IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 2 Ver. V (Mar. - Apr. 2017), PP 60-70
www.iosrjournals.org

Design of Combined Savonius-Darrieus Wind Turbine

C.Srinivasan*, G.Ajithkumar, S.Arul, G.Arulprasath, T.M.Dharunbabu
Assistant Professor, Department of Mechanical Engineering, Muthayammal Engineering College, Rasipuram, Namakkal (Dt), Tamilnadu, India.
UG Students, Department of Mechanical Engineering, Muthayammal Engineering College, Rasipuram, Namakkal (Dt), Tamilnadu, India.

***Abstract**: In this project an attempt is made to utilize the advantage of Darrieus and Savonius rotors, to improve the efficiency of power conclusion. This combined wind turbine with a lift-type Darrieus rotor is providing main power, and a drag-type Savonius rotor is providing starting power. At low wind speeds the Savonius rotor starts rotating, pulling along with it the Darrieus rotor, through the free wheel. When the Darrieus rotor reaches its critical speed, it starts rotating at faster speed, decoupling itself from the Savonius rotor. Now for the same low wind speed, both the Savonius rotor and Darrieus rotors rotate at their own speeds, the output of which will be fed to a two input epicyclic gear box, so that an augmented output will be obtained from the gear box. The combined Savonius-Darrieus rotor can increase the wind turbine efficiency in low wind speed and also enable self-starting in Darrieus turbine. The diameter ratio of the turbines can be varied to assess the optimum value.The minimum height and the dependence of power conversion on the height of the mill and analyze the performance of the system using CFD.*

***Keywords:** Savonius rotor, Darrieus rotor, Power co-efficient, Tip speed ratio, Overlap ratio, Velocity, Combined vertical axis wind turbine, Design calculation, Modeling, CFD.*

I. Introduction

Wind Energy

In many parts of the world, wind energy has already grown to be mainstream energy source. It is the most attractive solution to the world's energy challenges. It is clean and fuel free. Wind energy can make major contribution towards satisfying the global need for clean and renewable energy within the next thirty years. The energy that can be extracted from the wind is directly proportional to the cube of the wind speed. Thus, an understanding of the characteristics of the wind (velocity, direction, variation) is critical to all aspects of wind energy generation, from the identification of suitable sites to predictions of the economic viability of wind farm projects, to the design of wind turbines themselves, all is dependent on characteristics of wind. The most striking characteristic of the wind is its random nature. The wind is highly variable, both geographically and temporally.

Wind Turbines

Winds result due to the earth's equatorial regions receiving more solar energy than the Polar Regions and this sets up large-scale convection currents in the atmosphere. Meteorologists estimate that about 1 percent of the incoming solar radiation is converted to wind energy. Solar energy received by earth in just ten days has an energy content equal to the world's entire fossil fuel reserves (coal, oil, gas). It is encouraging to know that the global wind resource is so large and is very widely distributed. Due to the worldwide energy crisis with a growing focus on renewable energy, interest in the design of wind turbine has also been increasing.

II. Vertical Axis Wind Turbines

Recent VAWTs have been gaining popularity due to interest in personal green energy solutions. Small companies all over the world have been marketing these new devices such as Helix Wind, Urban Green Energy, and Wind spire. Because VAWTs are small, quiet, easy to install, can take wind from any direction, and operate efficiently in turbulent wind conditions, a new area in wind turbine research has opened up to meet the demands of individuals willing to take control and invest in small wind energy technology.
A Vertical axis Wind turbines are classified into two types, they are,

- Savonius wind turbine
- Darrieus wind turbine

Savonius Wind Turbine

Savonius wind turbines Shown in Fig 1.5 are a type of vertical-axis wind turbine (VAWT), used for converting the force of the wind into torque on a rotating shaft. The turbine consists of a number of aerofoils usually but not always vertically mounted on a rotating shaft or framework, either ground stationed or tethered in airborne systems.

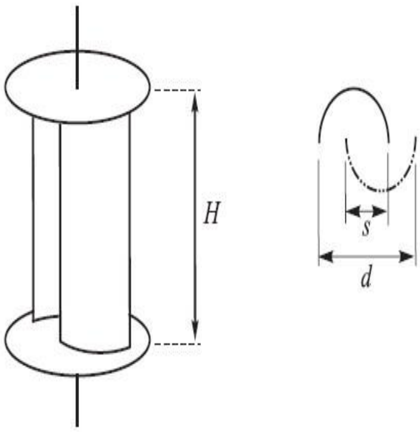


Figure.1. Savonius wind turbine

Devices, Savonius turbines extract much less of the wind's power than other similarly-sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights.Savonius turbines are used whenever cost or reliability is much more important than efficiency. For example, most anemometers are Savonius turbines, because efficiency is completely irrelevant for that application.

Overlapping Savonius Rotors

A simple modification to the original Savonius rotor is to by overlap the rotors, allowing air to flow between each of the sides, which significantly increased the efficiency. This study concluded the two stage overlapping Savonius rotor Shown in Fig 1.6 was the most efficient of the combinations tested. This also allowed the turbine to be started with wind from any direction because offsetting the stages will ensure that one "bucket" is always in the direction of the wind.

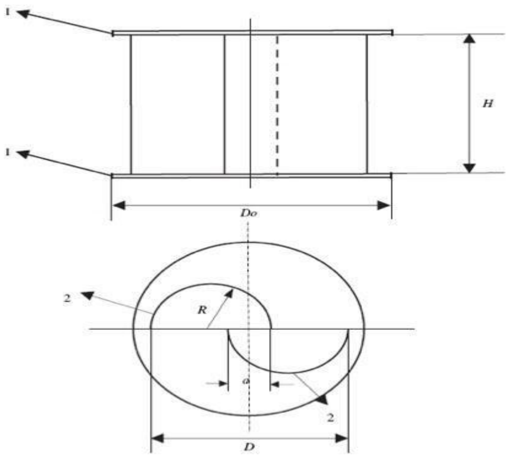


Figure.2. Overlapping Savonius rotors

Darrieus Wind Turbine

The Darrieus turbine Shown in Fig 3 is the most famous lift type vertical axis wind turbine. It is characterized by its –C shaped rotor blades which give it its eggbeater appearance. It is normally built with two or three blades, but it is not self-starting. Therefore a small motor is required to start off the rotation. This turbine generates less torque than a Savonius but it rotates much faster.

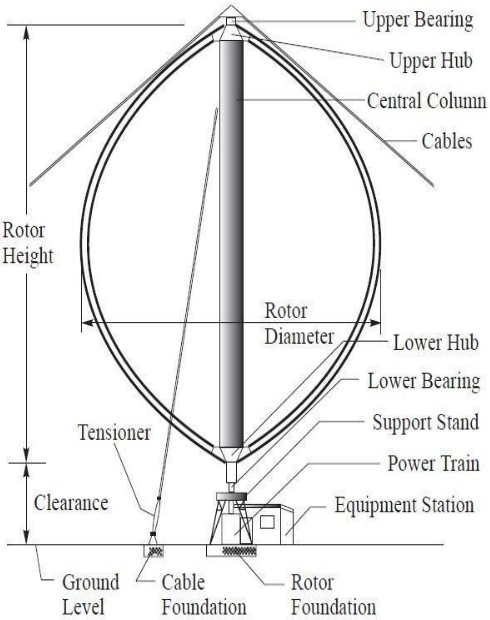


Figure.3. Darrieus wind turbine

Combined Savonius-Darrieus Vawt

The combined Savonius-Darrieus Shown in Fig 1.8 hybrid wind turbine is small in size and due to its Vertical axis nature therefore it is possible to obtain output regardless of the wind direction. This wind turbine is a combination wind turbine with a lift-type Darrieus rotor which is providing main power, and a dragtypeSavonius rotor which is providing starting power. The combined SavoniusDarrieus hybrid wind turbine generator has been investigated by many scientists and its output characteristics related to the number of the Darrieus blade have been obtained.

Design
Principle:

The Savonius rotor is placed at the center of the eggbeater type Darrieus rotor and connected through a free wheel so as to get disengaged from the Savonius rotor after attaining the critical speed. The special epicyclic gear box combines the outputs of both rotors.

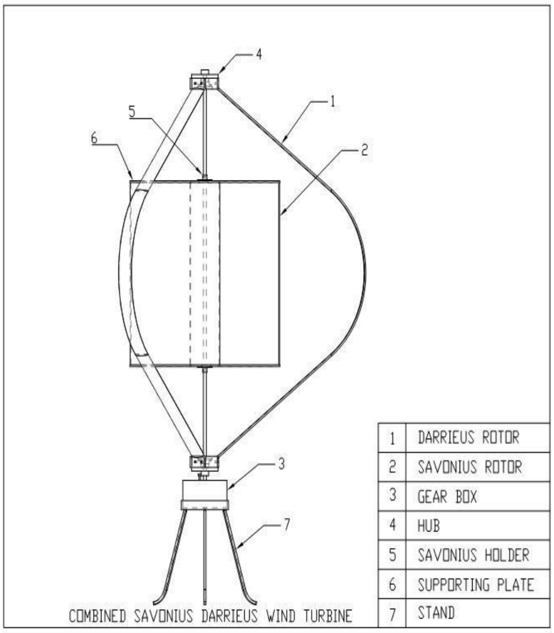


Figure.4. Combined Savonius-Darrieus Wind Turbine

Components Of Combined Savonius Darrieus Wind

Darrieus Blade:

It is Egg beated shaped rotor with cross section of NACA 0012 aero foil is shown in fig 5.

Figure.5. Darrieus Blade

HUB:

It is used to fix the 3 Darrieus rotor in 120 degree and also used hold the free wheel and bearing is shown in fig 6.

Figure.6. Hub

Savonius Blade:

It is S shaped rotor with overlapping and it is made up of plastic is shown in fig 7.

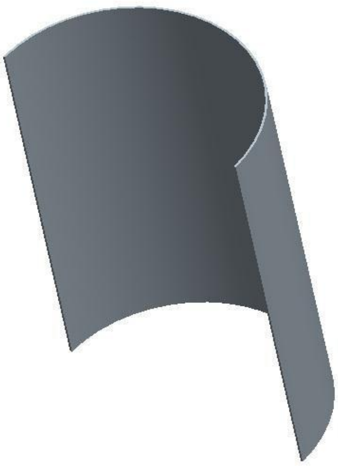


Figure .7. Savonius Blade

Savonius Holder:
It is used to transmit power from the Savonius rotor to the shaft plastic is shown in fig 8.

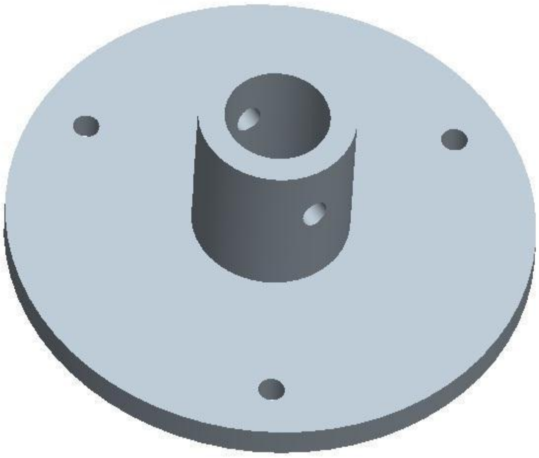


Figure.8. Savonius holder

Supporting Plate:
It is used to support the Savonius blades and also have the grooves to place the Savonius blades in proper positionplasticareshowninfig 9.

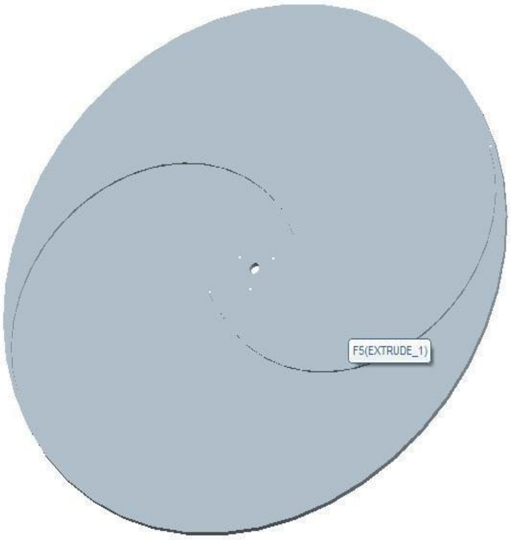


Figure.9. Supporting Plate

III. Design Calculations

Wind Power
Assume, wind velocity V=5m/s
Power P= $0.5*C_p*\rho*A*V^3$
Tip speed ratio= $R\omega/V$
Angular velocity $\omega= 2\pi N/60$
Torque $T= P/\omega$
Where,
Density of air $\rho= 1.225kg/m^3$
Diameter of Rotor $D_r= 1m$
Height of Rotor $H_r= 0.9m$
Belt'z constant $C_p= 0.3$
Tip speed ratio = 0.59

Savonius Calculation:
Assume,
C_P=0.4
ρ=1.225 kg/m^3
v=3 m/s
Diameter of the rotor D=(d+d-s)
D=0.6+0.6-0.1
D=1.1m
Radius of the rotor R=D/2
R=0.55m
Area A=D*H
A=1.1*1
A=1.1m^2
Power □=1/2 C_P □AU^3
P=1/2*0.4 *1.225*1.1*3^3
P=7.27Watt
Where,
ρ- Density of air (kg/m$^{3)}$
A- Swept Area
U- Velocity
Tip Speed □=R□/v
Assume λ=1,
ω=λv/R
ω=1*3/0.55
ω=5.45rad/sec
ω=2πN/60
Speed of the rotor N=5.45*60/2□
N=51.3rpm
Torque T=P/□
T=7.2/5.45
T=1.33Nm
Diameter d=0.6 m
Height h=1 m

Darrieus Calculation:
Assume,
C_P=0.4
ρ=1.225 kg/m^3

Therefore,
Area A=0.6 DH
A=0.6*2*2
A=2.4 m^2
Where,
D-Diameter of the rotor
H=Height of the rotor
Power □=1/2 C_P □AU^3
P=1/2*0.4*1.225*2.4*3^3
P=15.9 Watt
Where,
ρ- Density of air (kg/m$^{3)}$
A- Swept Area
U- Velocity
Tip Speed □=R□ /v
Assume λ=6,
Angular velocity □ = R□ /v
ω=6*3/1
ω=18 rad/sec
ω=2πN/60

Speed of the rotor N=18*60/2□
N=171.89 rpm
Torque T=P/□
T=15.9/18
T=0.88 Nm

Diameter d=2 m
Height h=2.03 m

MODELING

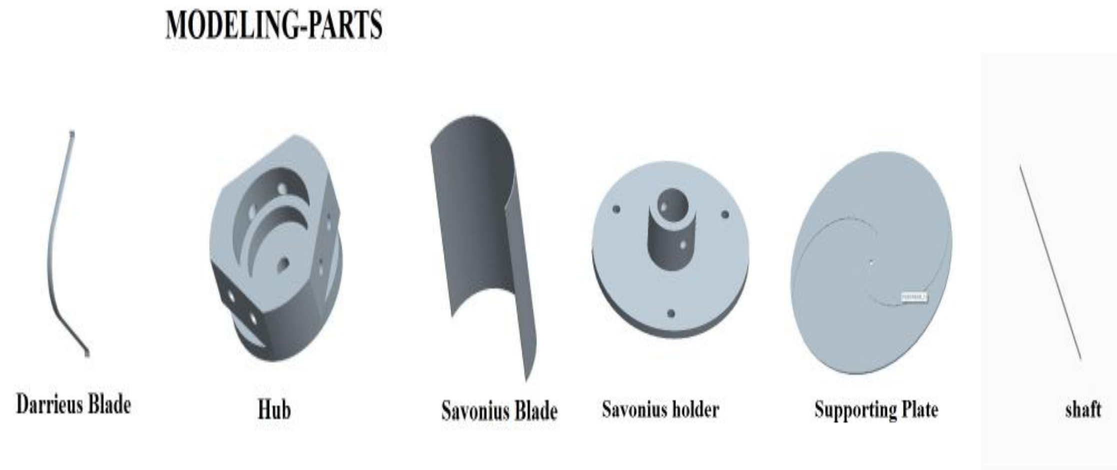


Figure.10.modeling-parts

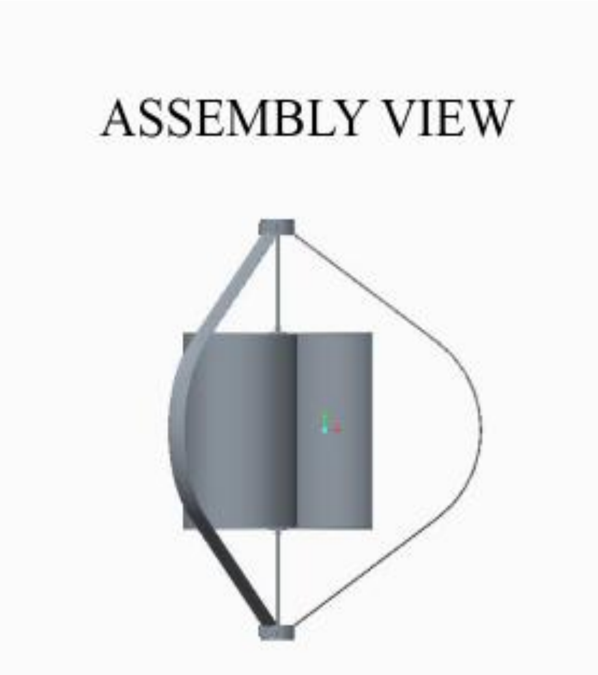


Figure.11. Assembly view

Cfd Analysis
The combined SavoniusDarrieus wind turbine is modeled by creo and meshed by using CFD software.

DESIGN MODEL

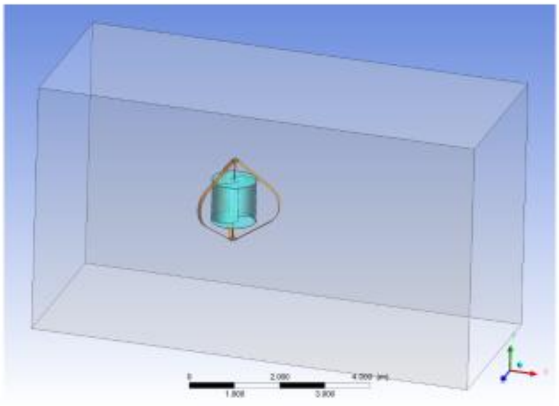


Figure.13. Design model

MESH MODEL

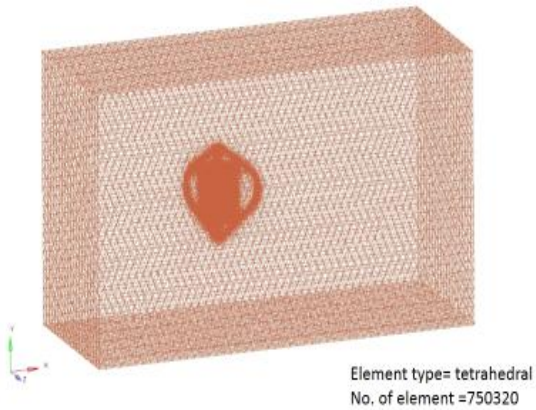
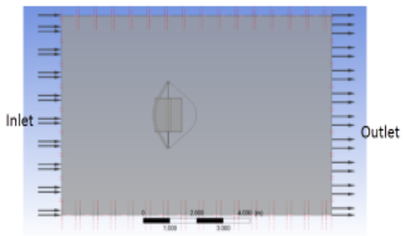


Figure.12. Mesh model

BOUNDARY CONDITION

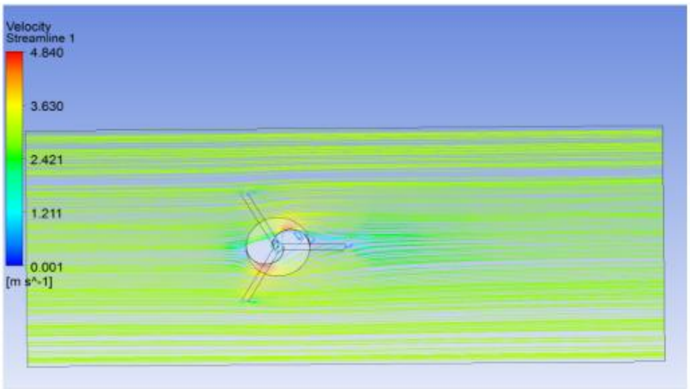


S.no	Boundary condition	value	unit
1	inlet velocity	3	m/s
2	outlet pressure	1	atm
material properties of air			
1	density	1.225	kg/m^3

Figure.14. Boundary condition

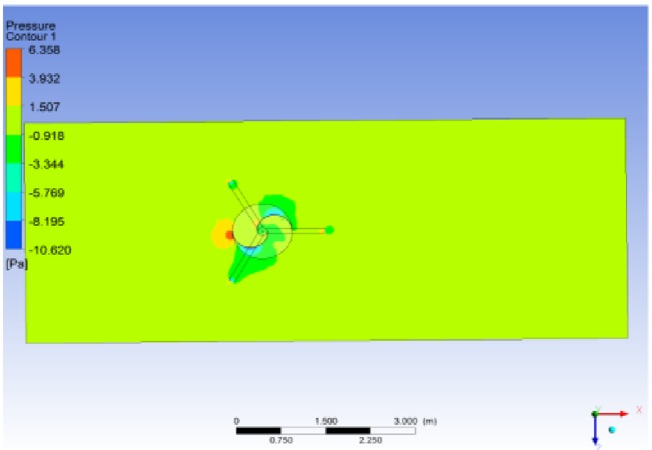
Wind velocity =3m/s

Velocity Streamline plot



Wind velocity=3m/s

Pressure plot



Wind velocity=3m/s

Velocity plot

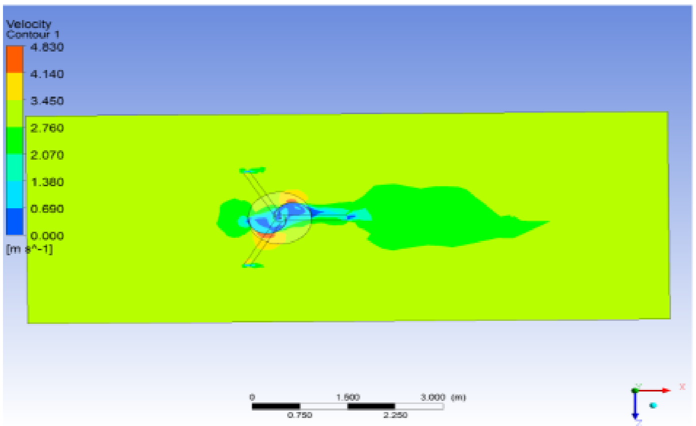
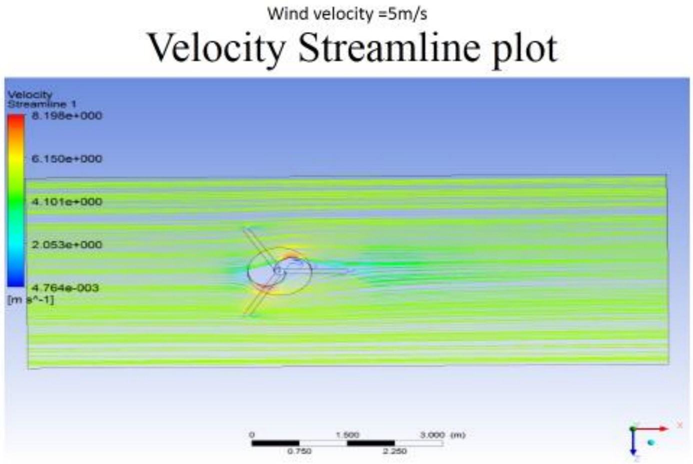
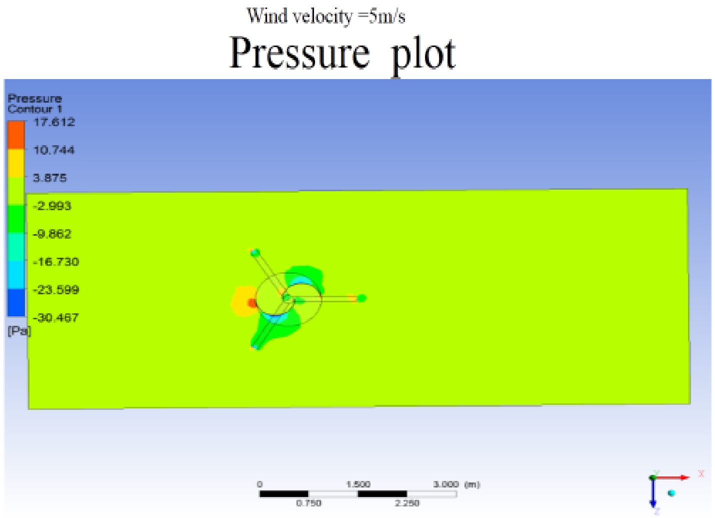


Figure.15. velocity=3m/s velocity streamline and pressure and velocity plot





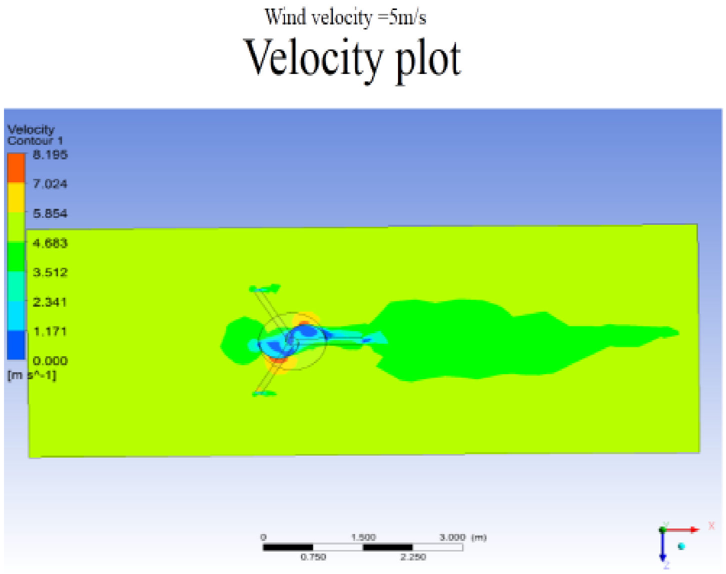


Figure.16. velocity=5m/s velocity streamline and pressure and velocity plot

Future Improvement

Due to Centrifugal force at maximum wind speed 12 m/s the Darrieus blade is changed into irregular shape shown in fig 17.To avoid the deformation to place the support with an aero foil structure at where maximum deformation occur shown in fig 18and also this support will increase torque into 1.08 Nm

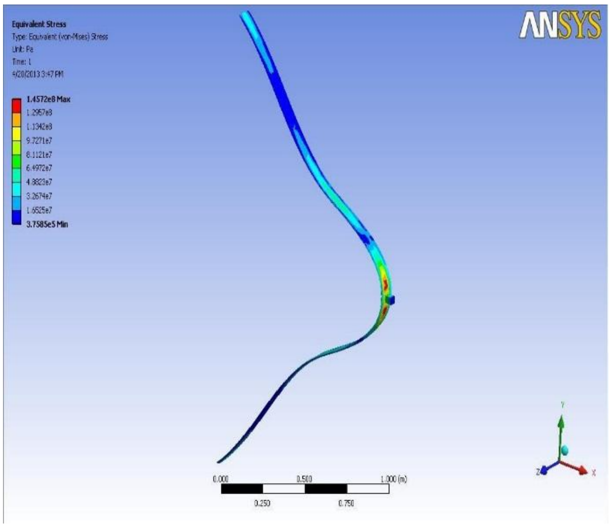


Figure.17. Effect of Centrifugal force on Darrieus blade without support

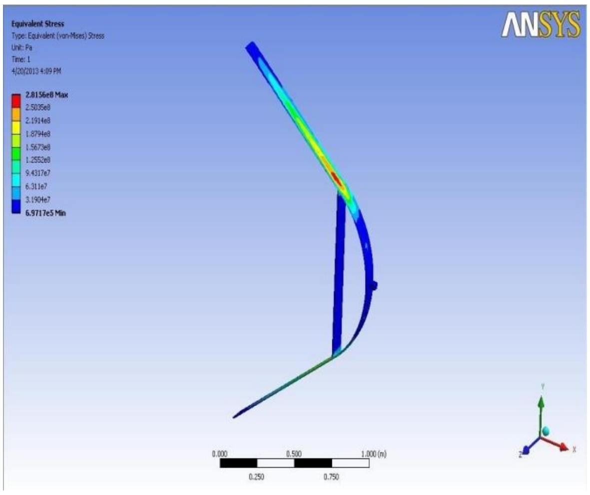


Figure.18. Effect of Centrifugal force on Darrieus blade with support

IV. Conclusion

As stated, the main goal of this project is that the combined Savonius-Darrieus rotor is used in order to increase the wind turbine efficiency in low wind speed and also to enable self-starting in Darrieus turbine. It is also used to vary the diameter height ratio of the turbines to calculated the optimum value and finally analyze the performance of the system using CFD.

References

[1]. Altan, Matalan B.D, Ozdamar. P (2008) 'an experimental study of the Savonius rotor performance with curtaining by, Experimental Thermal and Fluid Science 32' (2008), Page (1673–1678)

[2]. A.Kalaiyarasan, C.Srinivasan,R.Ramesh S.Sasidharan, S.Palanisamy ' Oxidation of Soot Particles in Diesel Exhaust Emission using Plasma Source IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 09, 2016 | ISSN (online): 2321-0613

[3]. Cherry. N.J. (1980) 'Wind energy resources methodology', J., Ind Aero . pp.247-80.

[4]. Cetin .N, Yurdusev .M, Ata .R, and Ozdemir .A, 'Assessment of optimum tip speed ratio of wind turbines in Mathematical and Computational Applications', vol. 10, no. 1, pp. 147{154, 2005.

[5]. Ferziger. J and Peric .M, 'Computational Methods for Fluid Dynamics', 3rd Edition. New York: Springer-Verlag, 2002.

[6]. Fluent, 'Fluent 6.3 user's guide,Fluent Inc.', Lebanon, NH, Tech. Rep., 2006.

[7]. Gipe, Paul, 2004. 'Wind Power', Chelsea Green Publishing Company, page 97.

[8]. Gupta, R., Biswas, A., Sharma, K. K. (2008). 'Comparative study of a three bucket Savonius rotor with a combined three bucket Savonius –three bladed Darrieus rotor. Renewable Energy', 33, Page (1974-1981)