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Optimization of Tesla Turbine Using Computational Fluid Dynamics Approach

Tan Wee Choon, Rahman. A. A., Foo Shy Jer
School of Mechatronic Engineering
Universiti Malaysia Perlis
Perlis, Malaysia
tweechoon@unimap.edu.my

Lim Eng Aik
Engineering Mathematics Institute
Universiti Malaysia Perlis
Perlis, Malaysia

Abstract— ***A Tesla turbine is developed in order to utilize the potential energy within household water supply and convert to electricity energy without significant head loss. Pressure within the water supply having higher potential energy compared to the energy needed to reach the reservoir tank. This extra potential energy can be utilized and convert to useful energy before it being waste after reach reservoir tank. The development of Tesla turbine is carried out to determine disc size, disk gap and number of disc base on theoretical calculation of Tesla turbine. Optimization is done by using Computational Fluid Dynamics (CFD) software package. Actual performance analysis for prototype based on RPM and torque also conducted. After the optimization, we observed that the Tesla turbine design yields torque of 0.0330N.m with an efficiency of 10.7% .***

Keywords - Tesla turbine; green energy; energy convertion; Compuational Fluid Dynamics

I. INTRODUCTION

8.30 pm till 9.30 pm on 26 of March each year is declared as Earth Hour around the globe starting in 2007 in Sydney, Australia. Behind the agenda of this Earth Hour is to increase the awareness of climate change among the human being around the world. Currently petroleum, natural gas, and coal is the main power source of Malaysia generating about 90 percent of power supply [1]. Besides, the combustion of this type of energy like oil, coal and natural gas is a major contribution to the emission of greenhouse gasses that raise the issue of climate change. Both of these issues are of major global environmental concerns that will have disastrous impact on the socio-economic development in Malaysia [2]. Thus, through utilizing any other available energy will be able to save energy from fossil fuel and minimize polluting the nature environment.

Thus, this paper is to develop a Tesla turbine for household usage as green energy with the objective to generate electricity using household water supply without significant head loss.

The Tesla Turbine was invented by Nikola Tesla in 1913. It is known as bladeless centripetal flow turbine [3, 4, 5]. Tesla Turbine consists of an array of parallel thin disks very close to each other, apart by spacers and assembled on a shaft, forming a rotor which is fitted in a cylindrical housing with its ends closed by plates properly fitted with bearings to hold the rotor shaft. In between the disks which are close to the rotating shaft, exhaust ports are opened in order to provide an exit to the atmosphere via the disk gap [6]. A nozzle is located tangentially to the bore of the casing, feeding the working fluid, onto the disks causing to rotate while proceeding to the exhaust port [7, 8, 9].

The efficiency of rotor which works within laminar flow is able to hit above 95% [10]. However, the flow rate value must be as low as possible in order to attain high rotor efficiency. In other words, it requires a large number of disks and hence a physically large rotor to achieve above objective [10].

Experimental results for prototype turbines available in literature indicate a somewhat linear relationship between turbine efficiency and rotor rpm. At fixed pressures and varying loads, the performance of this turbine based on air as the working fluid is reported to be 21% at 5k rpm, 24% at 7k rpm and 28% at 9k rpm [11], 24% at 12k rpm [12] and 22.5% at 8k rpm, 24.5% at 10k rpm and 26.5% at 12k rpm [10].

II. TESLA TURBINE

A. Basic Design

Tesla turbine is a rotor consisting of flat parallel co rotating disks spaced along a shaft [4, 13]. The working fluid flows between disks resulting into momentum exchange between the working fluid and disks. Due to this momentum exchange, it generates shaft torque and power under the principle of fluid viscosity. Since the rotor has no projections, it is very powerful [4, 13, 14].

B. Working Principle

Tesla turbine has a number of closely-spaced flat disks mounted on a shaft, driven by a fluid flowing between them, in spirals concentric with the shaft, toward a center outlet. The energy transfer does not occur through impingement. Instead, the fluid's energy is imparted to the disks through the force of adhesion. When the fluid makes contact with a disk its molecules adhere to the disk and resist motion. The force of the fluid works against the resistance of the disk and some of the fluid's energy imparts to the disk. The force of viscosity, or adhesion between layers of fluid molecules, enables more fluid to act on the disk than is able to adhere to it [15].

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III. DESIGN PARAMETERS

In any design process, all design factors and parameters have to be considered and optimized in order to achieve the best performance of a product.

A. Working Fluid

The working fluid is water which is supplied to the residents of Perlis. Outlet water from Tesla turbine should at least reach the reservoir tank of single storey building in Perlis residential area.

B. Size of Disk Gap

The disk gap, b is a critical parameter in the design [16]. The optimum gap size to maintain the boundary layer is [17]

$$b = Ph \times (v / \omega)^{1/2} \quad (1)$$

where v indicates the kinematic viscosity of the working fluid, ω indicates the rotor rotational speed of the system and the Polhausen parameter, Ph is suggested within the range of

$$2.5 \geq Ph < 3.5 \quad (2)$$

C. Number of Disks

Hasinger and Kehrt [18] provided a dimensionless parameter, A that has essential machine data. Based on this dimensionless parameter, the number of disks, N is estimates as [18]

$$N = n + 1 \quad (3)$$

where n indicates the number of gap within the system which is connected with working fluid flow rate, Q and flow rate of working fluid between the parallel disks, q by

$$n = Q / q \quad (4)$$

$$q = (0.16 A v r_o^2) / b \quad (5)$$

The dimensionless parameter, A is suggested within the range of

$$10 \geq A < 20 \quad (6)$$

while the ratio of radius is suggested to be

$$r_o / r_i \geq 2.5 \quad (7)$$

D. Turbine Efficiency

Turbine efficiency is based on net head, H rather that gross head H_{gross}[19]. Specifically, $\eta_{turbine}$ is defined as the ratio of work done by shaft over work done by working fluid which is the water supply in this case. It is given by

$$\eta_{turbine} = (\omega T_{shaft}) / (gHQ) \quad (8)$$

where T_{shaft} is the torque of shaft within Tesla turbine, ρ indicate the density of working fluid, g is the gravity acceleration and V indicates working fluid velocity.

IV. EXPERIMENT SET UP AND PROCEDURE

In order to determine the actual value of the working environment and design parameters of Tesla turbine, some experiments need to be conducted.

A. Measurement of Household Water Supply Flow Rate

Three different locations are selected as the test subject. The equipments are set up as shown in Figure 1. Before conducting the experiment, the chosen locations have to be in a non-water consumption condition. Based on the measurement, three flow rate ranges were identified which are 0.32 kg/s, 0.40 kg/s and 0.48 kg/s.

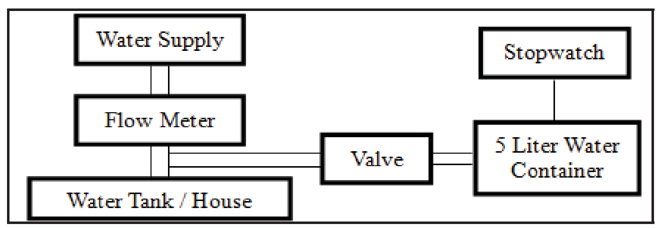

Figure 1. Schematic of equipment set up for measuring water flow rate of housing area.

B. Initial Design Parameters of Tesla Turbine

The initial design parameters of Tesla turbine are determined from earlier equations based on the flow rates identified. The design parameters are as shown in Table I. Based on the parameters in Table I, the Computer Aided Design (CAD) model for Tesla turbine can be shown in Figure 2.

TABLE I. INITIAL DESIGN PARAMETERS OF TESLA TURBINE

Design Parameter	Symbol	Unit	Value
Number of disk	N	-	21
Disk Gap	b	mm	0.31
Disk Size	r_o	mm	55
Size of Housing	DH	mm	115

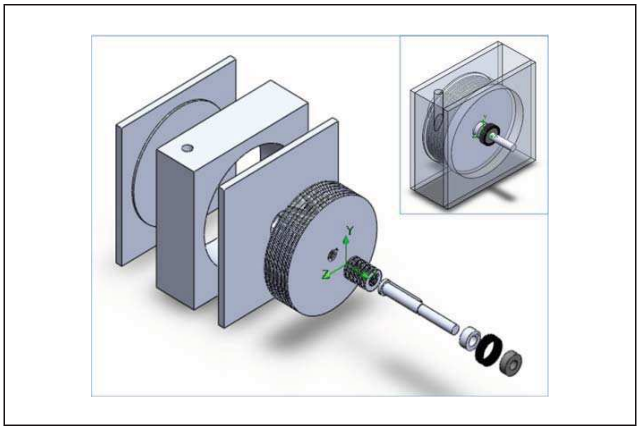

Figure 2. CAD Modeling of Tesla Turbine.

C. Computational Fluid Dynamics Analysis of Tesla Turbine

The Computational Fluid Dynamics (CFD) simulation result of Tesla turbine using available commercial software package of EFD.Lab is shown in Figure 3, the results are shown in Table II. Based on these results, the efficiency, pressure head and related head loss for this Tesla turbine system are calculated using equations given in section III and are shown in Table III.

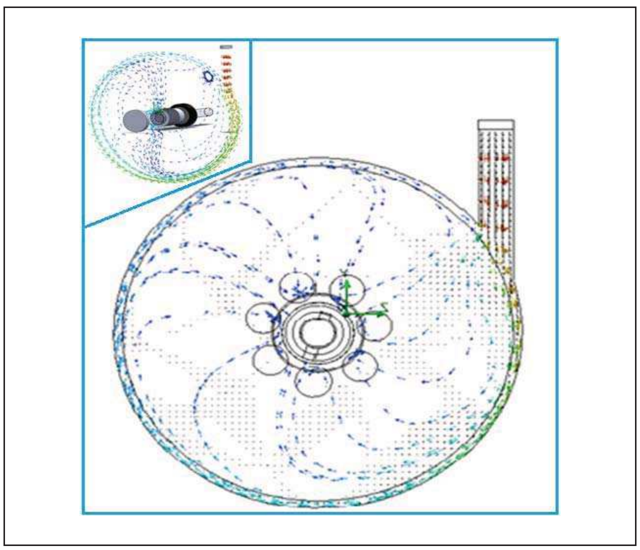

Figure 3. CFD simulation of Tesla Turbine.

TABLE II. PRESSURE, VELOCITY AND TORQUE OF TESLA TURBINE

Goal Name	Symbol	Unit	Value
Inlet Pressure	P_1	Pa	103896.076
Outlet Pressure	P_2	Pa	101325.006
Inlet Velocity	V_1	m/s	4.197
Outlet Velocity	V_2	m/s	0.680
Torque	T_{shaft}	N.m	0.0210

TABLE III. TESLA TURBINE'S EFFICIENCY AND HEAD LOSS

Output Data	Symbol	Unit	Value
Efficiency	$\eta_{turbine}$	%	6.8
Head of Tesla Turbine	H_T	m	0.7
Head Loss	h_L	m	0.44

D. Optimization Through Computational Fluid Dynamics Software

EFD.Lab is used again in order to optimize the above design parameters given in Table II. These values as shown in Table II are used as the initial step in order to obtain its optimum value. After the optimization process, the new values are given in Table IV. Based on these optimum values, Tesla turbine's simulation results are shown in Table V. The efficiency of the Tesla turbine, pressure head and related head loss for these new results are given in Table VI.

TABLE IV. OPTIMUM DESIGN PARAMETERS

Design Parameter	Symbol	Unit	Value
Number of disk	N	-	13
Disk Gap	b	mm	0.32
Disk Size	r_o	mm	70
Size of Housing	DH	mm	150

TABLE V. PRESSURE, VELOCITY AND TORQUE OF TESLA TURBINE

Goal Name	Symbol	Unit	Value
Inlet Pressure	P_1	Pa	103985.698
Outlet Pressure	P_2	Pa	101325.018
Inlet Velocity	V_1	m/s	4.186
Outlet Velocity	V_2	m/s	0.682
Torque	T_{shaft}	N.m	0.0330

TABLE VI. FINAL DESIGN TESLA TURBINE'S EFFICIENCY AND HEAD LOSS

Output Data	Symbol	Unit	Value
Efficiency	$\eta_{turbine}$	%	10.7
Head of Tesla Turbine	H_T	m	1.1
Head Loss	h_L	m	0.04

The head loss of the optimized Tesla turbine has a significant drop is due to the decrease of number of disk. The head loss in the Tesla turbine is caused by the 90° degree turn when the fluid flow from the disk gap into the outlet zone. This due to the fluid cannot make sharp 90° turns easily, especially at high velocity. As a result, the flow separates at the corners, and the flow is constricted into the vena contracta region formed in the midsection of the outlet region. Therefore, sharp-edge inlet acts like a flow constriction which leads to head loss.

The increase of torque is due to the increase of the disk size[21]. Larger disk size will produce larger torque, because it allows the fluid to spiral more turns before it exit to the outlet. Though larger disk size able to create more torque, it is limit by the limited water flow rate of the household area. Larger disk size requires larger start up torque, the water flow rate might not sufficient to rotate the rotor of the Tesla turbine.

V. PERFORMANCE ANALYSIS

Through EFD.Lab simulations, it is predicted that the Tesla turbine is able to yield a torque of 0.0330 N.m. whereas the initial design only produced 0.0210 N.m which is about 57% more. With the increment of torque the head loss of the system is also reduced to 91%. In this optimization, it does agree that the theoretical formula can be a guideline to design Tesla turbine for the energy conversion system but in order to obtain optimum output, the CFD software package is required.

With the optimum dimension obtained as in Table IV, Tesla turbine model was fabricated as shown in Figure 4. The fabricated model is used to conduct a series of experiment in order to determine the generated torque and the result is given in Table VII. The fabricated turbine produced torque which agrees well with the simulation result.

TABLE VII. COMPARISON OF SIMULATION AND EXPERIMENTAL RESULT

Characteristic	Unit	Simulation	Experimental
Torque	N.m	0.0330	0.0334

Figure 4. Tesla Turbine model.

VI. CONCLUSION

As a conclusion, a home-based Tesla turbine is developed using the available mathematics equations (pressured gas as the working fluid) which available in the literature. Based on these mathematics equations, the Tesla turbine (pipe water as the working fluid) is able to generate a torque of 0.0210 N.m with an efficiency of 6.8% from the water supply as the working fluid and cause head loss of 0.44 m.

By using Computational Fluid Dynamics approach, Tesla turbine is optimized and able to generate a torque of 0.0330 N.m with an efficiency of 10.7% from the water supply as the working fluid and cause head loss of 0.04 m.

The given total net head of the water supply from Jabatan Kerja Rakyat, Perlis Malaysia is given as 10.3 m. Thus, the remaining net head pressure is 10.26 m. The pressure is still sufficient to supply to a single storey water tank after consider the minor losses within piping system, since the height of water tank is only 3 m. Besides, it is also stated that the net pressure in the guideline of water demand the net head pressure shall not be lower than 7.6 m [20, 21].

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