International Journal of Theoretical and Applied
Mechanics. ISSN 0973-6085 Volume 12, Number 5 (2017)
pp. 881-889
http://www.ripublication.com

Study and Design of Bladeless Tesla Turbine

M. Sivaramakrishnaiah * Dr. Y. Santhosh Kumar Reddy**
G. Sudarsana Reddy ***

**Assistant Professor of Sri Venkateswara College of Engineering & Technology, (Autonomous), Chittoor. A.P, India.*
***Principal & Professor of P.V.K.K.Institute of Technology, Anantapuramu. A.P, India.*
****Associate Professor of Sri Venkateswara College of Engineering & Technology, (Autonomous), Chittoor. A.P, India.*

Abstract

In this Theoretical design of Tesla turbine is a non-conventional bladeless turbine it works on the principle of viscous boundary layer concepts. It set of a number of parallel discs fixed on a shaft with space between the discs. The fluid is steam to flow tangential to the discs inside a casing. Forces is transferred from the fluid to the discs due to viscous and adhesiveness. As per literature review explanations for different performances and efficiencies at various parameters. Finally we designed as per the standard required parameters like blade diameter, blade to blade gap, Nozzle size, in this final output performances and efficiencies at various parameters established.

Keywords: Boundary layer, Viscosity, gaps between dics, adhesiveforces

1. INTRODUCTION

The Tesla turbine is one of the disc turbine Fig. 1 because the shaft of this turbine is formed by a series of flat, parallel, co-rotating discs, which are closely gap and attached to a central shaft. The fluid is passed tangentially to the rotor by means of inlet nozzle. The injected fluid, which passes through the narrow gaps between the discs, approaches spirally towards the exhaust port located at the centre of each disc. The viscous force, created due to the relative velocity between the rotor and the working fluid, causes the rotor to rotate. There is a housing surrounding the rotor, with a small radial and axial clearance.

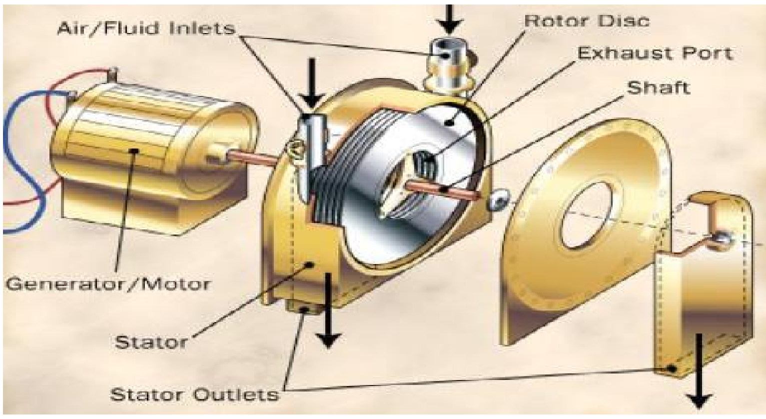

Fig.1 Parts of Tesla turbine

2. LITERATURE REVIEW

In Nikola Tesla [1] patented a turbine without blades that uses a series of rotating discs to convert energy of fluid flow to mechanical rotation, which can be used to perform useful work. A Tesla turbine is made of a set of parallel discs with nozzles, through which gas or liquid enters toward the edge of the discs. Due to viscosity, momentum exchange takes place between fluid and discs. As fluid slows down and adds energy to the discs, it spirals to the center due to pressure and velocity, where exhaust is. As disks commence to rotate and their speed increases, steam now travels in longer spiral paths because of larger centrifugal force. Fluid used can be steam or a mixed fluid (products of combustion). Discs and washers, that separate discs, are fitted on a sleeve, threaded at the end and nuts are used to hold thick end-plates together. The sleeve has a hole that fits tightly on the shaft. Discs are not rigidly joined; so each disc can expand or contract (due to centrifugal force and varying temperature) freely. The rotor is mounted in a casing, which is provided with two inlet nozzles, one for use in running clockwise and other anticlockwise. Openings are cut out at the central portion of the discs and these communicate directly with exhaust ports formed in the side of the casing. In a pump, centrifugal force assists in expulsion of fluid. On the contrary, in a turbine centrifugal force opposes fluid flow that moves toward center.

Tesla made some modifications. In new design there are two heavier endplates, which are tapered toward the periphery for the purpose of reducing maximum centrifugal stress. Inside discs are tapered in the same way or flat. Each plate has circular exhaust openings3 and washers 5, like spokes of a wheel that keep discs apart in the center. For peripheral spacing tight-fitting studs 6 are used on every second plate. This can also be achieved with protuberances which are raised in the plates by blows or pressure.

Naturally, the performance of Tesla turbines has already been characterized by a number of researchers. Rice's [2] analysis was among the first, and claims that turbines can be made up to 90% efficient. Designs by Ho-Yan [3] and Lawn [4] claim over 70% efficiency. Deam et al. [5] argued that at small scales (sub-cm diameters) viscous turbines outperform conventional bladed turbines and can provide ~40% efficiency. HoyaGuha [6], and Smiley analyzed medium to large Tesla turbines with computational models, experimentation, and analysis, claiming 25% efficiencies but demonstrating nozzle designs that could improve this. Though derived for mesoscale and macro-scale turbines, this prior research provides an excellent basis for verification of micro turbine designs. A large body of literature does exist on micro-scale inertial turbines and similar power generating micro electromechanical systems (MEMS); Epstein [7], Herrault [8], Jan Peirs [9], and Camacho [10] reported systems that operate between 100 K and 1 M rpm at power densities a full order higher compared with larger versions of the same.

3. SELECTION OF MATERIALS FOR SHAFT AND DISCS

The turbine casing, shaft, discs considered is AISI 4140 Steel material. Thermal and mechanical properties of tool and work piece material are shown in Table 1. AISI 4140 steel has 1% chromium - molybdenum and is medium harden ability, general purpose high tensile steel, generally supplied hardened and tempered in the tensile range of 850 - 1000 Mpa.

Table 1: Thermal and mechanical properties of the Work piece and tool material**.**

S.No.	Properties of material	AISI 4140 Steel
1.	Yong's modulus (Gpa)	219
2.	Density (kg/m^3)	7852
3.	Poisson ratio	0.29
4.	Thermal expansion (m/m°K)	13.7e-6
5.	Thermal conductivity (W/m°K)	42

4. PROPOSED APPROACH

The following are some steps followed to approach the completion and making successful of the project.

1. Mathematical design of various parts.
2. Calculation of various parameters as per the design requirements.
3. Calculations of turbine outputs as per the design.
4. Modelling of turbine parts by using solid-works.

5. COMPONENTS DESCRIPTIONS

5.1. Nozzle: A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe as shown in Fig.3.

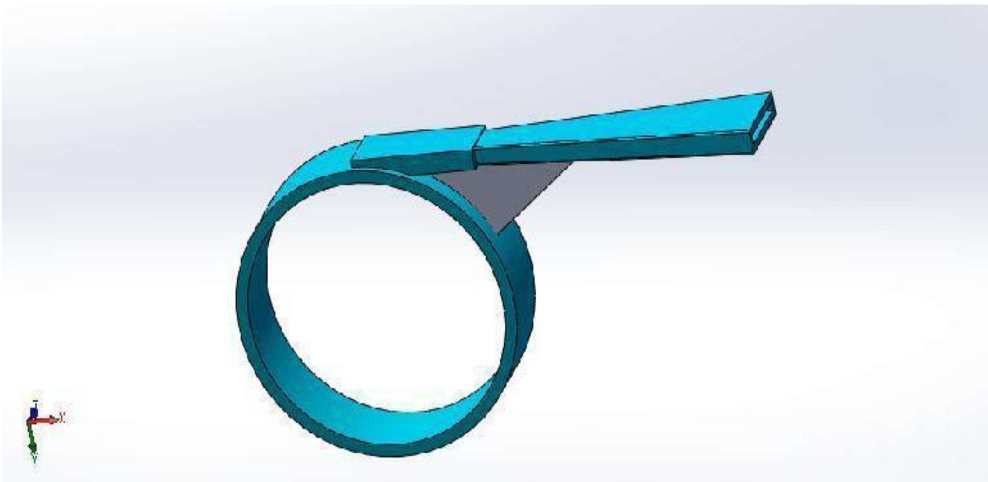

Fig.3 Nozzle mounted with housing ring

5.2 Annular discs:

Annular discs are the main parts of the tesla turbine which are mounted on the centre shaft. These are the components in which the steam coming out of the nozzle is allowed to impinge on the disc surface. The disc should be high enough to withstand the steam pressure and temperature. Annular discs can be of different types as shown in Fig.4

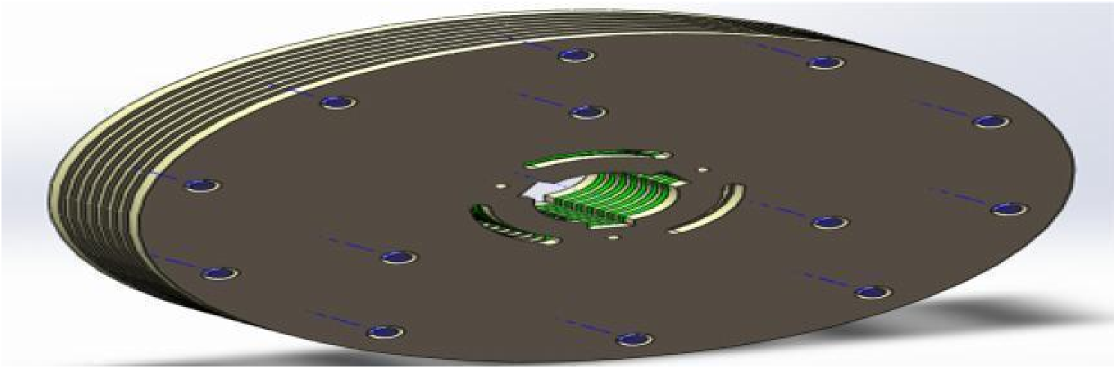

Fig: 4 Pack of discs attached together

5.3 Assembly model: The rotor of this turbine is formed by a series of parallel, discs, which are very close spaced and attached to a central shaft as shown in Fig.5. The working fluid is sending tangentially to the rotor by means of inlet nozzle. The injected fluid, which passes through the narrow gaps between the discs, approaches spirally towards the exhaust port located at the centre of each disc. The viscous force, produced due to the relative velocity between the rotor and the working fluid, causes the rotor to rotate. Housing surrounding the rotor, with a small radial and axial clearance.

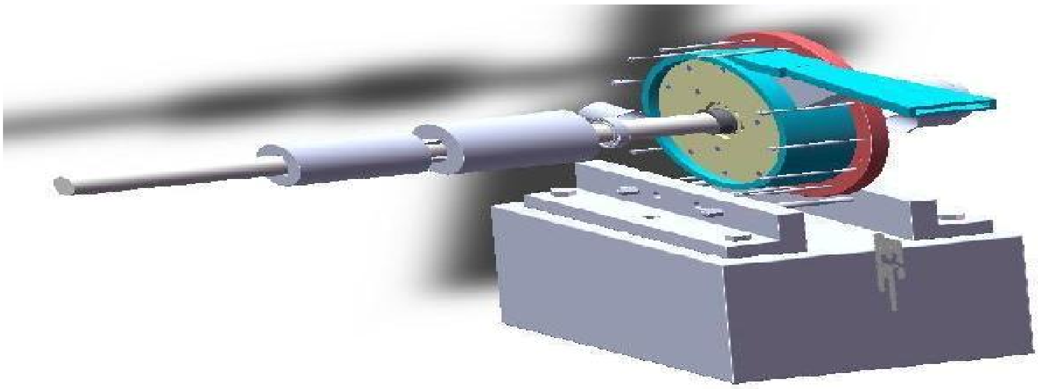

Fig. 5 Assembled Tesla turbine

6. DESIGN CALCULATIONS

Angular velocity of disc (ù)=V_{no}'/R_o= 848.1695391/0.250 = 3392.678156 rad/s

Circulation of the vortex (Ã)=$V_{no}'\times S$= $848.1695391\times966.0397245\times10^{-3}$= 819.3654679 mm

Torque for one side of disc (T)= $\frac{3\mu\Gamma(Ro2-Ri2)}{2h}$ =[3×1.44×10^{-5}×819.3654679×(250^{2}-57.35^{2})]/(2×3)

=3.48×10^{-1} Nm

Where, μ= dynamic viscosity from steam table

= 1.44×10^{-5}Pas

Torque for both sides of discs =2T = =2×3.48×10^{-1}= 6.96×10^{-1}

Total torque in 'N' number of discs=2TN= = 2×3.48×10^{-1}×8 =5.57 Nm

Power for one disc (P_1)=2T×ω =2×5.57×3392.678156 = 2361.303997 W Total power for 'N' number of discs (P)=N×P_1= 8×2361.303917 =18890.43 W

Angular velocities of disc (ω)=(V_{no}'/2)/R_o= (848.1695391/2)/250 = 1696.339078 rad/s

(As most of the time tesla operated the disc at ½ the peripheral velocity of steam.)

Relative velocity between steam vortex and disc at periphery (V_s-V_d)p=(V_{no}'-V_{no}'/2)

=(848.1695391-848.1695391/2) = 424.0847695 m/s

Relative velocity between steam vortex and disc at mean radius (V_s-V_d)=(V_{no}'-V_{no}'/2)×R_m/R_o

= (848.1695391-848.1695391/2)×153.75/250=260.812133 m/s

Characteristic length (L)=2×π×R_m = 2×π×153.75×10^{-3} = 0.966039725 m

Characteristic Reynolds Number (Re)= (V_s-V_d)m×L/= 0.812133×0.966039725/1.46764×10^{-5}

= 17167371.76

Where, ν=kinematic viscosity taken from steam table

= μ×(V_{gno}×X_{no}') = 1.46764×10^{-5} m^{2}/s

Drag friction co-efficient (C_d)= 0.4555/(log(Re))$^{2.58}$ = 2.76174×10^{-3}

(as we have neglect second term of Prandlt-Schlicting equation)

Drag force at mean radius (F_m)= $\frac{[(Vs-Vd)m]2\times Cd\times A}{2\times(Vgno)\times Xno'}$

$= \frac{424.084765\times 424.084765\times 0.002758709\times 2604234.807}{2\times 1.15929\times 0.88212923}$

= 238.8696022 N

Torque at mean radius (T_m)=$F_m\times R_m$ =238.8696022×153.75×10^{-3} = 36.72620134

Nm Power (P)= $T_m\times\omega$ = 36.72620134×3392.678156 =62300.095053 W

Efficiency of turbine:

Input power to the turbine (P_i) = (Outlet vapour enthalpy at actual expansion – inlet vapourenthalpy) × mass flow rate.

= (2789.9-2430.73168) × 0.5 × 10^3 = 179.584×10^3 W

Output power from the turbine (P) = 62300.095053 W

Now,

Efficiency of turbine (η_t) = $\frac{\text{output power}}{\text{input power}}$ ×100% = $\frac{62300.095053}{179584}$ ×100% = 34.69 %

7. RESULT

The design of tesla turbine has done on the basis of different assumptions. All the design of parts of tesla turbine has done on the basis of the properties of the steam at different assumed pressure at inlet of nozzle, at throat inlet and outlet of the nozzle i.e.inlet to the turbine itself. All the dynamic as well as the thermal calculation of the tesla turbine is also done on the basis of the properties of the steam. All the designed results are calculated from the data obtained from the steam Table 1 in accordance to the assumption of the input parameter.

As per our scope of the project, we designed the various components/parts of the turbine and calculated the output torque i.e. 62300.09503 W and input power of the turbine i.e. 179.584×10^3W. But as we had calculated the turbine out-put parameters the calculated parameters are not satisfactory. The output power of the turbine is quite less than the expected value so that the efficiency i.e.34.69% of the turbine is very less. In order to improve the output parameters of the turbine we designed the input parameters such as nozzle structure and annular discs structure and its spacing as per the assumed reliable input parameters but the obtained results is not as per the expectation. The results obtained by design are shown below Table.2 &3.

Table 2. Design parameters of Tesla Turbine

S.No.	PARTS	VALUES	Units
1	Inlet velocity of nozzle	34.48	m/s
2	Inlet diameter of nozzle	50.8	mm
3	Outlet diameter of nozzle	27.70	mm
4	Total length of the nozzle	246.35	mm
5	Efficiency of the nozzle	90	**%**
6	Number of discs	8	
7	Total torque acting on the disc	5.57	N-m
8	Total power for number of disc	18890	W
9	Total torque at mean radius	36.726	N-m
10	Power at the mean radius	62.3	KW

8. CONCLUSION

We cannot control the shaft speed, boundary layer. Tesla turbine probably cannot prove competitive in an application in which more conventional machines have adequate efficiency and performance. Thus, it cannot be expected to displace conventional water pumps or conventional water turbines or gas turbines. Tesla turbine can be considered as source of standard in applications in which conventional machines are inadequate. This includes applications for small shaft power, or the use of very viscous fluid or non-Newtonian fluids. It is an advantage that multiple-disk turbo machines can operate with abrasive two-phase flow mixtures with less erosion of material from the rotor.

REFRENCES

[1] Nikola Tesla, “Fluid Propulsion” (Nikola Tesla Original patent), Pub. No.: US 1913/1,061

[2] W. Rice, "An Analytical and Experimental Investigation of Multiple

Disk Turbines," Journal of Engineering for Power, vol. 87, pp. 29-36, 1965.

[3] B. P. Ho-Yan, "Tesla Turbine for Pico Hydro Applications," Guelph Engineering Journal, vol. 4, pp. 1-8, 2011.

[4] R. W. Lawn M. J, "Calculated Design Data for the Multiple-Disk Turbine using Incompressible Fluid," Journal of Fluids Engineering, Transactions of the ASME, vol.96, no. 3, pp. 252-258, 1974.

[5] L. E. M. B. C. R. Deam T. R., "On Scaling Down Turbines to Millimeter Size," Journal of Engineering for Gas Turbines and Power, vol. 130, pp. 052301--9, 2008.

[6] G. A. Hoya G. P, "The design of a test rig and study of the performance and efficiency of a Tesla disc turbine," Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, vol. 223, pp. 451-465, 2009.

[7] S. A. J. a. A. H. Epstein, "AN INFORMAL SURVEY OF POWER MEMS," in the International Symposium on Micro-Mechanical Engineering, 2003.

[8] F. Herrault, B. C. Yen, C.-H. Ji, Z. Spakovszky, J. H. Lang and M. G. Allen, "Fabrication and Performance of Silicon-Embedded Permanent-Magnet Microgenerators," Journal of MicroMechanical Systems, vol. 19, no. 1, pp. 4 13, 2010.

[9] D. R. F. V. Jan Peirs, "A microturbine for electric power generation," Sensors and Actuators A, vol. 113, pp. 86-93, 2004.

[10] A. Camacho, "The Design of a Micro-Turbogenerator," Duke University, urham,NC,2011.