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Effect of Environmental Factors on the Performance of Savonious Wind Rotor

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Abstract- Savonious rotors continue to interest research investigators in view of its many advantageous features. The simple design of the rotor enables the achievement of a low cost and compact wind power device, although its efficiency may not be comparable with other vertical axis machines such as Darraeus rotor. In low wind velocity zones, one can adapt these rotors with success. Different configurations of the Savonious rotor have been proposed to overcome some of the limitations of the earlier Savonious rotors, which have very low tip speed ratios. Design guidelines have been enunciated for the design of the rotors, based on experience with field-installed rotors. Although a few CFD investigations have been reported earlier on the flow analysis of Savonious rotors, there appears to be no serious attempt made for analysis of flow distribution in these rotors at rarified atmospheric conditions to enable a more realistic understanding of the rotor performance. The rarified atmospheric conditions result from the ambient temperature occurring as per seasonal variations. In the present paper, an attempt is made to carry out a detailed two-dimensional CFD analysis of the basic configuration of the Savonious wind rotor with eccentricity to assess the performance at different atmospheric conditions. A parametric analysis is carried out to understand the pressure and velocity distribution of the rotor. The commercially available Fluent has been used extensively in the present analysis.

Keywords- CFD analysis, wind power device .

I. INTRODUCTION

Savonious wind rotors can produce energy from wind power for the purpose of water pumping [1] and electricity [2] at low wind speeds. Although the efficiency is very low, high starting torque and simplicity in its construction and operation have enabled researchers to expend efforts at continual improvement of Savonious rotors. The disadvantages include difficulty of designing for high wind speeds.

Although many earlier investigators [3–6] have reported on the design, development and testing of Savonious rotor, very few investigators have reported a detailed three-dimensional CFD analysis of these rotors. Cochran et al [7] have discussed a three-pronged approach for the design including CFD analyses and wind tunnel testing. Rahai et al [8] have reported a method for aerodynamic optimization to improve the torques in split Savonious rotors.

Since there appears to be no serious attempt made for analysis of flow distribution in these rotors at rarified atmospheric conditions (resulting from the ambient temperature occurring as per seasonal variations) to enable a more realistic understanding of the rotor behavior, a detailed CFD analysis of a practical configuration of Savonious rotor is carried out in the present paper.

Earlier, the authors had carried out an analysis of the Savonious rotor, results of which have been correlated with those from wind tunnel tests by earlier investigators or with reported test data on actual rotors in site conditions.

II. FORMULATION OF THE PROBLEM

Fig.1 shows the mid-section of a typical Savonious wind rotor having an offset e. The blades of the Savonious rotor are taken as a semi-circular shape with radius 0.2m and having a 75 mm offset. Here two vanes are used on the rotor, which are placed adjacent to each other but facing in opposite direction with the offset. The area of interest around the rotor taken as a circular boundary of radius, 1.5m is also modeled in the analysis.

The wind is assumed initially to comprise of pure air under standard conditions of temperature of 25^{o}C and density of 1.19 kg/m^3. The wind density keeps reducing with an increase in temperature, which is the major causative factor being analyzed for. Typical atmospheric temperature conditions of 25 ^{o} C, 35^{o} C, 38 ^{o}C, 40 ^{o}C and 50 ^{o}C are used in the different analyses.

The velocity regime considered in the present work is 5 m/s, which value is imposed as a boundary condition, in a direction normal to the axis of the rotor.

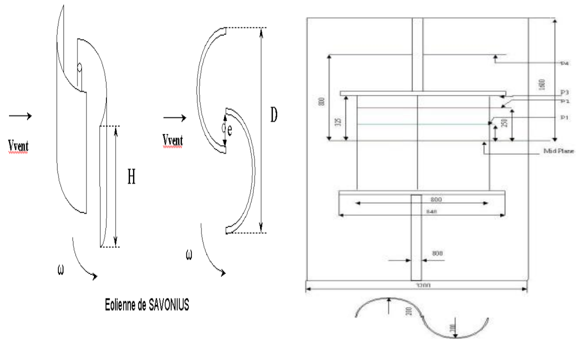


Fig 1. Sectional View of the Savonious Wind Rotor.

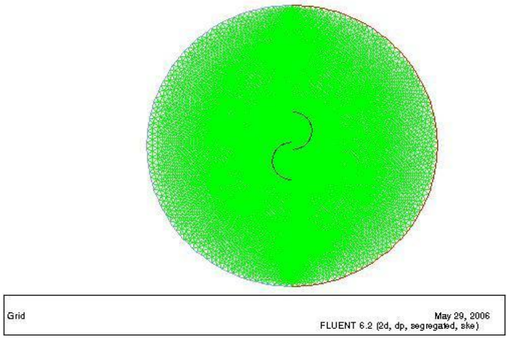


Fig 2. Mesh for Savonious Rotor with 75mm eccentricity

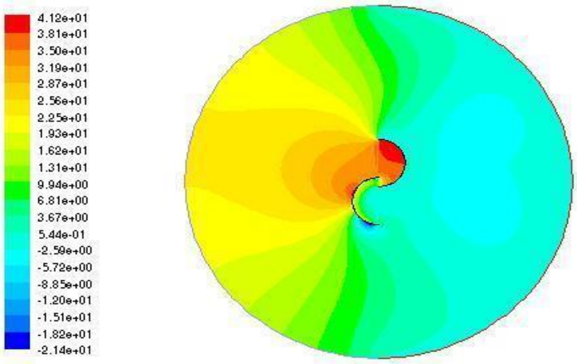
Gambit software is used as the pre-processor for constructing the geometry, mesh building and assigning the boundary zones on the geometry of the Savonious rotor. The domain is meshed with triangular elements and the critical region is densely meshed. The velocity inlet and pressure outlet boundary zones are assigned and the model is exported to Fluent, which is used for solving and post processing. In the model shown in Fig.2 , the inlet wind velocity condition is imposed in the x- direction on the left side.

A segregated 2D implicit model is used and the fluid, air, properties are assigned. The governing conservation of mass, momentum and turbulent equations are discretized using second order upwind scheme and pressure velocity coupling equation is represented with SIMPLE algorithm.

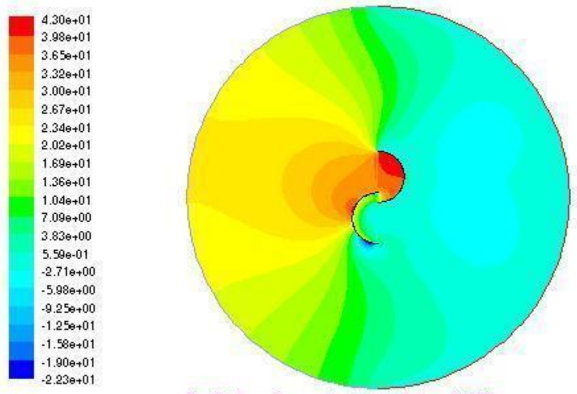
An earlier investigation by the authors has revealed that the k-ε model is the preferred model for simulating turbulence and the same has been used in the present analysis. Appropriate convergence criteria have been utilized to check the results.

III. RESULTS AND DISCUSSION

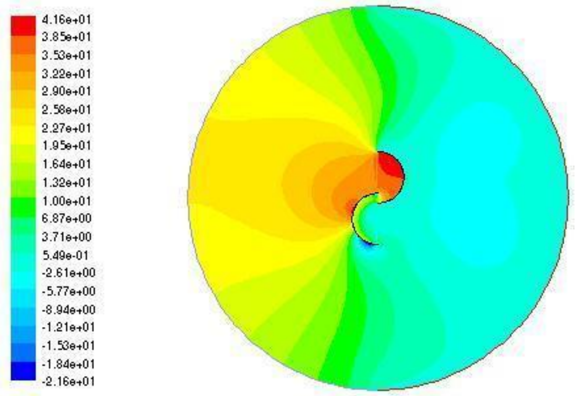
The contours of static pressure in the analysis domain for one of the cases are presented in Fig.3. The contours for the rotor with vane eccentricity of 75mm give an idea of these distributions in the different configurations of the rotor at 25°C, 35°C, 38°C, 40°C and 50°C.



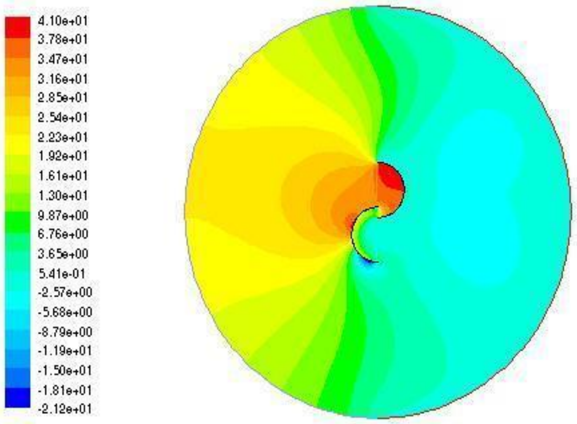
Pre Contours for ω =5 rad/s, Vel=5 m/s, p =1.14



Pre Contours for ω p=5rad/s,Vel=5m/s,p=1.1897



Pre Contours for ω =5 rad/s, Vel=5 m/s, p =1.151



Pre Contours for ω =5 rad/s, Vel=5 m/s, p =1.132

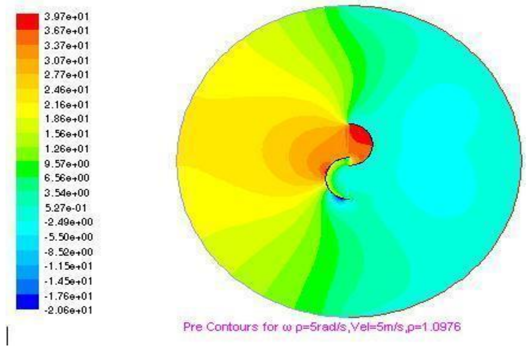
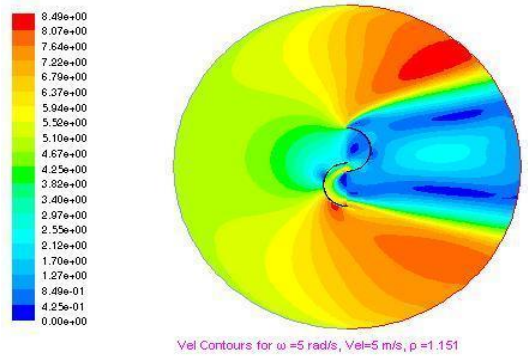
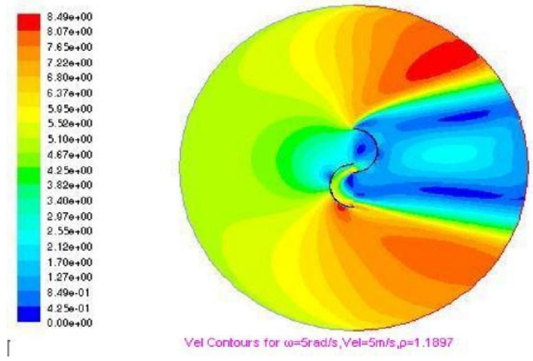
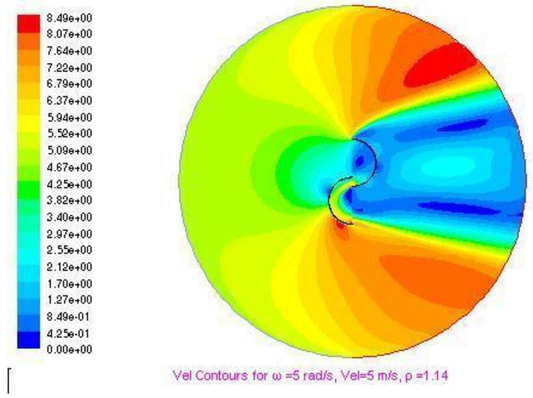


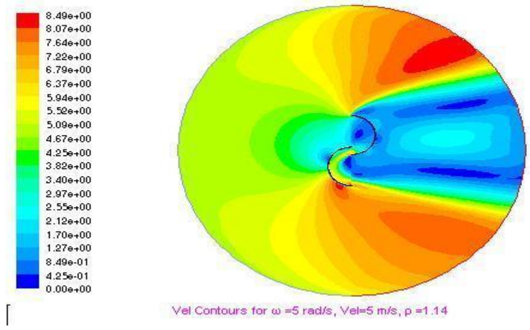
Fig 3. Static Pressure contours along the cross section of the rotor at different temperatures.

It is observed from the analysis that as the temperature of the atmosphere increases, the static pressure raise on the rotor decreases. It is because the density of the air decreases as the temperature of the air increases.









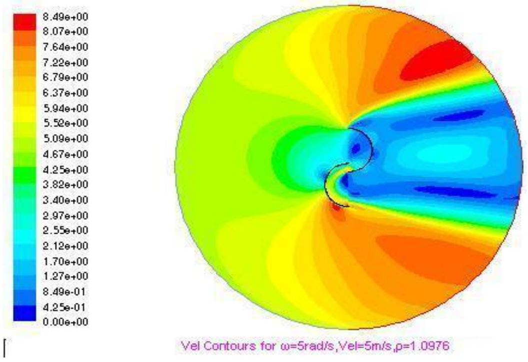


Fig 4. Velocity contours along the cross section of the rotor at different temperatures.

The Velocity contours for the rotor with vane eccentricity of 75mm in the different configurations of the rotor at 25^{o}C, 35^{o}C, 38^{o}C, 40^{o}C and 50^{o}C are shown in Fig. 4. It is observed from the analysis that with variation of atmospheric temperature does not affect the velocity variation in the domain considered.

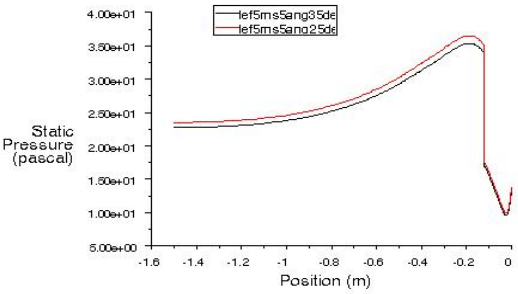


Fig 5. Variation of static pressure on the left.

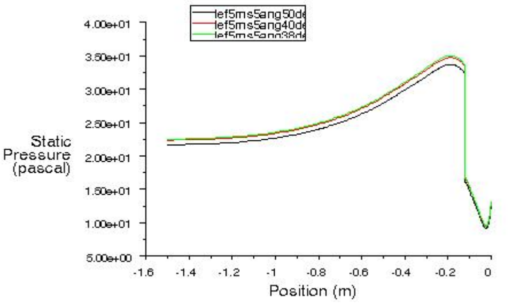


Fig 6. Variation of static pressure on the left side cup side of the cup 25, 35 deg Celsius of the 38, 40, 50 deg Celsius.

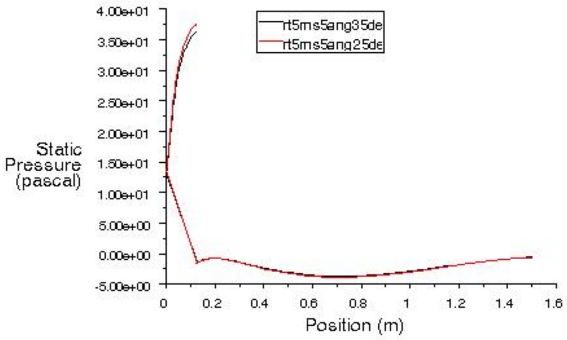


Fig 7. Variation of static pressure on the right side.

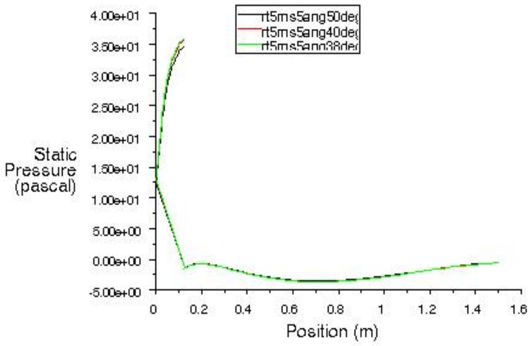


Fig 8. Variation of static pressure on the of the cup 25, 35 right side 38, 40, 50 deg Celsius.

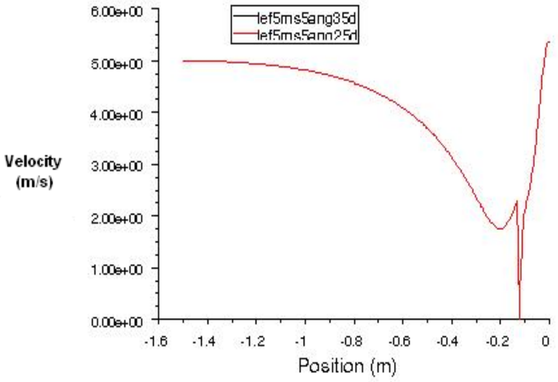


Fig 9. Variation of Velocity on the left side.

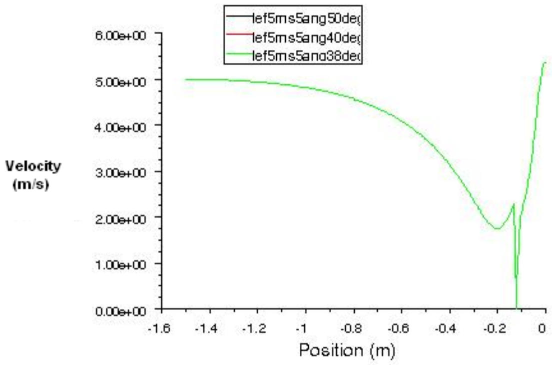


Fig 10. Variation of velocity on the left side of the cup 25, 35 of the cup 38, 40, 50.

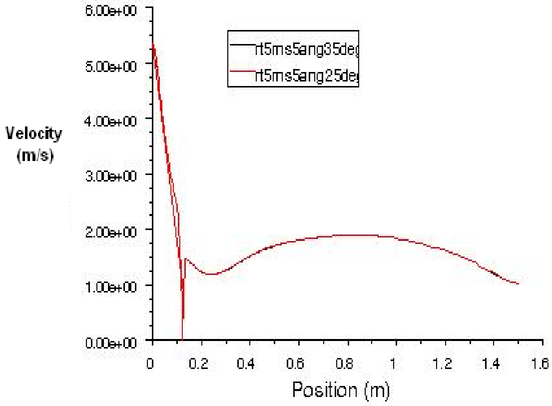


Fig 11. Variation of Velocity on the right-side.

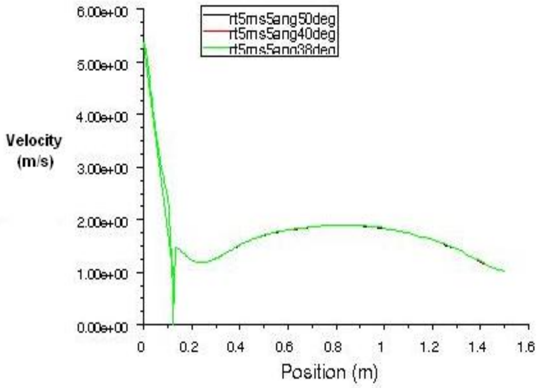


Fig 12. Variation of velocity on the right side of the cup 25, of the cup 38, 40, 50.

Figures 5,6,9,10 show the static pressure variation and velocity variation in the upstream side of the rotor blade while the figures 7,8,11,12 show the static pressure variation and velocity variation in the down stream of the rotor blade. As air moves nearer to the rotor cup the kinetic energy of the air is converted to the pressure energy, so the static pressure rises in the cup.

As air strikes the rotor blades, the rotor blades engross pressure energy of the air, and the rotor is rotated. So, in the downstream of the rotor, the pressure decreases. In the down stream region of the rotor, a wake region is formed and as consequence eddies is formed in this region as can be seen from the figures.

IV. CONCLUSION

A two-dimensional analysis of Savonious rotor has been carried out in the present analysis at different atmospheric conditions. The deviations in the velocities and pressures have been highlighted.

There are small but discernible variations in the static pressure as the ambient temperature increases while the velocity does not appear to change substantially.

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