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Abstract- *The purpose of this paper is to exhibit the comparison of the aerodynamic characteristics of Helical Savonius Wind Turbine with and without circular fin. The turbines, modeled in Solidworks, having the same dimensions- diameter 24 inch and height 34 inch in both two cases, were simulated in ANSYS CFX. Dynamic mesh and k-$\mathcal{E}$ turbulent model were used in this analysis. Flow characteristics around the two rotors were analyzed to illustrate the correlation between flow and rotor performance. The analysis shows that the power coefficient at 135 degree angular position of rotor without fin is greater than the power coefficient of rotor with fin at the same position. Oppositely, the power coefficient at 225 degree angular position of rotor without fin is less than the power coefficient of the rotor with fin at the same position. Similar outcome of the analysis in the case of torque coefficient of the two rotors has been found.*

Keywords: Helical savonius turbine, CFX, Power coefficient, Torque coefficient, Tip speed ratio

1. INTRODUCTION

As use of fossil fuel is threating for environment, on the other hand, fossil fuel is decreasing day by day, therefore, alternative energy sources are required to meet the future need of energy. Renewable energy can fulfil this demand. Wind is a good source of renewable energy. Huge amount of fossil fuel is consumed for producing electric power; this high amount of fuel causes global warming and climate change. By using wind energy, it can be possible to produce electric power without those harms. But the proper use of wind energy depends on the design of wind turbine. There are two types of wind turbine: Horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). HAWT is used where the direction of the wind is not continuously changed and the wind speed is relatively high. VAWT is mainly used for generating electric power at low speed wind; it doesn't depend on the direction of the wind. Among the VAWT, helical savonius type wind turbine is most popular and simplest form [1].

There are many theoretical and numerical aerodynamic investigations on savonius wind turbine. The power coefficient of helical savonius wind turbine was investigated experimentally by T. Bhaumik et al. [2]. The power and torque coefficient were measured in an open jet wind tunnel test under various operating condition by M. A. Kamoji et al. [3]. The investigations show relatively lower power and torque coefficient in helical savonius turbine. B. Anggara investigated the power produced by fin and unfinned savonius rotor and found more power in finned rotor than the other [4]. Similarly, using fim with the helical savonius turbine may change the power and torque coefficient.

In this paper the effect of circular thin fin on aerodynamic characteristic of helical savonius turbine was investigated. The result shows change in power and torque coefficient at different angular position of rotor.

2. PHYSICAL MODEL

Two helical savonius rotors having same dimensions have been designed in solidworks 2016. The rotors have 610 mm diameter, 1220 mm height and 180 degree helical angle. The rotors has no central shaft. The finned rotor has two end fin and one middle fin having thickness 2.5 mm. A subdomain which contains the rotating rotor has been designed with dimensions: 760 mm diameter and 1520 mm height. A main domain which contains the whole turbine has been designed whose dimensions are: 2520 mm height, 2030 mm width and 2520 mm depth.

Fig.1: Helical savonius rotor without fin

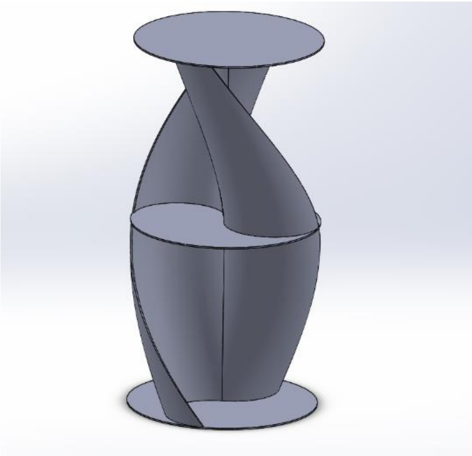


Fig.2: Helical savonius rotor with fins

3. NUMERICAL MODEL

In this analysis, the subdomain with rotor and main domain has been meshed differently; then the two models has been combined at the CFX solver. For unfinned rotor the combined element number was 265732 where for the finned rotor the number was 269800. The inflation mesh method has been applied for meshing subdomain with rotor. First layer boundary option has been selected where the first layer height was 0.5mm and the number of maximum layer was 5. Then the meshed model has been dropped to the ANSYS CFX solver for setting up the necessary steps and performing the analysis. To investigate the aerodynamic characteristics of the wind turbine, the rotor has been kept rotating at 85 rev/min angular velocity where the wind velocity at inlet was 7 m/s. Therefore the tip speed ratio has been kept 0.8 for the investigation which has been run under k-Ɛ turbulent method. After performing the simulation, the aerodynamic characteristics have been found by the following formulae:

$$C_p = \frac{P}{\frac{1}{2}\rho V^3 A} \quad (1)$$

$$C_t = \frac{T}{\frac{1}{2}\rho A r V^2} \quad (2)$$

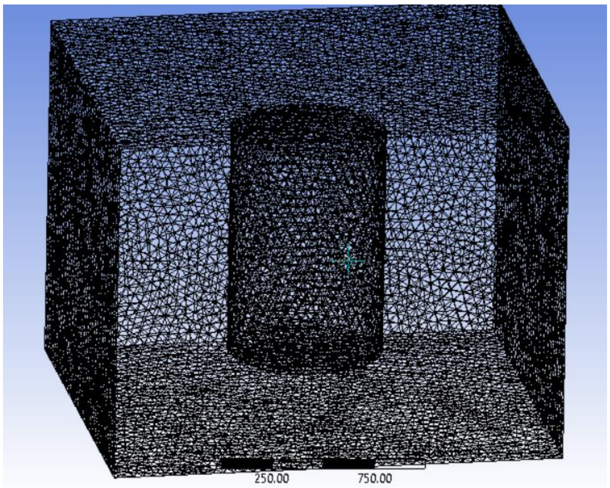


Fig.3: Mesh of main domain

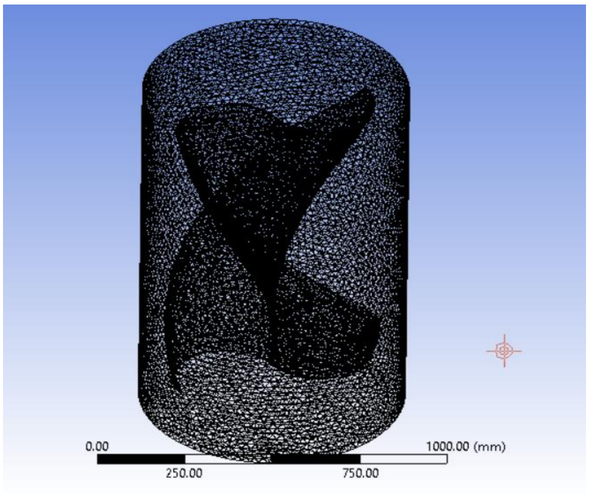


Fig.4: Mesh for subdomain with unfinned rotor

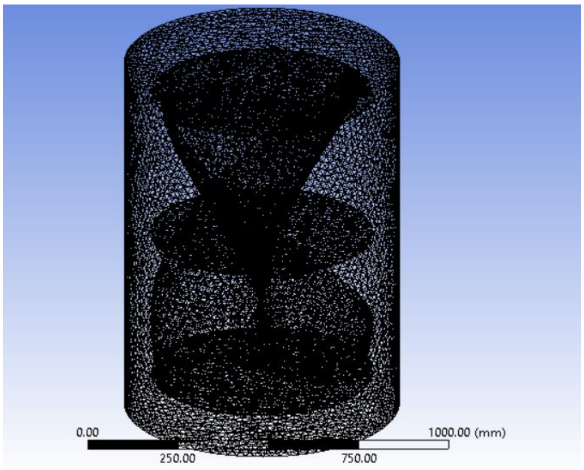


Fig.5: Mesh for subdomain with finned rotor

4. RESULTS AND DISCUSSION

The variation of power coefficient and torque coefficient with angle of rotation of rotor at 0.8 tip speed ratio with 180 degree rotor twist angle has been shown in Fig.6 and Fig.7 respectively. The maximum power coefficient obtained 0.111 and 0.113 at 135 degree and 315 degree respectively during one revolution for unfinned rotor, whereas, for finned rotor the power coefficient had been found 0.094 and 0.086 at the same angular position of rotor. But the maximum power coefficient had been found 0.094 and 0.097 at 135 degree and 338 degree angular position of finned rotor. On the other hand, the minimum power coefficient of unfinned rotor had been found 0.048 whereas for finned rotor it was 0.071. Similar case had been found for investigating torque coefficient. The maximum torque had been found for unfinned rotor was 0.29 at 315 degree angular position and for the finned rotor it was 0.25 at 338 degree angular position. The minimum torque coefficient for unfinned rotor was 0.120 and for finned rotor it was 0.182. The fluctuation of power and torque coefficient of unfinned rotor was very high than the finned one. Therefore, the use of fin with the turbine rotor reduces the fluctuation of power and torque for different angular position of rotor. But it also reduces the optimum power and torque coefficient. The velocity contour of finned and unfinned rotor for different angular position has been given in Fig.8 and Fig. 9.

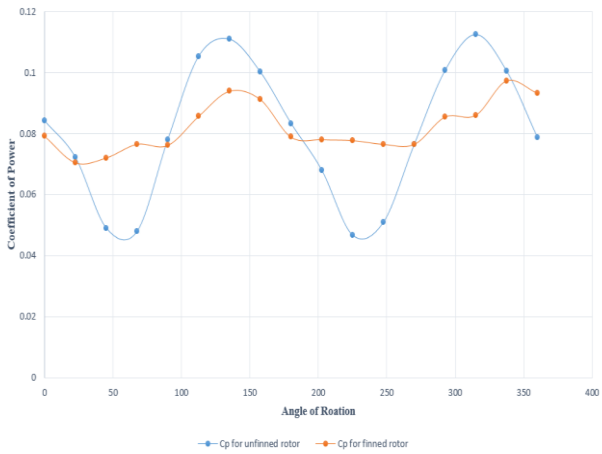


Fig.6: Comparison of Power coefficient between finned and unfinned rotor for different angle of rotation

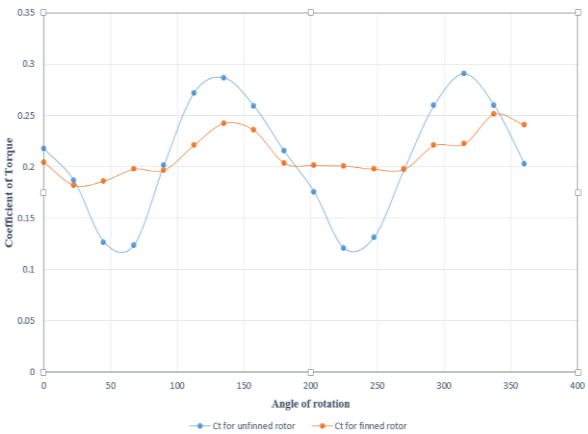
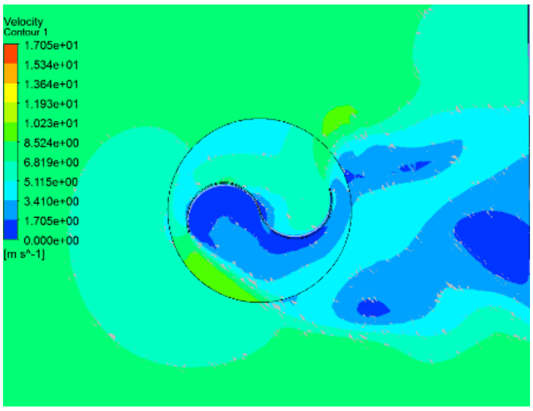
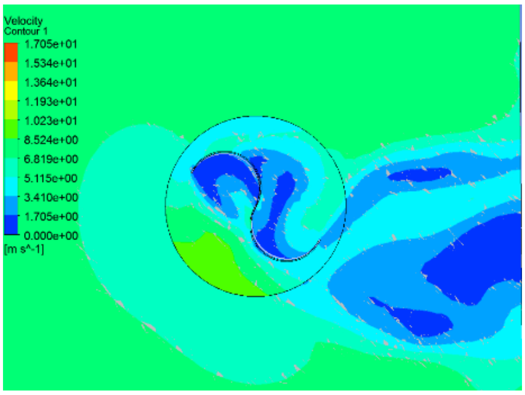


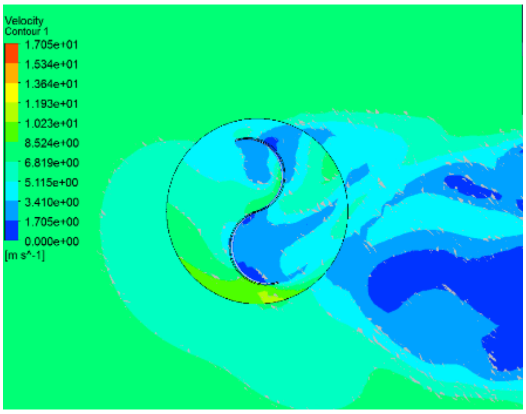
Fig.7: Comparison of torque coefficient between finned and unfinned rotor for different angle of rotation



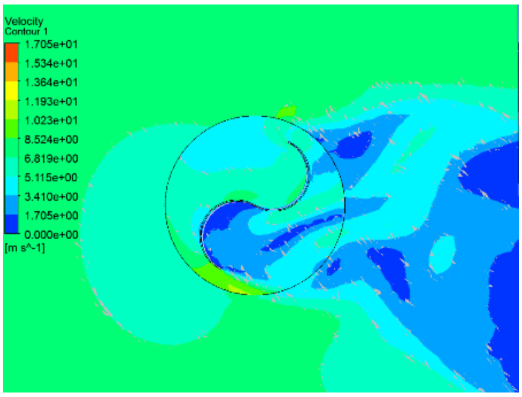
(Θ = 0 degree)



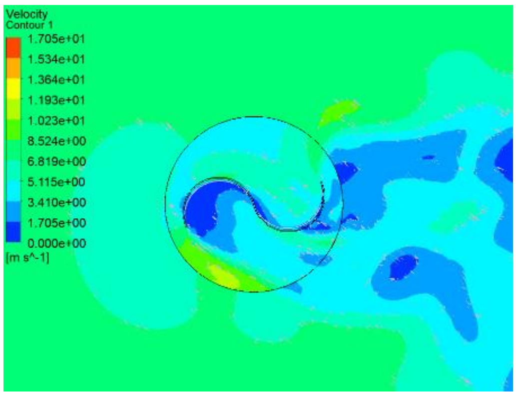
(Θ = 45 degree)



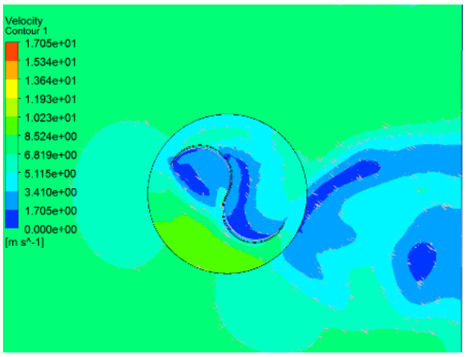
(Θ = 90 degree)



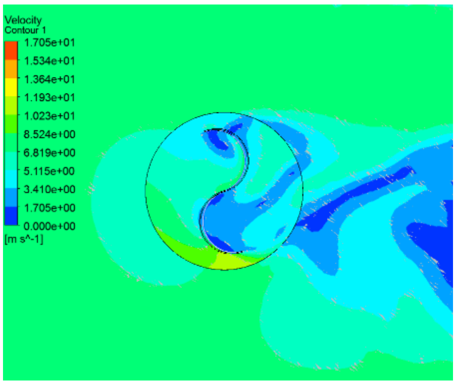
(Θ = 135 degree)



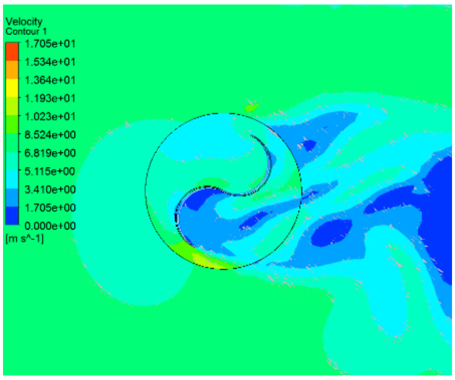
(Θ = 180 degree)



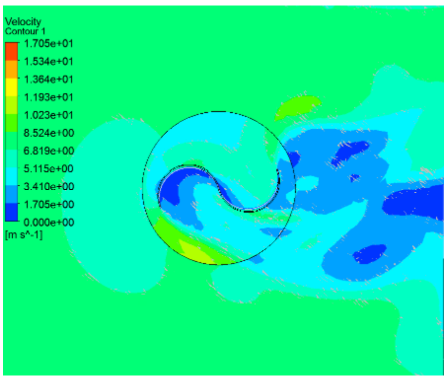
(ϴ = 225 degree)



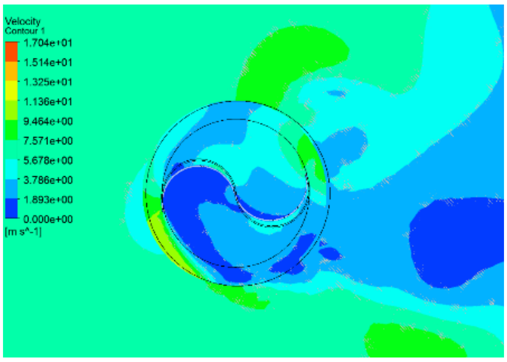
(ϴ = 270 degree)



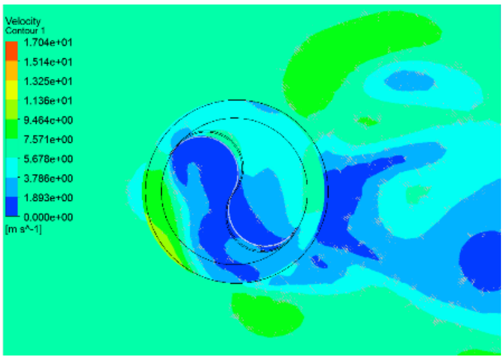
(ϴ = 315 degree)



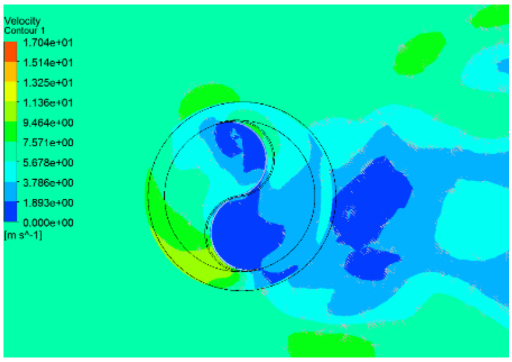
(ϴ = 360 degree)



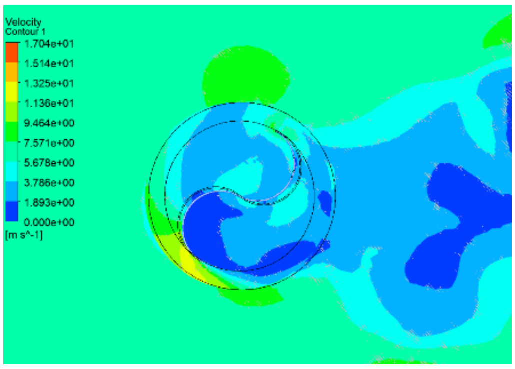
(ϴ = 0 degree)



(ϴ = 45 degree)

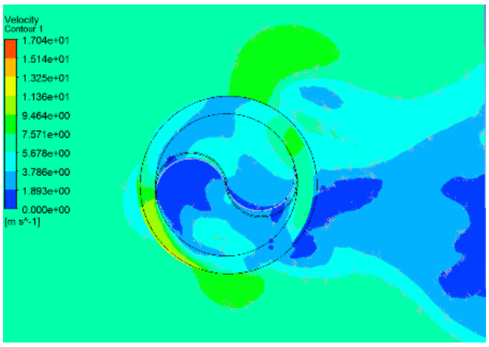


(ϴ = 90 degree)

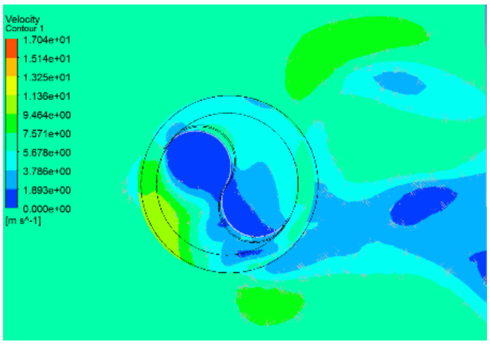


(ϴ = 135 degree)

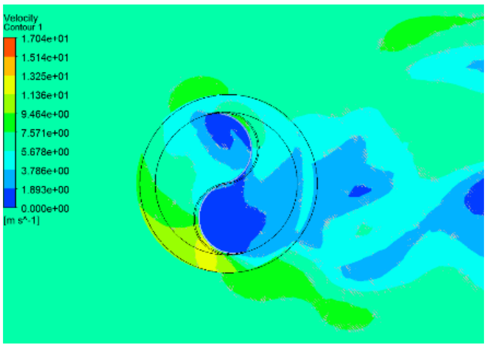
Fig.8: Velocity contour for different angle (ϴ) of unfinned rotor



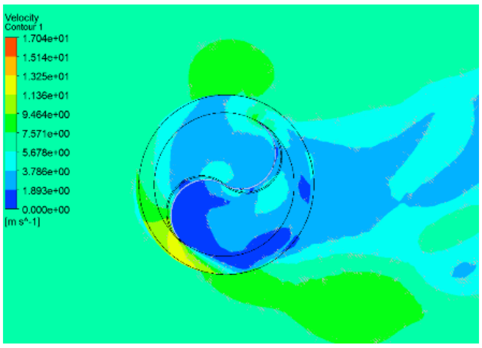
(Θ = 180 degree)



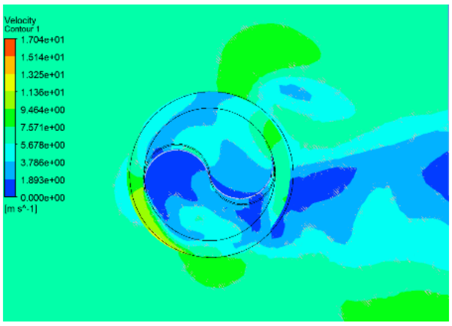
(Θ = 225 degree)



(Θ = 270 degree)



(Θ = 315 degree)



(Θ = 360 degree)

Fig.9: Velocity contour for different angle (Θ) of finned rotor

5. CONCLUSION

It is apparent from the analysis that the aerodynamic characteristics for finned rotor are less fluctuating than the unfinned one. But the optimum power coefficient in unfinned rotor is 0.113 and in finned rotor that is 0.097. So, the power coefficient of unfinned rotor is greater than than that of finned rotor. Therefore it can be conclude that

- The use of additional circular thin fin does not eventually increase the output power of the wind turbine.
- But it can supply more stable power than the unfinned rotor
- The unfinned rotor has the optimum power and torque coefficient.

6. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning	Unit
C_p	Power coefficient	Dimension less
C_tA	Torque coefficient	Dimension less
P	Power	Watt
T	Torque	N-m
ρ	density of air	Kg/m^3
V	Velocity of air	m/s
A	Area of rotor	m^2
r	Radius of rotor	m