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Design, Manufacturing and Testing of a Hybrid Tesla Turbine

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Abstract*: *A Hybrid Tesla Turbine with boundary layers and blades was designed, built and tested in this study. To investigate the effect of disc material and air flow direction, three hybrid turbines were constructed. To experimentally determine the moment of inertia of each system, a brake mechanism was also designed and manufactured for deceleration tests of turbines.* Three turbine models were tested to understand the effect of disc material and direction of air flow. Using aluminium discs instead of steel discs had a minor increase in predicted maximum power. *The maximum power was achieved when using a tangential air outlet, instead of a central outlet design. However, the proposed hybrid turbine design created much less power than of the turbine designs in literature.

Index Terms*: *Boundary Layer, Frictional Force, Tesla Turbine, Thrust Force.

I. INTRODUCTION

The Tesla turbine, despite its relatively simple design, can reach speeds higher than 35,000 rpm [1]. The patented turbine design of Nikola Tesla (1913), is made of parallel discs attached to a shaft [2]. A fluid enters tangentially through the casing and passes between the discs, developing a boundary layer. The fluid then exhausts from the holes near the centre of the discs and casing. The boundary layer creates a frictional force, which rotates the discs and the shaft. Air, steam or water can be used as working fluid for the turbine. That invention of Tesla is known as Tesla Turbine, boundary layer turbine or friction turbine.

Recently, there has been a considerable renewed interest, mostly outside the academic field. Therefore, there is limited information that focuses on designing without any analysis. Moreover, instead of evaluating the conditions inside the turbine, most of these studies considered increasing the rotational speed. The Tesla Turbine has no significant practical application in power generation, but the Tesla pump is widely used in some industries, especially in deep sea oil wells [3].

Although academic studies concluded that the Tesla Turbine is an inefficient system, it still has a potential because of its simple, cost effective design. For this purpose, it would be useful in many cases to optimize the design parameters of the turbine. Considering the focus on the Tesla's basic design, the aim of this study is to create a hybrid system that uses both Tesla's frictional force principle and classic thrust force on turbine blades.

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II. DESIGN AND MANUFACTURING

Nikola Tesla designed and patented the Tesla Turbine in 1913 and then produced three prototypes of the Tesla turbine. One of these prototypes had 60 discs with a diameter of 1.5 m, and reached 3600 rpm and 500 kW. Steam was used as the working fluid and applied fluid pressure was 5.5 bar. The experiments concluded that the discs were greatly distorted and the turbine would eventually fail [4]. These results prevented the development of these turbines for many years. However developments in material technology have recently increased renewed interest in Tesla Turbine. The Tesla Turbine uses a series of parallel discs, called the rotor, with a minimum spacing and the discs are attached to the drive shaft (Figure 1). The rotor assembly is housed within a casing called the stator. Each disc and casing have holes close to the centre and these holes serve as exhaust ports for the working fluid. The inlet (nozzle) for the working fluid is attached tangentially to the casing and to the discs [5].

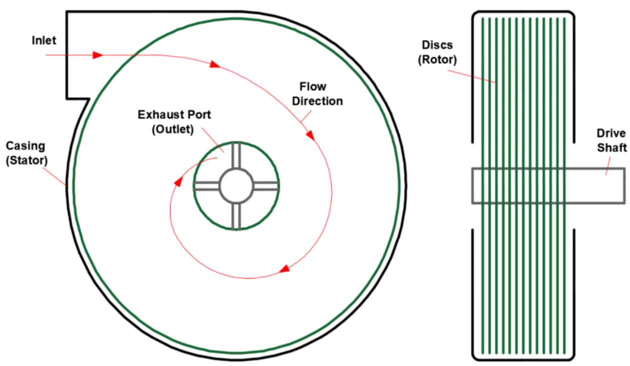

Fig.1: Schematic view of a Tesla Turbine

A Hybrid Tesla Turbine was designed as shown in Figure 2. This design consists of blade-shape washers between the discs thus, the ides in this design was to benefit both frictional force on discs and thrust force on blades (Figure 2). Three Hybrid Tesla Turbine models were designed to understand the effect of disc material and the path of fluid on turbine's efficiency: Model A, with steel discs and air outlet from holes near centre; Model B, with aluminium discs and air outlet from holes near centre; and Model C, with steel discs and air outlet tangential to the discs.

The casing chambers of three models were manufactured in 3D printer. Sides of casings were machined from aluminium billet. Two ends of the hexagonal brass shafts were machined to fit the roller bearings on both sides of casing.

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The diameter and the thickness of the discs were taken as 100 mm and 1 mm, respectively. Discs were manufactured at a CNC laser cutting machine. All these parts mounted together as shown in Figure 3. The gap between the discs were taken as 1 mm. Three Hybrid Tesla Turbine models were manufactured as mentioned above.

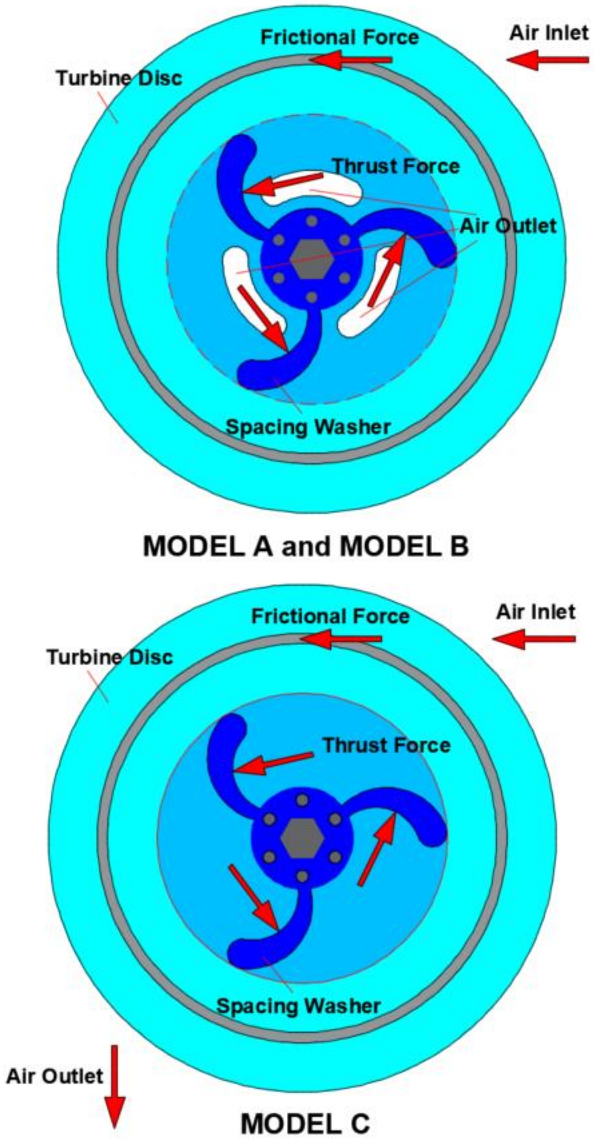

Fig.2: Flow path and force production principles of proposed turbine models.

III. TURBINE DECELERATION TESTS

The overall performance of the system is effected directly by the rotational speed of the disc package. The generated torque from the turbine can be calculated as,

$$T = I \, . \, \alpha \tag{1}$$

where I is the moment of inertia of the system and α is angular acceleration of the system. Time (t) dependent change in angular velocity (w) is recorded and then the Equation 1 can be written as,

$$T = I.\frac{dw}{dt} \tag{2}$$

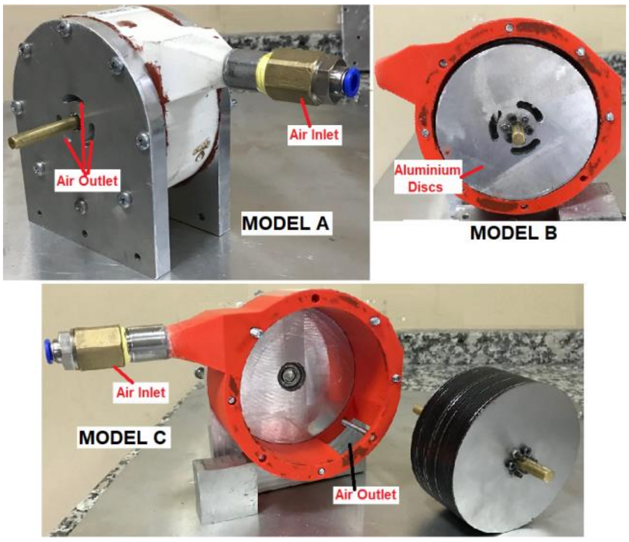

Fig.3: a) Finished design of Model A; b) Inside view of Model B; c) Demounted view of Model C

As stated in Equation 1 and 2, the moment of inertia of the system must be known to be able to calculate the generated torque from the turbine. However, the calculation of the moment of inertia of the system is difficult because of its complexity. Therefore, a brake mechanism was designed and built as shown in Figure 4. A constant air pressure of 4 bar was applied to turbine and turbine speed reached to a maximum. After that, a load was applied to the brake disc through the brake shoe, which caused a braking torque of 0.0243 N.m until the angular velocity decrease from maximum to zero. The braking time data was recorded and then the moment of inertia of the system was calculated from Equation 2 for each turbine models.

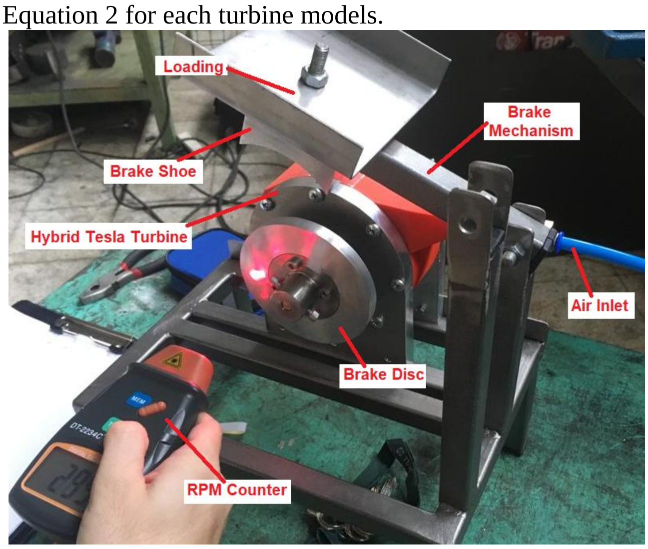

Fig.4: A brake mechanism to decelerate the turbine

IV. TURBINE ACCELERATION TESTS

The torque generated from the turbine should be measured to be able to determine the power of the Turbine. The efficiency is directly determined by the power potential of the system. The system torque is measured from the shaft and is simply calculated from the acceleration of the system.

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In turbine acceleration tests, an inlet air pressure of 4 bar was applied to the turbine and then the acceleration time data from zero to maximum speed was recorded. The moments of inertia of each turbine system from the deceleration tests were then substituted in Equation 2. The mechanical power of the system was calculated as,

$P = T . w$

(3)

According to time dependent angular velocity data.

V. RESULTS AND DISCUSSION

The angular velocity rev per minute (RPM) data during deceleration period of three Hybrid Tesla Turbines was shown in Figure 5. The slopes of the deceleration lines represent the angular accelerations of turbines and calculated as 10.301 s^{-2}, 26.345 s^{-2}, and 7.871 s^{-2} for Model A, Model B and Model C, respectively. Since the applied braking torque was 0.0243 N.m, the moments of inertia of the Model A, Model B and Model C, by using Equation 2, was calculated as approximately 0.0024 $kg.m^2$, 0.00092 $kg.m^2$ and 0.0031 $kg.m^2$, respectively.

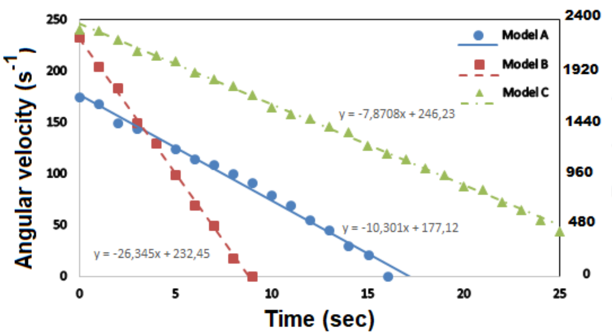

Fig.5: RPM and angulr velocity data from deceleration tests.

The proposed Hybrid Tesla Turbines were accelerated from zero to maximum speed and angular velocity vs. time (w-t) and rev vs. time (RPM-t) graphics were drawn as shown in Figure 6a. The maximum speeds were determined as 1395 rpm, 2060 rpm and 2280 rpm for Model A, B and C, respectively. The resulting polylines for three turbine models in the form of equation 4;

$w = a.x^2 + b.x + c$

(4)

The derivative of this polynomial gives the acceleration line. The resulting equation for acceleration line is,

$\alpha = 2.a.x + b$

(5)

The resulting curves are shown in Figure 6b. The maximum acceleration values are determined as approximately 3.62 s^{-2}, 8.75 s^{-2} and 4.88 s^{-2} for Model A, B and C, respectively. The values from Equation 5 should be multiplied by the moment of inertia of each turbine model, which are calculated from the deceleration tests above, to calculate the system torque. According to results of these multiplications, the resulting torque vs. time graphs are shown in Figure 6c. The maximum torque values are calculated as approximately 9 N.mm, 8 N.mm and 15 N.mm for Model A, B and C, respectively. The torque vs. angular velocity (w) curves are also plotted in Figure 6d, since a comparison of torque vs. time graphs does not have much meaning. Figure 6 has demonstrated that the Model C is the most efficient hybrid tesla tribune design compared to the Model A and B.

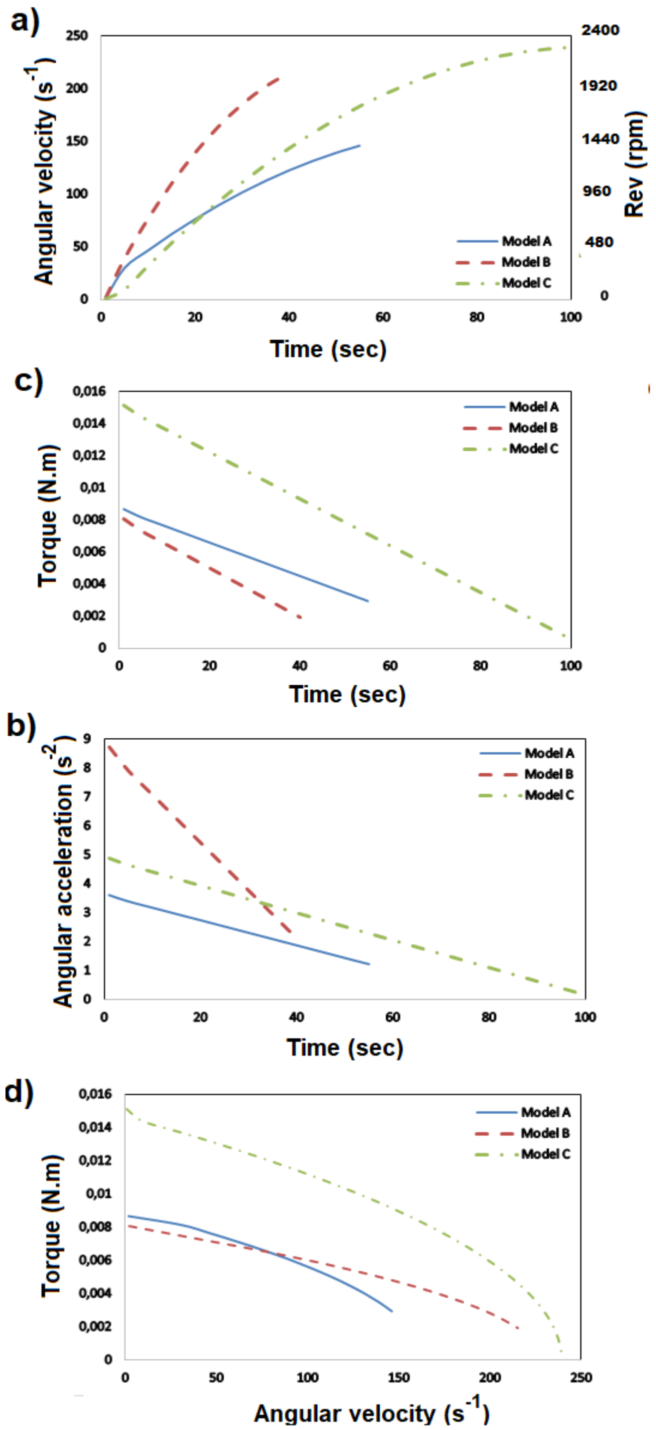

Fig.6: Comparison of acceleration tests of three proposed turbine models: a) speed (w) vs. time, b) acceleration (α) vs. time, c) Torque (N.m) vs. time, d) Torque (N.m) vs.speed (w).

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The values from speed vs. time and torque vs. time curves in Figure 6 a and c must be multiplied each other according to Equation 3, in order to calculate the power of the system. The resulting Power to speed (w) curves for each turbine models was shown in Figure 7. The maximum power was obtained as 1.4 W from Model C, which is approximately 2 fold higher than Model A and B.

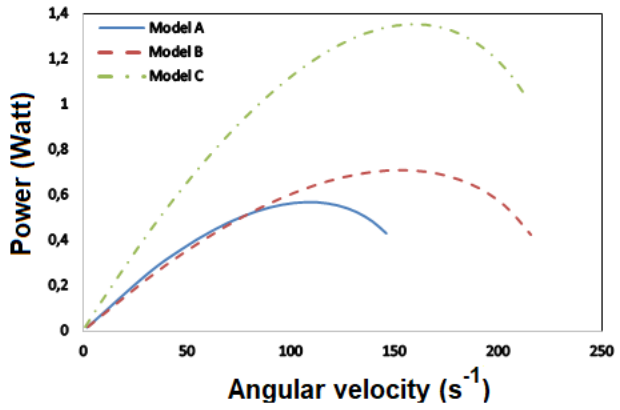

Fig.7: Comparison of Power (Watt) versus speed (w) curves of three proposed turbine models.

The results of proposed Hybrid Tesla Turbine was compared to of the literature for classic Tesla turbine designs in Table 1. The results demonstrated that using a combination of frictional and thrust force had a negative effect on predicted efficiency of Tesla turbine.

VI. CONCLUSION

A Hybrid Tesla Turbine, in which an air flow creates both a frictional force on disc surfaces and thrust force on blade-shape washers between discs, was proposed in this study. Three turbine models were tested to understand the effect of disc material and direction of air flow. Using aluminium discs instead of steel discs had a minor increase in predicted maximum power. Changing the direction of the air flow from the outlet at central holes to outlet tangential to casing, caused a significant effect on predicted power. However, a comparison of current design to classic designs in Literature demonstrated that the proposed hybrid turbine design create much less power than of the turbine designs in literature.

Table 1. Comparison of features of proposed hybrid turbine with the literature.

Reference	Disc Diameter (mm)	No. of Discs	Disc Spacing (mm)	Operating Pressure (bar)	Max Speed (rpm)	Max Torque (N.m)	Max Power (Watt)
Tesla (1913) [2]	457	25	n/a	8.6	9000	n/a	150k
Leaman (1950) [6]	126	4	3.2	5.8	9000	0.1	87
Hoya and Guha (2009) [7]	92	8	0.2	3.6	25000	0.7	140
Romanin (2012) [8]	73	10	1.2	5.4	24170	n/a	n/a
Holland (2015) [9]	92	8	0.2	3	9100	0.21	74
This Study	100	22	1	4	2280	0.015	1.4

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