0 Introduction
Global climatic changes have been a direct effect of environmental pollution due to excessive use of fossil fuel. This calls for use of clean renewable energy in day to day activities to safeguard the flora and fauna. The concept of harnessing wind energy has been overwhelmingly embraced all over the world.

A wind turbine is a device that utilizes wind energy to generate mechanical or electrical power. There are two types of wind turbine: Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). HAWTs are most commonly known type of wind turbines which operates parallel to the direction of the wind whereas VAWTs rotors operates perpendicular to the direction of wind. Under conditions of low wind speeds, HAWTs generally don't perform so well, a locally manufactured VAWT would perform amicably in these conditions considering the installation and maintenance cost.

Design and implementation of wind turbine projects both locally and globally have boosted power supply to the national grid and other associated works. In view of this, Arid and Semi-Arid Lands (ASALs) have been noted to have average wind speed of about 4m/s or higher and constant strong wind patterns which can be utilised.

2.0 Methodology
2.1 Field and Market Assessment
The identified companies in Kenya includes: RIWIK (EA), Craft skills and Power technics. During the study a questionnaire was filled and areas of interest included design procedures, fabrication, testing, challenges and opportunities in the market. The picture below shows what was obtained from the local companies that were visited.



Riwik (EA)   Craft skills

Powertecnics

2.2 Empirical Design Calculations

Various blade parameters, e.g., diameter, height, chord length and swept area were obtained from existing formulas.

PARAMETER	VALUE 1	VALUE 2	VALUE 3
Output power	250W	500W	1KW
Power coefficient	0.15	0.15	0.15
Swept area	8.5m^2	17m^2	34m^2
Wind speed	5m/s	5m/s	5m/s
Tip speed ratio	0.5	0.5	0.5
Diameter	3.29m	4.65m	6.58m
Height	2.6m	3.7m	5.2m
Chord length	0.9m	1.2m	1.7m
Number of blades	2	2	2
Torque coefficient	0.3	0.3	0.3
Solidity	0.7	0.7	0.7
Angular velocity	1.52rad/s=14.5rpm	1.07rad/s=10.2rpm	0.76rad/s=7.3rpm
Aspect ratio	3	3	3
Overlap ratio	0.25	0.25	0.25
Cross section profile	Semi-circular	Semi-circular	Semi-circular

Much of comparison with the previous similar research was done. (Design and Analysis of a 5 KW Savonius Rotor Blade by Widodo, Chin, Haeryip Sihombing, and Yuhazri, in 2009 at Supergen).

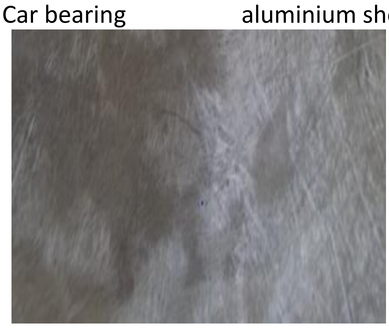
Parameter	Value
Power Generated	5 kW
Swept Area	23.5m^2
Rated Wind Speed	10.5 m/sec
Aspect Ratio	2
Tip Speed Ratio	1.0
Solidity	2.114
Diameter – Height	3.5 m – 7 m
Number of Blade	2

2.3 Materials Selection and Purchase

Materials were selected by considering the materials' properties that can withstand the environmental conditions as well as the cost.

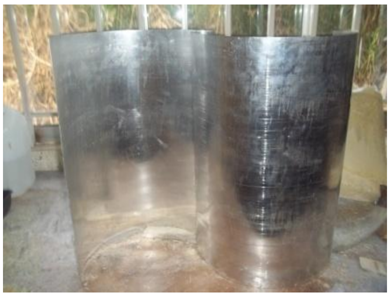


Car bearing aluminium sheet metal Galvanized Iron pipe




Fibre mat Pipe & car bearing fitted among others

2.4 Development of a Small Prototype

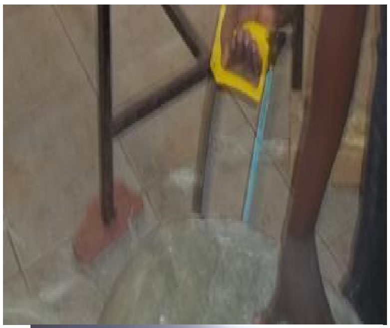


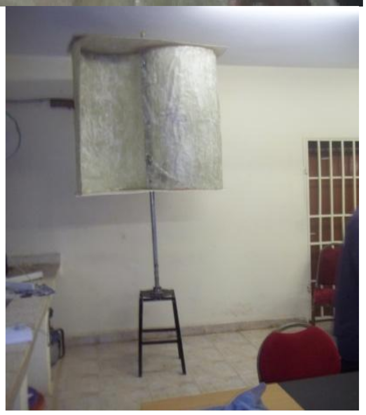

2.5 Prototype Testing and Understanding

Testing of the prototype was done in the lab using a fan as a source of wind.

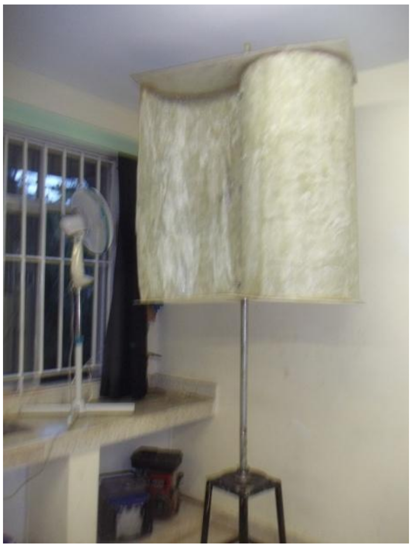
2.6 Design and Aerodynamic Development of a High Efficient Rotor Blade

Since the prototype design was a downscalling of the rotor blade. To design the efficient rotor blade an upscalling was done by a factor of 6.5 from the prototype.Tooling involved fabrication of the rotor blade mould, support frame and fitted on a car bearing, moulding of the casing, testing for the revolutions, and finishing.



Assembling and installation; Fitting the rotor blades to other wind turbine components (transmission system, and tower) will be done next and basic performance assessment of the turbine will be finally done. The picture below is the complete rotor blade undergoing lab test with the same fan as the wind source used for testing the prototype.



3.0 Results and Discussion

When the prototype was tested, the following results of RPM were tabulated.

Leading edge	**Trailing edge**
5.01	1.78
6.07	2.37
4.54	1.97
4.88	1.60
6.55	1.37
4.97	1.41
5.44	2.53
Average=5.35	**Average=1.86**

From the above results, more revolution was experienced when the wind blows to the leading edge than to the trailing edge. From the Savonius power equation, P_{max}=0.36kg m^{-3}*h*r*υ^3. By inserting the dimensions with h=0.6m, r=0.4m and υ=5ms^{-1},then the power output becomes 10.8 watts, with 0.56rad/sec maximum and 0.2rad/sec for minimum as the angular velocity thereby torque becomes 19.3 and 54 N M respectively.

When the real model was tested, the following results of RPM were tabulated.

Leading edge	**Trailing edge**
17.34	10.81
20.22	10.20
17.14	10.97
16.22	9.43
15.55	11.23
27.35	11.43
41.05	11.41
Average=22.12	**Average=10.78**

From the above results, more revolution was experienced when the wind blows to the leading edge than to the trailing edge. From the Savonius power equation, P_{max}=0.36kg m^{-3}*h*r*υ^3. By inserting the dimensions with h=1.2m, r=0.5m and υ=5ms^{-1}, then the power output becomes 27 watts, with an angular velocity of 2.32 rad/sec maximum and 1.13rad/sec for minimum thereby torque becomes $P_{m/}\omega$ =11.64 and 23.9NM respectively. This implies that when the angular velocity is low then the torque is high and vice-versa. More tests will be done by using the natural wind hence more analysis will follow.

4.0 Conclusion

The research work has been able to develop a wind conversion technology that makes the system affordable, locally manufactured and more efficient than current existing system. A key achievement of the system has been the ability to provide the local small wind energy sector a process and material matrix to be used in developing of more efficient vertical axis wind turbine blades that are more adaptable towards Kenya's average wind speed of ≤ 4m/s.

Researchers have found that a savonius rotor with small rotational speed (angular velocity) produces higher torque i.e., savonius rotors has high starting torque hence more modification will be done to achieve this and the results above are subject to changes. The rotors above can still produce high starting torque which is mostly required in case of pumping water which is the main application of this project.

Acknowledgement

Much thanks to the Almighty for his tender care throughout the research period.I first and foremost acknowledge The National Council of Science and Technology (NACOSTI) for funding this research project. I also thank my supervisors- Mr. Francis Ochien'g and Prof. Robert Kinyua for their maximum assistance at all the times.The mechanical Engineering technicians are also remembered for their assistance and support. Never will I forget my entire family for their maximum cooperation and moral support during the period.

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