Computational Analysis of Vertical Axis Savonius Rotor

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Abstract-*Savonius rotor has simple design and always gives positive torque at every velocity of air. In this paper, I am doing CFD Analysis with the help of Ansys 14.0. Aspect ratio of Savonius rotor will be 1.45 and overlap ratio will be zero. Pressure, velocity and Turbulence Kinetic Energy Analysis will be performed at 0^0, 30^0,60^0,90^0,120^0 and 150^0 attack Angle. In this simulation, I am doing modelling in Ansys 14.0 and Air inlet velocity will be 4 m/s. CFX solver will be used for the CFD analysis. Basic objective is to see pressure, velocity and TKE distribution around the rotor.*

Key Words:Wind Rotor, Savonius, CFD Analysis, CFX Solver, Ansys 14.0

1. INTRODUCTION

Wind energy is very important because one of the clean energy resources. Wind rotors are the most important tool of wind energy. Savonius rotor is a turbine vertical axis wind. It is simple in structure, has good startup characteristics, relatively low speeds operation and ability to capture the wind from any direction. But it has a low aerodynamic efficiency [1]. Savonius rotor was invented in 1929-1931 by S.J. Savonius and is used in electricity generation and water pumping [2]. Savonius rotor performance has been studied by many researchers from 1977 to 2010 in order to determine the optimal design parameters of this rotor. Then the main trends of these studies are summarized and discussed.

C.R. Patel et al. has used ANSYS 12 for optimizing the overlap ratio. In their research, they used Savonius rotor as a hydro rotor. They used PRO-E for modeling. And ANSYS 12 was used for CFD analysis. They conducted CFD analysis on overlap ratio at 0, 0.1 and 0.2. The simulated at 0^0, 45^0, 90^0 and 135^0. And they concluded that rotor gave good result at 0.2 overlap ratio. The overlap ratio of 0.2 provides highest coefficient factor of power and torque among all studies overlap ratios. Maximum coefficient of power of nearly 0.5 was achieved at TSR of 1.2 for the overlap ratio of 0.2 [3].

BhaskarJyoti Choudhury et al has conducted CFD analysis on two bladed Savonius rotor. They used CFD ANSYS-FLUET. Variations of drag and torque coefficients were studied for both the 2D and 3D models at different rotor blade angles at each 10° interval.Static pressure and velocity magnitude were found to reach their maximum at a 0^o rotor angle. The vorticity magnitude and turbulent kinetic energy were found to reach their maximum at a 30° rotor blade angle. They used standard k-ε turbulence model to analyses the drag and torque coefficient analysis, pressure and velocity contour analysis and vorticity and turbulence kinetic contour analysis. And they found out 60 J/kg as maximum turbulence kinetic energy at 30^o[4].

2. MODELLING

The geometrical modelling of the complete Savonius rotor in a single domain is very simple. I used Ansys 14 Workbench for geometric modeling. In present work, two blade single stacking Savonius-rotor turbine model used as it provides smoother rotor fluctuation force to the turbine blades. Dimension of modeling are following. Fig-1 is showing the modeling pic of Savonius rotor and Table-1 is showing the dimension of the Savonius rotor.

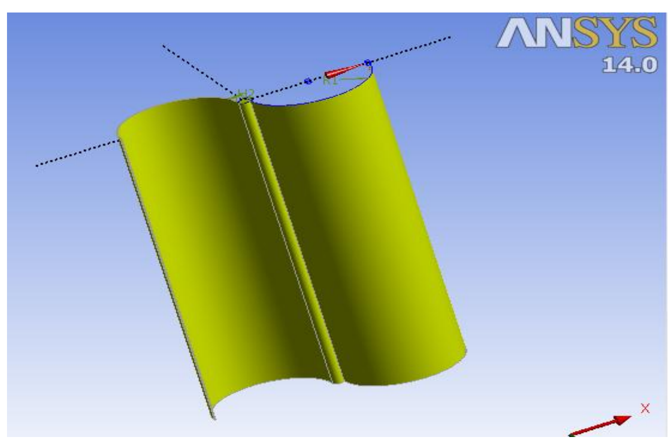


Fig-1 Savonius Rotor

Table- 1

Sr. No.	Input data	value
1	Height of Rotor, H	600 mm
2	Diameter of Rotor, D	415 mm
3	Arc Angle	180^0
4	Thickness of Blade	2 mm

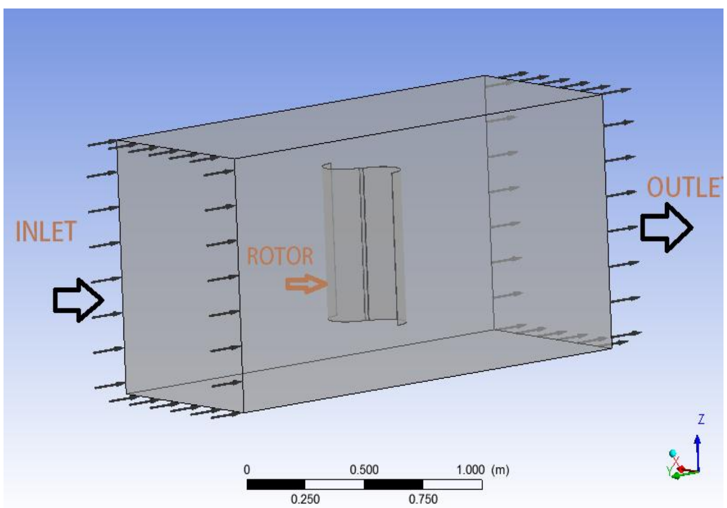


Fig-2 Complete Assembly of Savonius Rotor

3. MESH GENERATION

The complete assembly of Savonius rotor is divided into two parts i.e. Savonius rotor and Duct. For each flow domain tetrahedral mesh is generated and then assembled through the proper interfaces between all domains. The mesh quality is refined by using different quality parameters. In this mesh, nodes are 334382 and elements are 1877252. Fig-3 is showing the pic of meshing.

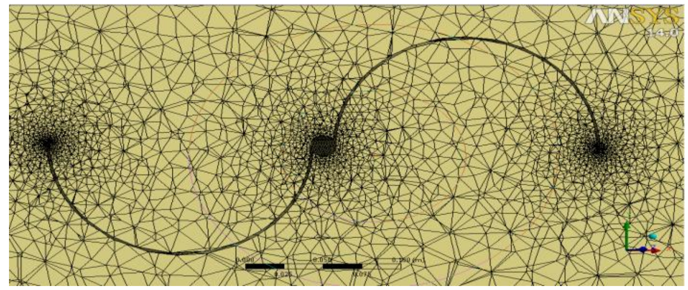


Fig-3 Meshing of Savonius Rotor

4. BOUNDARY CONDITIONS

The boundary conditions are applied at the inlet and outlet of complete flow domain. Walls of all flow domains are assumed to be smooth and no slip condition. Hence the following boundary conditions are as

- **Inlet condition**: Air temperature is 25 degree Celsius and inlet air velocity is 4 m/s.
- **Outlet condition**: The relative pressure is zero pascal.
- **Wall conditions**: Walls of complete flow domains are assumed to be smooth and no slip condition is given.
- **Turbulence Model**: There are many turbulence models and but in the present thesis Shear stress transport (SST) κ- ω are used.

5. VELOCITY CONTOUR ANALYSIS OF SAVONIUS ROTOR

Variation in the velocity magnitude at different rotor angles is depicted in **Chart-1** where it is observed that near the advancing rotor blade tip the velocity attains its maximum at a 150^o. And **Figure-4** is showing velocity contour at different rotor angles.

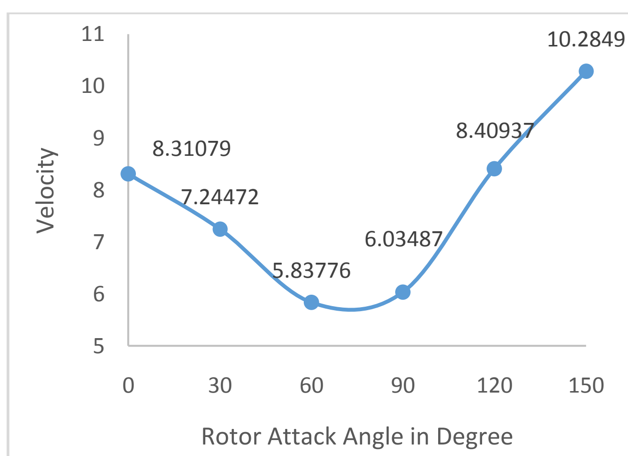
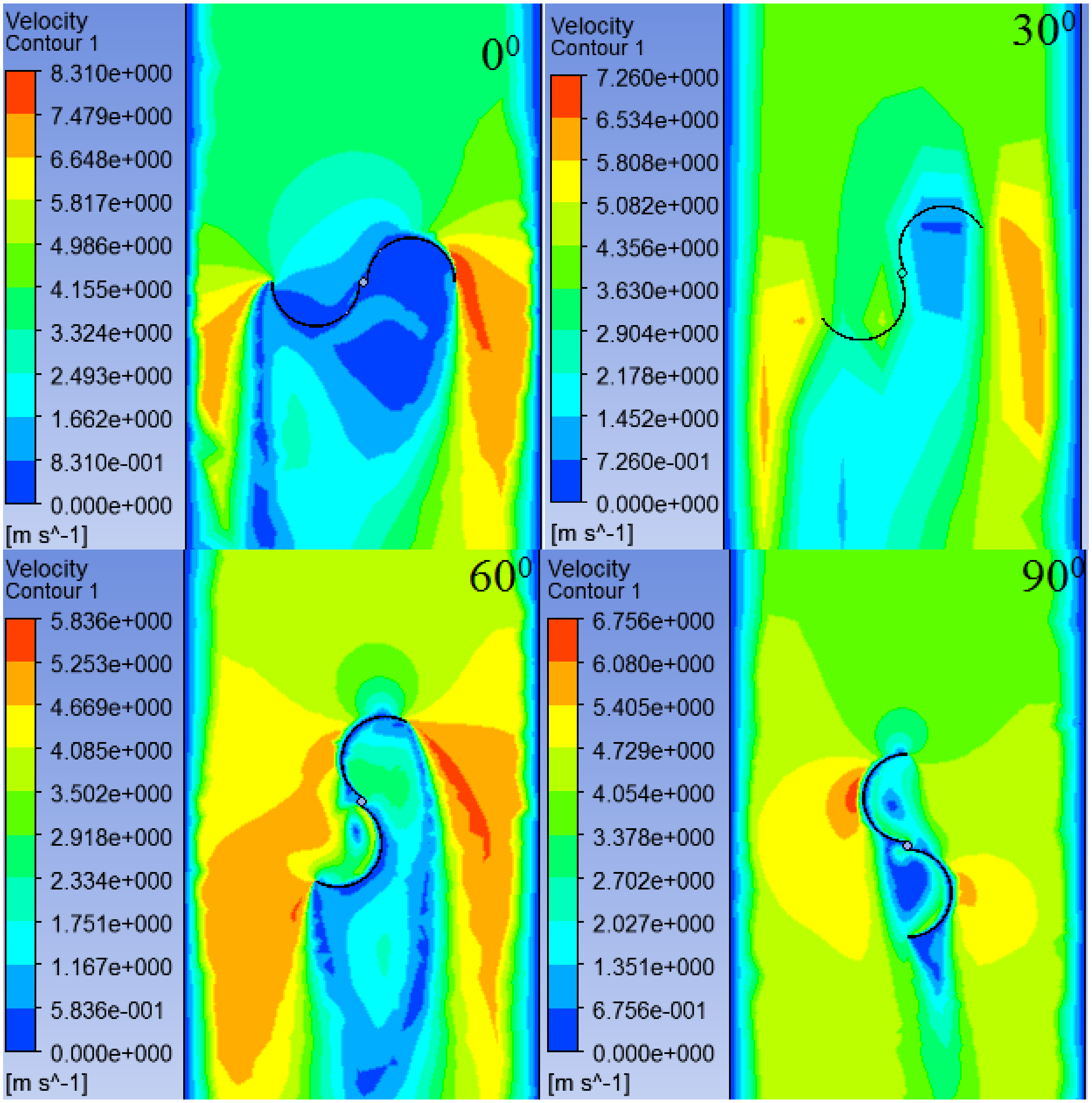


Chart-1 velocity developed at different rotor angles


Velocity
Contour 1
8.310e+000
7.479e+000
6.648e+000
5.817e+000
4.986e+000
4.155e+000
3.324e+000
2.493e+000
1.662e+000
8.310e-001
0.000e+000
[m s^-1]
0⁰
Velocity
Contour 1
7.260e+000
6.534e+000
5.808e+000
5.082e+000
4.356e+000
3.630e+000
2.904e+000
2.178e+000
1.452e+000
7.260e-001
0.000e+000
[m s^-1]
30⁰
Velocity
Contour 1
5.836e+000
5.253e+000
4.669e+000
4.085e+000
3.502e+000
2.918e+000
2.334e+000
1.751e+000
1.167e+000
5.836e-001
0.000e+000
[m s^-1]
60⁰
Velocity
Contour 1
6.756e+000
6.080e+000
5.405e+000
4.729e+000
4.054e+000
3.378e+000
2.702e+000
2.027e+000
1.351e+000
6.756e-001
0.000e+000
[m s^-1]
90⁰

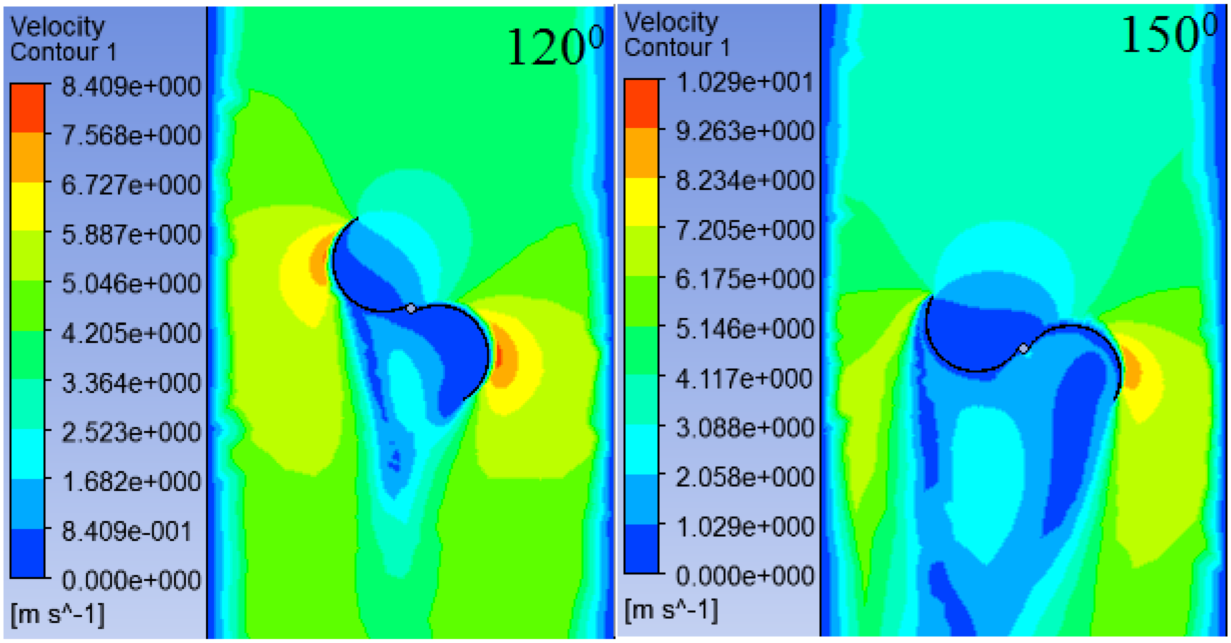


Fig-4 Contours of velocity magnitude at different rotor angles

6. PRESSURE CONTOUR ANALYSIS OFSAVONIUS ROTOR

Variation in the pressure magnitude at different rotor angles is depicted in **Chart-2.** The pressure attains its maximum at a 0°. And **Figure-5** is showing pressure contour at different rotor angles.Maximum Air Pressure is found at 0^0 attack angle and value is 21.3469 pascal.

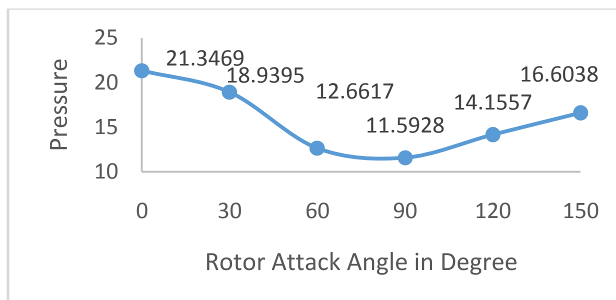
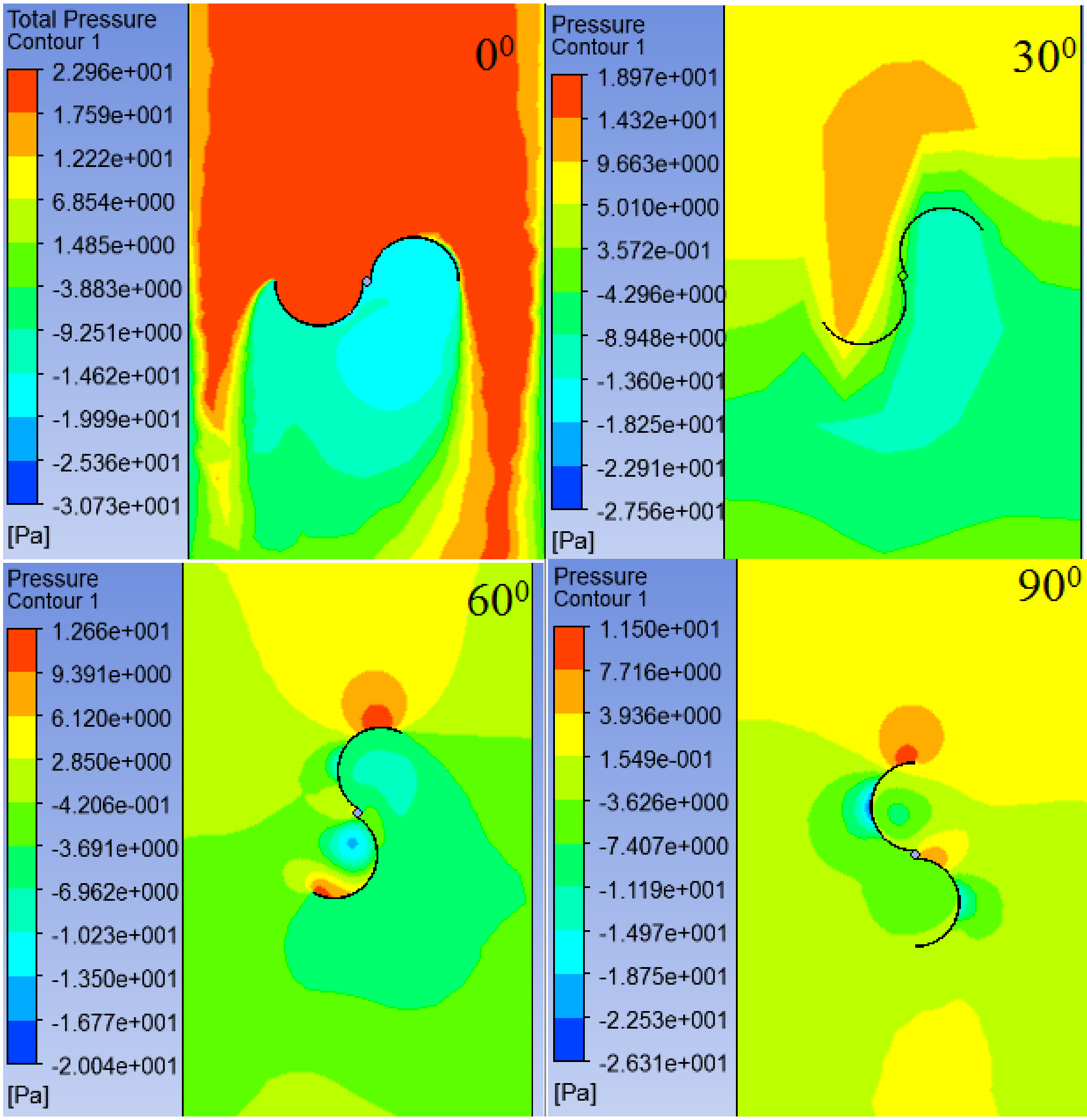


Chart-2 Pressure developed at different rotor angles


Total Pressure
Contour 1
2.296e+001
1.759e+001
1.222e+001
6.854e+000
1.485e+000
-3.883e+000
-9.251e+000
-1.462e+001
-1.999e+001
-2.536e+001
-3.073e+001
[Pa]
0⁰
Pressure
Contour 1
1.897e+001
1.432e+001
9.663e+000
5.010e+000
3.572e-001
-4.296e+000
-8.948e+000
-1.360e+001
-1.825e+001
-2.291e+001
-2.756e+001
[Pa]
30⁰
Pressure
Contour 1
1.266e+001
9.391e+000
6.120e+000
2.850e+000
-4.206e-001
-3.691e+000
-6.962e+000
-1.023e+001
-1.350e+001
-1.677e+001
-2.004e+001
[Pa]
60⁰
Pressure
Contour 1
1.150e+001
7.716e+000
3.936e+000
1.549e-001
-3.626e+000
-7.407e+000
-1.119e+001
-1.497e+001
-1.875e+001
-2.253e+001
-2.631e+001
[Pa]
90⁰

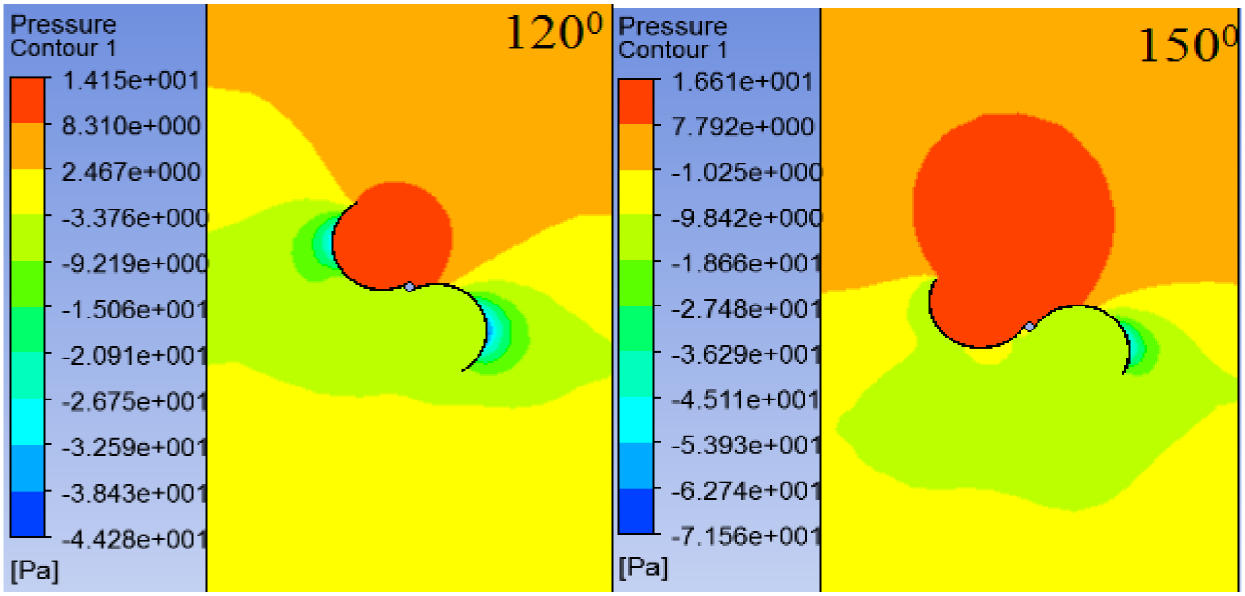


Fig-5 Contours of pressure magnitude at different rotor angles

7. TURBULENCE KINETIC ENERGY CONTOUR ANALYSIS OF SAVONIUS ROTOR

Variation in the turbulence KE magnitude at different rotor angles is depicted in **Chart-3**. The turbulence KE attains its maximum at a 0^o. And **Figure-6** is showing velocity contour at different rotor angles.Maximum Turbulence Kinetic Energy is found at 0^0 attack angle and value is 3.23383 m^2/s^2.

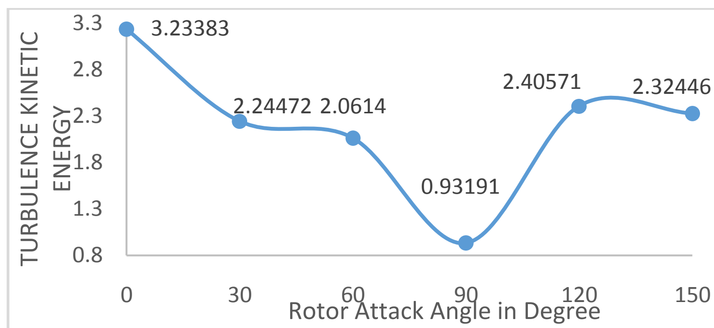
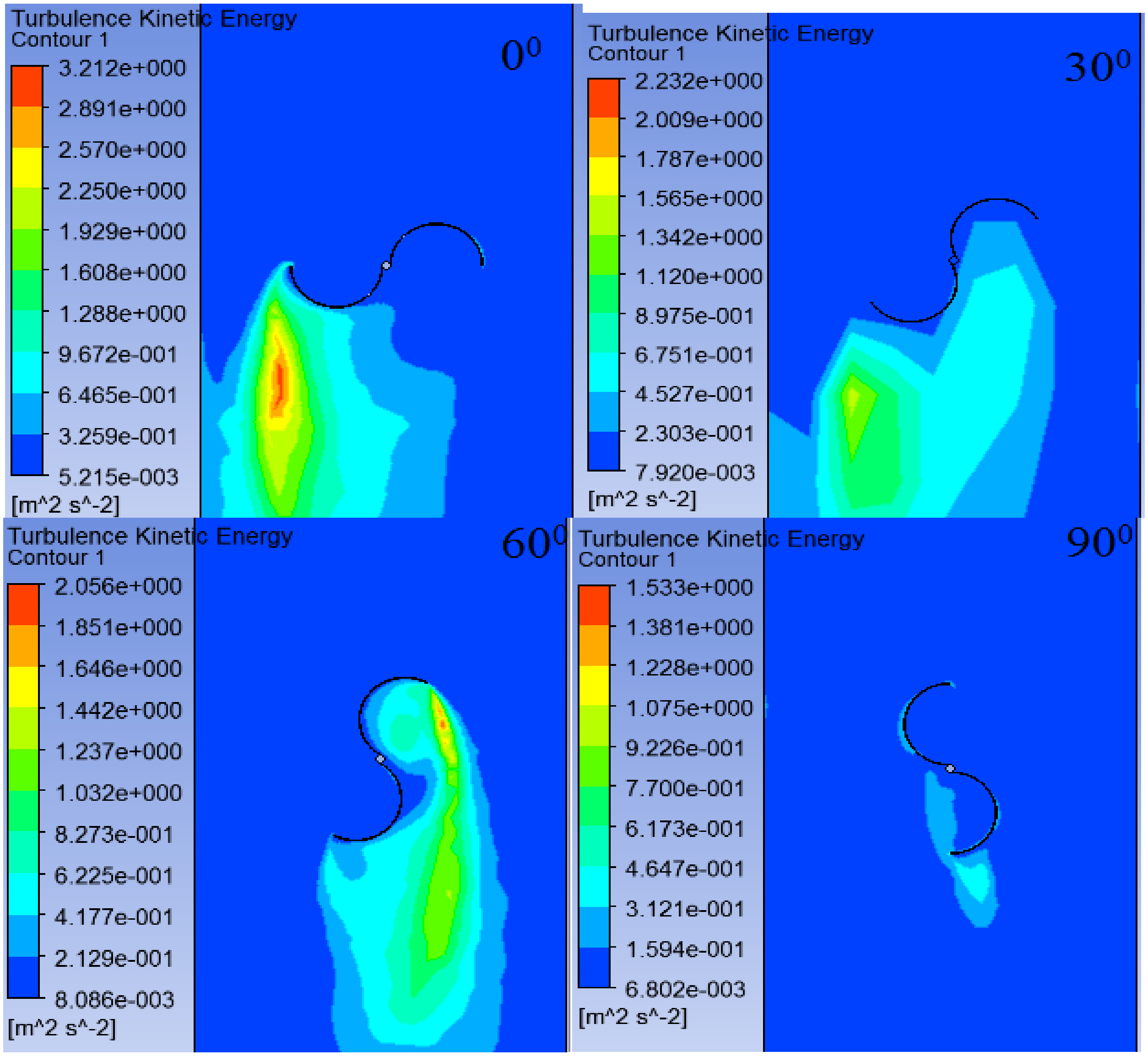


Chart-3 Turbulence kinetic energy developed at different rotor angles


Turbulence Kinetic Energy
Contour 1
3.212e+000
2.891e+000
2.570e+000
2.250e+000
1.929e+000
1.608e+000
1.288e+000
9.672e-001
6.465e-001
3.259e-001
5.215e-003
[m^2 s^-2]
0⁰
Turbulence Kinetic Energy
Contour 1
2.232e+000
2.009e+000
1.787e+000
1.565e+000
1.342e+000
1.120e+000
8.975e-001
6.751e-001
4.527e-001
2.303e-001
7.920e-003
[m^2 s^-2]
30⁰
Turbulence Kinetic Energy
Contour 1
2.056e+000
1.851e+000
1.646e+000
1.442e+000
1.237e+000
1.032e+000
8.273e-001
6.225e-001
4.177e-001
2.129e-001
8.086e-003
[m^2 s^-2]
60⁰
Turbulence Kinetic Energy
Contour 1
1.533e+000
1.381e+000
1.228e+000
1.075e+000
9.226e-001
7.700e-001
6.173e-001
4.647e-001
3.121e-001
1.594e-001
6.802e-003
[m^2 s^-2]
90⁰

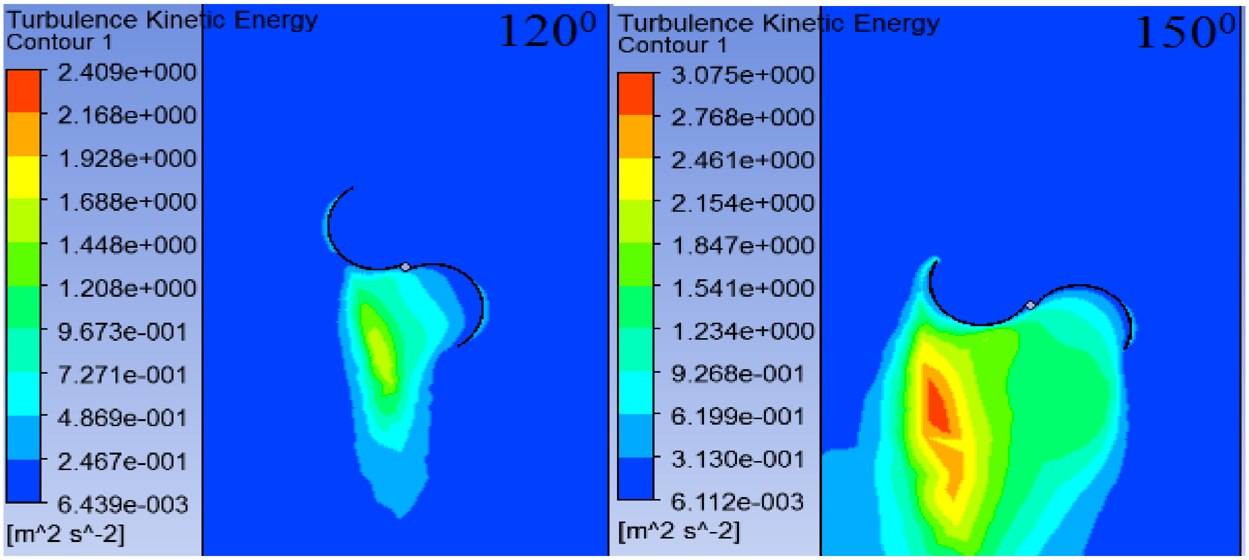


Fig-6 Contours of turbulence KE magnitude at different rotor angles

8. CONCLUSION

In this Analysis, Maximum Air Velocity is found at 150^0 attack angle and value is 10.2849 m/s. Maximum Air Pressure is found at 0^0 attack angle and value is21.3469 pascal. Maximum Turbulence Kinetic Energy is found at 0^0 attack angle and value is 3.23383 m^2/s^2.

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