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INVESTIGATION ON THE ENHANCEMENT OF THE PERFORMANCE OF THE SAVONIUS ROTOR DEPENDS ON PARTIAL DIFFERENTIAL EQUATION

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Abstract: Currently, people think about the Drag type of vertical axis wind turbine as a reliable wind machine to save in future energy supply. The advantage to this emerges from the building and maintaining cost, which is cheaper than the wind turbines with Horizontal axis. Nevertheless, such rotor is facing problems from efficiency. This study proves the improvement of Savonius rotor performance, a basic geometry of drag machine, as dependent to partial differential equation. The report shows investigations conducted to show the effect of geometrical configuration on the rotor performance in terms of coefficient of torque and power, and power output. In proving the above case, the study will consider simulation Computerized Fluid Dynamics, which will help in analyzing the flow, attributes of the rotor. The equations of continuity and Reynolds Averaged Navier-Stokes together with the realizable K-ϵ epsilon turbulence model will help in the judgment of the case. The results obtained shows that partial differential equation is important in the enhancement of the performance of the savonius rotor. Likewise, the performance coefficient of an optimal rotor reaches 0.2 with a rotor having two blades and H/D = 6:1, e = 0.3, ɵ = 180^0.

Keyword: Savonius rotor, Tip speed ratio, Numerical analysis of savonius rotor, CFD.

I. INTRODUCTION

Acute energy crisis facing most of the developing nations propagates the requirement for renewable energy. The sources of renewable energy include wind, which help to reduce dependency on fossil fuels. One advantage of using wind power relates to minimal pollution it causes to the environment, thus use of the energy source is very economical to any region. Recent developments have been ongoing to expand on the production capacity of the wind energy. Considering that the physical component of wind energy uses the concept of savonius rotor, various experiments have been done to help improve the performance of the device (Ackermann).

Through the various experiments, scientists have examined various effects of design parameters for the savonius wind rotor, which help in improving the performance of the device. One experiment deals with the effect of deflecting plate to the performance of the device (Ogawa). Another experiment relates to the effect of curtain in improving the power performance of the device (Burçin Deda Altan[a],*, Mehmet Atılgan[a], Aydog ˘an Özdamar[b]). Other experiments showed the improvement of the performance of the device by use of a guide-box tunnel (Adkins and Davidson).

This study introduces a new concept of partial differentiation equation as a way of improving the performance of the savonius rotor.

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II. SCHEMATIC DIAGRAM OF THE DEVELOPED BLADE

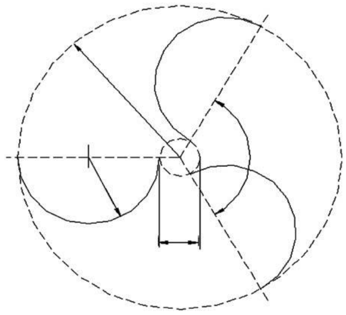

Fig.1 Top view of semicircular bladed rotor

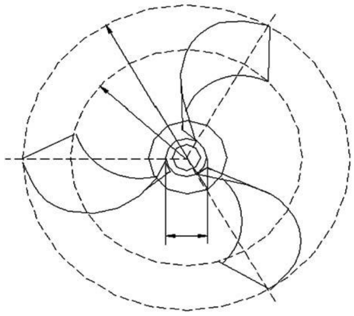

Fig.2 Top view of twisted bladed rotor

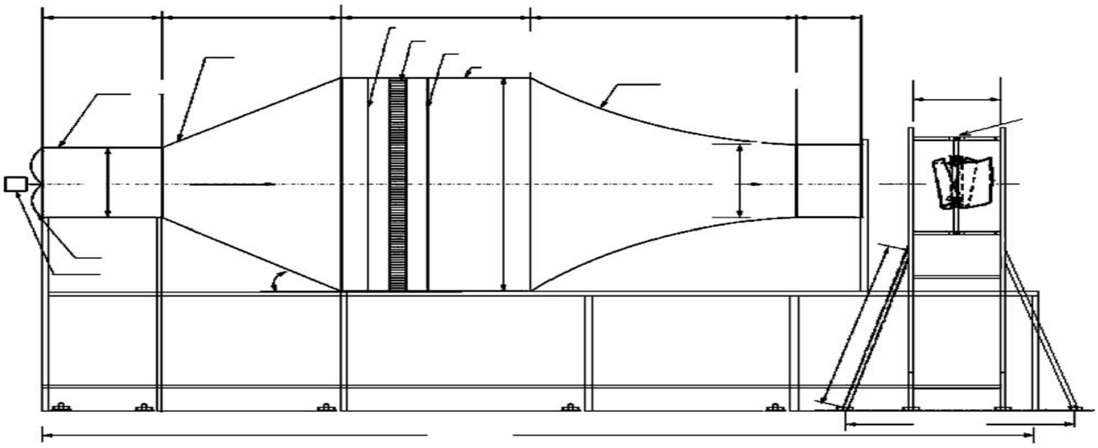

Fig.3 Schematic diagram of the wind tunnel with Savonius rotor.

The above presentation shows the geometrical structure of savonius rotor. The rotor follows the requirements as shown in the principles of the present invention. Savonius rotor is a simple drag device capable of producing high torque. The structure of the rotor presents a simplified way that helps it in the production process. As mentioned earlier, various ways can be applied in improving the performance of the device. However, in this segment, the author will use the concept of partial differential in the performance factor. Experiments show that partial differentiation has the ability of improving the rotor performance (Balser).

III. COMPUTATION MODELING AND PROCEDURES

Commercially there is software used for the purpose of determining the *turbulence flow field* in Savonius rotor models. The GAMBIT and FLUENT software are identified to be effective in determining the key concepts of the *k-ε turbulence model*. The software assists in determining the simulation flow that occurs around the Savonius rotor design with differences in the overlapping ratios. GAMBIT software plays a key role in analysing mesh generation experienced in the rotor models. Using the numerical simulation, there are two key variables that are considered when applying the use of GAMBIT. These are velocity value and the pressure value at all nodal points on the rotating blades. This can be shown using a 2-D mesh generation of three blades at 0°, 90°, and 180° using this software. Below are the presentations of a 2-D gambit diagrams and a graphical presentation for the three blades used.

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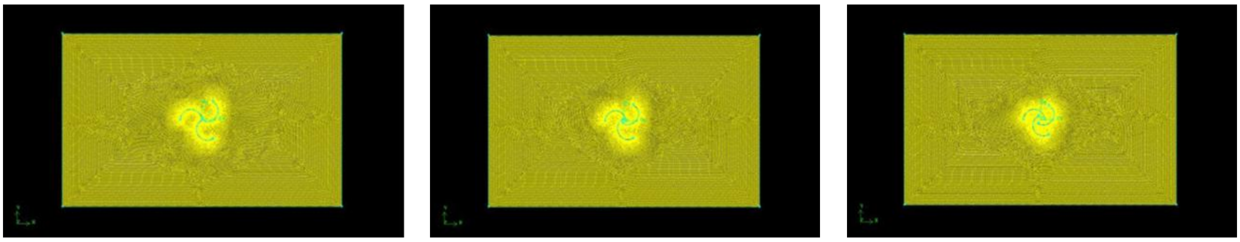

Fig.4 Gambit software presentation for mesh generation

Graphically, this can be presented in this form:

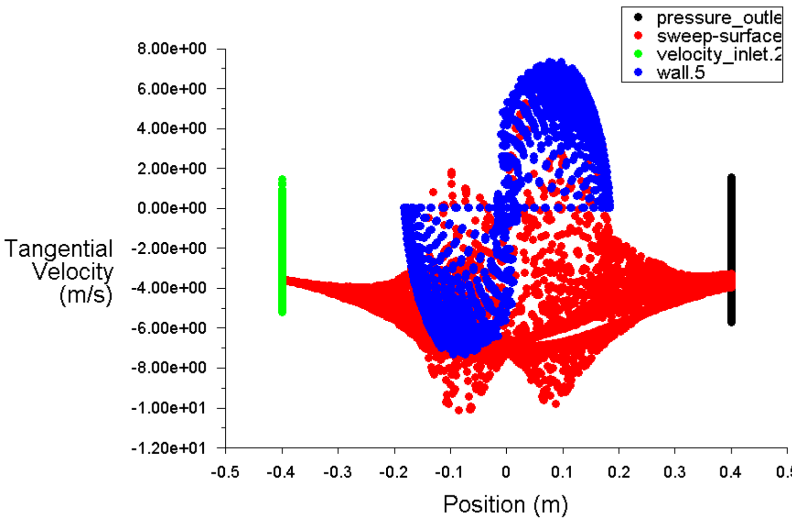

Fig.5 Tangential velocity Vs Position at 90° rotor angle (Plot direction X1, Y0, Z0)

FLUENT software, on the other hand, relies of the products of GAMBIT software that are generated during the mesh generation determination. The Fluent software is basically used for post processing of the computer generated meshes in the gambit.

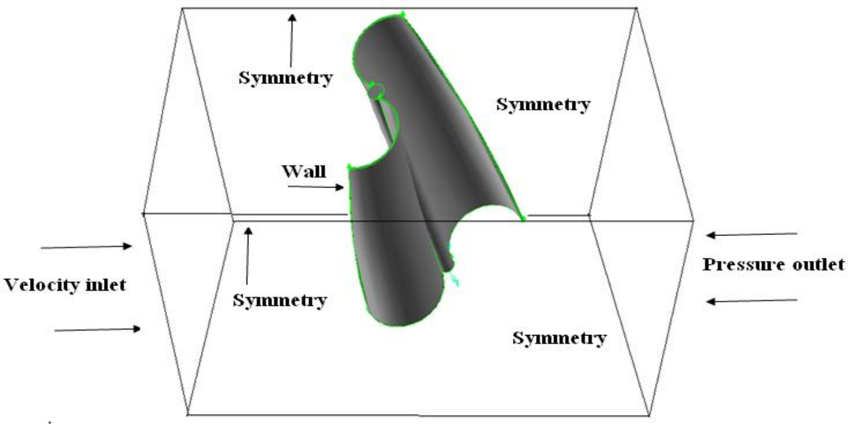

Fig.6 computational domain with boundary condition

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IV. TURBULENCE MODEL

This study uses the Standard k-ϵ turbulence model together with a logarithmic surface function. The turbulent flow gives a momentum equation that uses *x*, *y*, and *z* as the components of velocity. The equation also uses turbulent kinetic energy *(k)* together with the dissipation rate of turbulent kinetic energy (ε). The named equations are solved using the Gambit program. This model uses the iteration method where individual equation couple in the central point of the cells. Working on the second order interpolation that has a high reliability level will be used. The following shows the standard k-εequation can be shown as follows:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k$$

$$\frac{\partial}{\partial t}(\rho \varepsilon)+\frac{\partial}{\partial x_i}(\rho \varepsilon u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon$$

G_k shows turbulence kinetic energy production as an element of mean velocity gradients. Y_M is a contributing factor of the fluctuations that dilate from the turbulence to the general dissipation rate. $C_{1\varepsilon}$ and $C2_\varepsilon$ represent constants as σ_k and σ_ε represents the turbulent Prandtl for k and Ɛ respectively. S_k and s_ε define the user-defined source terms.

V. ANALYSIS OF SAVONIUS ROTOR

After converging the solution, values of the power co-efficient (C_p) are determined for individual input air velocity, angle of the bucket positioning, rotational speed and the ratios measuring the tip speed (λ). Acquiring the power coefficient, the following equations apply

$$C_P=\frac{P}{\frac{1}{2}\rho A V^3}$$

C_p represents the coefficient of power, *P* represents air density, *A* represents wind turbine area and *V* representing the speed of wind.

VI. VARIATION OF POWER COEFFICIENT AT DIFFERENT ROTOR ANGLE

The figures showed below represents maximum power coefficient at different speed ratios. According to the definition, a tip speed ratio represents a ratio of the speed of a rotational blade to that the stream velocity moving freely. These vastly rely on the use of FLUENT software since they are post mesh generation processing. They rely entirely on the information generated in the GAMBIT software analysis.

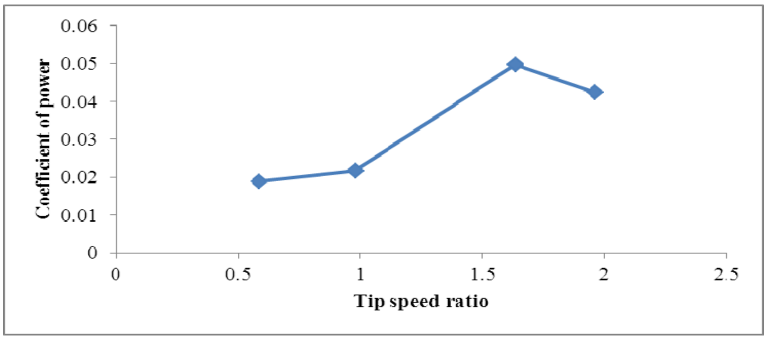

Fig.7 Variation of coefficient of power at 0^0 rotor angle with TSR.

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According to the figure, a speed ratio of 0^0 rotor angle offers a maximum power coefficient at a point 0.0498 with a TSR of 1.636.

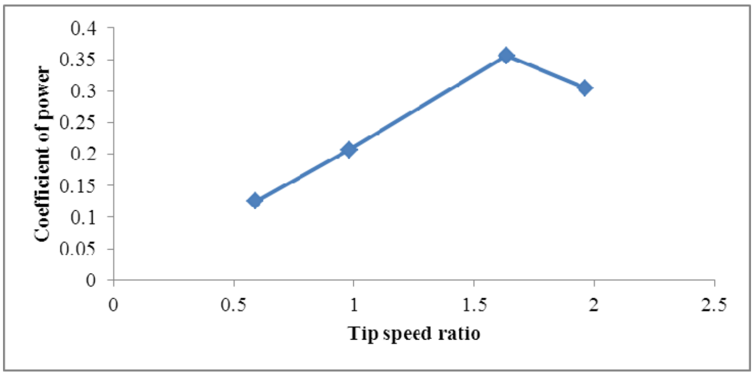

Fig.8 Variation of the coefficient of power at 90^0 rotor angle with TSR using FLUENT software.

The above figure shows an angle of 45^0 owing to the *power coefficient* of 0.4742 with a TSR of 1.636. Continuous the power coefficient. Angles 45^0, 90^0, 225^0 and 270^0 give maximum coefficient as 0^0, 135^0, 180^0 and 315^0 gives the worst coefficient.

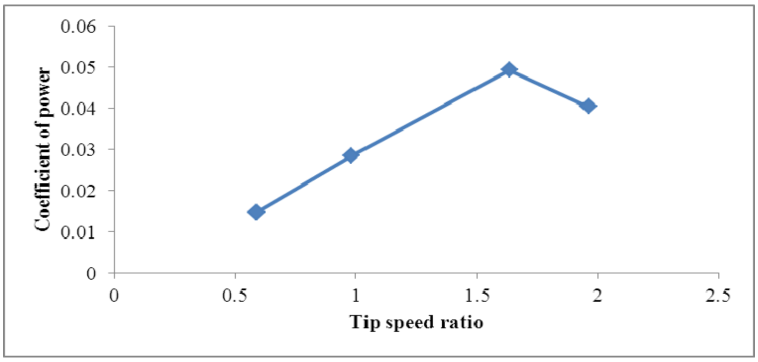

Fig.9 Variation of coefficient of power at 180^0 rotor angle with TSR.

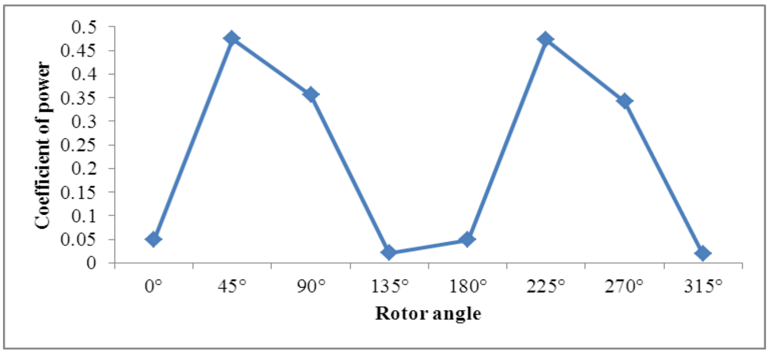

Fig.10 Variation of coefficient of power at 360^0 rotor angle with TSR.

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VII. IMPROVEMENT IN SAVONIUS ROTOR

From the power variation coefficient analysis of the rotor, there are a number of improvements that have been recorded based. These are the best justified by a number of suggestions presented by various authors Rajat Guptal , Bachu ,Debl and R.D.Misralin their explanations on the performance improvement present an arithmetic presentation that improves the savonius rotor performance from TSR of 0.4742to 1.636.These changes are experienced as a result of the blade angle alternation from 45º to 315º .These performance change are also presented in the graphical figures 7,8,9,and figure 10.

These can be determined using the formula

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k$$

And

$$C_P=\frac{P}{\frac{1}{2}\rho A V^3}$$

VIII. CONCLUSION

From the above experiment, one finds out that an increase in tip speed ratio increases the power coefficient to a certain limit (1.636). This will further decrease with an increase in speed ratio. This means that an optimum speed ration where the power coefficient is at the maximum exists.

The second finding is that coefficient values for the rotor angles are positive reflecting a positive power coefficient from the rotor. A higher value of power of coefficient is reached with an advance stroke of rotation from 45^0 to 110^0.

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