International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 06 | June -2017 www.irjet.net p-ISSN: 2395-0072

DESIGN AND FABRICATION OF PORTABLE WATER TURBINE

Damodhar R[1],Mruthyunjaya K N[2],Naveen[3], K Pavan Prabhakar[4], Rakhesh H S[5]

[1,2,3,5] *Student, Dept. of Mechanical Engg. , New horizon college of engg. Bangalore 560103, Karnataka, India*
[4] *Professor, Dept. of Mechanical Engg. , New horizon college of engg. Bangalore 560103, Karnataka, India*

---***---

Abstract - *In this paper a water turbine is designed and fabricated based on the ideals of Tesla's turbine. In remote places due to frequent power cuts the alternate source of energy for house hold power requirements is very essential. Also, it is necessary that this source should be portable and easily operated by common man. The purpose of this work is to design and fabricate a portable water turbine using the principle of Tesla turbine. The main aim of this turbine is to utilize the potential and kinetic energy of a conventional water supply. Appropriate changes are made in the existing plate, shaft and nozzle design with respect to the literature survey. This paper includes design and fabrication of portable water turbine along with necessary results and calculations.*

***Key Words*: Tesla turbine, bladeless turbine, domestic purpose, design and fabrication, energy conversion**

1.INTRODUCTION

1.1 Tesla's turbine

Tesla's turbine is a bladeless turbine which uses series of rotating discs to covert fluid flow energy into mechanical energy .This turbine is popularly known has Tesla's turbine patented in the year 1913 by Serbian mechanical and electrical engineer Nikola Tesla. A Tesla turbine consists of a set of smooth disks, with nozzles applying a moving fluid to the edge of the disk. The fluid drags on the disk by means of viscosity and the adhesion of the surface layer of the fluid. As the fluid slows and adds energy to the disks, it spirals into the center exhaust. Since the rotor has no projections, it is very sturdy. The Tesla turbine has the trait of being in an installation normally working with a mixture of steam and products of combustion and in which the exhaust heat is used to provide steam which is supplied to the turbine, providing a valve governing the supply of the steam so that the pressures and temperatures can be adjusted to the optimum working conditions.

The reason for selecting this turbine is its simplicity in the design and concept. The impact of water on the plates exerts a centripetal boundary layer effect causing its rotation .The water creates vortex inside the casing escaping through the centre of the plate and out of the turbine. This turbine is so versatile that it can be used for multiple applications. Since the design by Tesla is highly efficient. This turbine is very much stable at high rotating speeds.

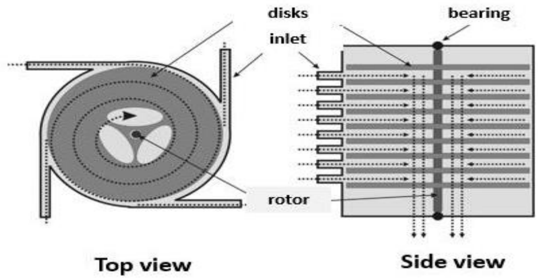

Fig -1 Front and top view of Tesla's turbine

1.2 Need for the project

There are large variety of turbines currently in the market that are very expensive and efficient but very seldom are economic and effective for low heads. If a turbine can generate a medium amount of power on a regular basis produced by a low head it would provide significant help to people living in remote places. The purpose of this project is to design and fabricate low head water turbine based on Tesla's turbine design.

Based on Tesla's model modifications are planned to the design to improve the efficiency. The modifications planned so that the turbine is made suitable for low head applications. The changes are made in the blade design to help reduce the losses during the exit of the water from the plates and also the exhaust outside the housing.

2. LITERATURE REVIEW

With reference to multiple literature papers the design parameters illustrated by Vedavalli Gomatam Krishnan from her paper "A Design And Fabrication Of Cm-Scale Tesla Turbines (2015)". This dissertation discussed the design and scaling characteristics of Tesla turbine and offers design solutions for achieving optimum performance given the input specifications. The research covered turbines ranging from sub-watt power scavenging designs to watt-range mobile applications to kilowatt-range renewable energy applications. The characteristics of the turbine are demonstrated using micro fabrication, theoretical analysis, and ANSYS, COMSOL, and MATLAB simulations. A MATLAB GUI is provided for generating design specifications and turbine performance sensitivity.

TABLE -1 NOZZLE SPECIFICATIONS

ID	Type	Area mm^2	Length mm	Width mm	Width arc °	Angle to tangent °	edge
N1	Slit	3.28	3.5	1	19.3	37.3	15
N2	Slit	3.28	3.5	1	15.9	45.8	25
N3	Slit	2.28	2.5	1	37.3	26.5	0
N4	Slit	3.28	3.5	1	37.3	26.5	0
N5	5Array	0.69	0.4	0.4	7.5	37.3	15
N6	Slit	3.28	3.5	1	14	53.2	35
N7	Slit	7.14	4.0	2	53.2	37.3	15
N8	Same as N4 in dimensions, located 180 degrees around the rotor.						

TABLE -2 PLATE SPECIFICATION

ID	Diameter (cm)	Disks	Gap (µm)	r_i / r_o inner/outer radius ratio	exhaust/entry area ratio
R1	1	20	125	0.47 (pattern 1)	0.105
R2	1	20	125	0.51 (pattern 2)	0.143
R3	1	13	250	0.47 (pattern 1)	0.105
R4	1	8	500	0.47 (pattern 1)	0.105
R5	1	20	125	0.6 (pattern 3)	0.2
R6	2	20	125	0.32 (pattern 4)	0.105

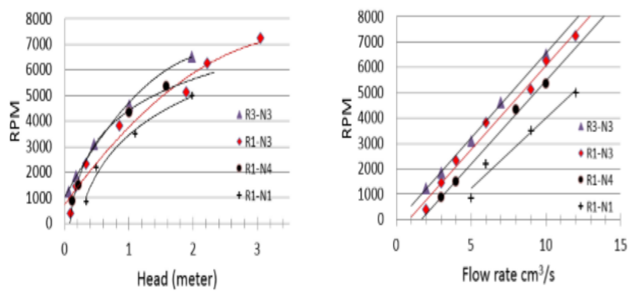

Fig -2 Graphs showing the variation of the design parameters.

TABLE -3 DESIGN CONSTRAINTS

Name	Value Range
b inter-disk space	[10* particulate size]< b ; b ↑ power density ↓ filter the medium to minimize b ; b nominal < 200 µm
ε aspect ratio = b / r_o	Smaller than 0.05 to satisfy the assumptions in the rotor flow characterization. ε nominal < 0.01
ξi, radius ratio	0.3 < ξi,< 0.4 ; 0.4 for micro to 0.3 to large turbines
t disk thickness	t < b/2, as minimum as possible, but enough disk mass to support the power/disk. t ↓ tip loss ↓
c clearance	(b +t) < clearance to keep tip loss < 2%
s gap	[20 * (b+t)] < gap to keep the gap loss < 2% ; higher the rotor radius or lower the flow indicator , higher the gap loss

3. DESIGN OF WATER TURBINE

The design constraints were all analysed by studying the literature survey carefully and choosing the best possible design for the most efficient outcomes for the required low head applications.

3.1 Parts Of The Turbine

- Plates
- Shaft
- Bearings
- Housing
- Nozzle

The design constraints are obtained from the research papers studied. All the necessary design constraints are as shown in the above table, as per the constraints required calculations are made. Each of the major parts are designed using SOLIDEDGE V18 with all the calculations made . The calculations made for the parts and 2D & 3D view of the components are shown in the next section.

3.2 Basic Design Parameters

- Based on the available thickness (t) of the sheet metal which was $0.4x10^{-3}$m the specifications were calculated. Therefore, t=$0.4x10^{-3}$m.
- The inter-disk spacing(b) based on the thickness is calculated using the relation, t< b/2. Therefore, b is found to be $0.8x10^{-3}$m.

3.3 Design Specifications of Plates

The design of the plates is mostly based on the thickness of the plates. According to the literature it was found the R3-N3 design was best suited for low head applications. Due to fabrication constraints the least thickness (t) that could be used was 0.4mm stainless steel sheet metal. The use of stainless steel was due to its corrosion resistant properties as we were using it for water applications.

- The interdisk spacing(b) was calculated using the relation t<b/2 and was found to be 0.8mm.
- Aspect ratio (ϵ): b/r_o <0.01, using which 'r_o' was calculated to be 80mm but we took 100mm for more surface area .
- Radius ratio (ϵ_i): 0.3< r_i/r_o<0.4, using this relation 'r_i' was found to be 0.04m.
- With respect to the nozzle entry angle the bend that could be introduced onto the plates was found to 26.5°. This relation was assumed by taking the geometric relation of interior alternate angles between the coinciding axis between the two parameters.
- Distance between center of 'r_i' and center 'r_o' is 15mm.

- Cone calculation for the process of fabrication was found from the relation, θ = (r/s)*360 in which r signifies ro and s the slant angle of the cone drawn at 26.5 degrees.
- Height of the plates was calculated to be 32.4mm.
- The shaft hole that was assumed was 18mm.
- The first plate was to be made with the exit hole whereas the rest of the 12 plates required holes for the exit of the water.

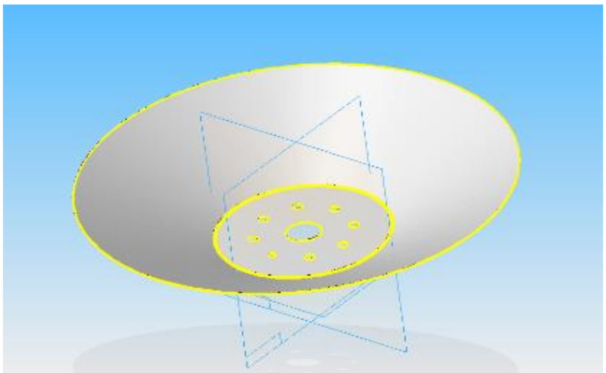

Fig -3 3d model of the plate with the holes.

3.4 Design Specifications of Shaft

- Shaft diameter (d) = 19 mm
- On top end of the shaft step turning to a diameter of 17 mm is made to fit the bearing and generator to a length of 30 mm
- On the other end step turning to a diameter of 17 mm is made to fit the bearing to a length of 5 mm
- Gap (s) = 20*(b+t)<s. Therefore, 's' was taken as 24mm.
- Shaft (L) = {(number of plates*thickness)+ (height of plate) + (interdisk spacing) +2*(s)+30mm+5mm} Therefore, 'L' was found to be 130.2mm.

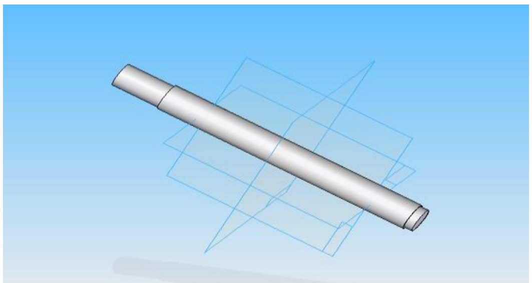

Fig -4 3D view of Turbine shaft.

3.5 Design Specifications of Bearing

- The bearing was purchased from the store, a DPZ L-17 magneto type bearing with following specifications,
  - I.D = 17mm
  - O.D = 40mm
  - Thickness=10mm

Fig -5 magneto bearing.

3.6 Design Specifications of Housing

- Clearance(c): (b+t) < c. Therefore, using this relation c was found to be 1.4mm.
- Diameter of the housing(D): (Plate diameter + clearance)
- D = 200mm+2*1.4. Therefore, D = 203mm.
- Height of the housing (H): H= 127.8mm. This includes the total height of the plates including gap and 16mm on the top and bottom to accommodate the bearings.
- Thickness of housing = 10mm
- A hole of 17.5mm was made on top of the housing for the shaft to pass through it and multiple holes of 20mm were made at the bottom for the exit of the water.
- A nozzle is made on the surface of housing for inlet of water.

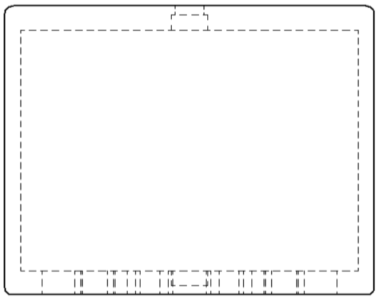

Fig -6 2D model of the housing

3.7 Design Specifications of Nozzle

With reference to the design parameters illustrated in the literature the nozzle parameters were calculated.

- Width of the nozzle with reference to the journal was found to 10mm.
- Length of the nozzle is the total length of the stacked plates which is 14.8 but this was reduced to 14mm
- Tangents are drawn on either ends to get uniform flow.

3.8 Design of Washer

- A washer is placed in between each place so as to provide frictional fit between each plates .
- A washer is designed with following specification0s.
  I.D = 19 mm
  O.D = 26 mm
  Thickness = 1 mm

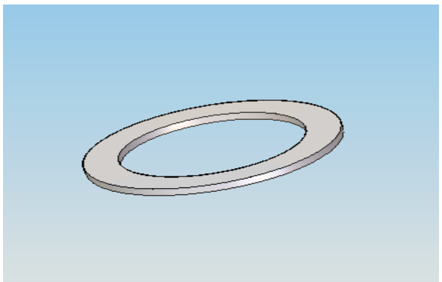

Fig -7 Design of washer

3.9 Assembly Of All Parts

All the parts are assembled as per the required design. All the 13 plates are arranged in sequence and washers are placed between the plates. Pins are used to lock the assembled plates so as to provide locking, which will hold all the plates rigidly and movement of individual plates is constrained.

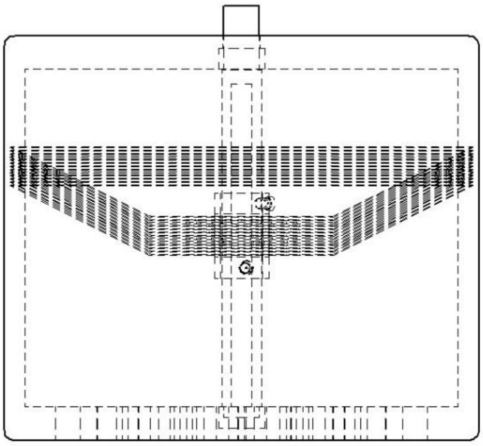

Fig -8 2D diagram of the entire setup

The above figure shows the full assembly of the water turbine in its 2D view consisting of all the parts which includes shaft, plates, washers, lock pins, housing.

4. FABRICATION OF WATER TURBINE

The design of water turbine is studied and fabrication process is planned based on design constraints and the available materials, machining processes and equipment's. The water turbine parts are fabricated and all the parts are assembled.

Fabrication Process:

4.1 Plates:

- Material used :- stainless steel 304 sheet metal of 0.4 mm thickness
- The plates are cut as per the cone calculations using the relation θ = r/s*360
- Tungsten inert gas (TIG) welding is used for joining the sheet metal so as to obtain desired plate design .
- Araldite is applied for the plates to obtain strength

4.2 Shaft :

- Material used :- Aluminium 6061
- The material procured is turned as per the required dimension using Lathe

4.3 Housing:

- Material used ,
  - Aluminium of thickness 10mm for cylinder
  - Aluminium of thickness 16mm for cover plates
- 10mm thickness Al is rolled to obtain a cylindrical shape and is joined by arc welding process.
- The bottom cover plate is bored to place bearing and the holes are drilled as per the design is joined by means of arc welding.
- The top cover plate also is bored as per bearing dimension to fit the bearing.

4.4 Assembly of all parts:

Fig -9 Complete assembly

5 RESULTS AND DISCUSSIONS

The turbine was designed and fabricated as per the calculations made from the literature. The obtained results were tabulated and graphs were made to show the variation of different parameters.

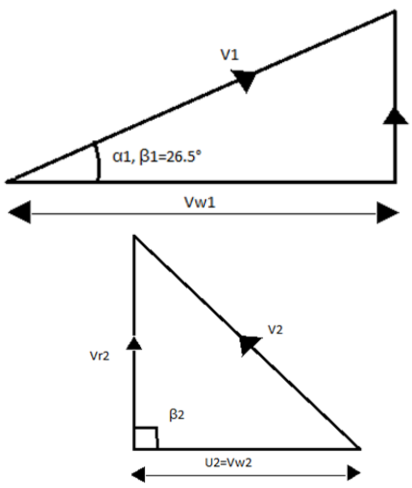

Fig -10 Inlet & Outlet velocity triangle

From the above figure, we can see that the inlet angle α_1 and blade angle β_1 are both 26.5°. The β_2 is 90° because of axial outlet of the water dude to which the entire outlet triangle cancels out. Further the relations to calculate the other parameters are given below.

5.1 FORMULAE USED:

Tangential velocity of rotor at inlet in m/sec (U)

$U=\pi DN/60$ (1)

Tangential component of absolute velocity or whirl velocity @ inlet in m/sec (Vw_1): $V_{w1}=V_1 cos\alpha$ (2)

Absolute velocity of fluid inlet in m/sec (V_1)

$V_1=Q/A$ (3)

Mass flow rate in kg/sec (m)

$m=Q*p$ (4)

Force in newton (F)

$F = m*(V_{w1}\pm V_{w2})$ (5)

Power in watt (P)

$P= F*u$ (6)

Torque of shaft in N-m (T_{shaft})

$T_{shaft}= F*r$ (7)

Angular velocity in m/sec (ɯ)

$ɯ =2\Pi N/60$ (8)

Efficiency (η)

$\eta= ɯ\ T_{shaft}/pgHQ$ (9)

Where,

D = Diameter of shaft in m
N = Speed in rpm
α = The blade angle
A = Area of the pipe in m².
ρ = Density of the fluid in kg/m³
Q = volume flow rate in m³/sec.
Vw_1=Tangential component of absolute velocity or whirl velocity @ inlet in m/sec.
Vw_2=Tangential component of absolute velocity or whirl velocity @ exit in m/sec
r= The radius of shaft
H = Net head of the water inlet.
g = acceleration due to gravity.

5.2 Test Readings And Calculations

Table -4 TABULAR COLUMN FOR TEST RESULTS

Speed 'N' in RPM	Time taken "t" for 5 liters in sec	Volumetric flow rate 'Q' in m³/sec	Tangential velocity 'U' in m/sec	Absolute velocity 'V_1' In m/sec	Whirl velocity 'V_{w1}' in m/sec	Mass Flow rate 'm' in Kg/sec
33	28	.0178x10⁻³	0.0294	0.5665	0.5069	0.178
40	18.5	0.270 x10⁻³	0.0356	0.8594	0.7691	0.270
68	16.5	0.30 x10⁻³	0.0605	0.9549	0.8546	0.30
108	13	0.384 x10⁻³	0.0961	1.2223	1.0939	0.384
120	11.2	0.446 x10⁻³	0.1068	1.4196	1.2704	0.446
128	10	0.5 x10⁻³	0.1139	1.5915	1.4243	0.5
134	10.4	0.48 x10⁻³	0.1193	1.5279	1.3674	0.48
140	8.5	0.58 x10⁻³	0.1246	1.846	1.6520	0.58

Force 'F' in N	Power 'P' in W	Torque 'T' in N-mm	Angular velocity 'ɯ' in rad/sec	Efficiency 'η' in %
0.0902	0.0026	.7664	3.4557	1.516
0.2076	0.0073	1.7646	4.1889	2.79
0.2564	0.0155	2.1794	7.1209	5.27
0.4200	0.0404	3.57	11.3097	10.71
0.5666	0.0605	4.8161	12.5663	13.83
0.7121	.0811	6.0529	13.4041	16.54
0.6563	.0783	5.5785	14.03	16.62
0.9581	.1194	8.14	14.66	20.97

5.4 Graphs

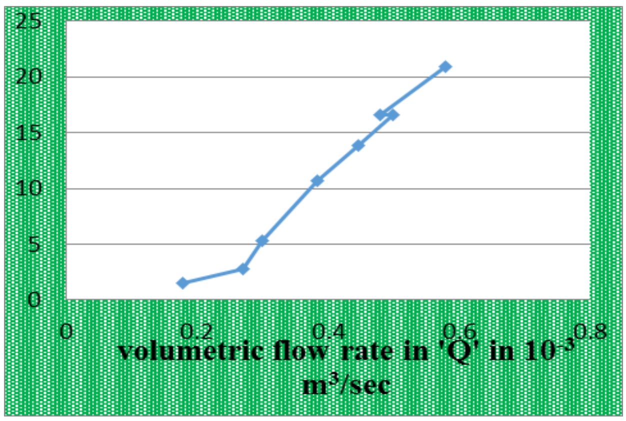

Fig. 11 Efficiency 'η' Vs. Volumetric flow rate 'Q'

The above graph show the variation of efficiency with flow rate. We notice that the efficiency increases linearly until 0.5m^3/sec where we notice a stability and a linear increase again.

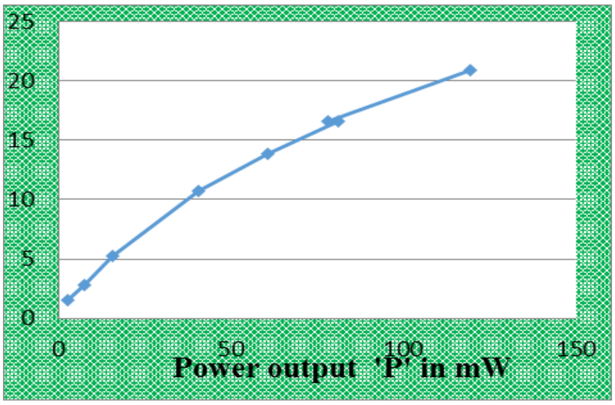

Fig. 12 Efficiency 'η' Vs. Power output 'P'

This graph shows the variation of efficiency with power output, we notice that the efficiency becomes linearly parabolic after 80mW of power.

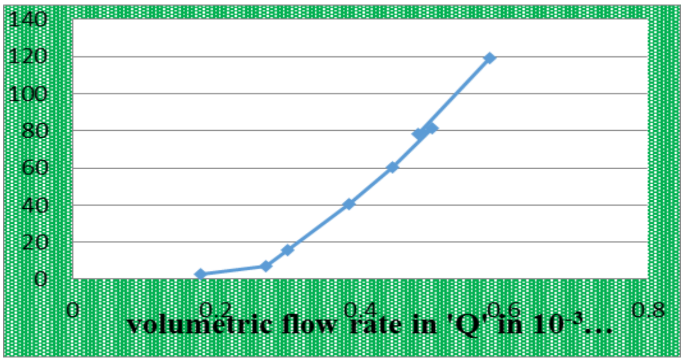

Fig. 13 Power output 'P' Vs. Volumetric flow rate 'Q'

The above graph shows the variation of volumetric flow rate with power output. This shows a linear increase in the power output as the flow rate increases.

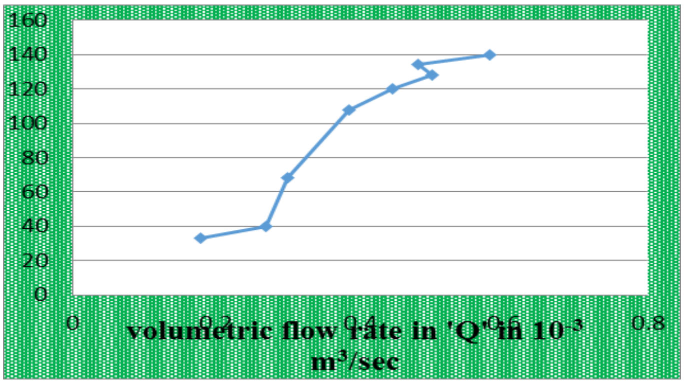

Fig. 14 Speed 'N' in RPM Vs. Volumetric flow rate 'Q'

The above graph shows the variation of speed with volumetric flow rate. We notice that there is a parabolic increase in the speed with the increase in the volumetric flow rate until 0.5 after which there is a stability is the speed.

6 SCOPE OF FUTURE

- Turbine performance can be improved by introducing flow directors.
- Improving design of housing.
- Add another nozzle to improve the stability.
- Add magnetic bearing to reduce rolling friction.
- Incorporating better design for exhaust of water.
- Use of lighter material for housing like epoxy resin will reduce overall weight of the turbine.
- Shape of shaft and also be changed to minimize rotational losses.

7 CONCLUSION

By understanding the working principle of the Tesla turbine, the available design is modified with respect to various parameters and fabrication is done. As the water flows into the gap within the plates, the velocity keeps dropping throughout the flow till the exit. As the maximum loss in the blades is due to the axial exit of the water this loss is overcome by changing the design of the plates. Introducing a bend of 26.5° which is related to the angle made by the nozzle, this bend provides a more uniform exit of the water without hampering the rotation of the plates.

The turbine can be used in remote locations where there is shortage or no supply of electricity. It can also be used to regenerate the lost power in pumps. It is also a major advantage for various domestic applications. Since it is portable it can be carried easily and used where a source of water is available to generate power.

8 REFERENCES

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

[2] 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.

[3] 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.

[4] R. C. North, "An Investigation of the Tesla Turbine," Mechanical Engineering, University of Maryland, 1969.

[5] E. Beans, "Performance Characteristics of a Friction Turbines," Mechanical Engineering, Pennsylvania State University, 1961.

[6] Armstrong J. H., "An investigation of the performance of a modified Tesla Turbine," M.E. department, Georgia Institute of Technology, Atlanta, 1952.
[7] S. J. S. B. H. J. D. Williamson, "Low head pico hydro turbine selection using a multi- criteria analysis," Sweden, 2011.
[8] Tesla N..United States of America Patent 1,061,206, 1913.
[9] A. Camacho, "The Design of a Micro-Turbogenerator," Duke University, urham, NC, 2011.
[10] Y. M. M. S. Z. Z. J.A.Razak, "Application of Crossflow Turbine in Off-Grid Pico Hydro Renewable Energy System," Recent Advances in Applied Mathematics, pp. 519- 526, 2010.
[11] Kalogirou S.A., "Seawater desalination using renewable energy sources," Progress in Energy and Combustion Science, pp. 242-281, 2005.
[12] V. P. Carey, "Assessment of Tesla Turbine Performance for Small Scale Rankine Combined Heat and Power Systems," Journal of Engineering for Gas Turbines and Power, vol. 132, pp. 122301-1 122301-8, 2010.
[13] W. Rice, "An Analytical and Experimental Investigation of Multiple Disk Turbines," Journal of Engineering for Power, vol. 87, pp. 29-36, 1965. 85
[14] 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.
[15] S. B. Guha A., "Experiment and analysis for an improved design of the inlet and nozzle in Tesla disc turbines," Journal Power and Energy, vol. 224, no. 2, pp. 261- 277, 2009
[16] S. A. J. a. A. H. Epstein, "AN INFORMAL SURVEY OF POWER MEMS," in The International Symposium on Micro-Mechanical Engineering, 2003.
[17] 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.
[18] D. R. F. V. Jan Peirs, "A microturbine for electric power generation," Sensors and Actuators A, vol. 113, pp. 86-93, 2004.
[19] V. G. I. Z. M. M. M. Krishnan, "A micro Tesla Turbine for power generation from low pressure heads and evaporation driven flows," in Solid-State Sensors, Actuators and Microsystems Conference (TRANSDUCERS), 2011 16th International, Beijing, 2011.
[20] D. S. A. L. C. J. B. T. S. G. Kandlikar, "Characterization of surface roughness effects on pressure drop in single-phase flow in minichannels," Phys. Fluids 17, 100606, 2005.