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Design and Modelling of Varticle Axis Savonius Water Turbine

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Abstract — **To produce electricity by using renewable resources is very essential in this time. Hydropower from the rivers, canals and streams are one of the best renewable sources and green cheap and easily available resources to produce electricity from flow of water. For generation of electricity using the kinetic energy of natural water resources, Savonius rotor is one of the best types of turbine. The savonius turbine is more popular as wind turbine. In hydrokinetic turbines, Savonius turbine is easy to design and fabricate. In present work, a working model of savonius rotor is built and analyzed analytically and practically. The effect of overlap ratio is investigated for performance enhancement of savonius turbine. In present investigation four different overlap ratios, 0.20, 0.25, 0.30 and 0.35 are analyzed. It is found that the maximum torque can be obtained at overlap ratio 0.35.**

Key words — **Overlap ratio, Savonius turbine, Working Model, Hydropower, Co-efficient of power, Co-efficient of torque.**

I. NOMANCLATURE

α Aspect ratio
β Overlap ratio
ρ Density $[kg/m^3]$
ω Angular velocity $[rad/s]$
d Diameter of the Blade $[m]$
D_r Diameter of rotor $[m]$
e Gap between two paddles $[m]$
F Force of turbine $[N]$
H Height of rotor$[m]$
N Rotation velocity $[rpm]$
P Power $[watts]$
m mass flow rate$[kg/s]$
A Area of jet $[m^2]$
T Torque of model $[Nm]$
V Current velocity $[m/s]$
U velocity of blade$[m/s]$
C_p Co- efficient of power
C_t Co-efficient of torque

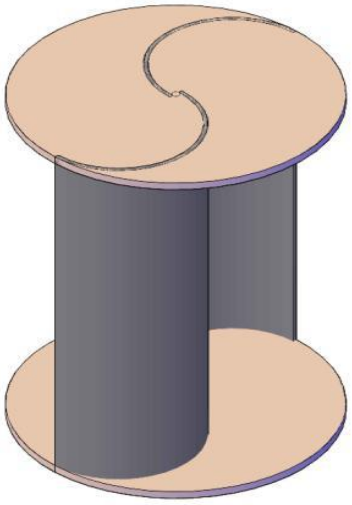


Fig. 1 Savonius Rotor [5]

II. INTRODUCTION

Hydropower from the river is one of the best renewable sources. Hydropower source is predictable compared to wind or solar energy. Hydrokinetic turbine electricity generation is mainly aimed for rural use at sites remote from existing electricity grids. It is a useful tool for improving the quality of life of people in these locations and for improving local economies. Different designs of water current turbine are available for the extraction of energy from the river water or canals. Based on the alignment of the rotor axis with respect to water flow, two generic classes exist. They are horizontal axis turbine (axial turbines) and vertical axis turbine (cross-flow turbines). Commonly used vertical axis turbines are Savonius turbine, helical turbine, Darrieus turbine, and H-shaped Darrieus turbine.[3]

The Savonius type vertical axis wind rotor was first invented by S. J. Savonius in 1929. The design was based on the principle of Flettner's rotor. The rotor was formed by cutting a Flettner's cylinder from top to bottom and then moved the two semi-cylinder surfaces sideways along the cutting plane so that the cross-section resembled the letter 'S'. It can be directly placed in flowing stream of water to generate mechanical power from kinetic energy of flowing fluid. Applications of Savonius rotor, in general, include ventilation pumping water, driving an electrical generator. [1]

Figure 2 indicates comparison of coefficient of power of some of the hydro kinetic turbines, at different Tip Speed Ratio (λ).However, coefficient of performance of Savonius rotor is comparatively low, but it has excellent starting capability. Performance of Savonius type turbines is critically affected by 2 particular parameters, (1) Aspect ratio, (2) Overlap ratio . Present work focused on study of the effects of overlap ratios on the performance of the Savonius turbine in relation to its output torque.[3]

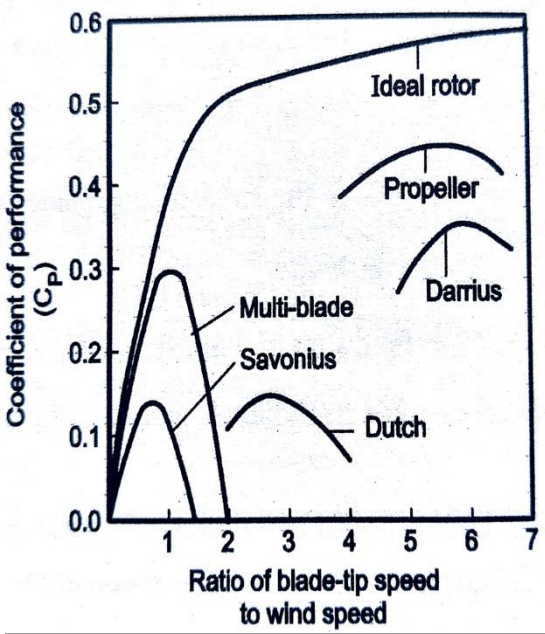


Fig. 2 Comparison of Cp-λ performance curves [3]

III. PERFORMANCE PARAMETERS OF SAVONIUS ROTOR

Figure 3 indicates schematic diagram of Savonius rotor with nomenclatures used. Two parameters, (1) aspect ratio α, (2) Overlap ratio β, are predominantly affecting performance of Savonius turbine. Present work mainly focused on performance enhancement by variation of overlap ratio. [5]

A. Aspect ratio:

The aspect ratio represents the height of rotor relative to diameter. The relation is shown by [5]

$$\alpha = \frac{H}{D_r} \qquad (1)$$

B. Overlap Ratio

The equation for the overlap ratio is given by [14]

$$\beta = \frac{(e-e')}{d} \qquad (2)$$

Overlap ratio is one important factor affecting the performance of the turbine. In present study, effort is made to find optimum overlap ratio to get best coefficient of performance.

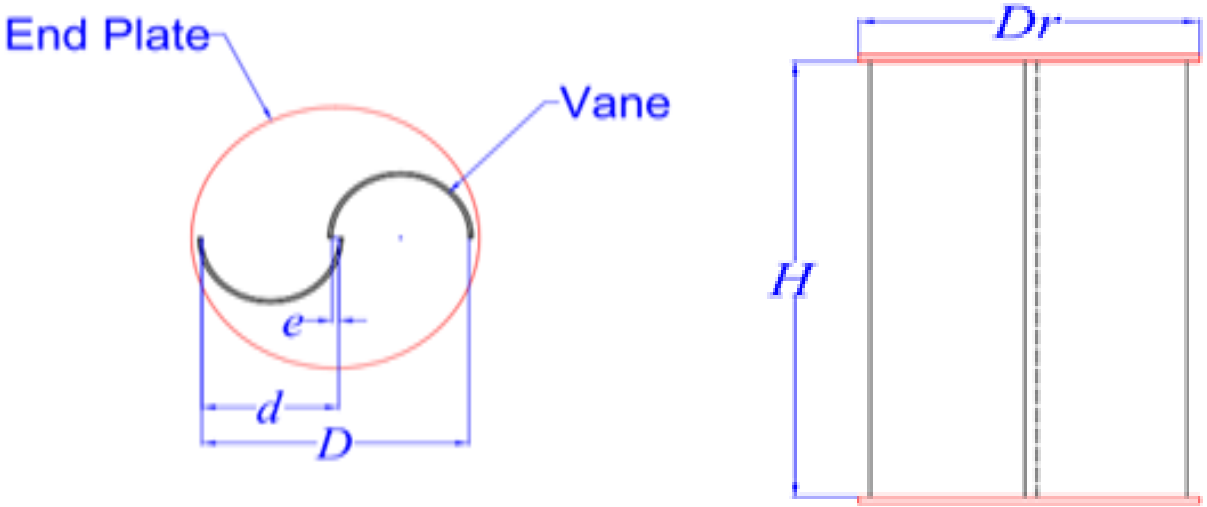


Fig. 3. Schematic diagram of a Savonius rotor. [5]

IV. MODEL

To take practical readings, we find a canal in which we put our working model and. As per canal dimensions and requirements, we design a small model of savonius turbine in Auto cad and made it in actual. Canal dimensions and as per design different dimensions of savonius rotor is given in below tables.

Table 1 Detail specifications of canal

Sections Dimensions	Sections Dimensions
Canal width	3 m
Canal height	1.2 m
Water height in canal	0.6m
Water height in pipe	0.72m

Table 2 Details specification of component of setup

Sr. No.	Component	Material	Parameters	Dimensions
1	Rotor blade	PVC Pipe	Height	0.3m
			Diameter	0.1524m
2	Upper & lower plates	Acrylic sheet	Diameter	0.305m
			Thickness	0.005m
3	Upper & lower support plates	Water proof plywood	Length	0.915m
			Width	0.600m
4	Drum shaft	Mild steel	Diameter	0.025m
5	Structure rod	Mild steel	Cross section area	$0.000625m^2$
			Height	0.740m

As per dimensions we made savonius rotor in Auto cad and then after we mad actual working model which are given below

Fig. 4 Actual rotor as per dimensions

V. CALCULATIONS

Equations to calculate analytically and practically

Mass flow rate of jet [4] $\dot{m} = \rho A V$ *kg/s* (3)

Velocity of blade [4] $U = \frac{\pi d N}{60}$ rad/s (4)

Force [4] $F = \dot{m}(V - U)$ *N* (5)

Torque [4] $T = F \times \frac{D_r}{2}$ *Nm* (6)

Power [4] $P = \frac{2\pi NT}{60}$ *watt* (7)

Co-efficient of torque [15] $C_t = \frac{T}{\rho U D_r H}$ (8)

Tip speed ratio [15] $TSR = \frac{\omega D_r}{2U}$ (9)

Co-efficient of Power [15] $C_p = TSR \times C_t$ (10)

VI. RESULTS AND DISCUSSIONS

Theoretically readings

V=0.8m/s [5]

N=50 RPM [5]

We calculate analytically below parameters which are given in table 3

Table 3 Theoretical Observation Table

Sr. No	Overlap ratio	Torque(Nm)	Coefficient of torque	Coefficient of power	Tip speed ratio	Power(Watt)
1	0.20	3.0067	0.0666	0.1076	1.6153	15.7426
2	0.25	2.8958	0.0663	0.1036	1.5629	15.1624
3	0.30	2.7891	0.0661	0.0999	1.5106	14.6040
4	0.35	2.7818	0.0659	0.0995	1.5106	14.5655

Practically readings

We take setup in canal and performed a practical at different overlap ratio, we use pitot tube to measure a velocity of flow of water by that we measure that velocity of water in canal is V= 0.5 m/s and to measure RPM of rotor we use Techo meter by that we get different RPMs for different Overlap ratios which all are given in below Observation table. Practical performance is shown in picture.

Fig. 5 Actual practical performed in canal

Table 4 Practical Observation Table

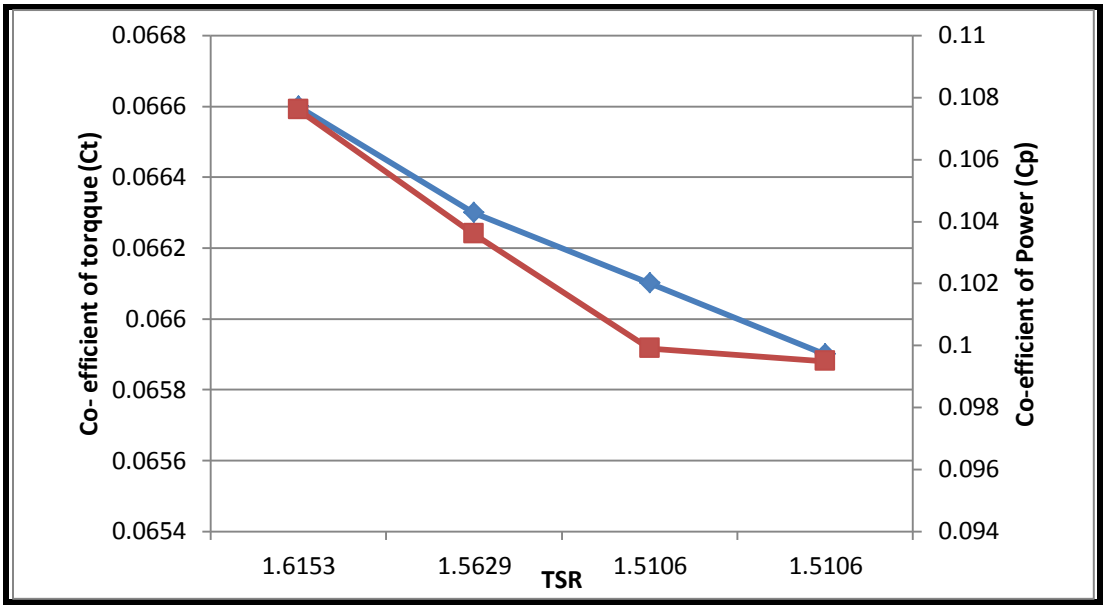
Sr. No	Overlap ratio	RPM	Torque(Nm)	Coefficient of torque	Coefficient of power	Tip speed ratio	Power(Watt)
1	0.20	40	1.6912	0.0499	0.0725	1.7221	7.0840
2	0.25	35	1.6288	0.0497	0.0725	1.4587	5.9698
3	0.30	31	1.8304	0.0693	0.1039	1.4977	5.9421
4	0.35	28	2.0863	0.0988	0.1679	1.6918	6.1142

VII. CONCLUSIONS

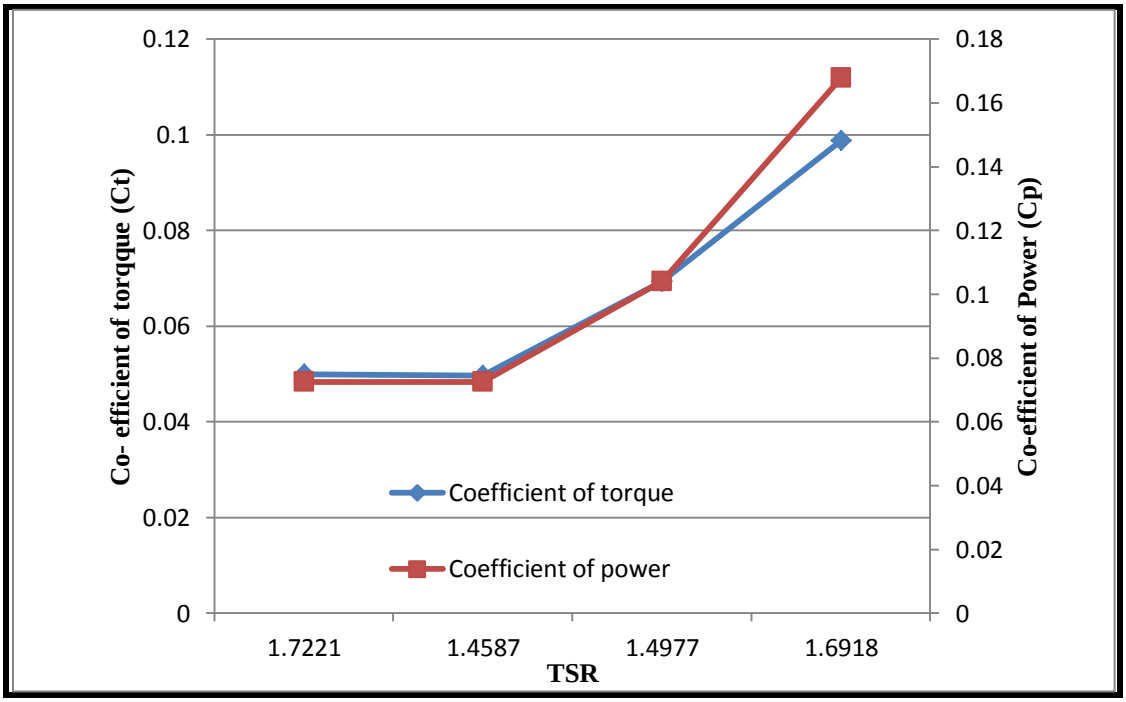
The most recommended overlap ratio for this type of turbine is β=0.20. With increase TSR, Co-efficient of power increase and Co-efficient of torque decreases as per simulation [5] and analytical calculations which is shown in Graph 1. But in practical performance most recommended overlap ratio is β=0.35 and with increase in co-efficient of torque and co-efficient of power which is shown in Graph 2.

The results obtained by practically and analytically are plotted for different overlap ratio as shown in below graphs. The results indicate that practically overlap ratio of β=0.35 provided highest Cp and Ct among all analyzed overlap ratios practically. From analysis it can be conclude that, maximum Cp as nearly 0.2 can be achieved at Tip Speed Ratio 1.6918 for overlap ratio 0.35.

This practical study and analysis shows that vertical axis Savonius water turbine has good potential for low head hydrokinetic turbine at low velocity applications.

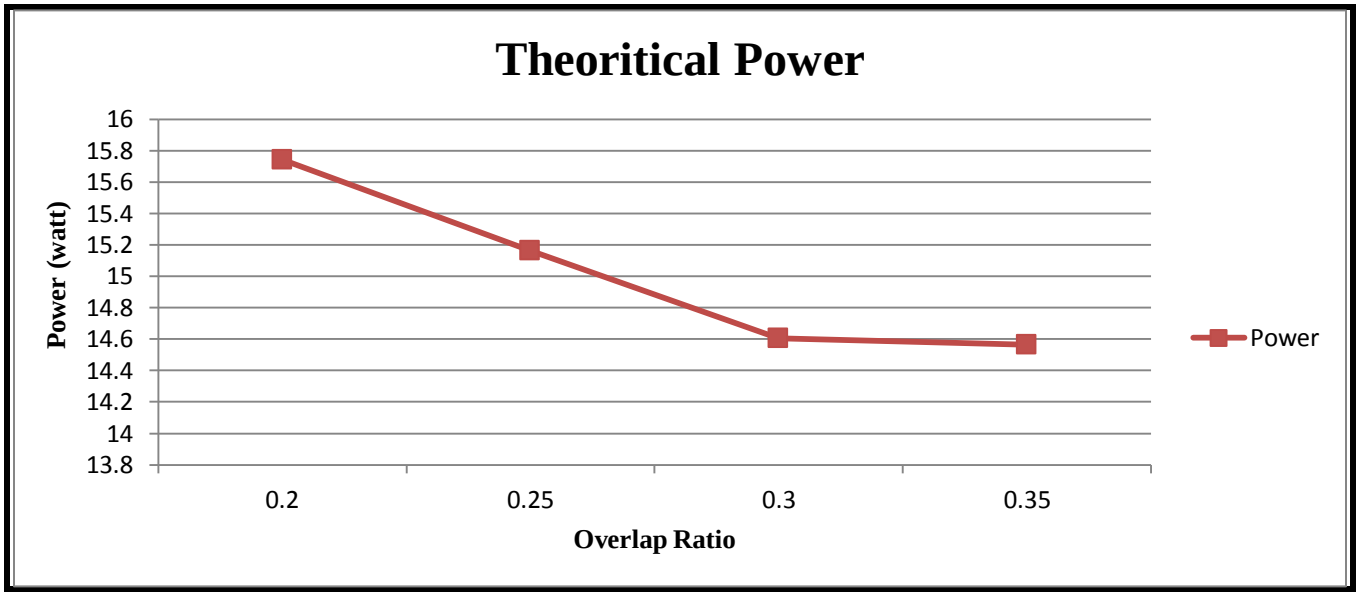


Graph 1 theoretically graph of Ct, Cp and TSR



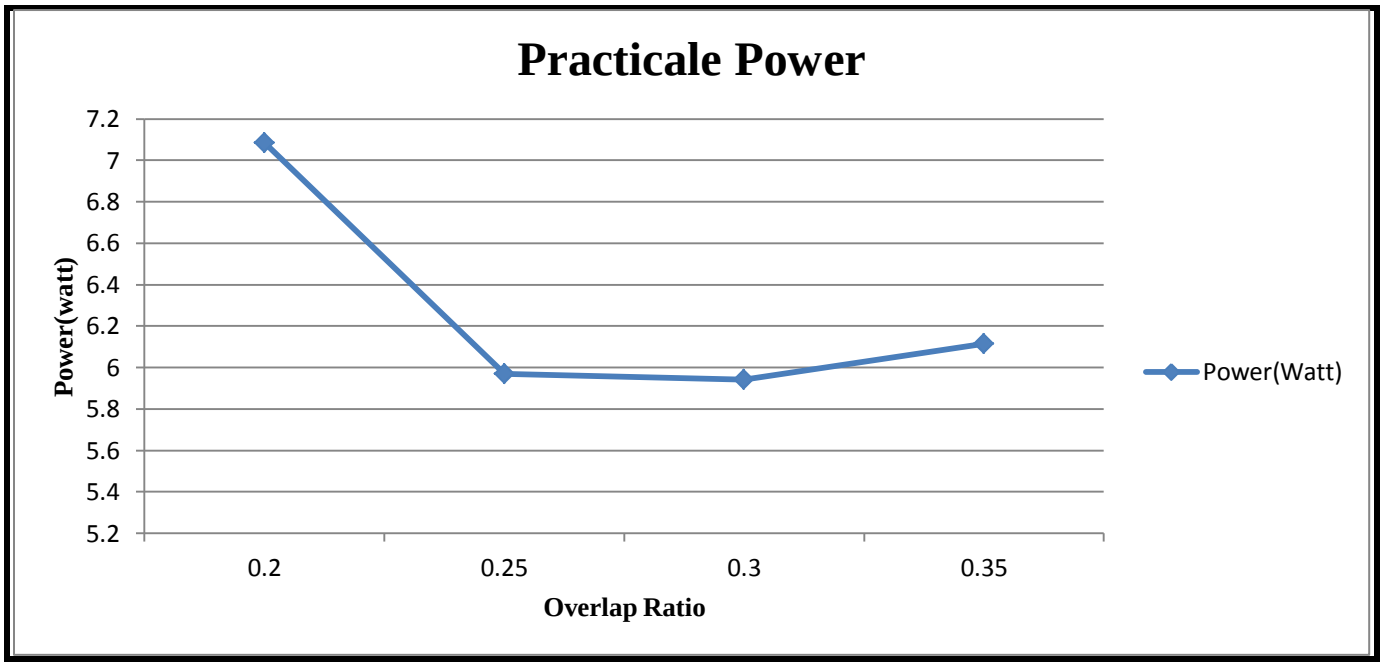
Graph 2 practically graph of Ct, Cp and TSR

Graph 3 presents theoretically calculated power. As above calculation power is decrease with increasing overlap ratio. So, that as per theoretical calculation most recommended overlap ratio is β=0.20 which is shown in Graph 3.



Graph 3 Theoretical Power ↔ Overlap Ratio

Graph 4 presents practically calculated power. As per practical readings power is maximum at overlap ratio 0.2. Sudden power is decrease and torque is increase with increase in overlap ratio. But torque is maximum at overlap ratio 0.35 and power is also gradually increase. So, practically most recommended Overlap ratio is β = 0.35 which is shown in Graph4.



Graph 4 Practical Power ↔ Overlap Ratio

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[15] Research Article,Performance Study ofModified SavoniusWater Turbine withTwo Deflector PlatesGolecha Kailash, T. I. Eldho, and S. V. PrabhuDepartment of Mechanical Engineering, Indian Institute of Technology,Powai, Mumbai 400 076, IndiaCorrespondence should be addressed to S. V. Prabhu, svprabhu@me.iitb.ac.inReceived 12 November 2011; Accepted 13 January 2012Academic Editor: Tariq Iqbal Hindawi Publishing Corporation International Journal of Rotating Machinery Volume 2012, Article ID 679247, 12 pages doi:10.1155/2012/679247