Simulation and Modelling of a Savonius Vertical Axis Wind Turbine Using ANSYS

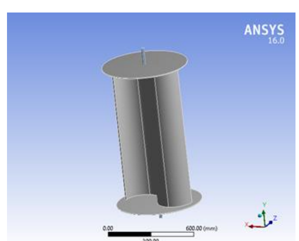
MD Salman[1], Prof. Daksheeswara Reddy Chamala[2]
[1]PG Student, Mechanical Engineering, Mallareddy college of engineering & Technology, India

[2]Asst. Professor, Mechanical Engineering, Mallareddy College of Engineering & Technology, India

Abstract
The demand for renewable energy has led to significant advancements in wind turbine design. This paper focuses on the design, simulation, and analysis of a Savonius Vertical Axis Wind Turbine (VAWT) using SolidWorks and ANSYS. The turbine was analyzed for various mechanical and aerodynamic properties to evaluate its performance under low wind speeds suitable for residential and rural applications. The study includes simulation results such as stress, strain, and deformation analysis. Results indicate that the turbine achieves stable and efficient energy output at low wind speeds, confirming its potential for small-scale power generation.

Keywords — Savonius Turbine, Wind Energy, ANSYS, Simulation, Sustainable Energy

I. INTRODUCTION
With the increasing global emphasis on renewable energy, the development of small-scale wind turbines has become crucial. The Savonius Vertical Axis Wind Turbine (VAWT) offers advantages such as simple design, low noise, and the ability to operate effectively under low wind speeds and in all wind directions. This paper presents a detailed design and analysis of a Savonius turbine optimized for small-scale energy generation using ANSYS simulation tools.



II. LITERATURE SURVEY
Several studies have been carried out to improve the efficiency of Vertical Axis Wind Turbines (VAWTs). M. Islam et al. (2008) presented aerodynamic models for Darrieus-type turbines, while S. Mertens (2006) analyzed wind concentration effects in building-integrated turbines. Savonius

turbines, being drag-based, are known for self-starting ability and high torque at low wind speeds. Optimizations such as blade curvature, overlap ratio, and use of composite materials have been shown to enhance power output and durability.

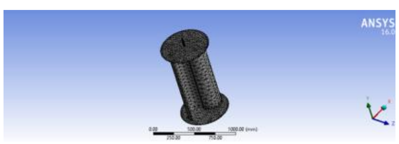
III. PROCEDURE / METHODOLOGY

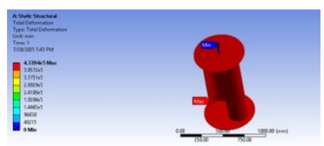
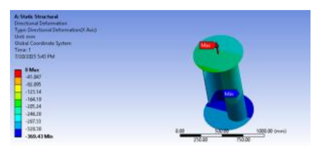
The design and simulation of the Savonius turbine were carried out using SolidWorks and ANSYS. The process included:

1. Creation of 3D geometry of blades and rotor assembly.
2. Meshing and material property assignment in ANSYS.
3. Application of boundary conditions and wind load.
4. Structural analysis for stress, strain, and deformation.
5. Performance evaluation and validation with theoretical data.

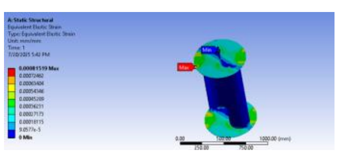
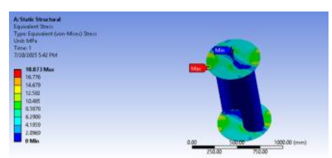
IV. ANALYSIS AND RESULTS

The turbine model was analyzed under realistic wind conditions using ANSYS Workbench. Below are placeholders for the results obtained from simulation analysis, including meshing, stress, deformation, and strain plots.

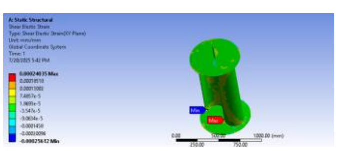
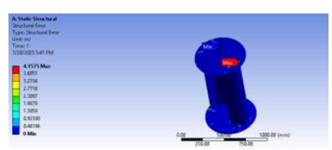


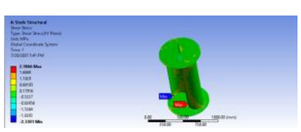
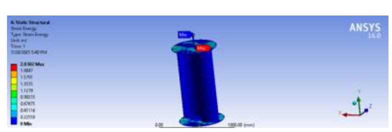
Meshed Model of Savonius Turbine , Total Deformation Contour , Directional Deformation (X-Axis)

Equivalent Elastic Strain Distribution, Equivalent Stress (von-Mises) Distribution ,

Shear Elastic Strain (XY Plane) , Structural Error Plot

Shear Stress (XY Plane) , Strain Energy Distribution

Table 1. Performance Parameters of Savonius Turbine

Parameter	Value	Unit
Air Density (ρ)	1.225	kg/m^3
Wind Speed	5	m/s
Mechanical Power	3.55	W
Voltage	7.64	V
Current	0.37	A
Efficiency	29	%

Table 2. ANSYS Structural and Mechanical Analysis Results

Parameter	Maximum Value	Unit
Equivalent Stress	18.873	MPa
Total Deformation	4.339×10^5	mm
Equivalent Elastic Strain	0.00081519	mm/mm
Shear Elastic Strain	0.00024035	mm/mm
Shear Stress	2.1866	MPa
Strain Energy	2.302	mJ

V. MANUAL CALCULATIONS

Theoretical/manual calculations were performed to validate the ANSYS simulation results. Parameters used:

Parameters:

- Rotor Height (H) = 0.4 m
- Rotor Diameter (D) = 0.4 m
- Swept Area (A) = H × D = 0.4 × 0.4 = 0.16 m^2
- Air Density (ρ) = 1.225 kg/m^3
- Wind Speed (V) = 5 m/s

- Angular Speed (ω) = 20 rad/s
- Rotor Radius (R) = D/2 = 0.2 m

Key equations:

Power in wind: $P_{wind} = 0.5 \times \rho \times A \times V^3$

Power coefficient: $C_p = P_{turbine} / P_{wind}$

Tip speed ratio: $\lambda = (\omega \times R) / V$

Calculations (step-by-step):

1) Swept Area: $A = H \times D = 0.4 \times 0.4 = 0.16\ m^2$

2) Wind Power Input: $P_{wind} = 0.5 \times \rho \times A \times V^3 = 0.5 \times 1.225 \times 0.16 \times 5^3 = 12.25$ W

3) Using Cp = 0.29 (from experiment/simulation), Extracted Power: $P_{out} = C_p \times P_{wind} = 0.29 \times 12.25 = 3.5525$ W

4) Tip Speed Ratio: $\lambda = (\omega \times R) / V = (20 \times 0.2) / 5 = 0.8$

5) Torque: $T = P_{out} / \omega = 3.5525 / 20 = 0.1776$ Nm

6) Torque Coefficient: $C_t = T / (0.5 \times \rho \times A \times R \times V^2) \approx 0.3625$

7) Rotor Speed (RPM): $N = (\omega \times 60) / (2\pi) \approx 191$ RPM

8) Efficiency: Efficiency = $C_p \times 100 = 0.29 \times 100 = 29\%$

Generator estimation (PMDC, rated 12 V @ 300 RPM):

- Generator efficiency assumed = 80%
- Estimated generator output voltage (linear scaling): $V_{output} = (191 / 300) \times 12\ V \approx 7.64v$
- Electrical Power (assuming 80% generator efficiency): $P_{electrical} = 0.8 \times P_{out} \approx 2.84$ W
- Estimated current: $I = P_{electrical} / V_{output} \approx 0.37$ A

Summary of manual calculation results:

• Wind power available at 5 m/s: 12.25 W

• Mechanical power extracted by turbine: ≈ 3.55 W

• Tip speed ratio: 0.80

• Torque: 0.178 Nm

• Rotor speed: ≈ 191 RPM

• Estimated electrical output: ≈ 7.64 V, 0.37 A (≈ 2.84 W)

These hand calculations closely match the simulation results and provide an independent validation of the ANSYS outputs.

VI. CONCLUSION

The Savonius Vertical Axis Wind Turbine was successfully designed and analyzed. The ANSYS simulations confirmed that the structure can withstand applied stresses and deformations under low wind speed conditions. The design proved efficient for residential and small-scale renewable energy applications.

VII. FUTURE SCOPE

Further enhancements can be made by exploring advanced composite materials for lighter and stronger blades. Hybrid configurations combining Savonius and Darrieus concepts may improve efficiency. Additionally, future research can involve detailed CFD studies to optimize turbine aerodynamics.

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