International Journal For Technological Research In Engineering
Volume 2, Issue 6, February-2015 *ISSN (Online): 2347 - 4718*

COMPARITIVE STUDY OF A SINGLE STAGE SAVONIUS WITH A COMBINED SAVONIUS-THREE BLADED DARRIEUS

Shrikant G.Gawade[1], Prof. D. S. Patil[2]
G.H. Raisoni College of Engineering
Wagholi, Pune

Abstract: The vertical axis wind turbine are low cost, simple in construction, self starting at low wind speed inexpensive, omni-directional, required no yaw mechanism continuously orient towards the wind direction. A combined Savonius-Three Bladed Darrieus Vertical Aixs Wind Turbine got man advantages over individual darrieus or savonius wind turbine. Combined rotor have better efficiency than savonius and higher starting torque than three bladed darrieus rotor. But less work was reported yet on Combined Vertical Axis Wind Turbine (CVAWT). In view of the above, two different types of models were designed and fabricated, one simple single stage savonius rotorand the other combined savonius-darrieus rotor. The savonius rotor was a two bucket system having fixed overlap. In combined rotor model savonius mounted at middle of three bladed H-rotor darrieus. These rotor were tested in a subsonic wind tunnel fabricated in department. Power coefficient were calculated for both rotor from present investigation, it has been seen that power coefficient for combined rotor is considerably improved as compaired to power coefficient of individual savonius rotor.

Keywords: Savonius, Darrieus, power Coefficient

I. INTRODUCTION

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 [1].Keeping goal to harnessed maximum power from wind, the present work on combined vertical axis wind turbine has been performed. S.J. Savonius first developed the vertical axis savonius rotor in late 1920 [2].Concept of Savonius developed by cutting cylinder into two halves along the central plane and rotating two semi cylindrical surfaces sideways along the cutting plane that the cross section resembled the letter's . Savonius tested more than 30 models in the wind tunnel to determine the best geometry. Savonius also conducted test in natural wind. He concluded that savonius rotor would run at higher speed natural wind than in wind tunnel for same wind speed. He reported maximum efficiency 37%.After few decade lots of research has been reported on savonius rotor. J.L.Menet presented study on single and double stage savonius & reported 0.30 power coefficient [3] A.A.Kadametal perform test on savonius in open wind as well as wind tunnel and investigated maximum power coefficient 0.29.[4]. Single , two and three stage savonius rotor system with identical stage aspect ratio keeping swept area same U.K.Saha [5] concluded that two stage savonius rotor perform better than other. Researcher presented two blade savonius rotor is more efficient than three and four blade savonius rotor. As blade number increase reverse torque also increase leads to decrease the net torque [6-7]. Burcin attempted curtain arrangement to prevent negative torque that occurs on the convex surface of savonius wind rotor [8]. S. Brusca et al [9] analyzed performance of H-rotor with different aspect ratio resulted low aspect ratio H-rotor perform better. J. Kjellin measure power coefficient of 12 kW H-rotor VAWT 0.29 at tip speed ratio 3.3[10]. 3D simulation highlighted that start-up capability of H-Darrieus influenced by presence of the over tip vertices and secondary flow [11-12]. After studying savinous and H-Rotor researcher observe that power coefficient not exciding 0.35 for individual performance of any VAWT. R.Gupta et al [13] made attempt for combined savonius-darrieusrotor, tested in wind tunnel reported maximum power coefficient 0.51 which was considerable improved. Fang Feng combined savonius with H-rotor investigated that H-rotor self started at low tip speed ratio [14]. As savonius rotor was low efficient but self starting at low speed. On the other hand H-rotor darrieus high efficient but not self stated. On combining this two rotor high efficient and self started VAWT were fabricated and successfully tested [15-16].

- Only few work have been conducted on the combined designs of VAWT rotor.
- Combined design of darrieus and savonius rotors exhibit better power coefficient than individual savonius or darrieus rotor

Considering all these, in this paper performance has been conducted in an open circuit subsonic wind tunnel to measure power coefficient of combined single stage savonius- three bladed H-rotor darrieus VAWT. Savonius rotor mounted at middle of darrieus rotor in present design.

Nomenclature

Specification
NACA0021 Airfoil section
Nb number of blades
V wind speed
A swept area of rotor

P	aerodynamic power
Cp	power coefficient
U	ωR peripheral velocity of the rotor
ρ	specific mass of the air
λ	velocity coefficient

Geometrical parameter of the prototype

a	diameter of shaft inside rotor
d_i	mean diameter of cylinder (chord of each paddle)
D	diameter of rotor
D_f	diameter of end plate
e	gap between two paddle: main over lap
H	height of rotor
R	radius of rotor
α	aspect ratio
β	over lap ratio

II. DESIGN PARAMETERS

This section described selection of blade geometry profiles and dimensions for required power output.

Design Velocity-

Average wind velocity 5m/s is chosen for designed wind turbine.

No. of Blades-

As reverse torque increases with increase of number of blades, for maximum torque H-rotor selected with three blades and for Savonius two blades selected which is an optimum number of blades.

Diameter of Turbine-

The relationship between required power output and the design wind speed was utilized to evaluate the diameter of the turbine.

Aspect Ratio-

Ratio of rotor height to chord length (mean diameter of cylinder).

III. SAVONIUS ROTOR

Great self-starting ability and high staring torque main advantage of drag-type vertical axis wind turbines like Savonius rotor.

$\alpha = H/d_i$

Value of α around 4.0 lead to best power coefficient for a conventional Savonius rotor. The best efficiencies are obtained for values overlap ratio β 20 to 30%.

$\beta = e/d$

Table-I Geometry Parameter of Savonius rotor

Total height of the rotor	H	400mm
Nominal diameter of the paddles	d_i	200mm
Diameter of the shaft	a	16mm
Diameter of rotor	D	400mm

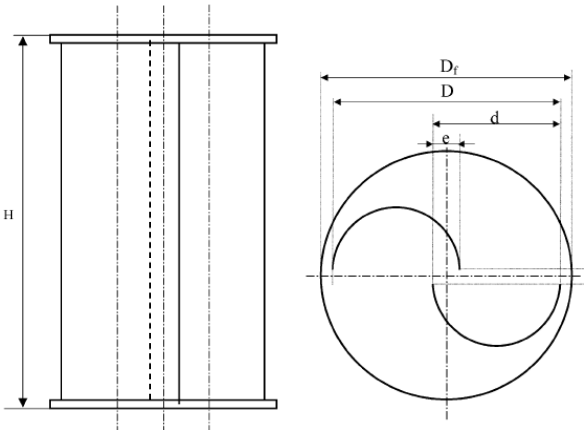

Fig.1 Single Stage Savonius Rotor

IV. COMBINED SAVONIUS-H-ROTOR

Fig.2 shows the combined VAWT and the geometric parameters of combined VAWT are show in table 2.

Fig.2 Combined Savonius-H-darrieus Rotor.

Table-2 Geometry Parameter of H-rotor

Blade aerofoil	NACA 0021
Number of blades H-rotor	3
Radius of H-rotor	250m
Height of blade	500mm
Chord of blade	100mm
Radius of Savonius	200mm
Height of Savonius	400mm

Selection of Aerofoil-

For Darrieus type VAWT, NACA 00XX series of airfoil are used and more specifically NACA 0015, NACA 0018 and NACA 0021 are more frequently used. High value of lift coefficient and low value of drag coefficient for NACA 0015 makes it most suitable from aerodynamic characteristics. But at the same time NACA 0015 is considered too thin for this design. Therefore NACA 0021 is chosen for this design considering its thickness and aerodynamics performance.

V. EXPERIMENTAL SET-UP

The tests were carried out in an open-circuit subsonic wind tunnel fabricated in the department. The operating range of the wind tunnel is 0-35m/s. Brief description of tunnel wag given in the paper[15].The status of the turbines in the wind tunnel is shown in fig.3.The wind tunnel speed has been controlled by changing the frequency of inventor.

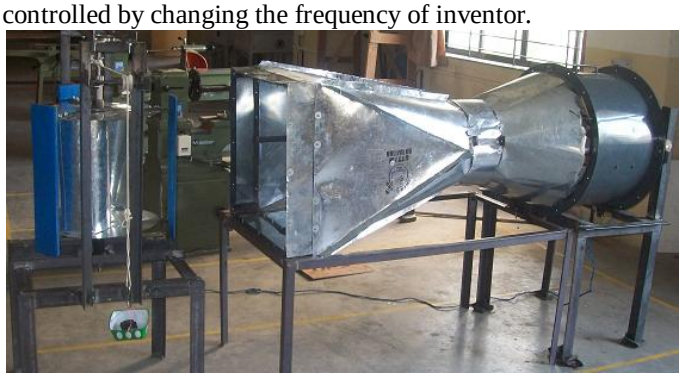

Fig.3 Test Set-Up Savonius middle of H-rotor in Wind Tunnel

VI. RESULT

The performance of wind rotor expressed in the form of power coefficient (C_p) versus wind speed. Power coefficient is ratio of mechanical power develop by rotor to maximum wind power.

$$\mathrm{Cp} = \frac{\mathrm{P\ rotor}}{\mathrm{pmax}}$$

Mechanical power produce by rotor, $P_{rotor}$is calculated as product of aerodynamic force transmitted by the bucket to rotor and speed of blade. In present experiment, reading is taken in steady-state flow condition. Using following equation performance evaluation completed.

$$Protor = (\frac{2\pi NT}{60})$$

$$T = Fr$$

$$F = (m - s)g$$

$$Pmax = (\frac{1}{2}\rho AV^3)$$

TABLE NO. 3 - SINGLE STAGE SAVONIOUS ROTOR

SINGLE STAGE SAVONIOUS		
V (m/s)	N (rpm)	Cp
2.2	89	0.093
3.7	121	0.118
4.9	195	0.139
6.5	289	0.159

TABLE NO. 4–COMBINED SAVONIOUS H-ROTOR

COMBINED SAVONIOUS H-ROTOR		
V (m/s)	N (rpm)	Cp
3.7	130	0.3099
5.2	213	0.329
7.2	459	0.385

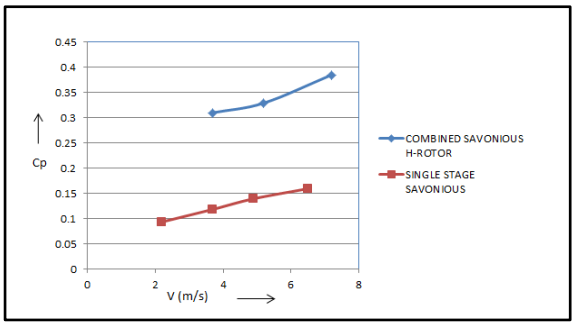

Fig. 4 Performance Comparison of Single Stage Savonious Rotor Vs. Combined Rotor

VII. CONCLUSION

In this paper attempt was made to measure performance of individual Savonius and combined Savonius-H-rotor savonius at middle of H-rotor. Following conclusion has been summarized from the experimental study.

- Combined H-rotordarrieus with savonius, shows self starting ability at low wind speed 3m/s.
- The maximum Cp for savonius of 0.16 is obtained while for combined savonius-H-rotor maximum Cp achieved by rotor 0.39 which is much more improved towards power production.

The present combined Savonius-H-darrieus rotor can be suitably placed in the built environment where it can harness maximum power from wind and, would self start in low wind condition.

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