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A Theoretical Study of Design Parameters of an Archimedean Screw Turbine

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Abstract—*This paper intends to study the design parameters and to design an Archimedean screw turbine for its optimum performance. A two bladed Inclined Axis Archimedean Screw Turbine was designed and theoretical calculations for power and efficiency was calculated. This paper also forewords the importance of Archimedes screw for its low head power generation and its very little impact on environment.*

1. INTRODUCTION

Archimedes screw has had a very long history in Greece and is one of the oldest machines still in use, and was mainly used in the ancient times for lifting water purpose for irrigation and drainage operation. Its invention is credited to Archimedes. The screw pump was first mentioned by Diodorus of Sicily, Athenaeus of Naucratis, Moschion etc [1, 2]. The Roman Engineer and Architect first gave the detailed informative description on construction of the Archimedes screw in his *de Architecture*, written in the first century B.C. [8, 2].

With the increase in energy crisis and at the same time the rise in the level of pollution, researchers are trying to find new and effective technologies for harnessing power form non-conventional energy sources. A lot of research has been conducted by using natural energy sources such as solar, wind, wave and water. According to sources of energy from water to run a turbine, there is a rapid change of technology in using such turbine which suitable for different kinds of flow river, much of them are used for high head to produce electricity [5]. Recently the inverse use of the screw as a turbine is under discussion among many researchers and engineers [5]. Compared to other micro hydro generation technologies, Archimedean screw turbine has shown to be excellent for hydropower under low head condition and is specially suited to large flow sites [4]. The renaissance is taking place actually throughout the world for the promotion and construction of Archimedean screw turbine [8]. Due to so many advantages, Archimedean screw turbines were installed by many companies in the last decade in central Europe [5]. The advantages of Archimedean screw turbine over the other turbine are its trouble free design, ability to carry debris laden water, low maintenance and cost [7, 4].

One of the very important advantages of this Archimedean screw turbine over other hydro turbine is that it is very unlikely to have an impact on habitat of fish and also other water lives available in that area [5]. Thus with the increase in concern for ecosystem and habitat conservation, technology which serves the purpose without harming the environment or any life form should be encouraged. In many countries there is ban to dam a river that can disturb its ecosystem.

The Archimedean screw also provides us the possibility of exploiting energy from renewable energy sources such as watercourses, marine and tidal current. Although this energy sources represents a large amount of renewable energy exploitation, this area has been given very little attention [9]. Thus exploitation of this renewable energy by Archimedean Screw Technology should be developed and encouraged.

Axial flow turbines like Kaplan and Pelton have also been energetically studied. However, not only because this type of turbine is not applicable to any river on that area due to its need of high head, but also because there is no chance for fish to move along the river due to the water in the dam has to flow through the turbine. Therefore, a turbine that can eliminate such a delicate problem is highly desirable [5].

2. DESIGN METHODOLOGY

Fig. (1) is the profile of a segment of a two bladed Archimedean screw. The screw is inclined with horizontal direction by making an angle of θ i.e. slope of the screw is tan θ. The geometry of the screw is governed by two types of parameters, these are

1. External parameters
2. Internal parameters.

1. External parameters are:
    a. Outer radius (R_0)
    b. Total length (L)
    c. Slope of screw (K)

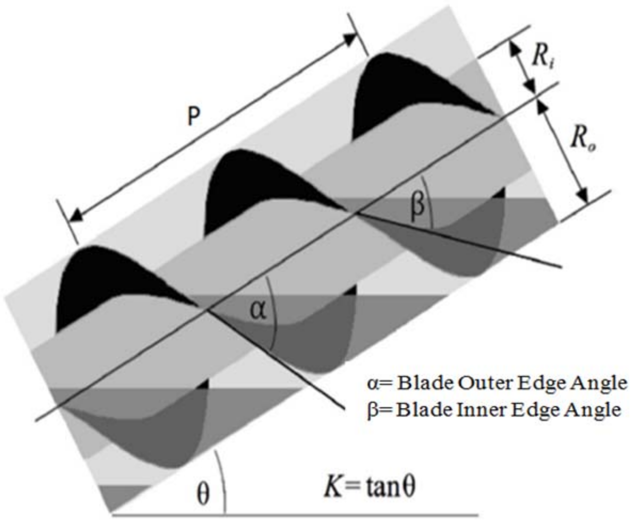

Fig. 1: Profile view of a segment of a Two- Bladed Archimedes Screw.

Values of these external parameters depend on the site of the screw and materials available for its construction [8].

2. Internal parameters are:

a. Inner cylinder radius (R_i) : $0 \leq R_i \leq R_o$

b. Pitch of one blade (P) : $0 \leq P \leq \frac{2\pi R_o}{K}$

c. Number of blades (N): N= 1, 2, 3, 4…

Here we take the external parameters as fixed. Now considering the assumption that the blade thickness is negligible, it can be seen that the total volume of water in one cycle of the screw is monotonically increases with the number of the blades. If the blades have non negligible thickness then they will occupy an increasing fraction of the volume of the screw as their number increase. In this case an optimal value of N is determined. In modern screws the blade number is taken as 1, 2 or 3 due to the manufacturing, weight and cost constraints. We have taken the blade number of the screw as 2. In order to optimize the performance of the screw turbine, Maximum volume of water in one cycle of the screw,

$$V_{Tmax} = \pi R_o^2 P \quad ----(1)[8]$$

Volume of one chute,

$$V_c = \frac{\pi(R_o^2 - R_i^2)L}{N} \quad ----(2)[8]$$

Volume of one bucket, $V_b = \frac{V_T}{N} \quad ----(3)[8]$

Here chute is the region bounded between two adjacent blades and inner and outer radii of the screw and the bucket is one of the maximally connected regions occupied by the trapped water within any one chute.

Now we have the fixed values of R_0, L, K and N and so to determine the values of R_i and P that maximize V_T.
Dimensionless Parameters:
To simplify the design calculation three dimensionless parameters are considered [8]. These are-

a. Radius ratio, $\rho = \frac{R_i}{R_o} \; (0 \leq \rho \leq 1) \; --(4)$

b. Pitch ratio, $\lambda = \frac{KP}{2\pi R_o} \; (0 \leq \lambda \leq 1) \; --(5)$

c. Volume ratio, $\vartheta = \frac{V_T}{\pi R_o^2 P} \; (0 \leq \vartheta \leq 1) - (6)$

From dimensional analysis it can be found that ϑ depends on the values of N, ρ and λ. So ϑ can be written as $\vartheta(N, \rho, \lambda)$. From the equations (1), (4), (5) and (6), V_T can be expressed in terms of λ and $\vartheta(N, \rho, \lambda)$ as shown below.

$$V_T = \frac{2\pi R_o^3}{K} \vartheta(N, \rho, \lambda) \quad ----(7)$$

For the fixed values of R_o, N and K, the maximum value of V_T depends on the maximum value of $\lambda\vartheta(N, \rho, \lambda)$ with respect to ρ and λ. Let the values of ρ and λ that maximize V_T are ρ^* and λ^* respectively. Now from equations (4), (5) and (6), the optimal values of R_i, P and V_T are given by,

$$R_i^* = \rho^* R_o \quad ----(8)$$

$$P^* = \frac{2\pi R_o \lambda^*}{K} \quad ----(9)$$

$$V_T^* = \frac{2\pi R_o^3}{K} \lambda^* \, \vartheta(N, \rho^*, \lambda^*) \quad ----(10)$$

Table 1: Optimum Ratio Parameters [8]

No of Blade (N)	Optimal radius ratio (ρ*)	Optimal pitch ratio (λ*)	Optimal volume per turn ratio (λ*υ(N,ρ*,λ*))	Optimal volume ratio (υ(N,ρ*,λ*))
1	0.5358	0.1285	0.0361	0.2811
2	0.5369	0.1863	0.0512	0.2747
3	0.5357	0.2217	0.0598	0.2697
4	0.5353	0.2456	0.0655	0.2667
5	0.5352	0.2630	0.0696	0.2647
6	0.5353	0.2763	0.0727	0.2631
7	0.5354	0.2869	0.0752	0.2619
8	0.5354	0.2957	0.0771	0.2609
9	0.5356	0.3029	0.0788	0.2601
10	0.5356	0.3092	0.0802	0.2592

Optimal parameters corresponding to N=2, from the table no.1 are given below.

$\rho^* = 0.5369$

$\lambda^* = 0.1863$

$\lambda^* \upsilon(N, \rho^*, \lambda^*) = 0.0512$

$\upsilon(N, \rho^*, \lambda^*) = 0.2747$

We have considered the values of the external parameters as $R_0 = 0.25$ m , K = tan30 , L = 1 m.

By calculating the optimal values of R_i^* , P^* , V_T^* and V_b^* from equations (3), (8), (9) and (10),

$$R_i^* = 0.125\,m$$
$$P^* = 0.5\,m$$
$$V_T^* = 0.02732\,m^3$$
$$V_b^* = 0.01366\,m^3$$

So the flow rate is Q= 0.02732 m^3/s

Hydraulic power developed, P= dgqH =134.0046 W

Where, d = density of water = 1000 kg/ m^3

g = acceleration due to gravity= 9.81 m/s^2

Q = flow rate

H = height of fall water = Lsin30 = 0.5m

Now efficiency is given by,

$$\eta = \frac{P_{out}}{P_{in}} \quad ----(11)[8]$$

Where, P_{in} = hydraulic power developed

P_{out} = Output power = Tω =T $(2\pi N)$ ----- (12)[8]

Where, T = torque developed in the shaft (Nm), ω = angular speed (rad/s),

n= rotational speed (rev/s)

There is a correlation for efficiency with respect to outer diameter of the screw, flow rate and the rotational speed of the shaft.

$$\eta = \frac{1-\frac{0.01125 D_O^2}{Q}(2n+1)}{2n+2} \quad --- (13)[1]$$

$$n = \frac{0.85}{n^{2/3}} \quad --- (14)[1]$$

Fig. 2: CAD Model of the Screw

3. CONCLUSION

Using the above correlations from equations (13) and (14), the values of n and η have been calculated.

n = 1.2492 rev/s

η = 0.6976 = 69.76%

The Archimedean screw turbine modelled with two number of blades has produced an overall efficiency of 69.76% at a net r.p.m. of 72.

4. FUTURE WORK

The Archimedean screw turbine modelled here would also be analyzed as a pump for irrigation purpose in the future course of the work.

REFERENCE

[1] Stergiopoulou, A., Stergiopoulos, V., Tsivolas, D., Stylianou, A. Two Innovative Experimental Archimedean Screw Energy Models In The Shadow Of Archimedes III. *5th International Conference on Experiments/Process/System Modeling/Simulation/Optimization,* Athens, 3-6 July 2013.

[2] Stargiopoulou, A., Stergiopoulos, V., Kalkani, E., Chronopoulos, C., Papadopoulou, D. Back to the Future: Rediscovering the Archimedean Screws as Modern Turbines for Harnessing Greek Small Hydropower Potential. Third International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE 2011) & SECOTOX Conference, Skiathos, June 19-24, 2011.

[3] Stergiopoulou, A. and Stergiopoulos, V. Greece in the Era of Transition: Archimedean Soft Small Hydropower Development Terra Incognita. Athens, Greece.

[4] Dada, O.M., Daniyan, I.A., Adaramola, O.O. Optimal Design of Micro Hydro Turbine (Archimedes Screw Turbine) in Arinta Water Fall in Ekiti State, Nigeria. *Research Journal in Engineering and Applied Sciences* 4 (2), 34—38, 2014.

[5] Fiardi, E. Preliminary Design of Archimedean Screw Turbine Prototype for Remote Area Power Supply. *Journal of Ocean, Mechanical and Aerospace-Science and Engineering* 5, 2014.

[6] Shappy, A., Knapp, P., Mullowney, J., Delaney, C. Optimization of an Archimedean Screw. Saint Michael's College, April 4 2013.

[7] Monserrat, J., Ortiz, R.G., Cots, L., Barragan, J. Energy Saving in a Variable-Inclination Archimedes Screw, Irrigation Drainage System Engineering. Open Access Journal 4 (1), 2015.

[8] Rorres, C. The Turn of The Screw: Optimal Design of an Archimedes Screw, *ASCE Journal of Hydraulic Engineering* 126 (1), 72—80, 2000.

[9] Mayrhofer, B., Stergiopoulou, A., Bernhard, P., Kalkani, E. Towards an Innovative Radial Flow Impulse Turbine and a New Horizontal Archimedean Hydropower Screw, *Journal of Energy and Power Sources* 1 (2), 72—78, 2014.