Design and Testing of Savonius Water Turbine for Parshall Flume

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Abstract - : *Hydropower source is predictable compared to wind or solar energy. For generation of electricity in such open channels or in natural source like river Savonius rotor is one of the best types of turbine. The Savonius turbine is more popular as wind turbine. However, in present work, attempt is made for use of Savonius rotor as hydro turbine application in the parshall flume.*

***Key Words*: Parshall Flume, Savonius Turbine, Overlap ratio, Aspect ratio, Coefficient of performance, tip speed ratio.**

NOMENCLATURE

α: Aspect ratio

β: Overlap ratio

ρ:Density [kg/m3]

ω:Angular velocity [rad/s]

θ: Angle of attack [rad]

d: Diameter of the Blade [m]

D: Diameter of rotor [m]

e: Gap between two paddles [m]

F: Force of turbine [N]

G: Coefficient of gravity [m/s2]

H: Height of turbine [m]

i: Number of angle of attack

n: Number of force on the rotor

N: Rotation velocity [rpm]

P: Power [watts] r Radius [m]

T: Torque of model [Nm]

V: Current velocity [m/s]

1. INTRODUCTION

The Savonius type vertical axis wind rotor was first invented by S. J. Savonius in 1929.Savonius rotor is a vertical axis rotor with simple in design and easy to fabricate at lower cost. The rotation of the rotor is due to the drag difference between the advancing blade and returning blade. Net driving force can be increased by reducing the reverse force on the returning blade or increasing the positive force on the advancing blade. The Savonius operates on the principle of drag as opposed to aerodynamic lift "catching" the flow of a fluid in wings shaped like halves of a bucket.

The Parshall flume is a fixed hydraulic structure originally developed to measure surface water and irrigation flows. The Parshall flume is now frequently used to measure industrial discharges, municipal sewer flows, and influent / effluent at wastewater treatment plants. Of all the flumes, the Parshall flume is the most recognized and commonly used.

Design of the Parshall Flume

The design of the Parshall flume consists of a uniformly converging upstream section, a short parallel throat section (the width of which determines the flume size), and a uniformly diverging downstream section. The floor of the flume is flat in the upstream section, slopes downward in the throat, and then rises in the downstream section; ending with a downstream elevation below that of the upstream elevation. The need to accommodate the required drop in the floor elevation, either by either modifying the downstream channel or by raising the elevation of the flume above the channel floor, may eliminate the flume from some applications.Formula for finding out Flow in channel using Parshall Flume is

Q= 4*B*h1.522 * (B) ^ (0.026)

Q= Discharge in cu. Feet per sec

B= Throat width in feet

h= Liquid head in feet measured at specific point in convergent section

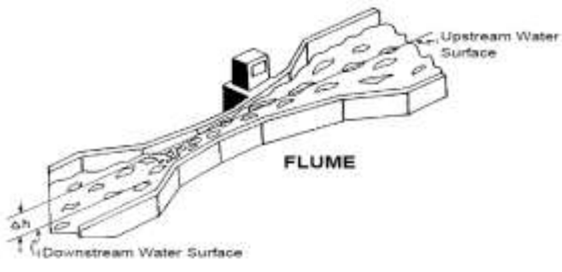

Image 1: Flume

2. DESIGN CONSIDERATIONS

spect ratio:

The aspect ratio represents the height of rotor relative to diameter. The relation is

....α =H / D

For our project we have taken aspect ratio as 1 due to limitations of depth of the channel.

Overlap Ratio:

The equation for the overlap ratio is given by

B= e / d

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. Patel C. R. [1], presented the optimum overlap ratio for the Savonius turbine as 0.2

Dimensions of Rotor:

Diameter of rotor = 300mm

Height of the blade = 300mm

Aspect ratio = 1

Overlap ratio = 0.2

Diameter of blade = 160mm

Eccentricity = 32mm

Thickness of blade = 2mm

Diameter of stacking plates = 320mm

The rotor blade is designed considering the maximum flow force of the water & channel dimension. A quick stress analysis is done in CATIA V5 to ensure the safety of rotor blades

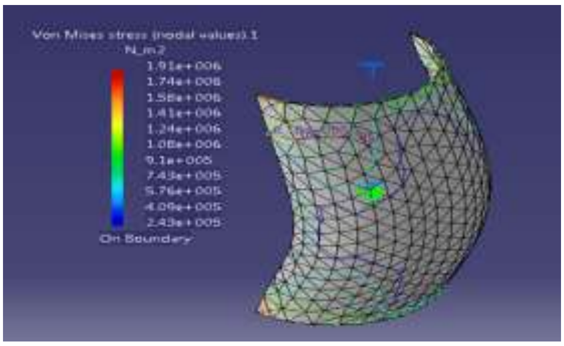

Figure 2: Static Analysis of Blade

Material:

The rotor blades are manufactured in the MS sheet for the this prototype phase for functional mapping.

3. CALCULATIONS

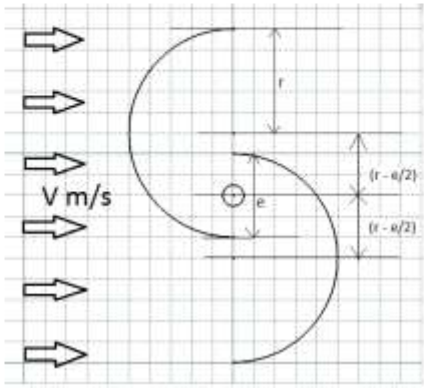

Image 3: Water Flow Direction &Turbine Construction

V1= Relative velocity of return cup w.r.t ‘ O’

= V- (r –e/2)ώ

V2 =Relative velocity of advancing cup

= V+ (r-e/2) ώ

Net torque about point ‘O’ is zero

Therefore

Drag force on return blade is equal to drag force on advancing blade

FD1= FD2

CD1 * (A ρ/2)* V12 = CD2 * (A ρ/ 2) * V22

(V̅1/ V2) = (CD2 / CD1) 1/2 = (1.2 / 2.3)1/2 = 0.722

(V- (r –e/2)ώ) / (V+ (r-e/2) ώ) = 0.722

By putting the values of r, e, & V we get the value of ώ =5.045 rad/sec

And N = 48.17 rpm

Force on each plate:-

F =CD1 * (A ρ/2)* V12 = 2.3 * ((0.16* 0.35))/2 * (2-0.064*5.045)2

= 181.14 N

Torque:

To = F * (r- e/2) = 181.4 *(0.08 – 0.032/2)

= 11.61 N-m

Theoretical Power (Pt) = (2π N T/ 60) = 58.57W

Theoretical Coefficient of Performance:

Water Power:

Pw = ρ * A * V^3 / 2 = 1000 * 0.32 * 0.35 * 8 = 448 W

Coefficient of Performance (Cp)

= Pt/ Pw = 58.57 / 448 = 0.13

Table1: Calculated Parameters

Parameters	Value
Force on each plate	181.14 N
Torque	11.6 N-m
Angular Velocity	5 rad/s
Speed (RPM)	48RPM
Power	58.6W
Theoretical Coefficient of Performance	0.13

4. MANUFACTURING & INSTALLATION

Image 4: Rotor Installation

The rotor blades are manufactured from 300mm diameter MS pipe by cutting it into two halves. These halves are then welded to MS sheet which where laser cut to circular shape of 400mm diameter.

Turbine is installed on MS C channel (100 X 100) frame. Thrust bearing are used for the shaft support. This assembly is then mounted with concrete bolts.

In our case the site consideration states that the channel is a parshal flume. Velocity of water is maximum at throat section in parshal flume. Considering the total length of a channel we installed our turbine at 2m from the starting of the conversing section where the velocity of water is maximum. Turbine is mounted at inlet of throat section so as to avoid loss in kinetic energy due to backflow of water.

Image 5: Rotor Installation

4. RESULTS

1) Reading of the RPM & torque are taken for the flow of 150 lakh m^3 /hour. The following valuues are observed:

- RPM: 72
- Torque: 16.7Nm

2) Coefficient of Performance Cp:

Power at turbine Pg= T * ω =

= 16.7 * 7.5

= 126.2 W

Water Power: 448 W

Cp= Pg / Pw = 126.2 / 448 = 0.28

3) Tip Speed Ratio,

= ω R / V

= 7.5 * 0.16 / 2

4) Result Table:

Table 2: Actual Values

Parameters	Value
Speed (RPM)	72 RPM
Torque	16.7 Nm
Power	126.2W
Coefficient of Performance	0.28
Tip Speed Ratio	0.6

5. CONCLUSIONS

1. Tip Speed ratio is found out as 0.6 which means turbine is 60% successful in converting linear velocity of water in rotational motion

2. The Savonius rotor turbine is surface water turbine. It works efficiently when it is fully submerged in water & installed near the free surface of water. If it is installed such that the turbine is partially submerged, the surface area on which the water impacts get reduced. This will reduce the drag forces acting on the blades which will reduce the torque generation.

3. If it is not installed near the surface but at some depth, its performance gets severely affected because velocity head is maximum at the free surface & goes on reducing with depth.

4. In the given study, the actual torque & RPM values are greater than theoretical values. This happens because of Flume effect. In the flume as width of the channel reduces, the velocity head increases. This provided more velocity to water.

5. This concludes that parshal flume is the place to install Savonius turbine.

REFERENCES

[1] Open Channel Flow in Aquaculture by J. David Bankston and Fred Eugene Baker

[2] A Simulation Study of Flow and Pressure Distribution Patterns in and around of Tandem Blade Rotor of Savonius (TBS) Hydrokinetic Turbine Model by B. Wahyudi, S. Soeparman, S. Wahyudi, and W. Denny

[3] Fluid Mechanics by R. K. Rajput

[4] Aerospace, Mechanical & Mechatronic Engg. 2005 University of Sydney

[5] Investigation of Overlap Ratio for Savonius Type Vertical Axis Hydro Turbine by Patel C.R., Patel V.K., Prabhu S.V., Eldho T.I.