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PERFORMANCE IMPROVEMENT IN COMBINED SAVONIOUS AND DARRIEUS TURBINE

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Abstract*-Savonius turbine has low tip speed ratio & low efficiency and Darrieus turbine has low start-up characteristics. Combined rotor has better efficiency than Savonius and higher starting torque than three bladed Darrieusrotor.In view of the above, three different types of models were going to be designed and analysed. The Savonius rotor was a two bucket system having fixed overlap. In combined rotor model Savonius mounted at middle of three bladed ϕ-rotor Darrieus. Moreover, good aerodynamic performance of the combined rotor could be expected by the presence of the Darrieus rotor on top which having no wake been formed downstream of the combined rotor. The analysis of the turbine was done by twisting the angle of blades, i.e. (0^o, 13^o,45^o) respectively. There is a strong impact noted on the performance of the turbine, when the angles of the blades were twisted.

Keywords-Savonious, darrieus, Turbine, Combine, Angle

INTRODUCTION

With a growing focus on renewable energy, interest in design of wind turbines has also been expanding. Wind energy is the most potential renewable energy resource low cost compared with convention fossil resources. Wind energy can help in reducing the dependency on fossil fuel. Many countries including India realized the importance of wind energy as important power resources. Necessary measures are being taken up across world to harness maximum power from wind and its effective utilization in power production. It has been predicted that roughly 10 million MW of wind energy continuously available on surface of earth. India's wind power potential is 45000MW. In today's market, the horizontal axis (windmill) turbine is the most common type in use; but, vertical axis (Darrieus) turbines have certain advantages. Darrieus turbines, which are lift-driven, have a higher power potential than the horizontal, or drag-driven turbines. Darrieus turbines require an external energy source to bring the device to a minimum rotational speed. This paper presents design, construction and testing of a vertical axis (Darrieus) wind turbine with 3 blades, starting solely from the low energy of the wind. A separate drag device (Savonius type turbine) on the middle of an existing Darrieus turbine was mounted to make the turbine self-start at low wind speed.

OBJECTIVE

This research presents a design concept and test results for a hybrid vertical axis turbine (Twisted Savonius along with Darrieus) in order to improve the turbine performance and produce higher torque. Combined rotors have better efficiency than savonius and higher starting torque than three bladed darrieus rotor.

SCOPE

- Electricity production using Renewable energy without polluting the environment.
- By using this concept, we can conserve non-renewable energy sources for our future generation.
- Achieving higher efficiency with twisted blades.
- No need of higher longitudinal space.

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- We can use it in normal human environment.
- For generating power for our daily uses by installing it in common public places.

PROBLEM STATEMENT

Many journals investigate the performance of the Savonius and Darrieus turbine both on the starting and running characteristics. According to those results, the both turbine has different disadvantages:

Savonius turbine: LowTip Speed Ratio (TSR ≈<1), Low Efficiency

Darrieus turbine:Lowstart-up characteristics

Here we are going to investigate the performance of Savonius and Darrieus turbine using twisted savonius blades instead of vertical blades. The twisted blades helps the turbine to rotate even at minimum wind flow and as well as at different directions of wind flow. Hence the efficiency and performance of the turbine will be increased without major incur of costs and time.

CATIA

CATIA enables the creation of 3D parts, from 3D sketches, sheetmetal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing &BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die.

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify,[1] and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies.

CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA v5 is able to read and produce STEP format files for reverse engineering and surface reuse.

COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. The technique is very powerful and spans a wide range of industrial and non-industrial application areas.

CFD codes are structured around the numerical algorithms that can be tackle fluid problems. In order to provide easy access to their solving power all commercial CFD packages include sophisticated user interfaces input problem parameters and to examine the results.

THE PHYSICAL MODEL

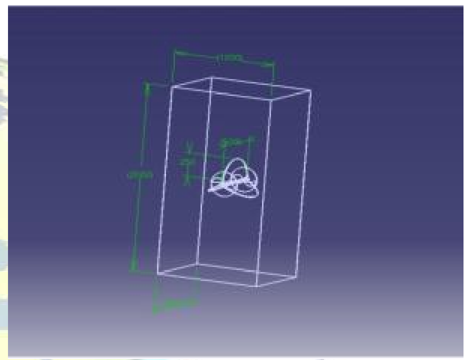

Fig no.1 Model Diagram

SPECIFIC DIMENSIONS

Blade airfoil	NACA 0012
Number of Darrieus blades	3
Radius of Darrieus -rotor	250mm
Height of blade	500mm
Chord of blade	100mm
Radius of Savonius	200mm
Height of Savonius	400mm
Diameter of the shaft	16mm
Diameter of rotor	400mm

DESIGN

DIFFERENT VIEWS IN CATIA V5

Part Design

1.Savonious Rotor

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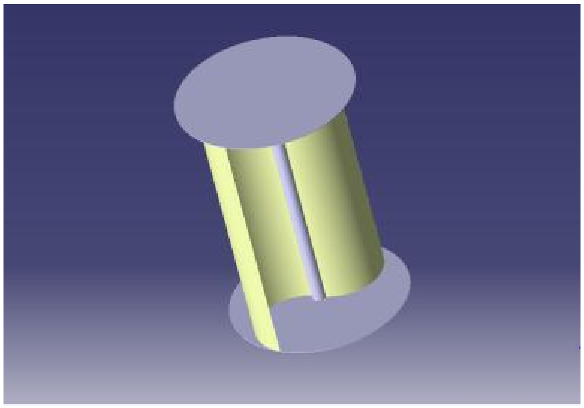
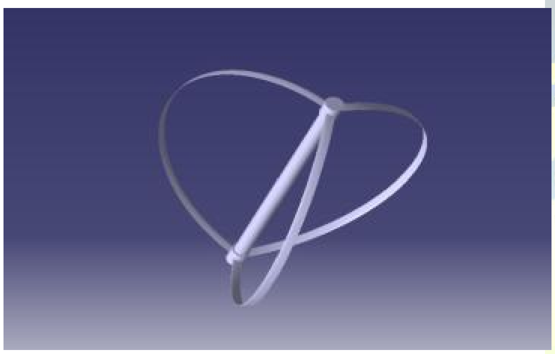
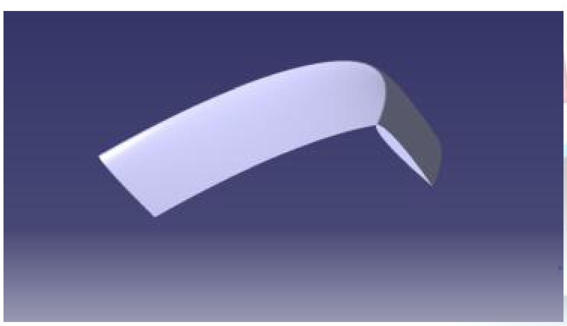


Fig no.2 Savonious Rotor

2.Darrieus Turbine



3.Airfoil Profile Cut Section



1.CombinedSavonious And Darrieus For Blade Angle 0°

Fig no.5 Combined SavoniousAnd Darrieus For Blade Angle 0°

2.CombinedSavonious And Darrieus For Blade Angle 13°

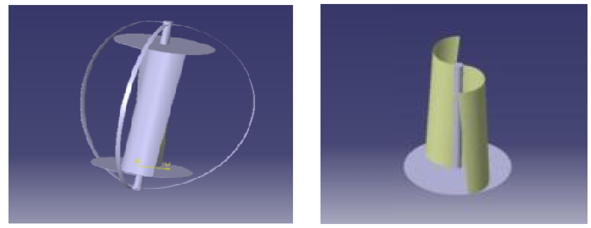


Fig No.6 Combined SavoniousAndDarrieus For Blade Angle 13°

3.Combined SavoniousAndDarrieus For Blade Angle 45°

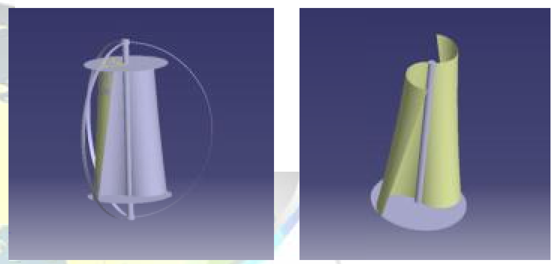


Fig no.7 Combined SavoniousAnd Darrieus For Blade Angle 45°

ANALYSIS

THE COMPUTATIONAL MODELLING

The three dimensional (3D) computational domain of the combined three bladed Darrieus and three bucket Savonius rotor along with the boundary conditions is shown. The 3D computational model of combined rotor was generated in gambit of the Fluent CFD software such that the dimensions of the rotor are exactly same as those of the rotor previously experimented. The computational domain resembles the original test section of the wind tunnel in Cross-section. The general geometric properties of combined Darrieus-Savonius rotor are not constant with varying span section of the rotor for which 3D analysis was performed.

1. For Blade Angle-0°
Computational Modelling

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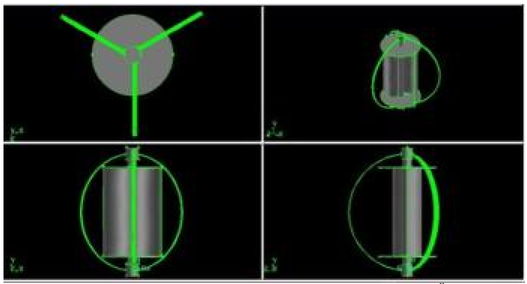
Fig no.7 Computational Model for 0°

Meshing Model

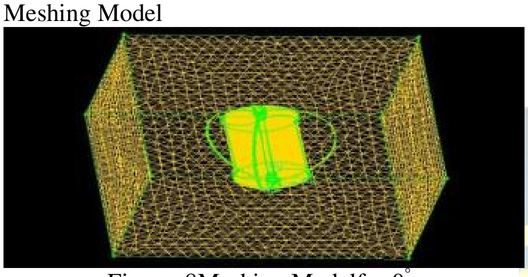
Fig no. 8Meshing Modelfor 0°

Pressure contour

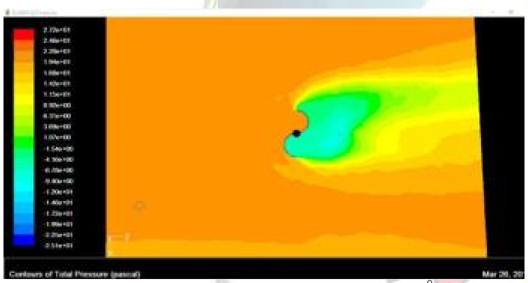
Fig no.8 Pressure contourfor 0°

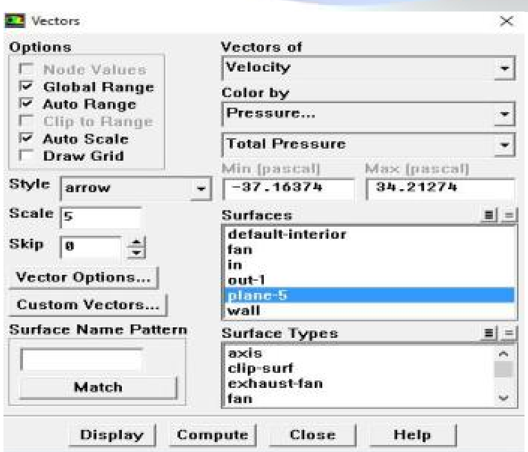

Fig no.9 Pressure value for 0°

Velocity contour

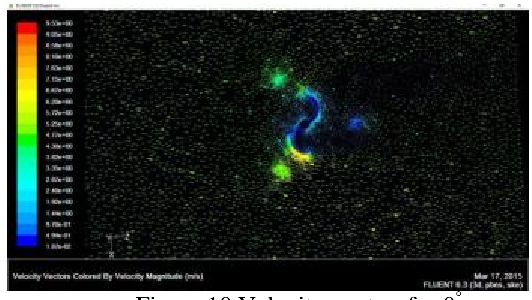
Fig no.10 Velocity contourfor 0°

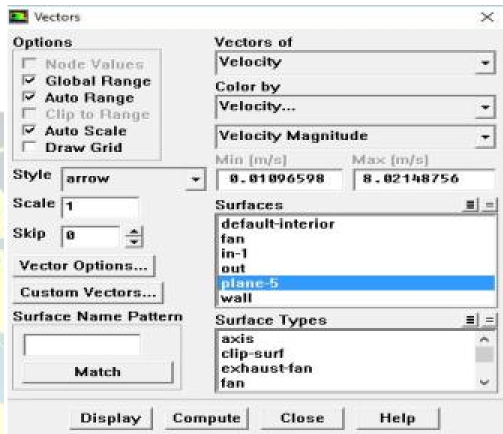

Fig no.11 Velocityvalue for 0°

2. For Blade Angle-13°

Computational Modelling

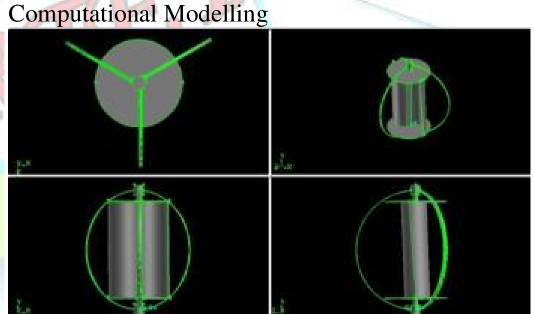
Fig no.12 Computational Model for 13°

Meshing Model

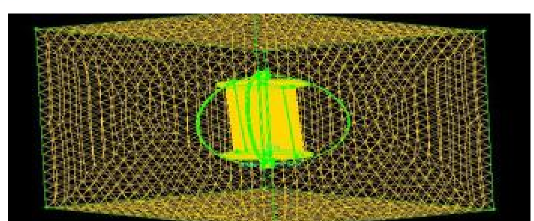
Fig no.13 Meshing Model for 13°

Pressure contour

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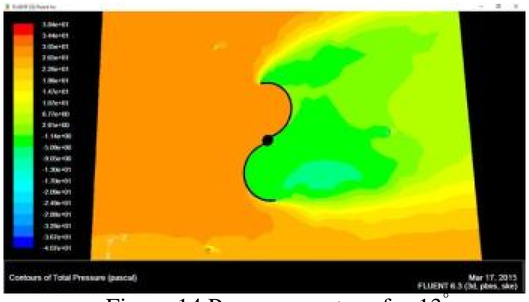

Fig no.14 Pressure contour for 13°

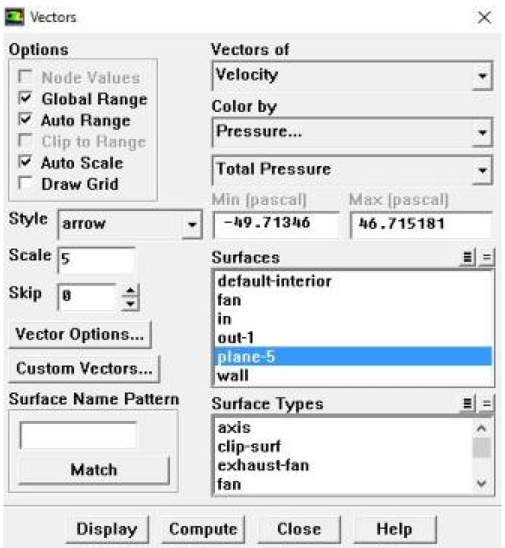

Fig no.15 Pressure value for 13°

Velocity contour

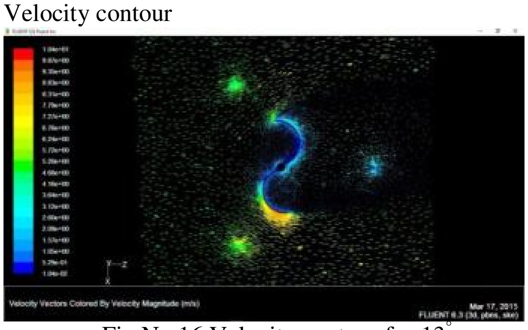

Fig No.16 Velocity contour for 13°

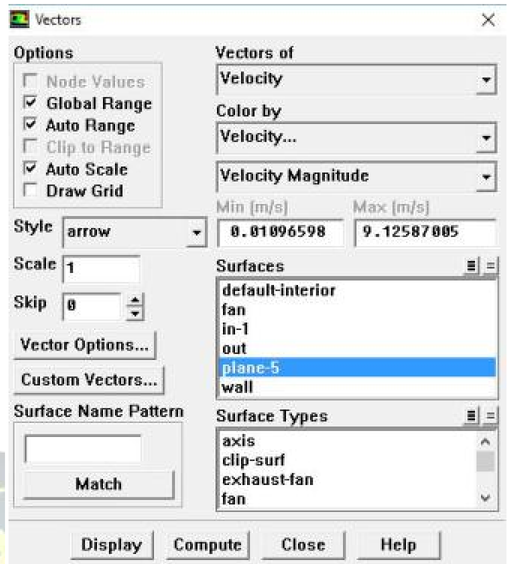

Fig No.17 Velocity value for 13°

3. For Blade Angle-45°

Computational Modelling

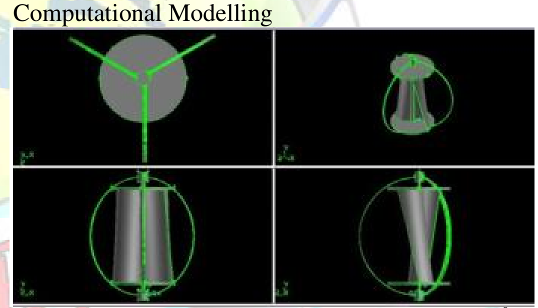

Fig No. 18 Computational Model for 45°

Meshing Model

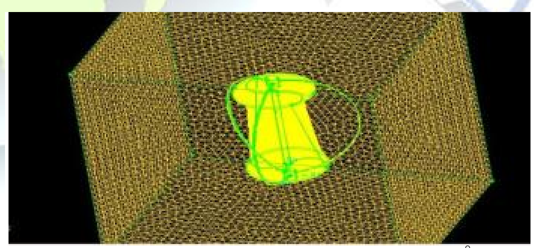

Fig No.19 Meshing Model for 45°

Pressure contour

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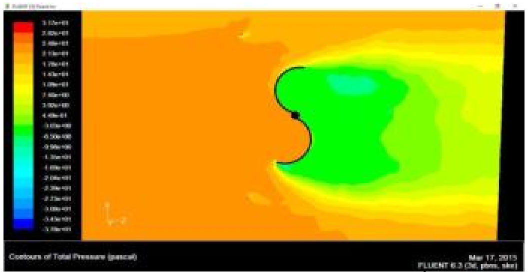

Fig no.20Pressure contour for 45°

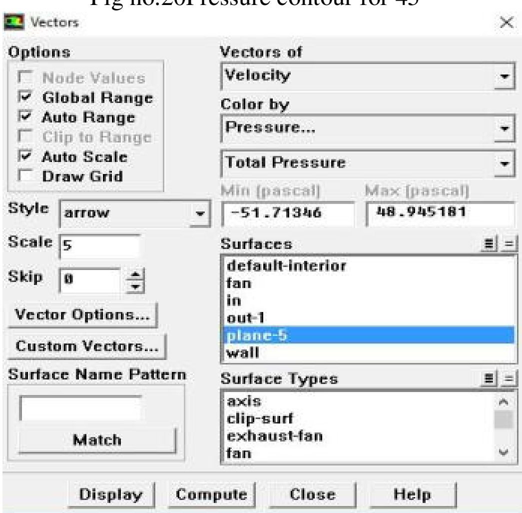

Fig no.21Pressure value for 45°

Velocity contour

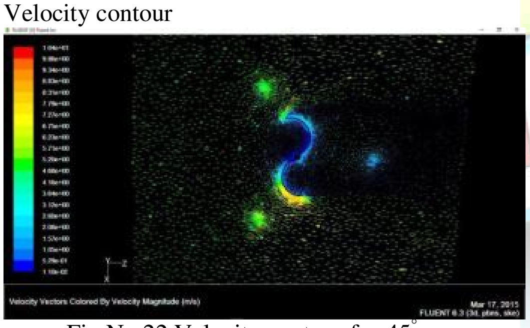

Fig No.22 Velocity contour for 45°

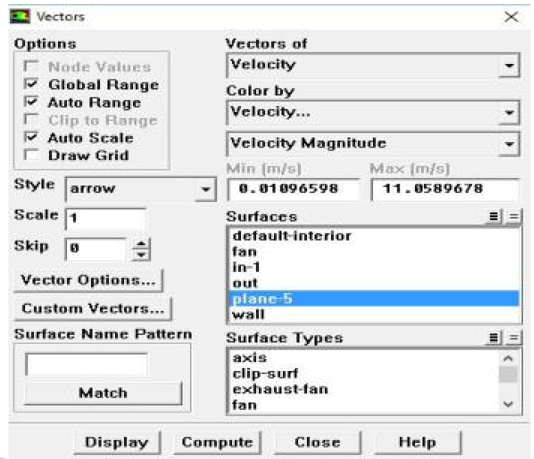

Fig No.23Velocity value for 45°

CFD RESULTS

Angle	Atmospheric velocity of wind m/s	Wind velocity at turbine m/s	Pressure at turbine Pascal
0 deg	5	8	34.21
13 deg	5	9	46.71
45 deg	5	11	48.94

DESIGN CALCULATION

TIP SPEED RATIO

Tip Speed Ratio (TSR)

$$= \frac{Tip\ speed\ of\ the\ blade}{Wind\ speed}$$

RPM

$$\text{RPM} = \frac{Velocity \times Tip\ Speed\ Ratio \times 60}{\pi \times Diameter\ of\ the\ turbine}$$

ANGULAR VELOCITY

$$\text{Angular Velocity} = \text{RPM} \times \frac{2\pi}{60}.\quad rad/sec$$

POWER

$$\text{Power} = \frac{1}{2}\rho AV^3.\quad MW$$

TORQUE

$$\text{Torque} = \frac{Power}{Angular\ velocity}.\quad \text{N.M}$$

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RESULTS

RESULT TABLE

Angle	Height m	Dia m	Density kg/m^3	TSR	Pressure Pascal	Velocity m/s	RPM	Angular velocity rad/sec	Power MW	Torque Nm
0	5	5	1.225	6	34.21	8	183.3	19.2	7.84	408.33333
13	5	5	1.225	6	46.71	9	206.3	21.6	11.16281	516.7969
45	5	5	1.225	6	48.94	11	252.1	26.4	20.38094	772.0052

GRAPHICAL RESULTS

RPM

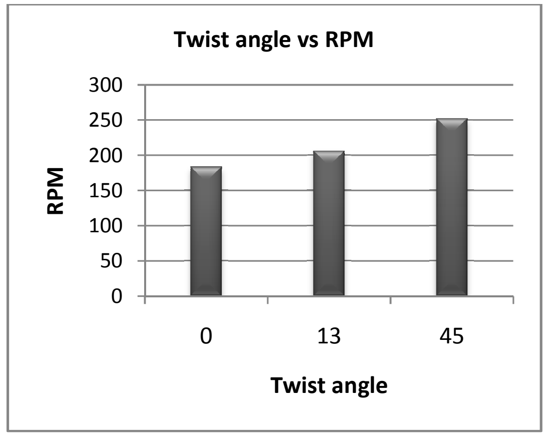

Fig No.24Graph between Twist angle and RPM for three models

Power

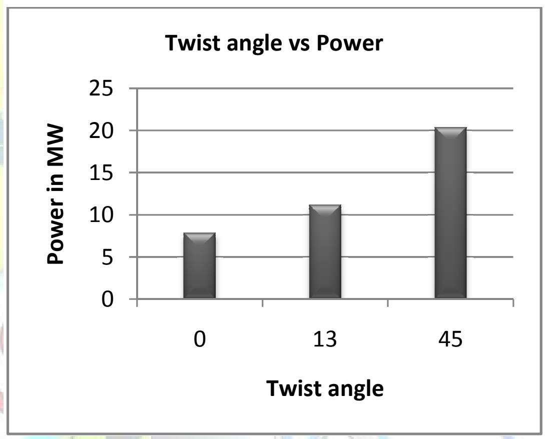

Fig No.25Graph between Twist angle and POWER for three models

Torque

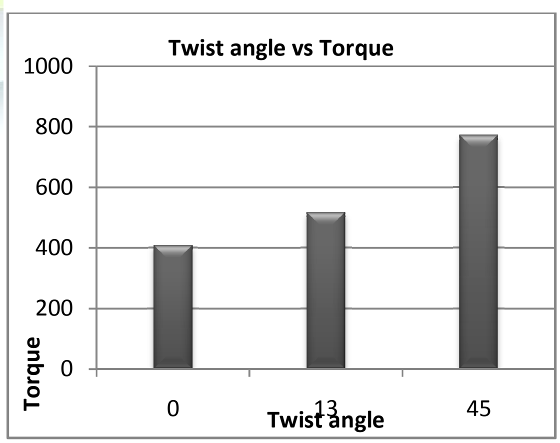

Fig No.26Graph between Twist angle and TORQUEfor three models

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CONCLUSION

In the present study, an attempt was made to study the unsteady aerodynamics of a combined three-bladed Darrieus and three-bucket Savonius rotor. The power coefficients of the combined rotor were first evaluated and the results were validated with the experimental results. Several aerodynamic models have been analyzed in this paper which is applied for better performance prediction and design analysis of combined three-bladed Darrieus-Savonius wind rotor. It has been found that, each of these three models has their strengths and weaknesses. Though among these three models, the model with blade twisted at 45^0 are considered to be the most accurate models according to the numerical analysis. It is clear that the power and torque generated in the **45°** model was higher than the other two models. Finally to conclude, future study could entail comparison of various turbulence models so as to determine the turbulence model that could predict the optimum performance of the present rotor.

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