Design and Simulasion Study of VAWT Blade using CFD Analysis

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Abstract- With the use of the computational fluid dynamics (CFD) tool known as ANSYS software, the purpose of this study is to investigate and develop a vertical-axis wind turbine (VAWT) for low wind speed. The Savonius type of wind turbine was chosen for this simulation; however, certain of its components were altered in order to improve the performance of its rotation. The simulation will be set up by positioning the turbine so that it is in the center of the wind tunnel and giving it an initial wind speed of 6.5 meters per second. These data from the simulation are utilized to analyze the dynamics of the wind flow as well as the rotational speed of the turbine that was designed here. It was discovered that the angular velocity is 62.90 radians per second, with an aspect ratio of 1.0.

Keywords- Vertical axis wind turbine, Torque, Savonius, Annova.

I. INTRODUCTION

Wind power is one of the most significant forms of renewable energy available today. A wind turbine is one of the most frequent ways that wind energy may be captured and converted into electricity. In general, there are two kinds of wind turbines: vertical and horizontal axis turbines. These turbines are used to transform the kinetic energy of wind into the mechanical energy that the wind turbine needs to function. Because of its omnidirectional capabilities even at moderate wind speeds, the vertical axis wind turbine (VAWT) is the kind of wind turbine that was used for this project. The Savonius wind turbine is the VAWT that was taken into consideration for this study. Savonius wind turbine is a drag driven wind turbine. During operation, the lift force exerts itself on the blades when they are in a certain angular position relative to the rotor and when the tip speed ratio is larger than one.

Computational fluid dynamics (CFD) is used for the simulations in this work to explore the aerodynamic properties of wind turbine designs and their performance. As can be seen in figure 1, the wind turbine that was utilized for the simulation was a Savonius model with two stacks. The turbine's physical parameters are detailed in table 1, which may be found here. The setup condition that must be used in CFD simulation is to position the wind turbine so that it is in the center of the wind tunnel and use a wind speed of 6.5 meters per second that is injected from the wind tunnel's intake. The rotational speed of the wind turbine is the data that was acquired from the simulation. This data was collected by positioning a measuring point in the middle of the blades. This measurement location will keep a log of the wind speed as a function of the passing of time. Calculating the rotational speed may be done with the help of its time evolution graph due to the natural decrease in velocity that occurs when one of the blades is moving past the place in question. The observed rotational speed may then be used as a starting point for the calculation of other physical quantities, such as angular velocity, torque, and the Reynolds number, amongst others.

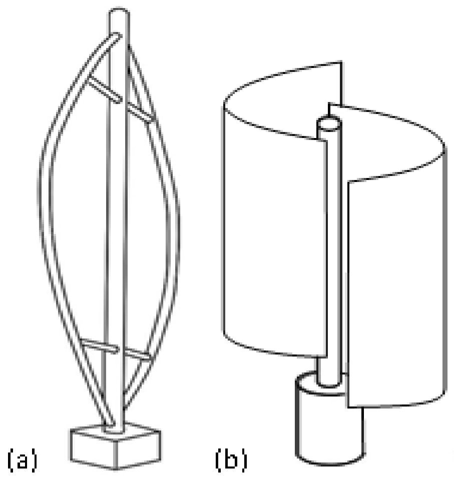

Figure 1. A schematic of vertical axis wind turbines (VAWTs):Savonius-type

Savonius wind turbines are commonly used owing to the simple design of its blades. Moreover, they are characterized by capability of self-starting, ability to capture wind from any direction, low manufacturing and maintenance costs, robustness and low cut-in speed. However, Savonius wind turbines have poor efficiency compared to other types of wind turbines. Therefore, many researchers have tried to modify blade design and geometical parameters of the Savonius rotors aiming to increase its efficiency.

2. METHODOLOGY/EXPERIMENTAL

This model is made by us as material PVC is Common household material, easy to find,n cheap, easy to work with and also its flexibility is strong, but we analyzed that it gets bulky and not really portable design as it needs more space to operate and does not fit to ournproblem statement. So, we decided to make it portable by reducing its required dimensions and specifications and modeled the 3D printed Savonius rotor

This research is included in the mixed-method design . There are six stages in this research, as shown in Figure 2. The stages are preliminary study, problem formulation, instrument design, data collecting, analysis, and conclusion

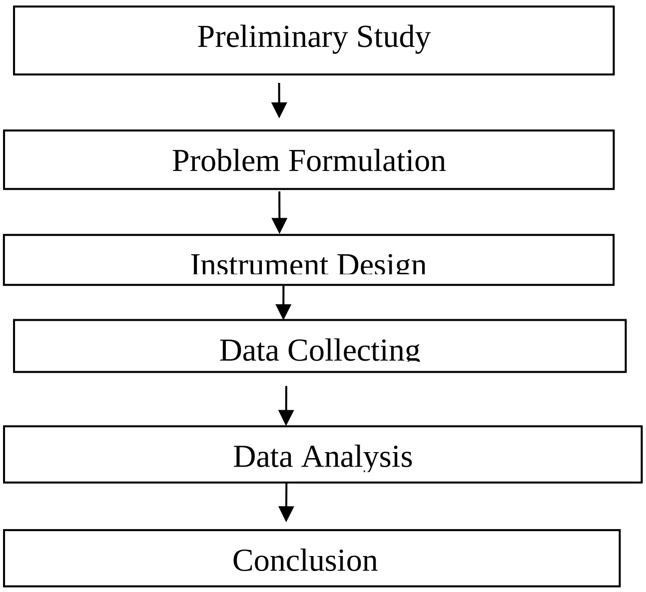

Figure2: *Research Stages*

2.1 Methods

Wind power: Wind power is a kinetic power that flows into wind turbine [4]. It can be calculated as follows:

$$Pwind = (1/2)\rho Av3$$

where ρ is air density (kg/m3), A is rotational area and v is wind speed (m/s)

Angular velocity. Angular velocity refers to how fast an object rotates or revolves relative to a reference poin. In general, angular velocity is measure in angle per unit time, which is radians per second in SI units. The unit can be change to rpm (round per minute) as shown

$$1 rad/s = (½) Hz = 60/\pi \ rpm$$

Reynolds number. The Reynolds number is a dimensionless value that measures the ratio of inertial forces to viscous forces and describes the degree of laminar or turbulent flow as shown:

$$Re = (\rho v/\mu) = vL/k$$

where Re is Reynolds number, μ is dynamic viscosity (Ns/m2), L is the blade chord length (m) and k the kinematic air viscosity (m2/s).

2.2 Geometrical details

There is only a single orientation of the blade throughout the height of 750 mm shown in the following Figure 3 Only two plates are attached at its end to increase the power performance

Table. 1 Illustration of Savonius wind turbine

Properties of the wind turbine	**Details**
Total height of the rotor	750 (mm)
Nominal diameter of the blade	200 (mm)
Diameter of the shaft	20 (mm)
Diameter of the rotor	380 (mm)
Diameter of the end plate	400 (mm)
Overlap	18 (mm)
Aspect Ratio	≈ 1.0
Swept area of the rotor	0.285 (m^2)
Nominal velocity of the wind	1 – 5 (m/s)

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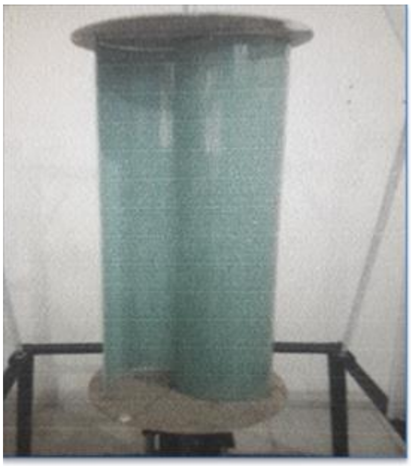

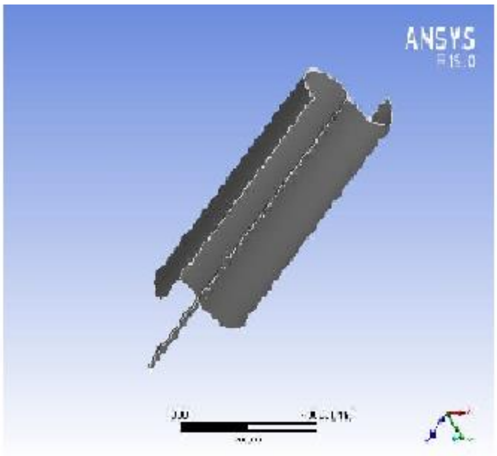

Fig. 3 vertical axis Savonius wind turbine (a)) Image of geography (b Image in 3D model

2.2 CFD simulation parameters: The simulation program used for study is ANSYSsoftware, the parameters for simulations are shown in table 2.

Table 2. numerical values of simulation parameters

Parameter	Values
Wind velocity	6.5 m/s
Air viscosity	1.81e-05 kg/ms
Air density	1.293 kg/m3
Force	29.4N

3. RESULT AND DISCUSSION

3.1 CFD Simulation

Specific details of the procedures taken as well as the explanation (based on our limited comprehension of these incredibly complex software tools and mathematical models) are providedin the subsequent paragraphs

Figure 2 shows the effected of wind speed on wind turbine blades, presented using contour plot**.** Note that the contour line on upper blade and lower blade are the same. It can be seen that the wind speed close to the blades ranges from close to 0 (in front of the blade) to around 13.37 m/s (at the back of the blade).

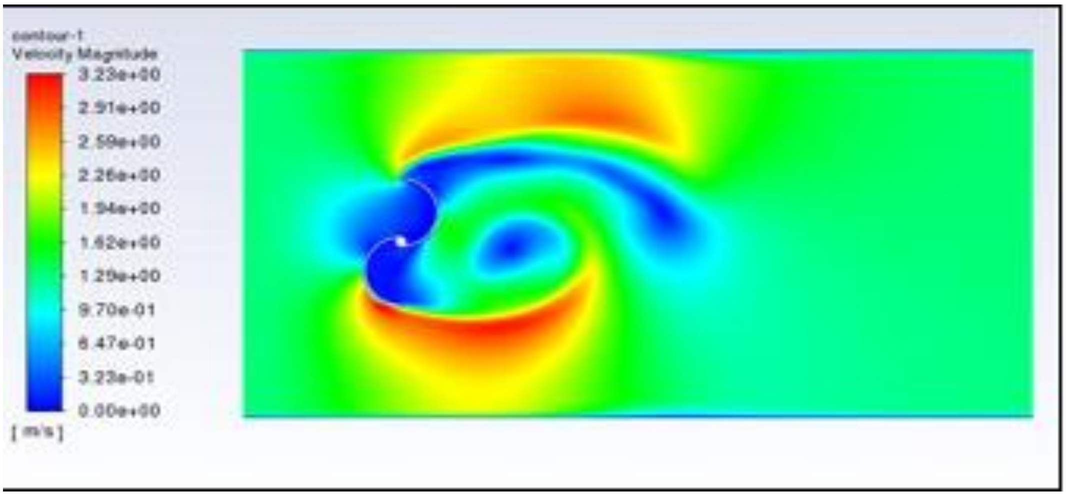

Figure 4. Contour line illustrating the wind speed on wind turbine blades at different time

Figure 5 demonstrates a time evolution of wind velocity of a single point inside the rotation region, used for measurement, in the simulation grid as marked in figure 4. It can be seen that the wind velocity varies up and down as the blades spin around The dropped values correspond to the moment where one of the blades coincide with the measuring point. Hence, the frequency of the dropped wind velocity can be used to estimate the rotational speed for the wind turbine. As a result, for a wind speed of

6.5 m/s, the rotational speed is equal to 744 rpm. Consequently, other parameters can be calculated i.e.the angular velocity is 60.90 rad/s. The aspect ratio is 1.0 which is normally too low for tip speed ratio standard for 2 blade type turbine. Reynolds number greater than 2000 which means that the flow around the blade is categorized as turbulence.

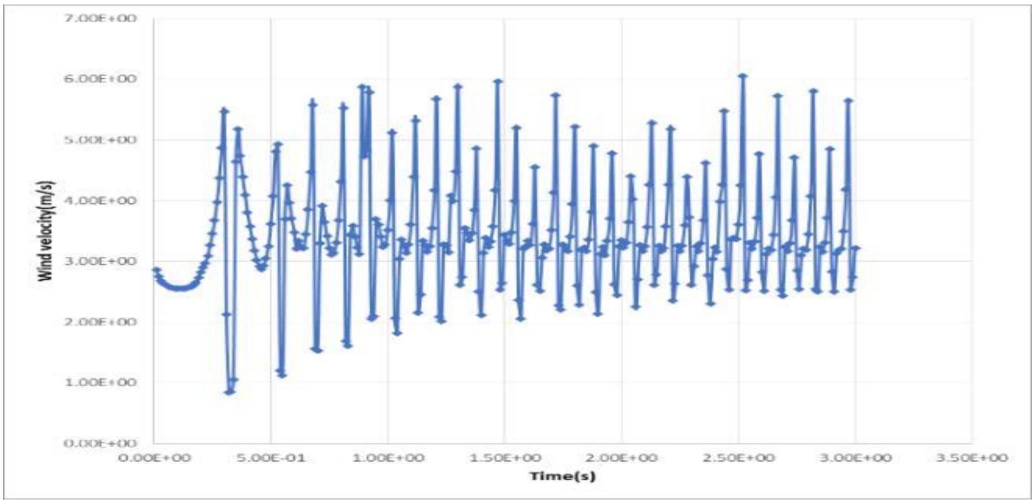

Figure 5. relationship between wind velocity and time

3.2 Finite element analysis (FEA)

Finite element analysis (FEA) is the use of calculations, models and simulations to predict and understand how an object might behave under various physical conditions. Engineers use FEA to find vulnerabilities in their design prototypes.

Equivalent Stress:

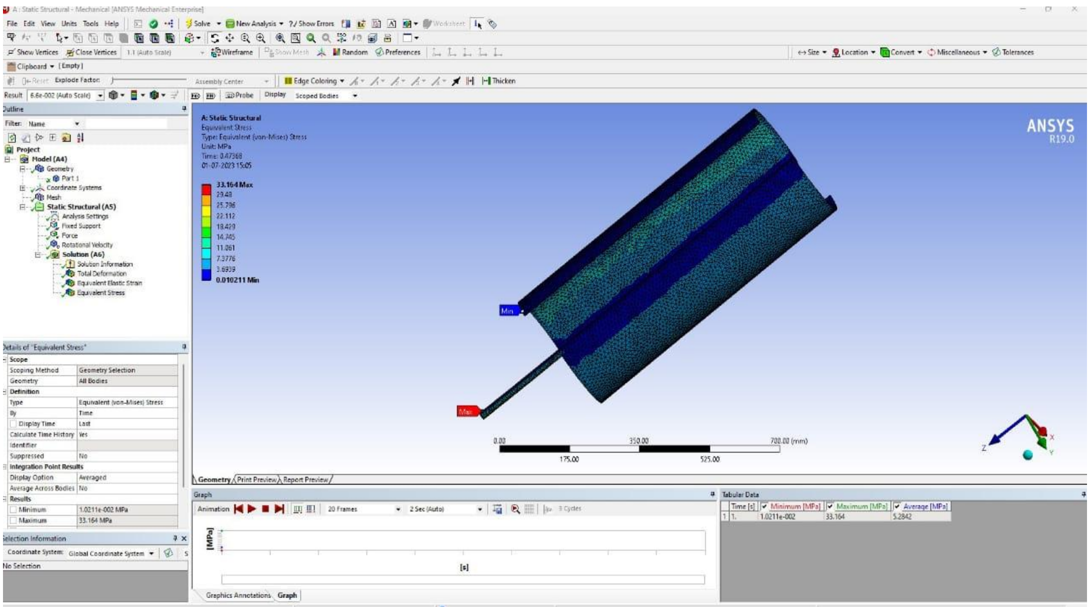

Fig.6 Equivalent stress

Equivalent Elastic Strain:

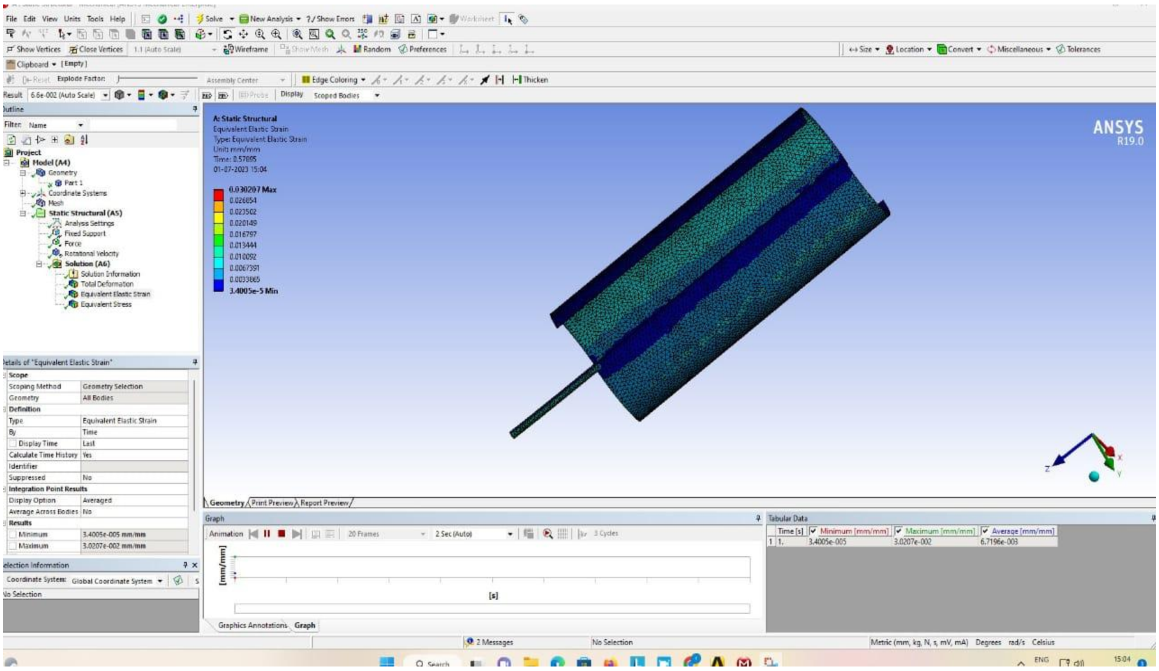

Fig.7 Equivalent stress

4. CONCLUSIONS

In this study using computational fluid dynamic, the results show that dynamic mesh method can be used to study the performance of wind turbine in pre-defined condition. The preliminary result show that the turbine has rotational speed of 60.90 rad/s at incoming wind speed of 6.5 m/s. Tip speed ratio and Reynolds number show that this wind turbine has a low efficiency but can perform at the low wind speed.

5. REFERENCES

1. Iqbal Ainur Rizki, Nadi Suprapto, Eko Hariyono, 2023. Designing vertical axis wind turbine prototype as future renewable energy Source in STEAM Learning *TEM Journal. Volume 12, Issue 1, pages 452-458, ISSN 2217-8309,* doi:10.18421/TEM121-55.

2. Umesh K. Patel, Nur Alom & Ujjwal K. Saha,2023. Aerodynamic analysis of a 2-stage elliptical-bladed Savonius wind rotor: Numerical simulation and experimental validation, *International Journal of Green Energy*, doi: 10.1080/15435075.2023.219497

3. Huaijie Xia, Song Zhang, Rongyuan Jia, Huadong Qiu, Shuhui Xu,2022. Blade shape optimization of Savonius wind turbine using radial based function model and marine *Energy Reports Volume 8*. doi: 10.1016/j.egyr.2022.09.062
4. Seyed Soheil Mousavi Ajarostaghi, Seyed Sina Mousavi, and Chandrasekhar Bhojaraju. 2022. Numerical analysis of double stack blade savonius wind turbine with Secondary Blades IOP Conf. Ser.: Earth Environ. Sci doi:10.1088/1755-1315/1149/1/012006
5. S Brusca, A Galvagno, R Lanzafame, S Mauro, M Messina. 2022. How to increase savonius power coefficient: ducted rotor performance with different overlap ratios. Journal of Physics. Conference Series. doi:10.1088/17426596/2385/1/01210
6. Heejeon Im and Bumsuk Kim,2022. Power performance analysis based on Savonius wind turbine blade design and layout optimization through rotor wake flow analysis. Energies 2022, 15, 9500. doi:10.3390/en15249500
7. Wenlong Tian, Jiaheng Bian, Guangyong Yang, Xiwen Ni, Zhaoyong Mao,2022. Influence of a passive upstream deflector on the performance of the Savonius wind turbine. *Energy Reports Volume 8*. Doi: 10.1016/j.egyr.2022.05.2
8. Mohamed R. Shouman, Mohamed M. Helal, Ahmed A. El-Haroun,2022. Numerical prediction of improvement of a Savonius rotor performance with curtaining and fin addition on blade. *Alexandria Engineering Journal, Volume 61, Issue 12*Doi**:** 10.1016/j.aej.2022.03.079
9. Kumail Abdulkareem Hadi Al-Gburi, Balasem Abdulameer Jabbar Al-quraishi Firas Basim Ismail Alnaimi, Ee Sann Tan and Ali Hussein Shamman Al-Safi. 2022.Experimental and Simulation Investigation of Performance of Scaled Model for a Rotor of a Savonius Wind Turbine. *Energies 2022, 15, 8808*.Doi:10.3390/en15238808
10. Zhongqiu Mu, Guoqiang Tong, Zhenjun Xiao, Qingyue Deng, Fang Feng, Yan Li and Garrel Van Arne, 2022. Study on Aerodynamic Characteristics of a Savonius Wind Turbine with a Modified Blade. *Energies 2022, 15, 6661* Doi: 10.3390/en151866
11. Islam HASHEM, Emeel KERIKOUS, Stefan HOERNER, Dominique Théveni 2022, Performance Investigation of a Savonius Wind Turbine withUnconventional Blade Designs Inspired by Sand Eels. The 18th International Conference on Fluid Flow Technologies Budapest, Hungary, August 202
12. Ratan U. Gaonka, Ramakrishna N. Hegde,2022. Performance of a two bladed Savonius wind turbine –A pre-investigative experimental study, to decide over ahorizontal axis machine.

International journal *of innovative research in technology. IJIRT* | Volume 8 Issue 11 | ISSN: 2349-600

13. Ketki Shirbavikar, Devendra Umbrajkar, Sakshi Deshmukh, Aniket Devadkar, Pradnya Chavan, Shreyas Dalvi,2022. Study of Variation of Aspect Ratio of Savonius Rotor. *YMER* || *ISSN: 0044-0477. VOLUME 21: ISSUE 12 (Dec) - 202287*
14. B Jeeva, S Jai Sandeep, N Ramsundram, M Prasanth and B Praveen. 2021. Experimental investigation of three bladed inclined savonius hydrokinetic turbine by using deflector plate.. doi:10.1088/1757-899X/1146/1/01200
15. Z Lillahulhaq, A Muchyiddin, R.W Suhadak, I Amirullah, F D Sandy, A C Embot.2021.Experimental Study Wind Turbine Performance of Straight- Savonius urnal of Physics: Conference Series 2117 012008. doi:10.1088/1742-6596/2117/1/012008