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Performance Analysis on Single and Double Stage Savonius Wind Turbine

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I.NTRODUCTION:

1.1WIND TURBINES:

Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. The earth’s surface is made of different types of land and water. These surfaces absorb the sun’s heat at different rates, giving rise to the differences in temperature and subsequently to winds. During the day, the air above the land heats up more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water. In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles. Humans use this wind flow for many purposes: sailing boats, pumping water, grinding mills and also generating electricity. Wind turbines convert the kinetic energy of the moving wind into electricity.

1.2TYPES OF WIND TURBINES:

1.2.1Horizontal Axis Wind Turbines (HAWT):

Horizontal axis wind turbines, also shortened to HAWT, are the common style that most of us think of when we think of a wind turbine. A HAWT has a similar design to a windmill it has blades that look like a propeller that spin on the horizontal axis. Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator.

1.2.2 Vertical Axis Wind Turbine (VAWT)

Verticalaxis wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT generally creates drag when rotating into the wind.

2. LITERATURE SURVEY:

India is a country with more than 1.2 billion people accounting for more than 17% of world’s population. It is the seventh largest country in the world with total land area of 3,287,263 sqkilometers. India measures 3214 km from north to south and 2993 km from east to west. It has a land frontier of 15,200 km and coastline of 7,517 km. India has 29 states and 7 union territories. It faces a formidable challenge in providing adequate energy supplies to users at a reasonable cost. It has economy which is fastest growing economies in the world and experienced an average 7 % growth rate in the last decade. India accounts for 2.4 % of world energy production and stands at eleventh position in the world in energy production.

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But the country accounts A. A. Kadam, et al [5]; has studied about Savonius wind rotors and identify the various performance parameters to increase its efficiency. The experimental results show that two blades rotor is more stable in operation than three or more rotor blades, the power coefficient increases with increasing the aspect ratio. The rotor blades with end plates gave higher efficiency than those of without end plates. CFD analysis was carried out to study the flow behavior of a rotating two bucket Savonius rotor. Model the complex flow physics around the rotating rotor was carried out by Fluent 6.3.26 software. For this purpose, data were taken from the experiments conducted earlier on the rotor in a subsonic wind tunnel for five different overlap conditions are 16.2%, 20%, 25%, 30% & 35%. and results shows that the maximum pressure drop is found in case of 16.2% overlap and minimum in case of 35% overlap, means that at 16.2% overlap condition power extraction is maximum from the wind.

3. DESIGN OF VERTICAL AXIS WIND TURBINES

3.1.1DRAFTING OF WIND TURBINES

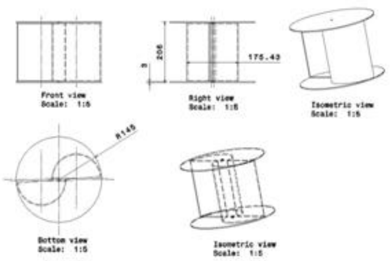


Fig.3.1 Drafting of single stage SVAWT

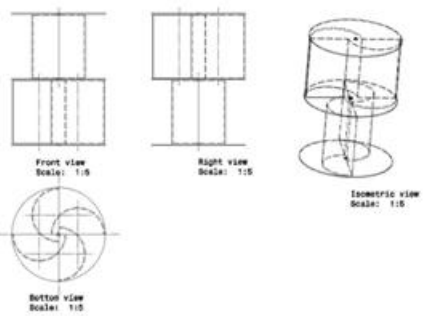
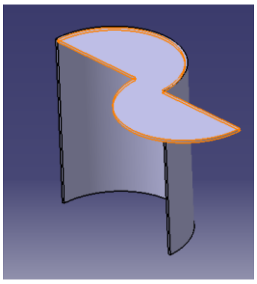
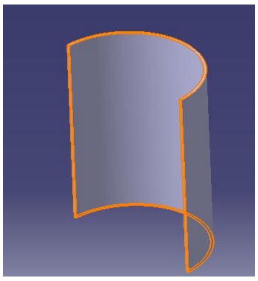


Fig. 3.2Draftingof double stage SVAWT

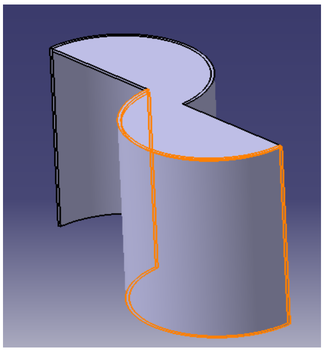
3.2. MODELLING OF SINGLE STAGE & DOUBLE STAGE



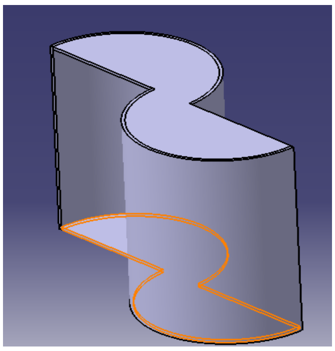
3D model Step.1



3D model Step.2



3D model Step.3



3D model Step.4

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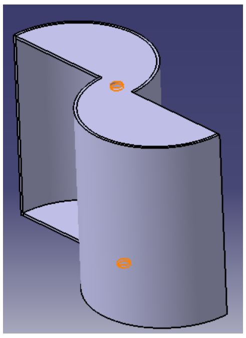
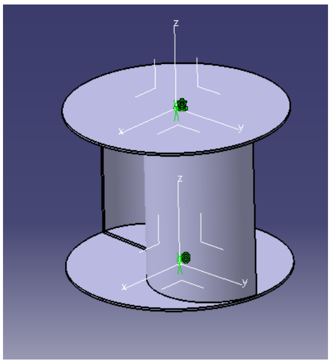


3D model Step.5



3D model of Single stage SVAWT

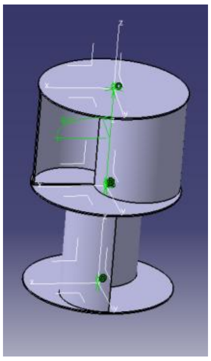


Fig. 3.103D model double stage SVAWT

3.3 MATERIALS USED FOR CONSTRUCTION OF EXPERIMENTAL SETUP

S.No	Material used	Volume
1.	DEPRON	4 feet x 8 feet
2.	Iron pipes	5 feet

Table 2: Material list for experimental setup

3.4 CONSTRUCTION OF VERTICAL AXIS WIND TURBINE

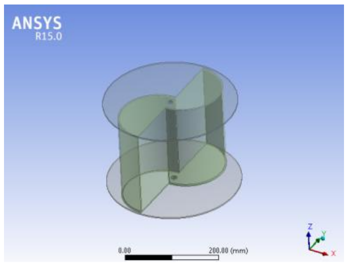
Fig. 3.17 Cutting of Depron sheets into required shapes

3.5 EXPERIMENTAL MODELS

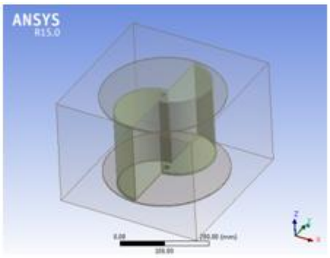
Single stage SVAWT

Double stage SVAWT

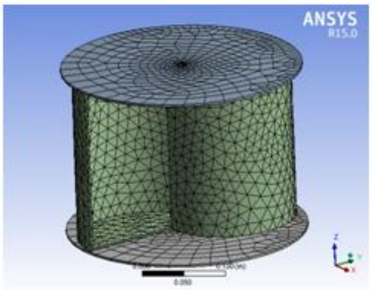
4. ANSYS PROCESS



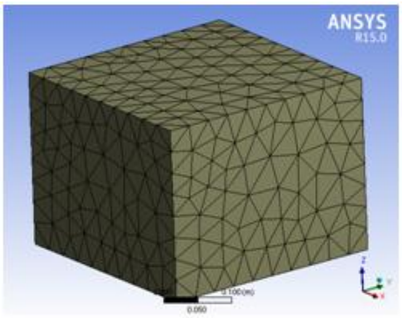
Initial Condition of Single Stage Savonius Vertical Axis Wind Turbine



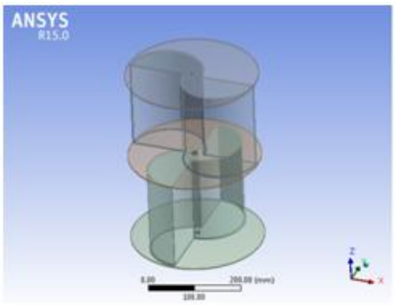
Single Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure



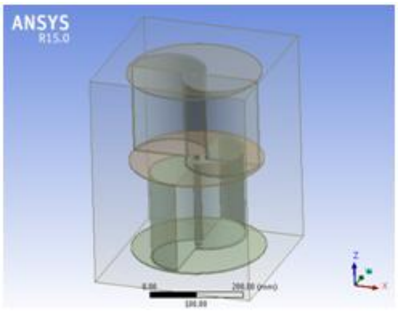
Single Stage Savonius Vertical Axis Wind Turbine meshed in Ansys Fluid Flow (Fluent)



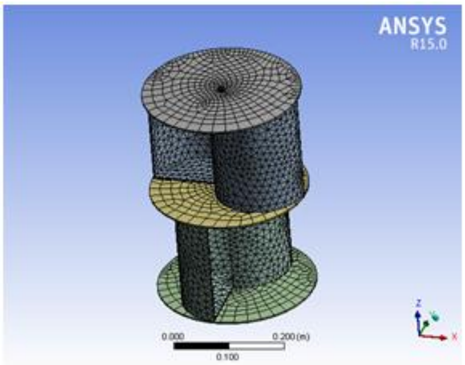
Single Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure meshed in Ansys Fluid Flow (Fluent)



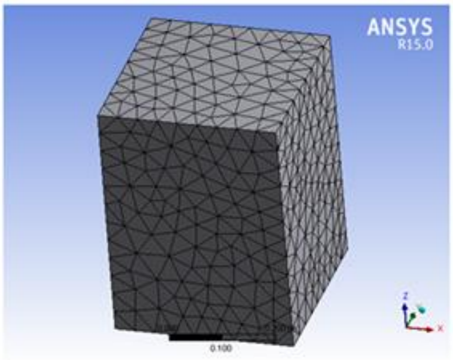
Initial Condition of Double Stage Savonius Vertical Axis Wind Turbine



Double Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure



Double Stage Savonius Vertical Axis Wind Turbine meshed in Ansys Fluid Flow (Fluent)



Double Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure meshed in Ansys Fluid Flow (Fluent)

4.2. EXPERIMENTAL PROCESS:

A 4- bladed and an 8-bladed Vertical Axis Wind Turbine have been designed and developed using Depron sheets. When these VAWT splaced against to the wind direction, the kinetic energy of the wind is converted into Mechanical energy further it can be

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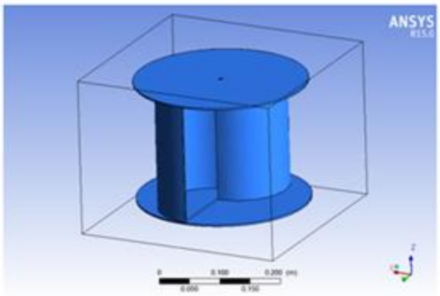
converted to electrical energy by adding some more components to the wind turbines.

RESULTS & DISCUSSION

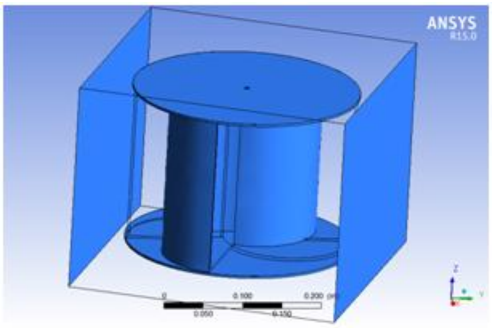
5.1 ANSYS RESULTS

Applying the load data on the imported setup and analyzing the results we get Pressure acting on the turbine, Temperature, Viscosity of air through the turbine, CFX of air Forward Flow through the Turbine, CFX of air Backward Flow through the Turbine, CFX of air Surface Flow on the Turbine.

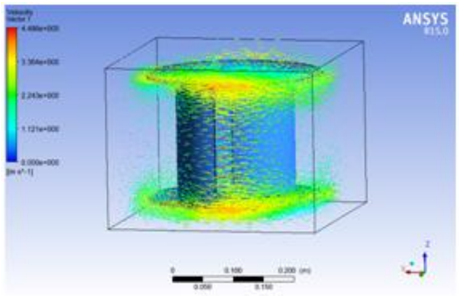
5.1.1 RESULTS PLOTTED FOR SINGLE STAGE AND DOUBLE STAGE SAVONIUS VERTICAL AXIS WIND TURBINES



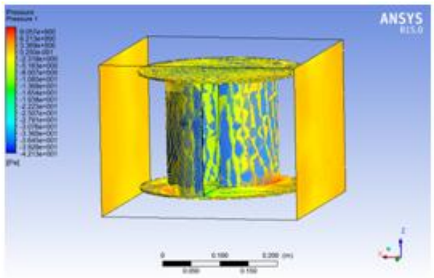
Initial Condition (No Wind Force on the SVAWT [Single Stage Savonius Vertical Axis Wind Turbine])



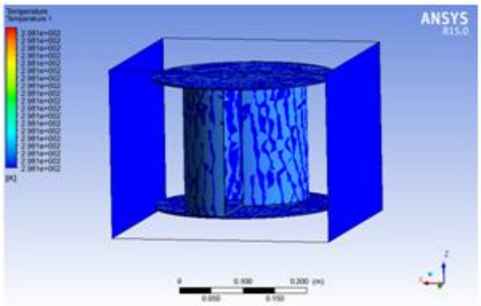
Max. Wind Force applied on the SVAWT to obtain better results. After Displacement the image is as below



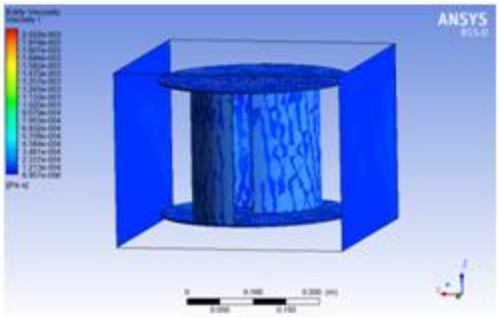
Vectors showing the velocity of wind



Pressure along the Wind Direction



Temperature along the wind Direction (remains constant)



Viscosity of air when flow through the SVAWT

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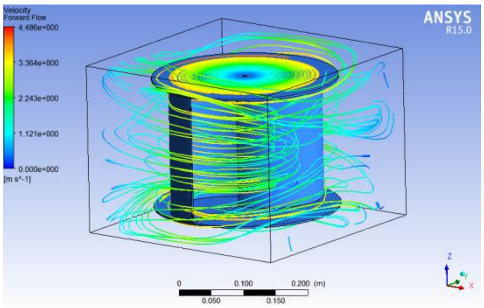
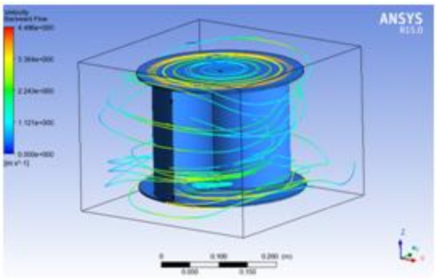
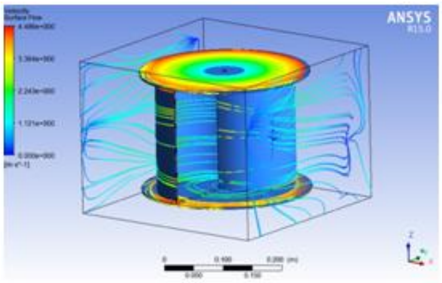


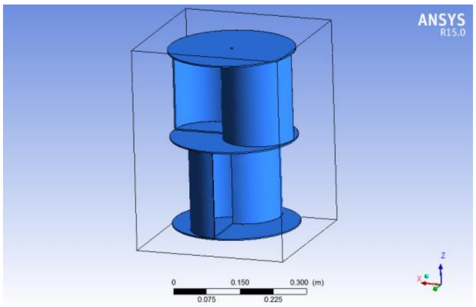
Velocity of Air flows through the SVAWT in Stream Lines (Forward Flow)



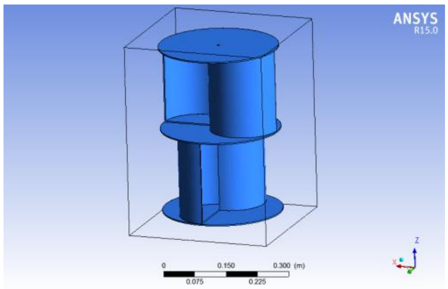
Velocity of Air flows through the SVAWT in Stream Lines (Backward Flow)



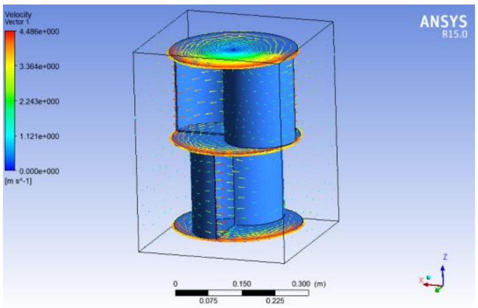
Velocity of Air flows through the SVAWT in Stream Lines (Surface Flow)



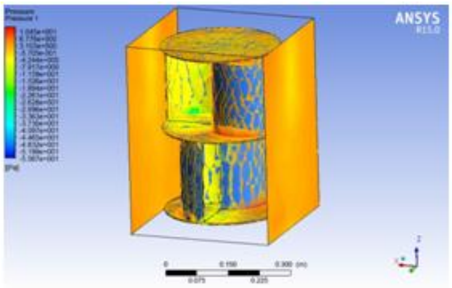
Initial Condition (No Wind Force on the SVAWT [Double Stage Savonius Vertical Axis Wind Turbine])



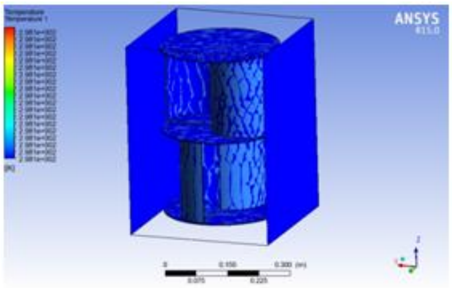
Max. Wind Force applied on the SVAWT to obtain better results. After Displacement the image is as below



Vectors showing the velocity of wind



Pressure along the Wind Direction



Temperature along the wind Direction (remains constant)

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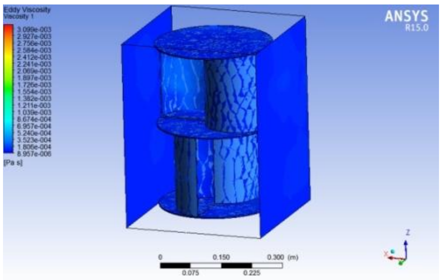
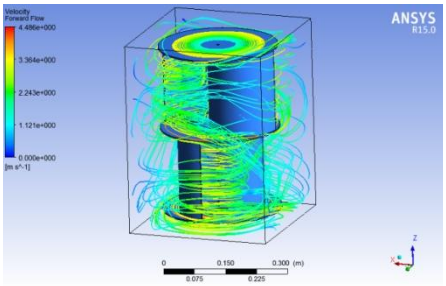
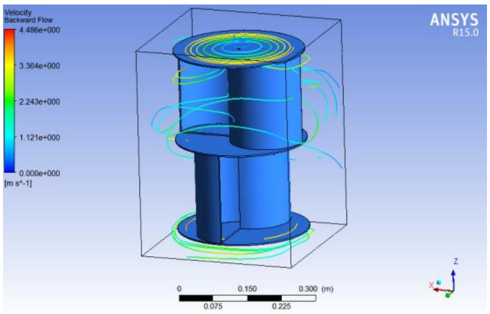


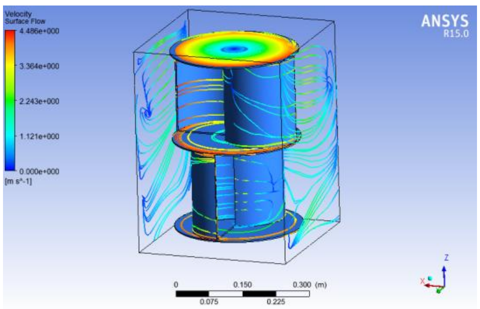
Viscosity of air when flow through the SVAWT



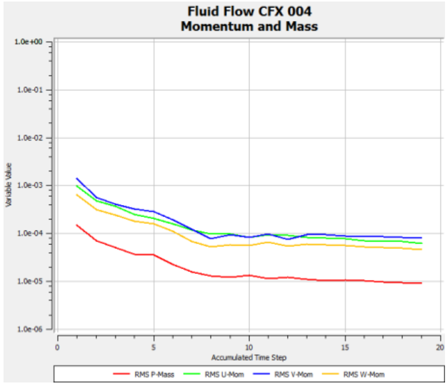
Velocity of Air flows through the SVAWT in Stream Lines (Forward Flow)



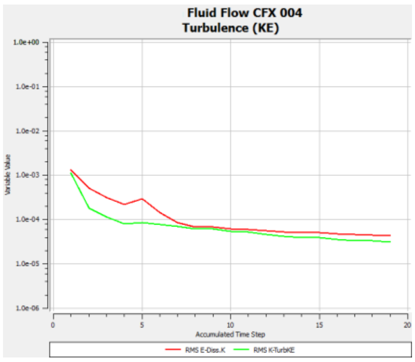
Velocity of Air flows through the SVAWT in Stream Lines (Backward Flow)



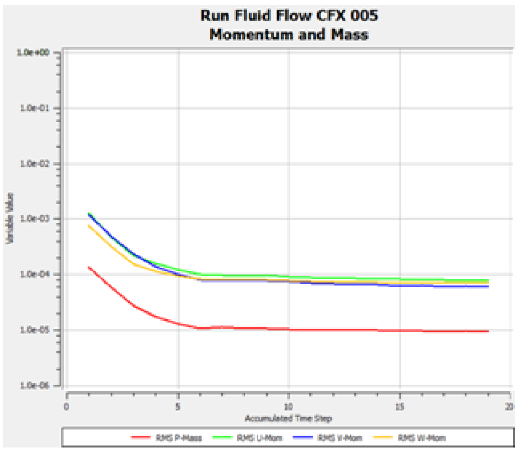
Velocity of Air flows through the SVAWT in Stream Lines (Surface Flow)



Graph plotted for Mass and Momentum for Single Stage SVAWT



Graph plotted for Turbulence and Displacement for Single Stage SVAWT



Graph plotted for Mass and Momentum for Double Stage SVAWT

Turbulence and Displacement for Double Stage SVAWT

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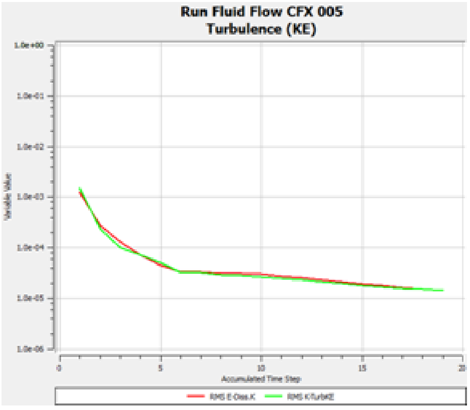

Graph plotted for Turbulence and Displacement for Double Stage SVAWT

5.2 EXPERIMENT RESULTS

S.No	Property	
1	Velocity (kmph)	18.71
2	Air flow rate (m^3/sec)	5.87
3	Relative Humidity %	72
4	Dew point Temperature (^{0}C)	25.8
5	Wet Bulb Temperature (^{0}C)	27.3

Table 11: Reading 1

Rpm
Single StageSVAWT - 172
Double StageSVAWT - 203

S.No	Property	
6	Velocity (kmph)	16.82
7	Air flow rate (m^3/sec)	5.65
8	Relative Humidity %	72
9	Dew point Temperature (^{0}C)	25.8
10	Wet Bulb Temperature (^{0}C)	27.3

Table 12: Reading 2

Rpm
Single StageSVAWT - 154
Double Stage SVAWT - 186

S.No	Property	
11	Velocity (kmph)	14.48
12	Air flow rate (m^3/sec)	5.23
13	Relative Humidity %	72
14	Dew point Temperature (^{0}C)	25.8
15	Wet Bulb Temperature (^{0}C)	27.3

Table 13: Reading 3

Rpm
Single StageSVAWT - 136
Double Stage SVAWT - 165

S.No	Property	
16	Velocity (kmph)	12.67
17	Air flow rate (m^3/sec)	4.53
18	Relative Humidity %	72
19	Dew point Temperature (^{0}C)	25.8
20	Wet Bulb Temperature (^{0}C)	27.3

Table 14: Reading 4

Rpm
Single StageSVAWT - 119
Double Stage SVAWT - 138

S.No	Property	
21	Velocity (kmph)	9.62
22	Air flow rate (m^3/sec)	3.75
23	Relative Humidity %	72
24	Dew point Temperature (^{0}C)	25.8
25	Wet Bulb Temperature (^{0}C)	27.3

Table 15: Reading 5

Rpm
Single StageSVAWT - 96
Double Stage SVAWT - 127

S.No	Property	
26	Velocity (kmph)	6.02
27	Air flow rate (m^3/sec)	1.45
28	Relative Humidity %	72
29	Dew point Temperature (^{0}C)	25.8
30	Wet Bulb Temperature (^{0}C)	27.3

Table 16: Reading 6

Rpm
Single StageSVAWT - 73
Double Stage SVAWT - 106

5.3 PERFORMANCE CALCULATION

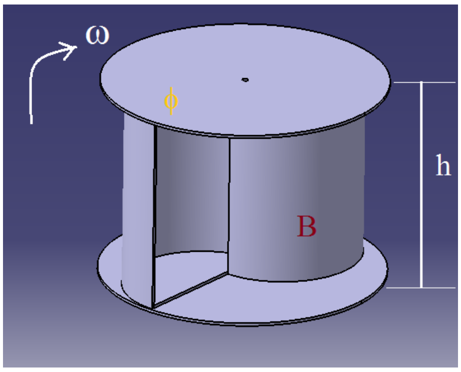

Fig 5.42 Parameters of Savonius VAWT

S.No	Velocity of air (kmph)	P_{Avail} (W)	$P_{Turbine}$ (W)	Cp	TSR
1	18.71	4.9864	0.8471	0.1699	0.50
2	16.82	3.6227	0.4781	0.1320	0.50
3	14.48	2.3113	0.2107	0.0912	0.51
4	12.67	1.5481	0.1082	0.0699	0.51
5	9.62	0.6777	0.0338	0.0500	0.54
6	6.02	0.1660	0.0078	0.0475	0.54

Table 17: Wind Speed Calculations for Single Stage Savonius VAWT

S.No	Velocity of air (kmph)	P_{Avail} (W)	$P_{Turbine}$ (W)	Cp	TSR
1	18.71	9.9729	1.9636	0.1969	0.59
2	16.82	7.2455	1.1078	0.1529	0.60
3	14.48	4.6226	0.5126	0.1109	0.62
4	12.67	3.0961	0.2907	0.0939	0.59
5	9.62	1.3554	0.0855	0.0631	0.62
6	6.02	0.3321	0.0155	0.0469	0.62

Table 18: Wind Speed Calculation for Double Stage Savonius VAWT

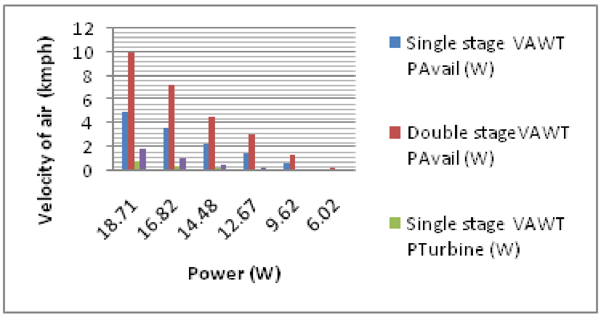

Fig. Velosity of air vs power

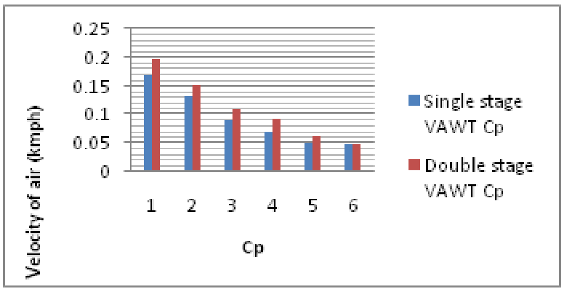

Fig. velocity of air vsCp

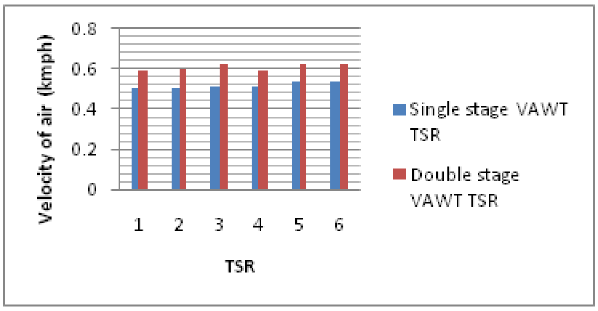

Fig. Velocity of air vs TSR

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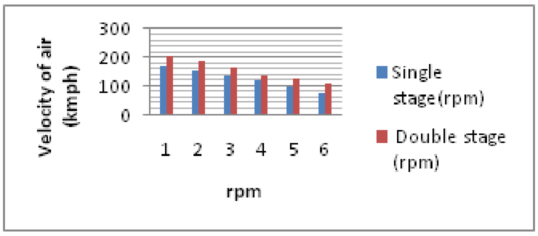

Fig.Velocity of air vs rpm.

6. CONCLUSION:

As per the Design & Analysis performed for Single Stage and Double Stage Savonius Vertical Axis Wind Turbines (SVAWT)the following are the conclusion

- CFX analysis performed on both Single Stage and Double Stage SavoniusVertical Axis Wind Turbines with Cartesian enclosure for air flow through the enclosure and we have observed that, in Single Stage SavoniusVAWT with Cartesian enclosure during the forward flow the velocity of the wind through the VAWT is 20.1 m/s. during the back ward flow the velocity of the wind through the VAWT is negligible when compared to forward flow because the air flows in opposite direction makes the turbine idle. The air passes through the turbine without making any angular motion at normal speed whereas we will observe an angular displacement at higher speeds.
- In Double Stage SavoniusVAWT due to the blades of the turbine placed perpendicular to each other, the turbine rotates continuously when the wind flows through it. We observed a high value of Tip speed ratio (TSR) in both cases such that the passes through the turbine and gets swirled at blades and opposes the wind flows on it.
- By calculating the coefficient of performance for Single Stage and Double Stage SavoniusVertical Axis Wind Turbines, we have observed the coefficient of performance for Single Stage and Double Stage Savonius Vertical Axis Wind Turbines is 0.1699 and 0.1969 respectively and TSR for 8 Single Stage and Double Stage SavoniusVertical Axis Wind Turbines is 0.51 and 0.60 respectively at a velocity of wind 18.71kmph or 5.197 m/s, air flow 5.23 m^3/s, relative humidity 72.0%, dew point temperature 25.8 ^{0}c, wet bulb temperature 27.3 ^{0}c. Coefficient of performance of Double Stage Savonius Vertical Axis Wind Turbine (SVAWT) is high when compared to Single Stage Savonius Vertical Axis Wind Turbine (SVAWT)
- Finally the results plotted were Vector Displacement of Wind on the Turbine, Pressure acting on the turbine, Temperature, Viscosity of air through the turbine are listed below

S.No	Type/Properties	Vector Displacement (m/s)	Pressure (Pa)	Temperature (K)	Viscosity (Pa S)
1	Single Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure	44.8	10.8	298.15	0.00210184
2	Double Stage Savonius Vertical Axis Wind Turbine with Cartesian enclosure	44.4	12.74	29.15	0.00320647

Table 19 : Results Plotted in Fluid Flow (CFX)

7. FUTURE SCOPE:

The development of effective alternators and dynamos can be used to harness wind energy from relatively small winds. The use of materials like Acrylic Plastic Sheets can be used to develop low cost VWAT.

Power output can be enhanced by the fallowing ways:

- Optimizing the design of blades so as to give better aerodynamics
- Using a best alternator which produces more voltage for low rpm
- Using gear mechanisms to increase rpm for alternator input and hence can have higher power output.
- Structural fabrication should be more accurate in order to have proper functions of wind turbine.
- Using fixed light weight material to reduce the weight of the whole system

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