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Design and Experiment of Rotating Fluid Flow in a Tesla Disc Turbine

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Abstract

Turbine discs were designed and building a prototype to improve the efficiency of the working fluid in Tesla turbines. The fluid flow field within tesla disc turbine have been investigated experimentally. The turbine is a bladeless centripetal and tangential flow turbine. The turbine runs by the principle of momentum transfer by developing a boundary layer on the smooth surfaces of the disks. Circular nozzles were analyzed using air as the working fluid and flow taken to be incompressible, turbulent and non-reacting. Different inlet velocity ranging from 20.0 to 70.0 m/s has been investigated. In the range investigated the lower velocity did not influenced the performance. Paper will develop an adequate design of nozzles contribute to increase the overall yield of a Tesla turbine.

Keywords: Design, Nozzle, Tesla Disc, Turbine, Velocity

1. Introduction

The study of analysing fluid path is important in various fields of fluid flow, such as in atmospheric science and oceanography. The huge economic growth in the worldwide depends of its energetic infrastructure. Thus, the building of renewable energy or alternative energy is important against the increasing global energy consumption. Conventional turbines for the production of work using superheated steam as working fluid. Condensation of steam can cause damages the turbine blades, which limits their application with saturated steam. Another type of turbine can be installed which can generate power which is a blade less turbine commonly known as tesla turbine. Tesla turbine can generate a useful power with low velocity by using working fluid. Tesla turbine can generate power for variety of working media like Newtonian fluids, non-Newtonian fluids, mixed fluids, particle laden two-phase flows[1] (many aspects of two-phase flow maybe found in Refs[2,3]. This turbine has self-cleaning nature due the centrifugal force field. This makes it possible to operate the turbine in case of nonconventional fuels also. In this paper, fluid velocity is analyzed by using different nozzles, viz. Tesla turbine[4], invented by the famous scientist Nikola Tesla has been investigated.

The fluid flow in striking with a rotating disc has been the subject-matter of many research studies. Dijkstra and Van Heijst[5] investigated the flow between two finite size rotating discs enclosed by acylinder. Zhou et al.[6] investigated both numerically

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by using Fluent Ansys and experimentally by using PIV measurements of laminar flow induced by an rotating disc. Sandilya et al.[7] reported numerically the effect of discs rotation on gas flow and mass transfer between two coaxially rotating discs. Andersson andRousselet[8] investigated slip flow over a lubricated rotating disc. Nozzles used in a Tesla turbine generally for high velocity and has the function of uniformly distributing the working fluid between the turbine discs. The different injector nozzle is cited as a major cause of low efficiencies of Tesla turbines[9–14].

The purpose of the present study is to analyzed circular nozzles of different nozzle diameter by using air as the working fluid and flow taken to be incompressible, turbulent and non-reacting at different inlet velocity that ranging from 20.0 m/s to 70.0 m/s.

2. Experimental Setup

The advancement of industrial technology develops interest in the development of turbo-machinery based on the principle proposed by Tesla. The schematic diagram of the experimental setup of tesla turbines is shown in Figure 1. The rotating discs are coupled on a shaft, constituting the rotor. The discs are covered with a casing, which is called the stator of the turbine. The discs have holes near the center to allow the exhaust of the working fluid. Working fluid is injected tangentially to the discs by a circular nozzle. A nozzle used in a Tesla turbine generally to increase the velocity and has the function of uniformly distributing the working fluid between the turbine discs. Figure 2 shows the typical shape of nozzles in a Tesla turbine. Nozzles are also used to increase the kinetic energy of fluid in several applications.

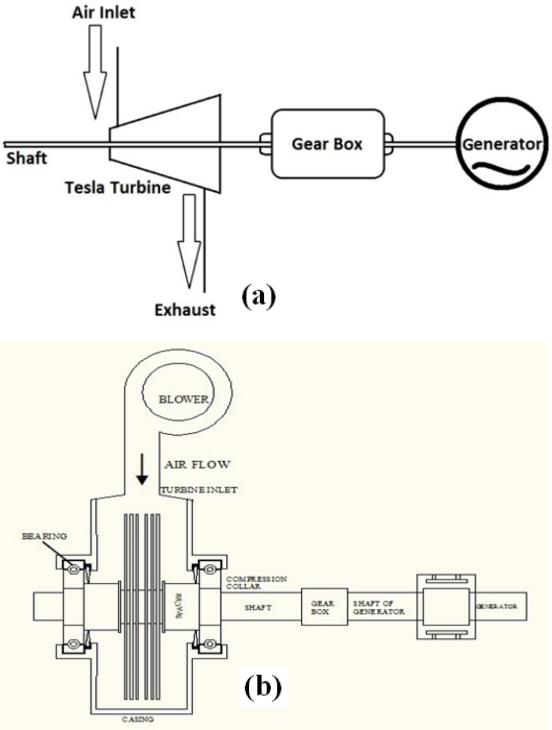

Figure 1. (a) Schematic diagram of the experimental rig, (b) Schematic drawing of a Tesla turbine.

Air is powered by a compressor that is capable of supplying a required mass flow rate. The system is determined by a digital anemometer with a probe-type turbine into a tube with an accuracy of 5%. The anemometer is positioned downstream of nozzle. The static pressure line and the pressure taps of the nozzles are measured by pressure transmitters with a range of 0–15 bar (accuracy 0.85%). A total of 4 nozzles were investigated. All nozzles had circular geometry at throat. The nozzles have been constructed with high-density polyurethane. The diameter (d) of nozzles is 4.0 mm, 5.0 mm, 6.0 mm and 7.0 mm.

3. Effect of Nozzle Angle

The working fluid is injected through a channel in a nearly tangential path by one or more inlet circular nozzle (Figure 2) through the periphery of the rotor of a Tesla disc turbine. In the present analysis, uniform flow rate throughout the periphery is considered. The tangential velocity of the working fluid entering into the relative rotational frame of reference ranging from 20.0 to 70.0 m/s.

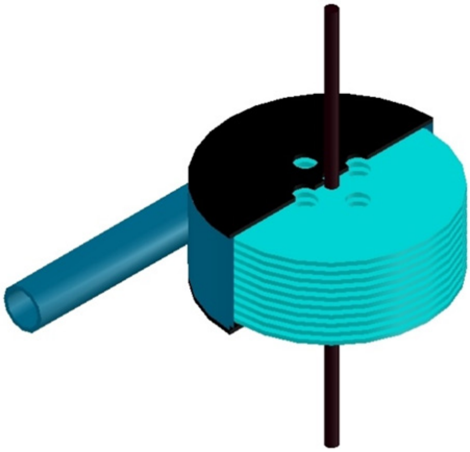

Figure 2. Nozzle considering isentropic flow.

4. Governing Differential Equations

The flow between the discs has been assumed to be steady, laminar and axisymmetric. In order to make the complex flow an analytical theory, a few more assumptions are made, which have been fully described by Sengupta and Guha[15]. The reference also includes a detailed order of magnitude analysis of the various terms of the three-dimensional conservation equations in the cylindrical coordinate system.

The continuity equation, the momentum equations and boundary conditions are written in terms of relative velocities. For this purpose the following relations between the absolute and relative velocities are used.

Continuity equation

$$\frac{\partial V_r}{\partial r}+\frac{V_r}{r}=0 \tag{1}$$

θ- Momentum Equation

$$\mathrm{Vr}\frac{\partial V_r}{\partial r}+\frac{V_r V_\theta}{r}+2\Omega\mathrm{Vr}=\mathrm{V}\frac{\partial^2 V_\theta}{\partial Z^2} \tag{2}$$

r- Momentum Equation

$$Vr\frac{\partial V_r}{\partial r}-\Omega^2 r-2\Omega V_r-\frac{V_\phi^2}{r}=-\frac{1}{\rho}\frac{dp}{dr}+v\frac{\partial^2 V_r}{\partial z^2} \tag{3}$$

z- Momentum Equation

$$\frac{dp}{dz}=0 \tag{4}$$

5. Experimental Result and Discussion

The first testing was conducted in the typical casing. These experiments focused on determining the energy contribution provided by the tesla disk. The preliminary results have been summarized in Table 1.

As seen from Table 1, the contribution of the tesla disk which increases the energy conversion efficiency with wind speeds. Also, result showing that the procedure is suitable to be further applied in designing a tesla turbine with more disk and different types of nozzles.

Figure 3 shows the variation of rpm with working fluid velocity for different circular nozzles. Rpm

Table 1. For varying inlet diameter and inlet velocity

Velocity	d = 4.0		d = 6.0		d = 8.0		d = 10.0	
(m/s)	RPM	Power (W)	RPM	Power(W)	RPM	Power(W)	RPM	Power (W)
20.26	765.00	23.13	886.00	27.75	936.00	27.39	835.00	21.62
26.92	925.00	32.22	1021.00	35.27	1147.00	38.83	1011.00	28.69
32.42	1189.00	49.87	1463.00	66.36	1587.00	69.95	1487.00	58.34
39.49	1314.00	54.26	1765.00	86.53	1922.00	93.83	1825.00	81.78
46.82	2469.00	154.84	2646.00	172.60	2841.00	187.26	2741.00	168.32
56.22	3789.00	349.25	3914.00	347.43	4169.00	371.31	3966.00	321.15
61.83	4369.00	430.78	4539.00	432.13	4723.00	450.92	4566.00	404.99
69.13	4968.00	514.16	5397.00	557.59	5522.00	550.52	5241.00	484.06

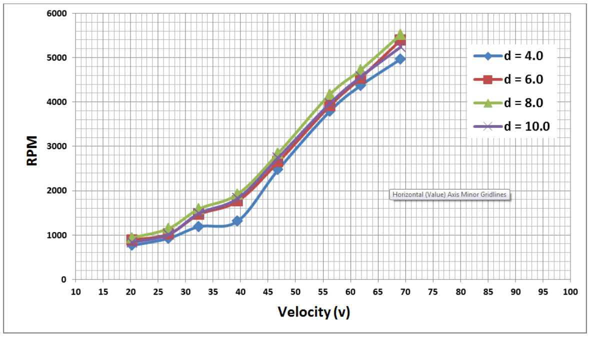

Figure 3. Characteristic curves for the tesla disk rotor RPM versus tangential velocity at different circular nozzle diameter.

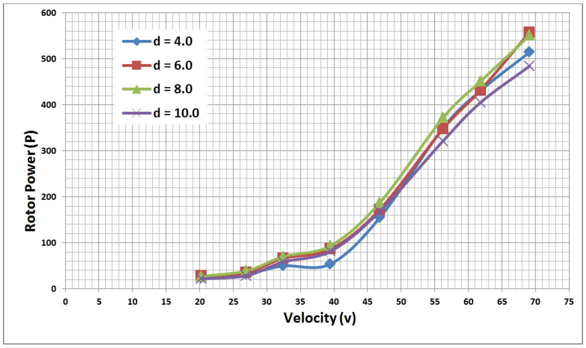

Figure 4. Characteristic curves for the tesla disk rotor Power versus tangential velocity at different circular nozzle diameter.

increases with increasing with fluid velocity. Circular diameter (d = 8.0) showing better result than the other circular diameter used in this present experimental investigation. One of the key things is the working fluid velocity, is that the amount of energy which it can generate. Rather energy increases by the cube of the velocity of the working fluid. Figure 4 shows the variation of tesla disk rotor power with tangential velocity at different circular nozzle diameter. It shows the power output (usually in watts) on one axis and the working fluid velocity on the other. From the Figure 4 one can see that a small difference in velocity within a given area can have a big impact on the amount of energy a tesla turbine can generate. Torque is also giving support with increasing velocity to develop rotor power. Rotor power increases with increase of velocity. Circular nozzle diameter (d = 6.0 and d = 8.0) shows some promising results over the entire velocity range.

Figure 5 shows pressure characteristic curves with tangential velocity at different circular nozzle diameters. There is apparent separation on the surface near the end wall, and the secondary flow of the rotor is stronger than that of the stator. A small separation occurs at the inlet of the pressure surface of the rotor. According to the optimized design, the variations of the passage and the stacking allow the main fluid flow to have more kinetic energy near the end-wall and thus to constrain the development of the boundary layer and the secondary flow.

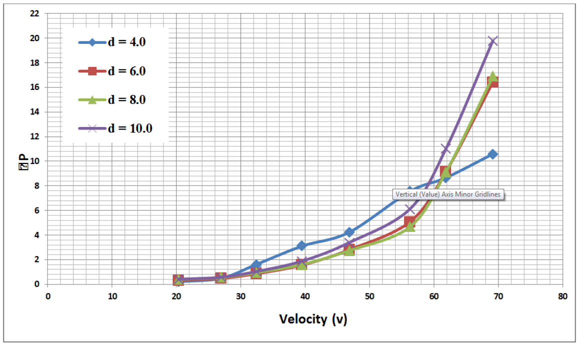

Figure 5. Pressure characteristic curves with tangential velocity at different circular nozzle diameters.

6. Conclusion

The paper objective is underlined by the necessity of increasing the maximum power which could be extracted from the air current by using tesla turbines. The conducted experiments have focused on the investigation of the energy contribution provided by a rotor by using different circular nozzles. The analysis of the obtained results shows that the use circular nozzle diameter (d = 8.0) have maximum power output. It can be considered that the mechanical torque is increases along with rpm and velocity. Thus, there has been noticed a good experimental determined sizes, resulting that the procedure issuitable to be further applied in designing a tesla turbine.

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