Design and Performance Analysis of Low Speed Vertical Axis Windmill

L.Natrayan, T.Amalesh , Sirajuddin Syed

Abstract: ***Renewable energy resources (RES) are much needed one, due to the existing use of fossil fuel which emits CO2 during utilization. This CO_2 causes global warming which means increasing earth temperature. Mostly CO_2 emission occurs in power generation. This global warming and CO_2 emission make earth is unsuitable for living. To avoid this, we have the best solution that is RES. In this RES, wind energy is the most likely unit for power generation; it is not only for power generation, and it can be used for pumping of water too. We use this wind energy from an earlier day. Wind energy is the most abundantly available clean form of renewable energy in the earth crust. Wind turbines produce electricity by using the power of wind to drive an electric generator. The present study aims to design and develop a low-speed vertical axis wind machine. New types of Savonius wind turbine 3D model was created using SolidWorks software. Numerical simulation of the new design for parametric investigation using ANSYS Fluent, evaluating the performance of the newly developed rotor and fabricate the proposed model.***

Index Terms: Low speed; windmills, vertical axis, drag.

List of symbols:
θ: Angle of attack of wind
U1: Wind speed approaching the turbine (undisturbed wind)
m: Mass of the selected wind strip of width dr
L: Length of blades (third dimension, not visible in the figure)
R: Radius of turbine
r: distance to the selected point from the center
ω: Rotational speed (Rad/s)
λ: Tip speed ratio
T: Torque
A: Area of turbine faced to the wind

I. INTRODUCTION

Renewable energy resources (RES) are much needed one, due to the existing use of fossil fuel which emits CO2 during utilization. This CO2 causes global warming which means increasing earth temperature [1]. Mostly CO2 emission occurs in power generation. This global warming and CO2 emission make earth is unsuitable for living. To avoid this, we have the best solution that is RES. In this RES, wind energy is the most likely unit for power generation. Wind energy is the most abundantly available clean form of renewable energy in the earth crust. Wind turbines produce electricity by using the power of wind to drive an electric generator. There is a current global need for clean and renewable energy sources [2]. Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies. Renewable energy will not run out ever. Other sources of energy are finite and will someday be depleted. Fossil fuels are non-renewable and require limited resources, which are dwindling because of high cost and environmentally damaging retrieval techniques. With populations increasing exponentially and our natural resources being strained by increases in demand, it is more important than ever to invest in renewable energy [3]. Our consumption of fossil fuels as energy has been traced to be a leading cause of environmental issues. The byproduct of fossil fuel consumption is carbon dioxide, which has been named to be a primary constituent leading to Global Warming [4]. So, the need for cheap and obtainable resources is much needed. An efficient and more feasible alternative option is wind energy. Though several renewable energy sources exist, Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such as sunlight, the wind, rain, tides, waves, and geothermal heat [5]. Renewable energy often provides energy in four critical areas: electricity generation, air, and water heating/cooling, transportation, and rural (off-grid) energy services.

A. *Wind Energy*

Wind energy is a form of solar energy. Wind energy describes the process by which wind is used to generate electricity [6]. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Mechanical power can also be utilized directly for specific tasks such as pumping water. The Wind is the movement of air from an area of high pressure to an area of low pressure [7-8]. The wind exists because the sun unevenly heats the surface of the Earth. As hot air rises, cooler air moves in to fill the void. As long as the sun shines, the wind will blow. And as long as the wind blows, people will harness it to power their lives. Wind energy is a fast-growing sector to meet the global demand for clean, renewable energy [9]. The traditional Horizontal Axis Wind Turbines (HAWTs) have already seen the widespread implementation and effective power production.

Revised Manuscript Received on 30 May 2019.
***** Correspondence Author
Natrayan L*, School of mechanical and building sciences, VIT Chennai, Tamilnadu, India-600127.
T.Amalesh, Department of mechanical engineering, SSN College of engineering, Chennai, Tamilnadu. India- 603110.
Sirajuddin Syed, School of mechanical and building sciences, VIT Chennai, Tamilnadu, India-600127.

However, these turbines are limited to larger footprint area that also characterized with high wind speeds [10].
To overcome these constraints, interest has been redeveloping in Darrieus (lift type) VAWTs to allow harnessing of wind energy in low wind zones with relatively lower noise pollution. To design and manufacture turbines which display sufficient efficiency and performance, the optimal design parameters need to be selected [11-12].
In the recommended design one side of the turbine blades are facing the wind direction to capture maximum force while another team is edging the blades to have minimum opposite torque. Wind tunnel test is recommended for the proposed turbine model. Pope et al. [13] reported two independent fluid flow formulations were used to investigate the aerodynamic performance of a Zephyr VAWT. The change of 2-D transient and 3-D time averaged numerical predictions of the power coefficient exhibit a comparable change in magnitude to the experimental results. This indicated that both mathematical formulations provide correct trends for the changes of flow dynamics and power coefficients for changes in the VAWT geometry. The literature review on the windmill suggests that an improvement in the torque developed by the vertical axis machine is essential since they are operated in low speed and domestic conditions. Aim of this research to design a new type of Savonius wind turbine, evaluating the performance of the newly developed rotor, numerically simulation of the original design for parametric investigation and fabricate the proposed design.

II. EXPERIMENTAL SETUP

The reason behind the efficiency drop in the Savonius turbine is the ripple force that acts on another blade (concave side) which also offers the air resistant. So design modifications in the turbine blades are to be done to compensate for the loss in efficiency. To avoid the air resistance and rippling force acting on the curved blade side, an innovative concept is derived which is the dynamical changing of swept area of the turbine blade. For that purpose, we use cloth (nylon taffeta rated at 190T or micro fabric with water repellent finish) instead of metal (surface). In each rotation, the cloth folds and unfolds to produce the required motion. The remaining setup is similar to the old Savonius wind turbine. Thus it is possible for generating more power at very lower wind speed (cut in speed) conditions.

In this project, we are focusing on the new design concept of the Savonius wind turbine. For that new design, we have designed an excellent supporting structure to get stable operation. For that, we require a blade frame, x-type bottom supporting structure, Centre supporting structure, hollow square box, waterproof cloth, bearing and dc motors for folding purpose

A. Solution

To avoid the air resistance and rippling force acting on the curved blade side, an innovative concept is derived which is the dynamical changing of swept area of the turbine blade. For that purpose, we use cloth (nylon taffeta rated at 190T or micro fabric with water repellent finish) instead of metal (surface). In each rotation, the cloth folds and unfolds to produce the required motion. The remaining setup is similar to the old Savonius wind turbine. Thus it is possible for generating more power at very lower wind speed (cut in speed) conditions.

B. Experimental Setup Parameters

In this project, we focused on the new design concept of the Savonius wind turbine. For that new design, we have designed an excellent supporting structure to get stable operation. For that, we require a blade frame, x-type bottom supporting structure, Centre supporting structure, hollow square box, waterproof cloth, bearing and dc motors for folding purpose.
In this phase, solid work 2015 software is used to design the new design of vertical axis wind turbine. This software used for making windmill develop and also used for analyzing the structural stability. Blade frame, x-type bottom support, supporting square box and central supporting shaft are designed using SolidWorks software. Table 1 shown below contains the details of the dimensions of the blade frame structure and supporting square box

Table.1 blade frame dimension

Name	Length	Width	Height
Blade frame	0.9	0.03	0.6
Supporting square box	0.2	0.2	0.2

Table 2 shown below contains the details of the dimensions of supporting structure.

Table 2 .supporting X-bottom structure dimension

Name		Dimension(Meter)
Central supporting beam		1.5
X-bottom support	Length (horizontal)	1
	Length (vertical)	1

C. SolidWorks Model Design

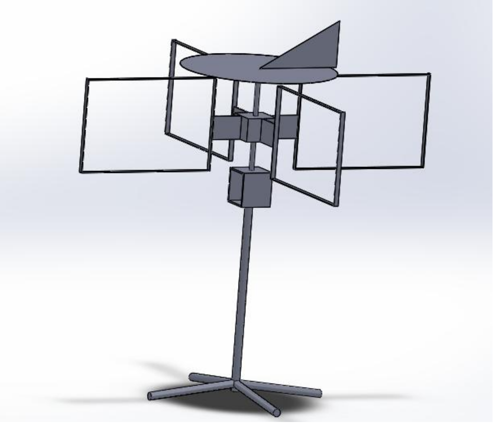


Fig 1: Model of Windmill

III. EXPERIMENTATION

Experimentation was contacted on the new Savonius windmill design in the velocity ranges from 1m/s to 5 m/s. The rpm and air in/out speed are noted for each iteration. The sensor is not used for the folding function, and hence the cloth is made to move horizontally to get the required output.

Fig 2: Experimental Model of Windmill

A. Processed new design

From the study on several research papers, it is clear that the vertical axis Savonius wind turbine can absorb a high amount of energy from the wind. But its output is low, and hence its efficiency is too low which is around 8% to 14%. The reason behind this efficiency drop is the ripple force that acts on another blade (concave side) which also offers the air resistant.

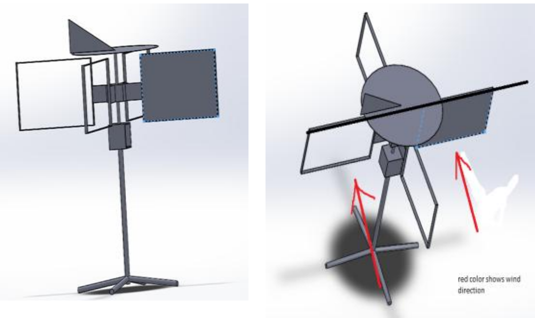


Fig 3: SolidWorks design of windmill with cloth setup

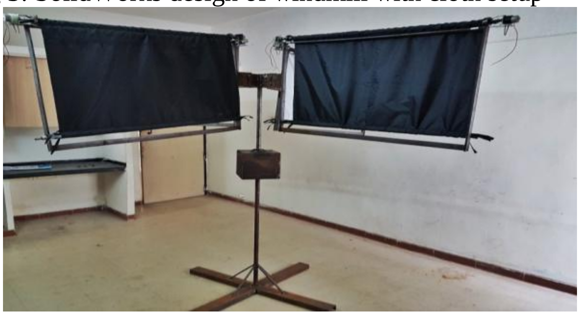


Fig 4: Experimental setup- New Windmill Design

To overcome this, the overlapped blade design is used which increase the efficiency by 22% to 24%. But still, it is not sufficient for promoting this turbine for energy generating device. Because the horizontal axis wind turbine has a higher efficiency than the Savonius turbine, so design modifications in the turbine blades are to be done to compensate for the loss in efficiency.

IV. Numerical Model

3D modeling is created using SolidWorks 2015. Here we also use some basic mathematical models for the new design [14]. Momentum theory and blade element theories are the most common and fundamental methods to evaluate aerodynamic forces on the wind rotor as well as to the flow field. Therefore, an empirical approach was proposed in this study to determine rotor performance. Linear momentum theory neglects all wake losses and flows field interaction, and this leads to deviation of expected return from the experimental results, and the aspect ratio of the proposed VAWT was used in its dimensioning for the different power outputs and applications [15]. In the initial stage, blade element theory was implemented by using simple flat plate theory with the assumption of low rotational speed for modeling the wind rotor performance. Due to mismatch with experimental data, linear momentum theory was used to guide the experiment, while the empirical model was used for analyzing the rotor performance. Assumptions: Flow is incompressible, Flow is steady, in viscid, irrational, Flow is one-dimensional and uniforms through the rotor, No flow interactions between flow layers or streamlines [16].

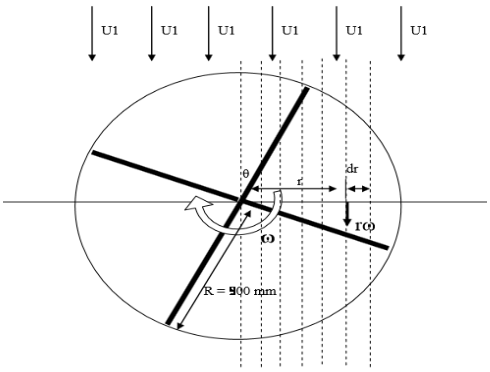


Fig 5: Nomenclature

A. Model Calculation and Formulae

Dimensions of the frame and blade are as given in the table above. The kinetic energy of the air is converted into rotational energy using blades [17]. Then the shaft is connected to the electrical power by generators or the shaft energy also used as hydraulic pumping or grinding purpose.

Angular velocity (ω) = (3.14*N)⁄(60)… ……. (5.1)

The rotor area is divided into thin flat strips along the span of the turbine and linear momentum theory is applied to each wind strip, (Refer fig 3.1)

Angular velocity (ω) = V/R ………………….. (5.2)

V=linier velocity of blade, R=radius of blade

Linear velocity (V) =√ (u^2-v^2) ……………. (5.3)

u =velocity of air at entry, v = velocity of air at the exit

By linear momentum theory, it can be found that the momentum change of each wind strip colliding on the blade at distance r from the shaft which is rotating at the angular speed of ω (see Fig.5) would be

$F = (U1 - r\omega)$………….. (5.4)

Mass flow of wind strip at velocity U1 length L and width of dr, in kg/s, is $m=\rho.U1.L.dr$………….. (5.5)

Force acting on the turbine blade due to momentum change of each wind strip, is

$(r) = \rho.U1.L.(U1 - r\omega)dr$ ………….. (5.6)

Torque on the shaft $(r) = \rho.U1.L.(U1 - r\omega).r.dr$……. (5.7)

By integrating torque for r = 0 to r = R, the resultant force on the rotor due to the wind is obtained as

$T = \int (r)\ R\ 0.dr$…….. (5.8)

$T = [(U12.r2)2 - U1.\omega.r3/3\ ]0R$…………..(5.9)

$T = [(U12.R2)/2 - U1.\omega.R3/3]$ ………….. (5.10)

$TurbinePower = T.\omega$………….. (5.11)
Turbine power = (2*3.14*N_rpm*T)/60…. (5.12)
Wind power= $(0.5.\rho.\, u_1^{3}.A)$ ….. (5.13)
Efficiency $Cp = TurbinePower/$ wind power [20] … (5.14)
$A = 2R.L$ ……….. (5.15)

B. Computational work

3-D Savonius wind rotor with two blade configuration and new blade profile design with four blade configuration is modeled using SolidWorks software, and ANSYS 15.0 is used as CFD package to simulate the work. Momentum equations, turbulent kinetic energy, and vortices rate of turbulent kinetic energy have been solved computationally using the ANSYS Fluent [18]. Boundary conditions and other parametric units are kept the same for all the test cases done.

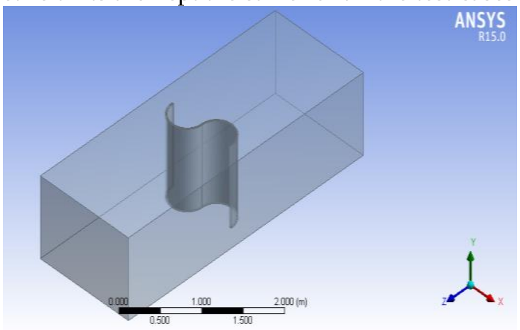


Fig 6: 3D view of the newly designed rotor blade with fluid domain

A pressure based solver with absolute velocity at steady state is used. Energy equation ON and K-Omega turbulence model with air as the working fluid. Inlet and exit boundary conditions are given, and the work is initialized using standard initialization to compute from the inlet. Second-order spatial discretization equations are used to solve the case [19].

V. RESULT AND DISCUSSION

A. New Windmill Design Experimental Data

In this section, 1st the numerical simulation results are discussed then we compare the simulation results to experimental results. In this numerical simulation analysis is done in the same software which is called Ansys workbench Fluent 15.0. The following types are analyzed in the Ansys software.

1. Savonius windmill with two-blade configuration
2. Overlapped Savonius windmill with two-blade configuration
3. New design Savonius windmill with four blade configuration

Table 3 New Windmill Design Experimental Data

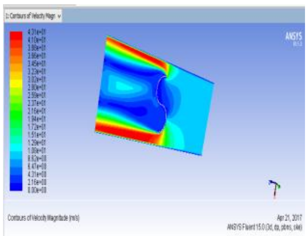
Air inlet (m/s)	Air outlet (m/s)	RPM	Velocity ω (rad/s)	T (Nm)	Shaft Power (Watt)	Air power (Watt)	Efficiency
1	0.8	3	0.314	0.229563	0.1201378	0.31428	0.382264
2	1.6	7	0.732667	0.882725	1.07790472	2.51424	0.42872
3	2.6	11	1.151333	1.959486	3.76003498	8.48556	0.44311
4	3.5	13	1.360667	3.601951	8.16842332	20.11392	0.406108
5	4.4	16	1.674667	5.650252	15.7704799	39.285	0.401438

B. Predicted Results from CFD Software

5.2.1 Savonius Windmill with Two Blade Configuration Table:

Table 4 Savonius Wind Mill with Two Blade Configuration

Air velocity (M/S)	Concave side Δp (Pa) p1	p2	Δp1	Convex side Δp (Pa) p3	p4	Δp2	DP (Pascal)	FORCE (N)	TORQUE(Nm)	UIN(M/S)	v out (M/s)	w (M/s)	ω (rad/s)	N rpm	P shaft (watt)	P air (watt)	efficiency (η)
1	101330	101319.6	10.37	101329	101319.6	9.37	1	0.54	0.27	1	0.83	0.56	0.278	2.65	0.07	0.31	0.238
2	101362	101318.4	43.65	101360	101318.8	41.18	2.47	1.33	0.67	2	1.72	1.03	0.513	4.90	0.34	2.51	0.136
3	101412	101317.4	94.65	101404.34	101317.4	86.99	7.66	4.14	2.07	3	2.84	0.97	0.483	4.61	1.00	8.49	0.118
4	101488	101315.3	172.66	101478.37	101315.3	163.03	9.63	5.20	2.60	4	3.60	1.74	0.871	8.33	2.27	20.11	0.113
5	101578.3	101314.8	263.55	101563.66	101314.8	248.91	14.64	7.91	3.95	5	4.73	1.62	0.811	7.74	3.20	39.29	0.082
6	101694	101311.6	382.41	101675.37	101311.6	363.78	18.63	10.06	5.03	6	5.68	1.95	0.973	9.29	4.89	67.88	0.072
7	101822.6	101308.2	514.37	101799.44	101308.2	491.26	23.11	12.48	6.24	7	6.58	2.40	1.199	11.45	7.48	107.80	0.069
8	101979	101305	674	101950.3	101299.3	650.96	23.04	12.44	6.22	8	7.24	3.40	1.700	16.24	10.57	160.91	0.066
9	102149	101300.8	848.21	102109.58	101300.8	808.79	39.42	21.29	10.64	9	8.55	2.82	1.408	13.45	14.98	229.11	0.065
10	102330	101307	1023.05	102279.8	101307	972.85	50.2	27.11	13.55	10	9.54	2.99	1.494	14.27	20.25	314.28	0.064
15	103600	101254	2345.98	103479.98	101254	2225.96	120.02	64.81	32.41	15	14.38	4.27	2.137	20.42	69.26	1060.70	0.065
20	105370	101187.3	4182.72	105183.2	101187.3	3995.92	186.8	100.87	50.44	20	18.93	6.45	3.223	30.79	162.54	2514.24	0.065
25	107675	101094.6	6580.38	107372.73	101094.6	6278.11	302.27	163.23	81.61	25	23.78	7.71	3.853	36.81	314.45	4910.63	0.064
AVERAGE EFFICIENCY																	0.093640303



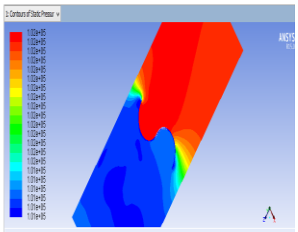


Fig 7: Velocity profile` Fig 8: Static pressure profile

5.2.2 Overlapped Savonius Windmill with Two Blade Configuration:

Table 5 Overlapped Savonius Wind Mill with Two Blade Configuration

Airvelocity (M/S)	Concave side Δp (Pa) p1	p2	Δp1	Convex side Δp (Pa) p3	p4	Δp2	DP (Pascal)	FORCE (N)	TORQUE(Nm)	UIN(M/S)	v out (M/s)	w (M/s)	ω (rad/s)	N rpm	P shaft (watt)	P air (watt)	efficiency (η)
1	101322.8	101321	1.79	101322	101321.3	0.7	1.09	0.47	0.24	1	0.31	0.95	0.47	4.53	0.11	0.31	0.356
2	101329	101320	8.98	101328.35	101322	6.35	2.63	1.42	0.71	2	1.26	1.55	0.78	7.42	0.55	2.51	0.219
3	101338	101328	10	101337.16	101332	5.16	4.84	2.61	1.31	3	1.57	2.55	1.28	12.20	1.67	8.49	0.197
4	101355	101320	35	101352	101325	27	8	4.32	2.16	4	2.52	3.11	1.55	14.85	3.36	20.11	0.167
5	101376	101312.5	63.46	101371.4	101320	51.4	12.06	6.51	3.26	5	3.16	3.87	1.94	18.51	6.31	39.29	0.161
6	101400	101320	80	101390.19	101330	60.19	19.81	10.70	5.35	6	4.41	4.07	2.04	19.45	10.89	67.88	0.160
7	101426	101304.9	121.13	101414	101320.2	93.84	27.29	14.74	7.37	7	5.16	4.74	2.37	22.62	17.45	107.80	0.162
8	101464.1	101310	154.09	101444.24	101325.2	119.05	35.04	18.92	9.46	8	5.88	5.43	2.71	25.93	25.67	160.91	0.160
9	101498	101300	198	101475	101320.4	154.64	43.36	23.41	11.71	9	6.63	6.09	3.04	29.08	35.63	229.11	0.156
10	101538	101300	238	101511.13	101323.3	187.79	50.21	27.11	13.56	10	6.84	7.30	3.65	34.87	49.47	314.28	0.157
15	101813	101285	528	101746.05	101325.8	420.27	107.73	58.17	29.09	15	9.48	11.63	5.81	55.55	169.11	1060.70	0.159
20	102216.5	101215.4	1001.13	102091.36	101277.9	813.42	187.71	101.36	50.68	20	14.80	13.45	6.72	64.25	340.83	2514.24	0.136
25	102722.2	101155.9	1566.35	102624.3	101253.7	1370.56	195.79	105.73	52.86	25	18.48	16.84	8.42	80.43	445.00	4910.63	0.091
AVERAGE EFFICIENCY																	0.175

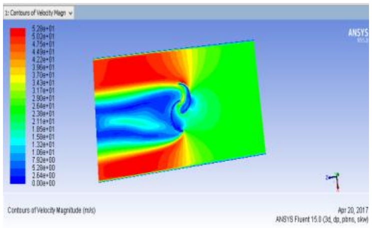


Fig 9: Velocity profile

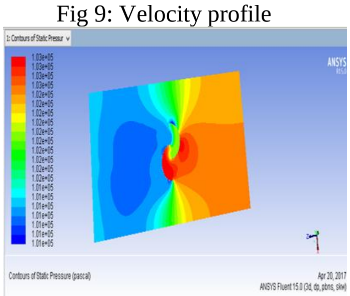


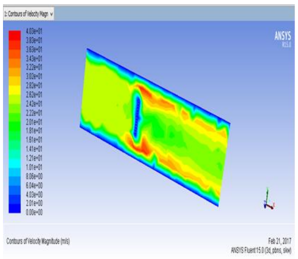
Fig 10: Static pressure profile

5.2.3 New Design Savonius Windmill with Four Blade Configuration

International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Table 6 New Design Savonius Wind Mill with Four Blade Configuration

VELOCITY	P1 (Pa)	P2 (Pa)	DP (Pa)	FORCE (N)	TORQUE (Nm)	V1 (M/s)	V2 (M/s)	DV (M/s)	U (M/s)	W (rad/s)	N(rpm)	P(shaft) (Kw)	P(wind) (Kw)	EFFICIENCY
1	101321.1	101319.9	1.24	0.6696	0.6696	0.8	0.715992	0.063678	0.356869	0.356869	3.409577	0.000238959	0.00031428	0.76
2	101324.5	101320.4	4.14	2.2356	2.2356	1.8	1.4408	0.582048	1.078933	1.078933	10.30827	0.002412062	0.00251424	0.96
3	101331	101320.9	10.14	5.4756	5.4756	2.8	2.4	1.04	1.442221	1.442221	13.77918	0.007897023	0.00848556	0.93
4	101338.1	101321.5	16.58	8.9532	8.9532	3.8	3.2	2.1	2.04939	2.04939	19.58016	0.0183486	0.02011392	0.91
5	101349	101322.3	26.73	14.4342	14.4342	4.7	4	3.045	2.467793	2.467793	23.57764	0.035620611	0.039285	0.91
6	101360.6	101323.2	37.32	20.1528	20.1528	5.7	4.8	4.725	3.074085	3.074085	29.37024	0.06195142 5	0.06788448	0.91
7	101379	101324.4	54.62	29.4948	29.4948	6.7	5.8	5.625	3.354102	3.354102	32.04556	0.098928567	0.10779804	0.92
8	101392	101325.7	66.34	35.8236	35.8236	7.7	6.4	9.165	4.281355	4.281355	40.90466	0.153373546	0.16091136	0.95
9	101411.1	101327.1	83.96	45.3384	45.3384	8.8	7.5	10.595	4.60326	4.60326	43.98019	0.20870443	0.22911012	0.91
10	101432.4	101328.7	103.65	55.971	55.971	9.5	8	13.125	5.123475	5.123475	48.9504	0.286766041	0.31428	0.91
15	101572.5	101292.7	279.77	151.0758	151.0758	14.5	13	20.625	6.422616	6.422616	61.36258	0.970301894	1.060695	0.91
20	101767.7	101353.7	413.95	223.533	223.533	19.6	16.8	50.96	10.09554	10.09554	96.45424	2.256687141	2.51424	0.90
25	102018.6	101306.6	711.98	384.4692	384.4692	24.6	21.5	71.455	11.9545	11.9545	114.2149	4.596135922	4.910625	0.94
AVERAGE	AVERAGE													0.91



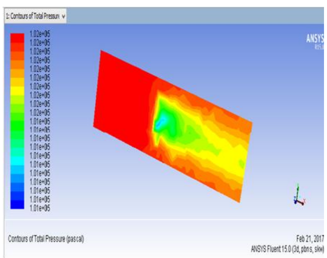


Fig 11: Velocity profile `   Fig 12: Static pressure profile

C. Comparison *results*

Figure 13 shows the variation of rpm concerning inlet air velocity. From the figure, we understand that when there is an increasing air velocity, the rpm gets increased. From the figure, it's clear that the rpm of the new design is high than others. But surprisingly the overlapped Savonius windmill gets more rpm than over experimental values. The last one is a standard Savonius windmill.

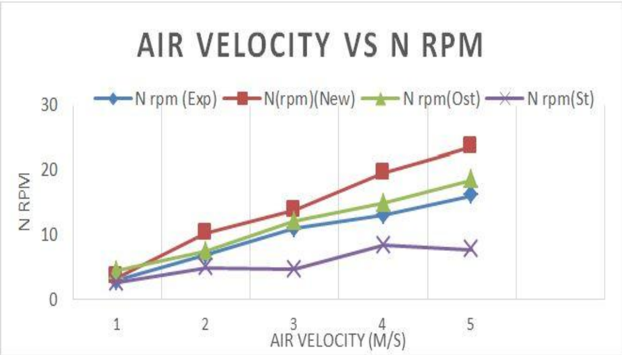


Fig 13: Air velocity Vs N_{rpm}

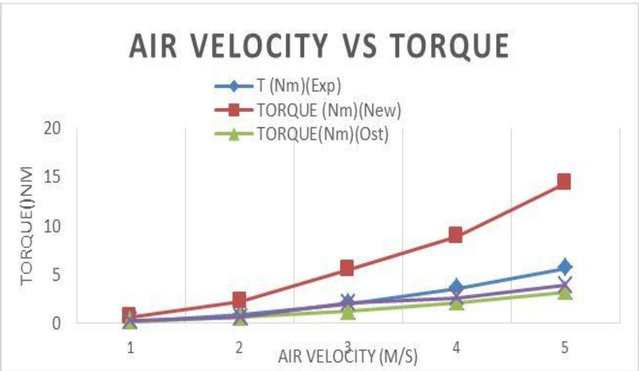


Figure 14: Air Velocity Vs Torque

From the figure 14, its shows that the torque is very high on the new blade design. The experimental setup has the 2nd highest torque. The surprisingly standard Savonius windmill has more torque than the overlapped Savonius windmill.

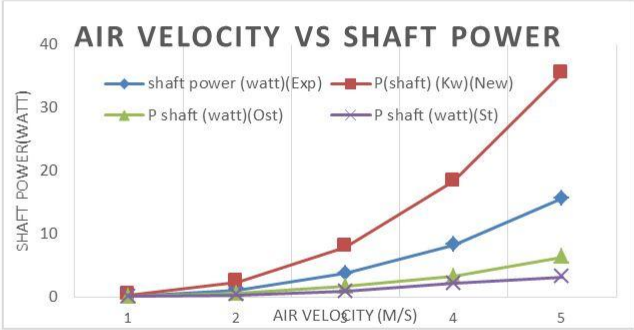


Fig 15: Air Velocity Vs Shaft Power

From the figure 15, the shaft power gets more values with increasing air velocity. From the figure 15, the shaft power of the new is higher than the others. The newer design has high amounts of rpm and torque than others. The 2nd point is, there is no force acting on it like ripple force and air resistance due to the rotation of a blade on its axis. The experimental setup gets 2nd place in shaft power list. The order is followed by overlapped Savonius windmill then standard Savonius windmill.

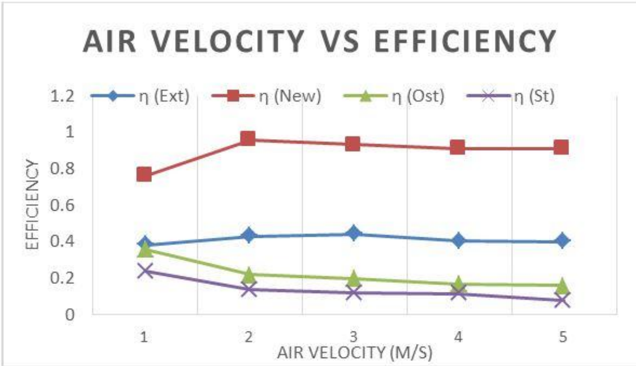


Fig 16 Air Velocity Vs Efficiency

From figure 16, the efficiency of the newer design is higher than the other two design. The experimental model gets 2nd place in the efficiency battle. The order is followed by overlapped Savonius windmill and standard Savonius windmill. The efficiency drops occur in the other two systems is due to the force acting on it like ripple force and the air resistance which arises due to the rotation of a blade on its axis.

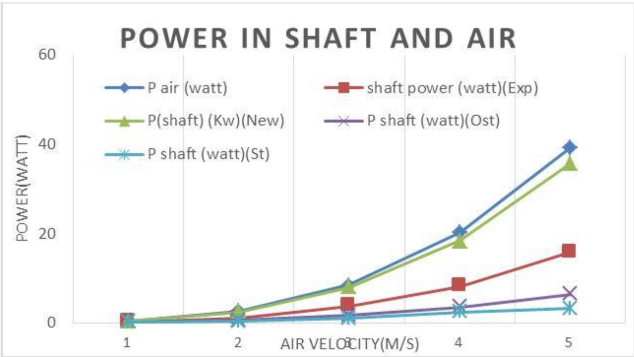


Fig 17 Power in Shaft and Air

In figure 17 the comparison is carried out for the power availability in the shaft as well as air. It clearly shows that the new design can extract more power from the air.

The experimental design is also able to achieve more power than conventional models. So, the modification has some improvement in the performance.

VI. CONCLUSION

A numerical simulation has been developed to investigate the performance improvement in the modified Savonius windmill design. An experimental setup has been designed to validate the numerical results. But the absence of the sensor system, the required design can't be made. So the experimental setup is done by an alternate technique which will offer somehow the approximate results. From the results, the new design has higher efficiency than conventional models. But it's not able to match the new design's effectiveness. Because of the absence folding cloth method. If it's possible to use the sensor means the efficiency of the system will increase. The efficiency of the new design concept varied from 70% to 80% from the numerical results (considering all the losses). The experimental results show that the efficiency of the system lays typically 38% to 44%. So, there is a chance to get increasing efficiency in the order.So that the new design offers more shaft power generation than the conventional one. In this new design, the blade is made up of cloth. So the overall cost comes down. For the domestic purpose, the experimental setup design is enough. For more considerable power-generating windmill, the sensor system is used for folding operations. This slow speed windmill can be installed at a lower level and suitable for the domestic purpose. Here the tradition blades are changed to air blocking clothes. For this purpose, it is proposed to dynamically adjust the swept volume of the module by adjusting its folding length which may reduce the gearbox cost and related mechanical losses. Thus it is possible for generating more power at very lower wind speed (cut in speed) conditions. A proper improvement of this system may help for large scale installation too.

REFERENCES

1. Wahyudi, B., Soeparman, S., and Hoeijmakers, H. W. M. (2015). Optimization design of Savonius diffuser blade with moving deflector for hydrokınetıc cross flow turbıne rotor. Energy Procedia, 68, 244-253.
2. L. Natrayan and M. Senthil Kumar. Study on Squeeze Casting of Aluminum Matrix Composites-A Review. Advanced Manufacturing and Materials Science. Springer, Cham, 2018. 75-83. (https://doi.org/10.1007/978-3-319-76276-0_8.)
3. Tian, W., Mao, Z., Zhang, B., and Li, Y. (2018). Shape optimization of a Savonius wind rotor with different convex and concave sides. Renewable Energy, 117, 287-299.
4. M. Senthil Kumar et. al, Experimental investigations on mechanical and microstructural properties of Al2O3/SiC reinforced hybrid metal matrix composite, IOP Conference Series: Materials Science and Engineering, Volume 402, Number 1, PP 012123. (https://doi.org/10.1088/1757-899X/402/1/012123).
5. Al-Faruk, A., and Sharifian, A. (2016). Geometrical optimization of a swirling Savonius wind turbine using an open jet wind tunnel. Alexandria Engineering Journal, 55(3), 2055-2064.
6. L.Natrayan et al. Optimization of squeeze cast process parameters on mechanical properties of Al2O3/SiC reinforced hybrid metal matrix composites using taguchi technique. Mater. Res. Express; 5: 066516. (DOI: 10.1088/2053-1591/aac873,2018).
7. Ricci, R., Romagnoli, R., Montelpare, S., and Vitali, D. (2016). Experimental study on a Savonius wind rotor for street lighting systems. Applied Energy, 161, 143-152.
8. S.Yogeshwaran, R.Prabhu, Natrayan.L, Mechanical Properties Of Leaf Ashes Reinforced Aluminum Alloy Metal Matrix Composites, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13, 2015.
9. P.Sakthi Shunmuga Sundaram , N.Hari Basker , L.Natrayan. Smart Clothes with Bio-sensors for ECG Monitoring, International Journal of Innovative Technology and Exploring Engineering, Volume 8, Issue 4, 2019, Pages 298-301.
10. Tartuferi, M., D'Alessandro, V., Montelpare, S., and Ricci, R. (2015). Enhancement of Savonius wind rotor aerodynamic performance: a computational study of new blade shapes and curtain systems. Energy, 79, 371-384.
11. Wenehenubun, F., Saputra, A., and Sutanto, H. (2015). An experimental study on the performance of Savonius wind turbines related with the number of blades. Energy procedia, 68, 297-304.
12. Vithanage, A. (2013). DESIGN AND PERFORMANCE ANALYSIS OF PITCHED-PLATE VERTICAL AXIS WIND TURBINE FOR DOMESTIC POWER GENERATION.
13. Pope, K., Rodrigues, V., Doyle, R., Tsopelas, A., Gravelsins, R., Naterer, G. F., and Tsang, E. (2010). Effects of stator vanes on power coefficients of a zephyr vertical axis wind turbine. Renewable Energy, 35(5), 1043-1051.
14. L.Natrayan et al. An experimental investigation on mechanical behaviour of SiCp reinforced Al 6061 MMC using squeeze casting process. Inter J Mech Prod Engi Res Develop., 7(6):663–668, 2017.
15. Apelfröjd, S., Eriksson, S., and Bernhoff, H. (2016). A review of research on large scale modern vertical axis wind turbines at Uppsala University. Energies, 9(7), 570.
16. Sharma, S., and Sharma, R. K. (2016). Performance improvement of Savonius rotor using multiple quarter blades–A CFD investigation. Energy Conversion and Management, 127, 43-54.
17. M. S. Santhosh, R. Sasikumar, L. Natrayan, M. Senthil Kumar, V. Elango and M. Vanmathi. (2018). Investigation of mechanical and electrical properties of kevlar/E-glass and basalt/E-glass reinforced hybrid Composites. . Inter J Mech Prod Engi Res Develop., 8(3): 591-598.
18. Muscolo, G. G., and Molfino, R. (2014). From Savonius to Bronzinus: a comparison among vertical wind turbines. Energy Procedia, 50, 10-18.
19. Hemanth RD., M. Senthil kumar, Ajith gopinath and Natrayan.L, Evaluation of mechanical properties of E-Glass and Coconut fiber reinforced with polyester and Epoxy resin matrices, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 2017, 7(5), 13-20.
20. Belabes, B., Youcefi, A., and Paraschivoiu, M. (2016). Numerical investigation of Savonius wind turbine farms. Journal of Renewable and Sustainable Energy, 8(5), 053302.