Angular velocity of a combined unloaded Savonius turbine with a vortex inducing chamber- A CFD approach

Abdullah Al-Faruk & Ahmad Sharifian

Faculty of Engineering and Surveying, USQ

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Introduction . . .

- Introduction
- Geometry of the designs
- Modelling
- Results and Discussions
- Conclusions

Introduction . . .

- Global warming is the greatest threat facing our planet.
- The main source of greenhouse gases is burning fossil fuels for energy production.
- It is necessary to develop renewable energy and improve energy efficiency of existing systems to reduce greenhouse gas emissions.

Introduction . . .

- Wind energy is one of the most promising sources of renewable energy.
- Horizontal axis wind turbines (HAWT) are more common compared with vertical axis wind turbines (VAWT) mainly because they have higher efficiency.
- However, VAWTs have several advantages than HAWTs.

Introduction . . .

- Vertical axis Savonius wind turbine proposed by Finnish Engineer Sigurd Savonius is basically a drag type rotor.
- Advantages

  - simple structure

  - ability to accept wind from any direction

  - high starting torque
- Disadvantages

  - slow running (tip speed ratio $\approx$ 1)

  - low coefficient of power (CoP)

Introduction . . .

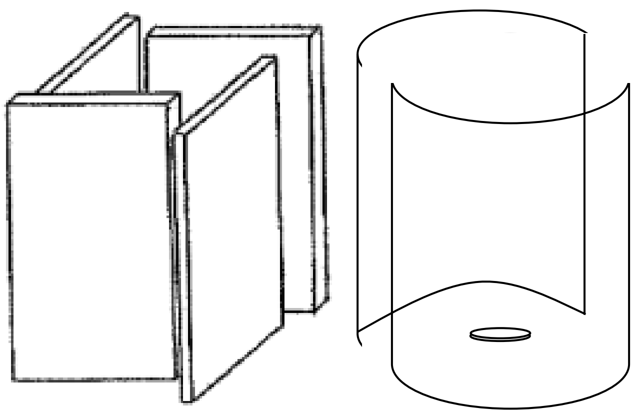
- An innovative low cost technique is considered to increases the angular velocity and CoP of Savonius turbines using industrial waste heat.
- Waste heat has no useful application due to the associated cost and possible adverse effects on the efficiency of the primary system.
- A system that is not expensive and does not degrade the efficiency of the main system is desirable.

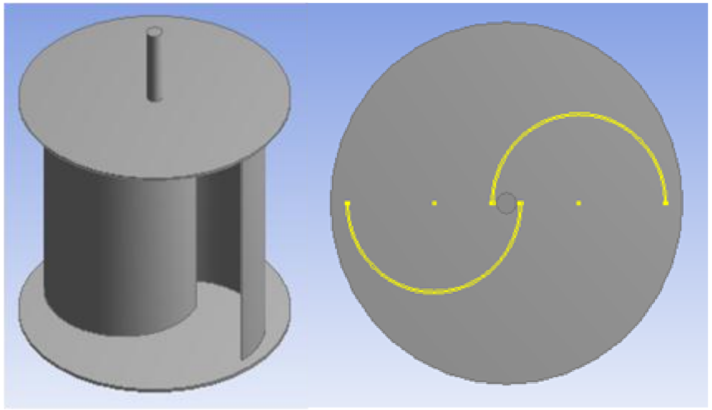
Introduction . . .

- A simple and an inexpensive configuration exists which produces a swirling flow and might be able to simultaneously resolve issues associated with the cost and efficiency of the VAWTs.
- Fire-whirls can be induced naturally as well as experimentally. The two common stationary configurations that induce fire whirls in laboratories are square enclosure and cylindrical enclosure.

Introduction . . .

- The obvious geometric similarities between the cylindrical enclosure to induce the fire-whirl and the Savonius turbine make it possible to combine the two mechanisms into one.



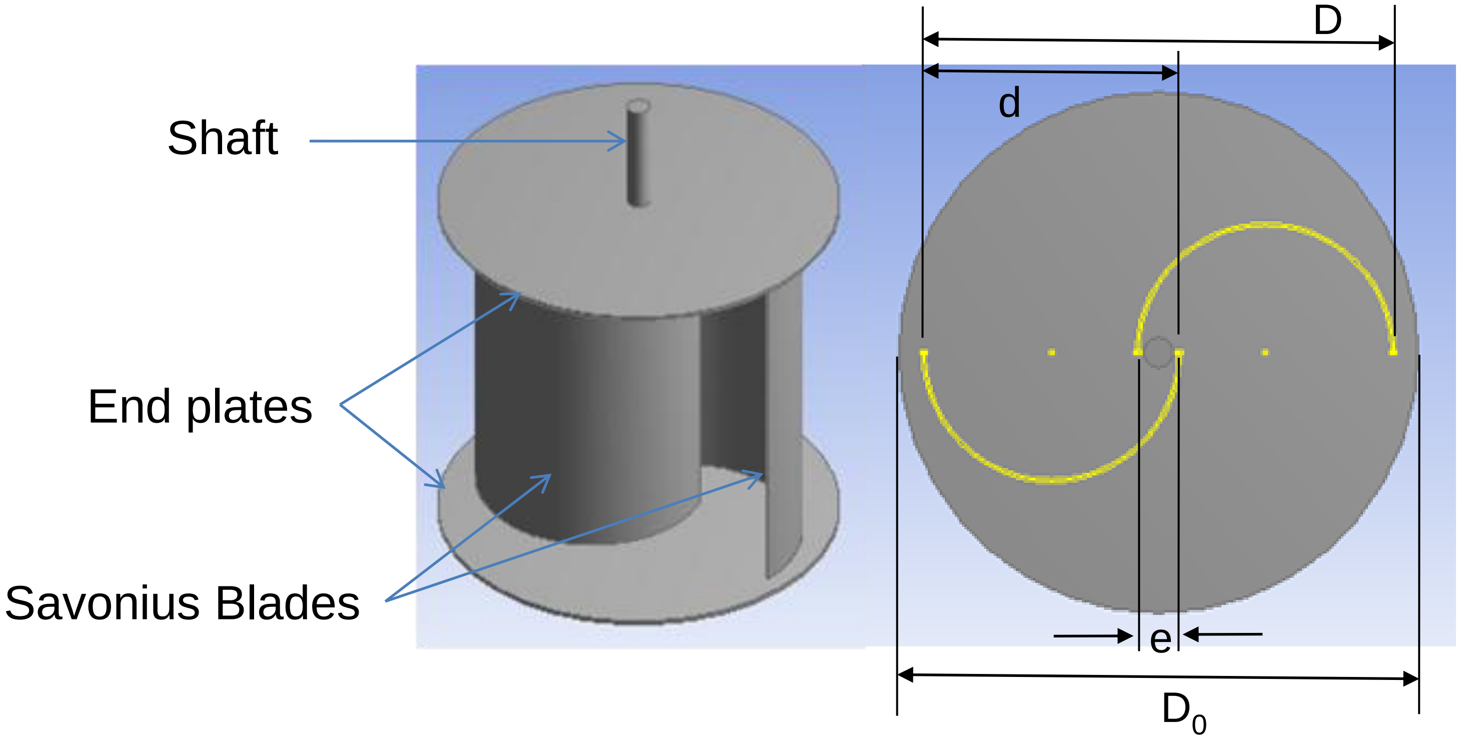


Introduction . . .

- Industrial waste heat could replace the fire.
- To combine the two mechanisms, some modifications to the Savonius turbine has been made which results to a new type of Savonius turbine.
- The performance of the such combined configuration was numerically investigated and then compared with the conventional Savonius turbine.

Geometry of the designs

The model of the conventional Savonius turbine and its geometrical parameters

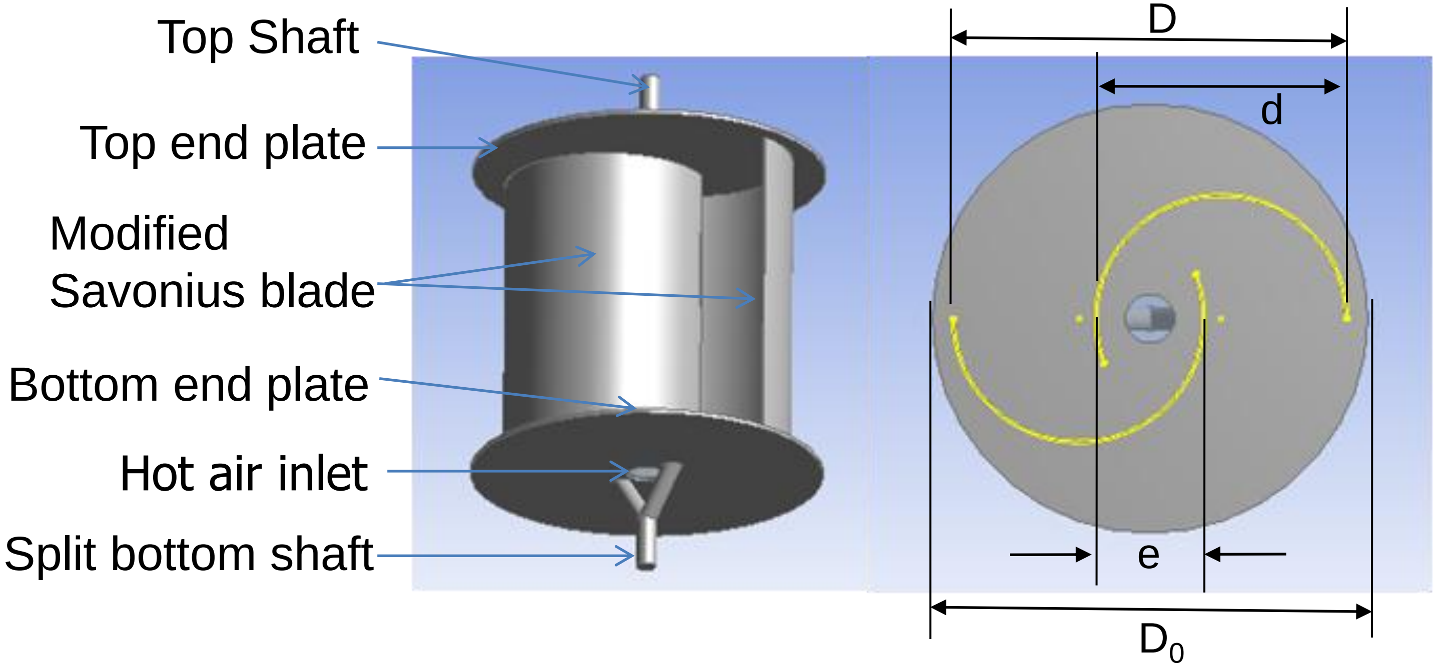


$D = 32$ cm
$D_0 = 35$ cm
$d = 17.1$ cm
$e = 2.6$ cm

Turbine Height = 32 cm
End plates thickness = 4 mm
Blade plate thickness = 2 mm
Turbine weight = 3.2132 Kg
Shaft Diameter = 2 cm

Geometry of the designs . . .

The model of the new combined Savonius turbine and its geometrical parameters



D = 32 cm
D_0= 35 cm
d = 20.075 cm
e = 8.55 cm

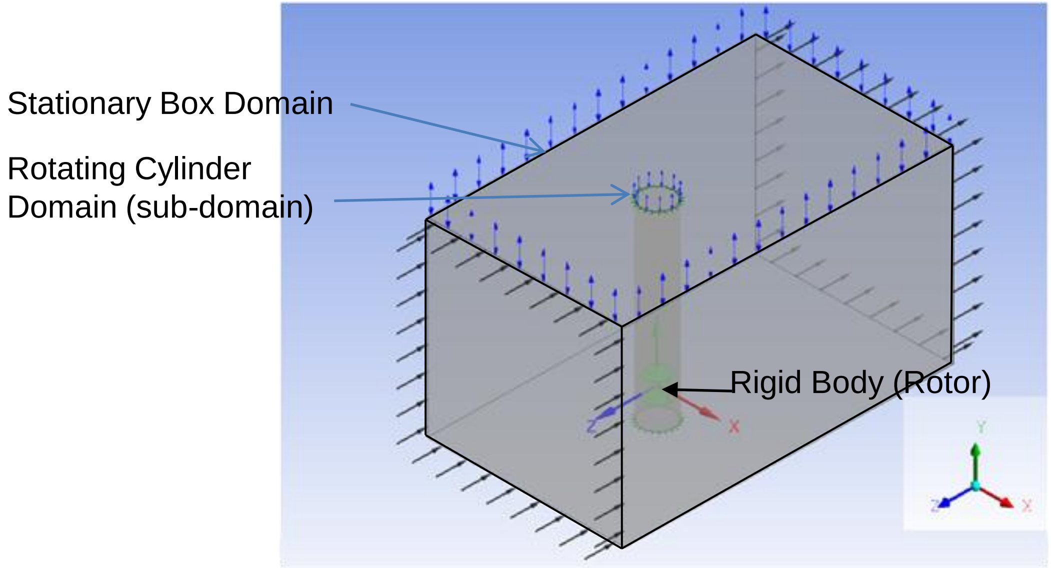
Turbine Height = 32 cm
Blade plate thickness = 2 mm
Hot air inlet diameter = 4 cm
Turbine weight = 3.2132 Kg
Shaft Diameter = 2 cm

Modelling . . .

- Turbine modelling is very difficult due to the its two-way coupling nature of fluid-structure interaction (FSI).
- The main problem is the procedure used to take into account the motion of the solid body in the solution of fluid dynamics equations.
- The strategy to solve this problem used in this work was a Rigid Body Solver with Sliding Mesh Model (SMM) approach.

Modelling . . .

- The rotor was treated as a rigid body which moves due to the fluid forces and torques acting upon it.
- The computational fluid domain was divided into two parts. The inner cylindrical domain that contains the rotor undergoes mesh deformation when the rotor turns, while the outer rectangular domain remains steady.



Modelling . . .

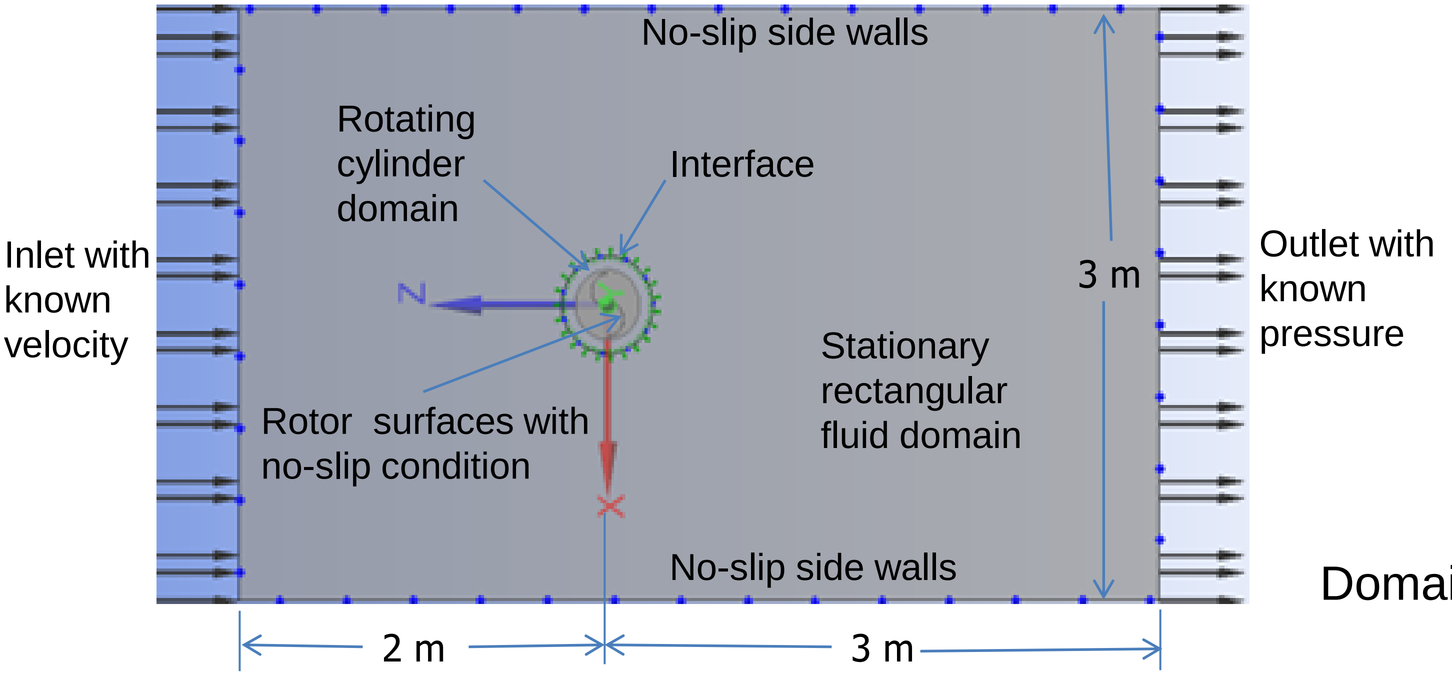
- To allow mesh deformation mesh motion has been defined which causes the whole cylindrical sub-domain to rotate with the same angular velocity as that of the rotor.

- The interface between the rotating cylindrical domain and stationary rectangular domain was handled by the sliding mesh feature.

- The *k-ε* turbulence model with 5% turbulence intensity was used for the simulations.

Modelling

Top view of the computational domain and the boundary conditions



Domain Height is 3 m

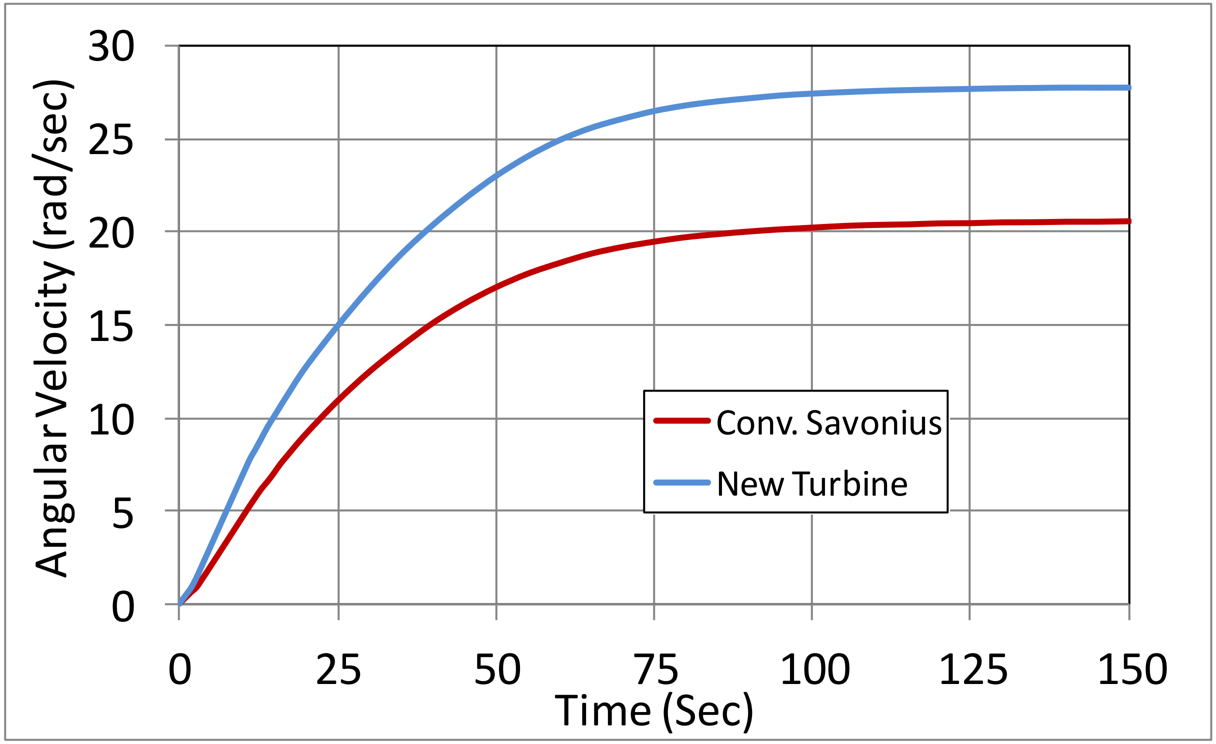
- The hot air inlet is 100°C at atmospheric pressure condition.
- The bottom had no slip wall boundary condition.
- The top had an opening boundary with the zero relative pressure and unknown direction.

Results and Discussions . . .

- Simulations conducted using rigid body solver and sliding mesh approach.
- The angular velocity and the rotor torque was taken from the simulation.
- Performance comparisons has been made between the two turbines in terms of angular velocity, power coefficient and torque coefficient.

Angular velocity

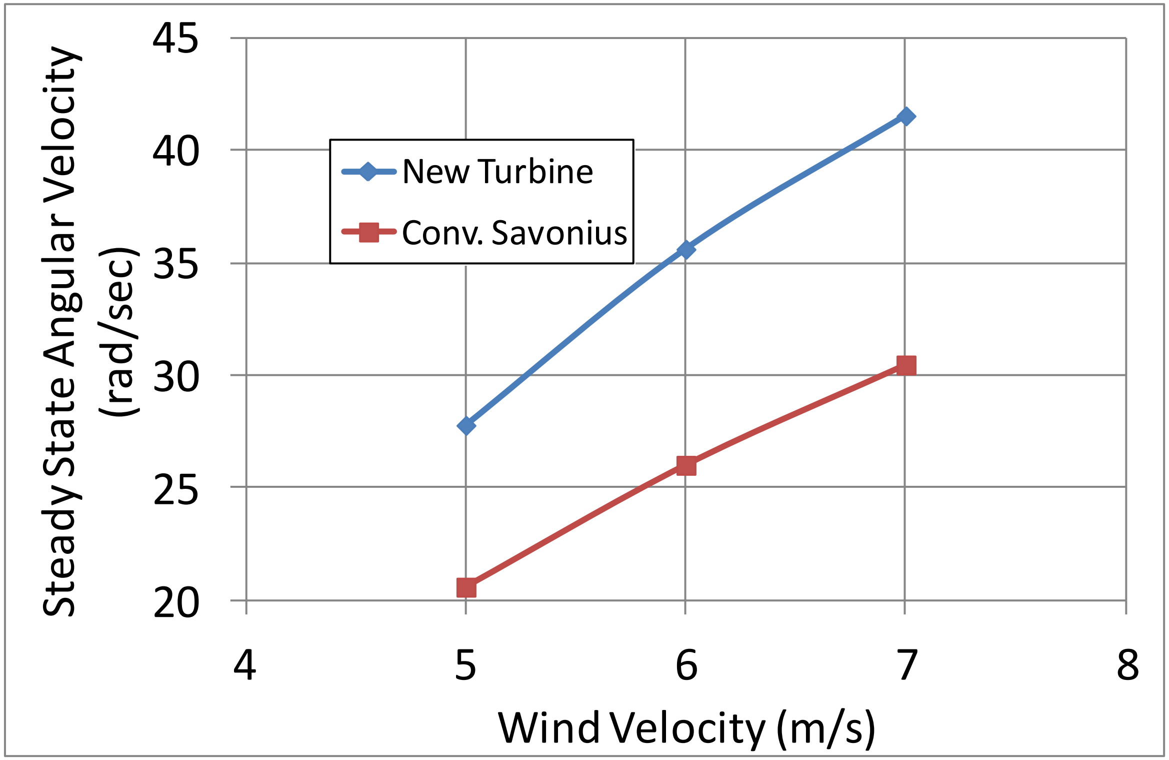
Comparison of angular velocity between conventional Savonius turbine and new combined turbine



35% increase in angular velocity for 5 m/s wind velocity

Angular velocity

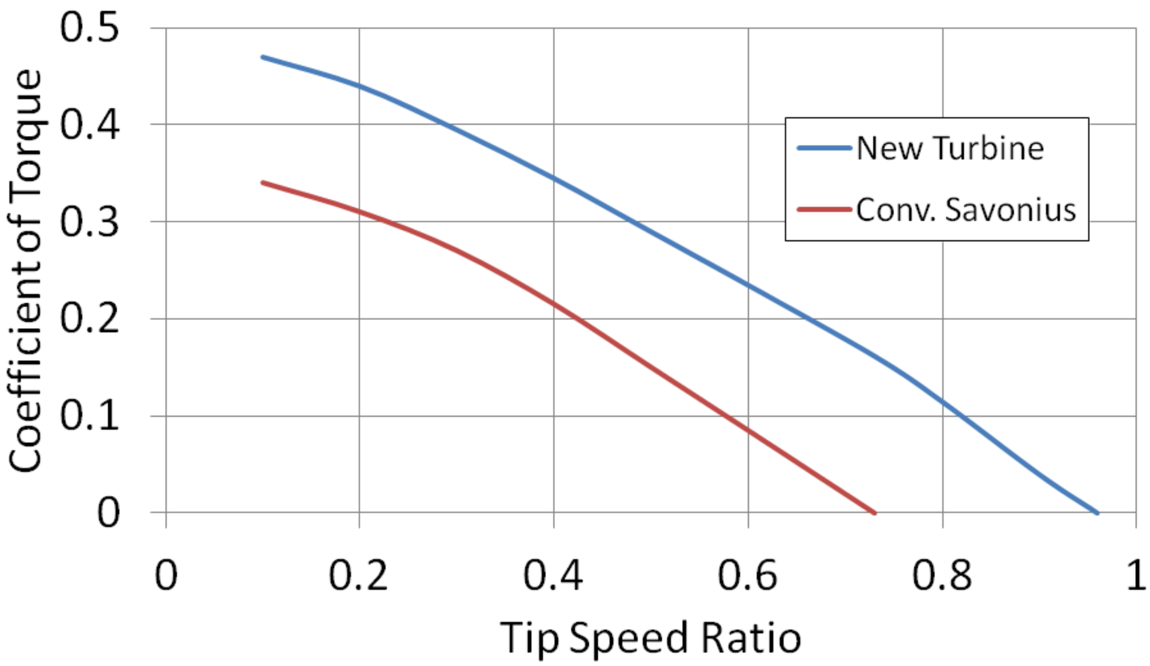
Variation of steady state angular velocity with free stream wind velocity



For each wind velocity about 35% increase in steady state angular velocity

Coefficient of torque

Comparison of torque coefficient between conventional Savonius turbine and new combined turbine



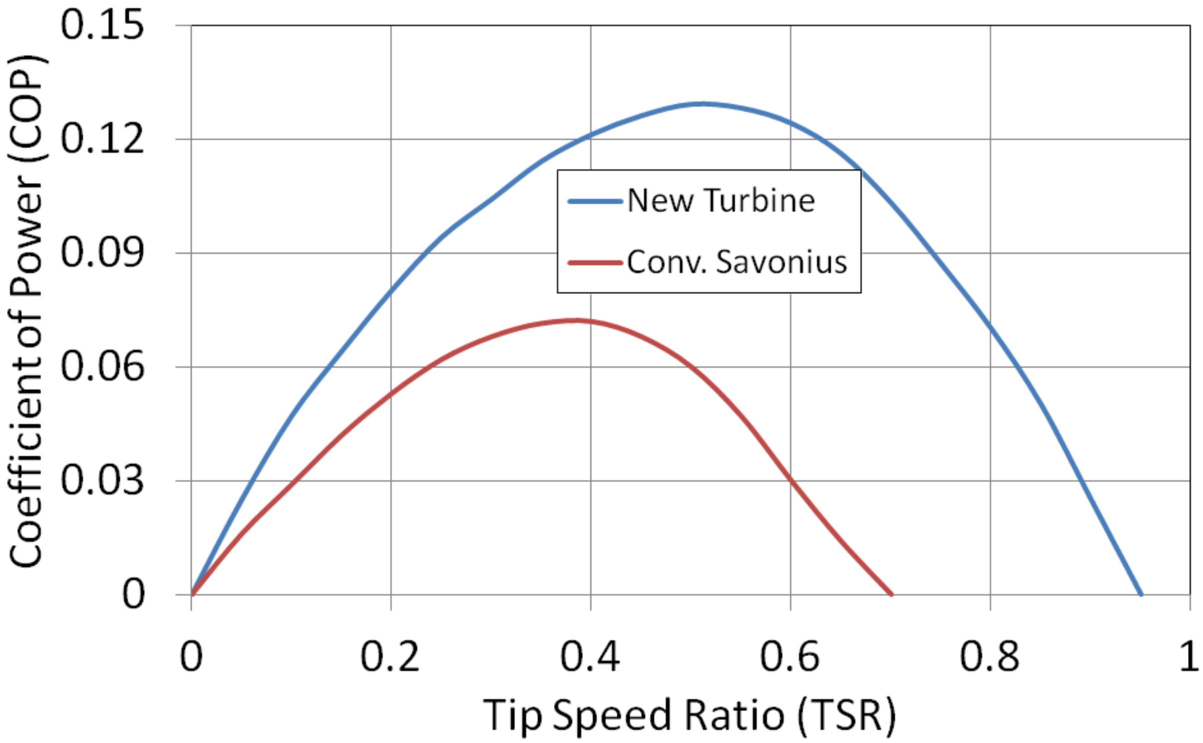
$$TorqueCoefficient = \frac{Rotortorque}{\frac{1}{2}\rho U^2 A}$$

$$TSR = \frac{TipVelocity}{WindVelocity}$$

37% increase in torque coefficient

Coefficient of power

Comparison of Power coefficient between conventional Savonius turbine and new combined turbine



$$COP = \frac{MechanicalPower}{WindPower}$$

$$TSR = \frac{TipVelocity}{WindVelocity}$$

85.5% increase in maximum COP

Conclusion

- Performance of Savonius wind turbine can be improved by incorporating a hot swirling flow inside the turbine enclosure.
- Angular velocity and torque coefficient of the unloaded combined new turbine increased by 35% and 37% respectively.
- Power coefficient of the unloaded combined new turbine also increased by 85.5%.

Further works

- Optimization of the rotor geometry.
- Experimental works to validate the computational results.

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Thank you

Abdullah.Alfaruk@usq.edu.au