Experimental Measurement of Functional Parameters for a Tesla Turbine

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Abstract: *A small-scale experimental set-up was designed and built, consisting of a Tesla turbine and electric generator, with casing, consumer and measurement devices. Experimental measurements were carried out, regarding the working performance of the turbine at different air inlet pressures. The other parameters measured were the inlet air velocity, the rotational speed and the output electrical power. The results were discussed and explained through graphs, and conclusions were drawn.*

Keywords: *Experiment, kinetic turbine, measurements, Tesla*

1. Introduction

The Tesla turbine, also known as multi-disc turbine, was patented by Nikola Tesla in 1913 [1] and is one of many creations that arouse the researcher's interest today. Due to its constructive simplicity and the fact that it is suitable for small scale applications, the Tesla turbine tends to regain a deserved position in research projects in recent years. This recent increase in the number of studies is related to the demand for energy efficiency solutions, particularly those involving low power output levels. Results of pioneering works in the analysis of Tesla turbine pointed to the potential use of this equipment as small-scale turbines [2], [3].
This type of hydraulic machine can be used both as turbine (hydraulic motor) or pump. Its use has a high potential in the area of renewable energy [3], [4], power supply and portable power unit [5], [6], compressed gas energy storage systems [7]. The fluid dynamics of the flow inside the Tesla turbine was studied experimentally [8], [9], by numerical simulations [10], [11] or combined [12].
The turbine works on the principle that all fluids have two important properties: viscosity and adhesion [13]. More turbine rotors placed on the same shaft receive the kinetic energy of the fluid (usually steam or air) by adhesion to their solid surface. The working fluid expands and accelerates in the injector, reaching its maximum velocity at its outlet and then injecting into the disc channels formed by adjacent disks [10].

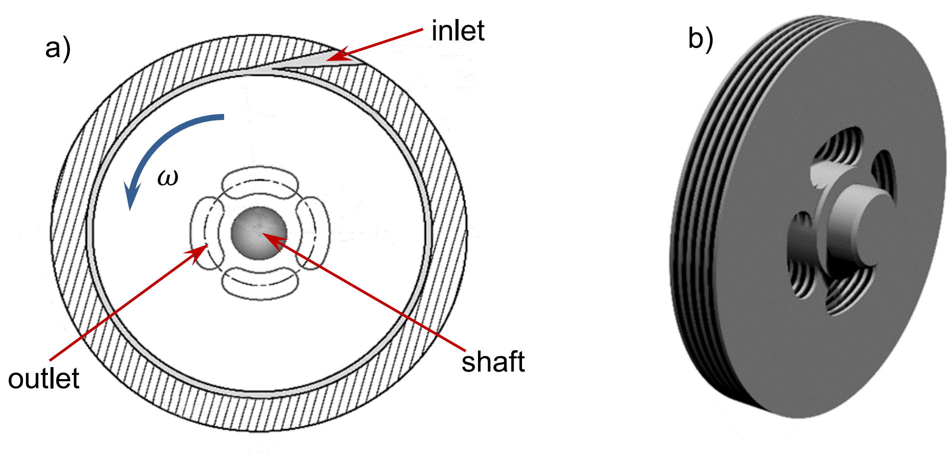

Fig. 1. Tesla turbine: schematic view (a) and 3D view of rotor (b) – adapted after [10]

Since all the energy is picked on the two sides of each rotor disk, the rotor blades are no longer needed. Thus, the overall size of the turbine is smaller. The fluid direction inside the turbine case is radial-axial: the pressurized fluid enters the turbine in tangential direction relative to the periphery of the rotor and exits axially after giving the energy to the rotor disks – figure 1.

2. Experimental facility

The experimental set-up is presented in figure 2 and was designed following the procedure described in the literature [13-16]. It consists of 9 main component parts:

1) The fluid (air) source used is a piston air compressor. The compressed air is sent from its hydraulic accumulator to the turbine injector through a flexible hose intended for compressed air;

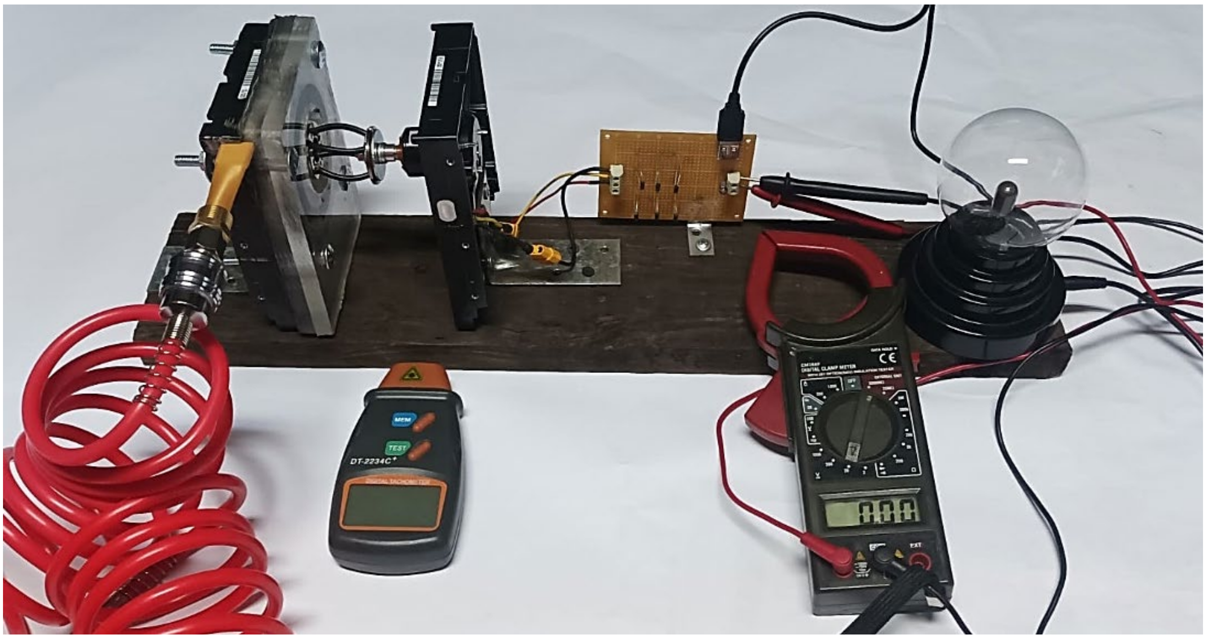

Fig. 2. View of experimental facility and measuring devices

2) The injector (nozzle) is sketched in figure 3 and was designed in the 3D software SolidWorks, following the uniform distribution of the air jet on the tangential surface of the turbine discs. It was 3D printed using PLA. Figure 3b shows also a ball valve used for controlling the air flow. The inner shape of the nozzle changes from a circular pipe (section 1) of 10 mm diameter at the inlet to a rectangular one (section 2) of 17 mm width and 2 mm height. The jet velocity at the nozzle inlet (V1) was measured with an anemometer, while the nozzle outlet velocity (V2) was computed from the continuity equation – the results are shown in table 1.

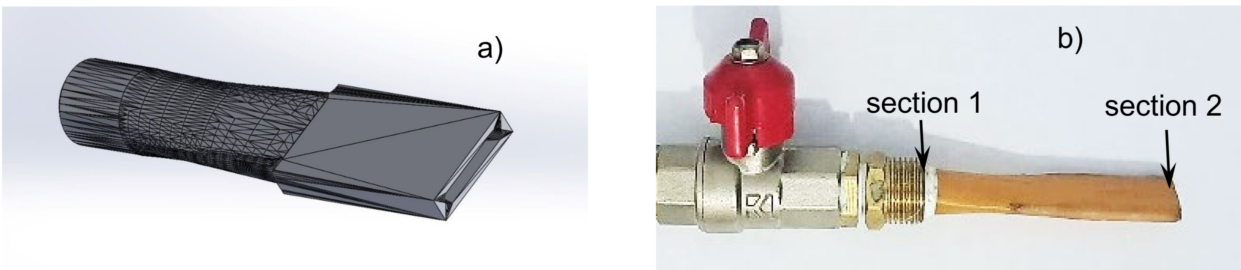

Fig. 3. Sketch (a) and view of the 3D-printed (b) jet nozzle

3) The turbine has 3 main components (figure 4):

- the turbine case, made out of plexiglass, which has been machined to meet the dimensional requirements; the case is closed using a hard-disk casing, which has a round and mostly uniformly machined enclosure. The inside diameter of the casing is 97 mm;
- the turbine discs, machined from 9 hard-disk platters with a diameter of 96 mm, they have low roughness and high tolerance machining/finishing due to the purpose of the previous service. This makes their preparation easier. Six holes were drilled, equidistant 8 mm in diameter, on a revolving trajectory around and close to the turbine shaft. These serve as outlets for the fluid. The discs are distanced with 0,5 mm spacers, a value resulting from the literature [2], finding 250 microns as the optimum value for the air adhesion layer at the turbine dimensions. Wanting the adhesion layers to bond we used double the distance as the value of the spacers between the discs.
- the shaft, which consists in the actual spindle of a hard-disk, together with its bearing. The length of the spindle is 9 mm, the length required for all the discs is 17 mm. Consequently, a copper tube was machined to the dimensions of the base spindle. It has a diameter of 25 mm and an additional length of 8 mm.

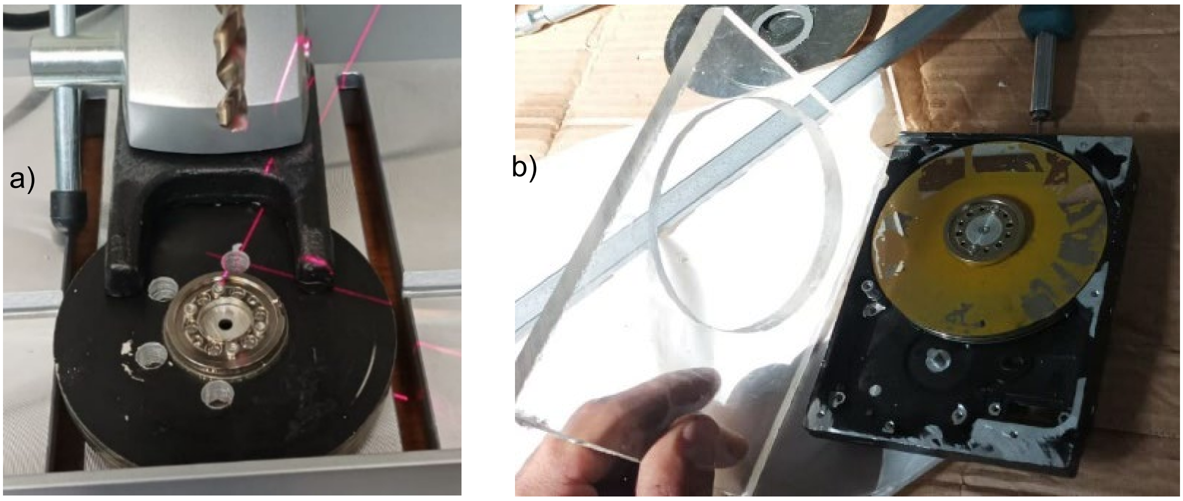

Fig. 4. Manufacturing the Tesla turbine for the experiments: turbine rotor (a) and case (b)

4) An elastic coupling (figure 5, a) is used between the turbine and the generator shaft, because of the lack of possibility of perfect centering. The high operating speeds and lack of alignment could have caused large and irreversible damage to the generator and/or turbine. It consists of 2 clamping plates made up of 2 smaller plates that ensure the fixing and tightening of 2 O-rings, the black and flexible elements in the coupling.

5) As a generator a model aircraft engine is used (figure 5, b), which can reach speeds of up to 30000 rpm. It is a brushless motor with a stator wound in a 12-ring delta configuration and a rotor with 14 neodymium permanent magnets.

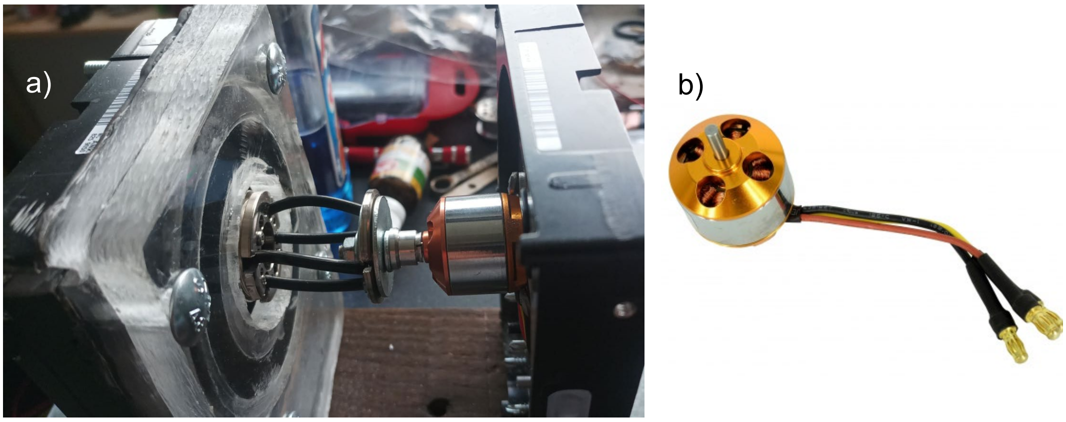

Fig. 5. The elastic coupling between turbine and generator shaft (a); the generator used for turning the mechanical power to electricity (b)

6) A digital tachometer (figure 6, a) was used to record the rotational speeds measured on the generator rotor.

7) A diode rectifier bridge was assembled and used to transform the three-phase alternating current produced by the generator into single-phase direct current required by the consumer. It also features a capacitor for voltage stabilization.

8) A digital wattmeter (figure 6, b) provides real-time power values during the experiment.

9) The consumer used is an electrostatic lamp (figure 6, c).

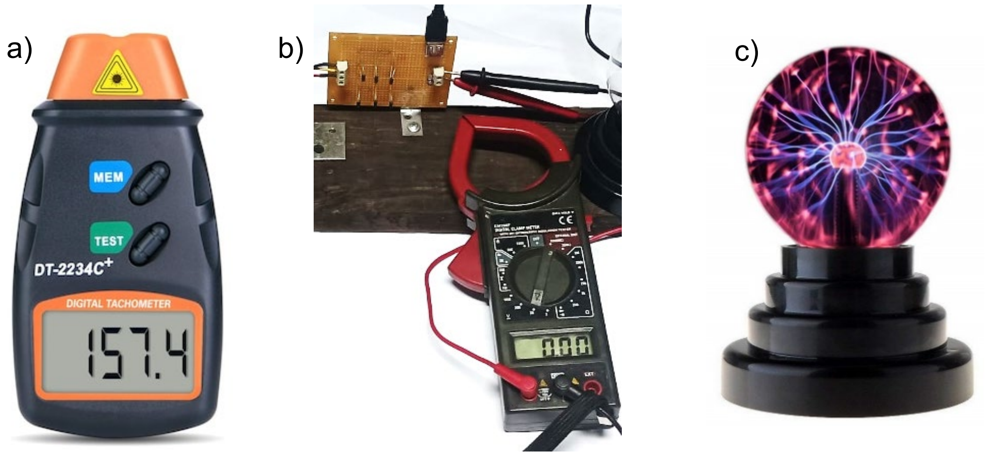

Fig. 6. The digital tachometer (a), wattmeter (b) and electrostatic lamp used as consumer (c)

3. Experimental measurements

The experimental procedure was the following: first the compressor cylinder was charged, the measuring devices were switched on, the nozzle was connected to the turbine and the circuit to the consumer was closed. By opening the spherical valve attached to the nozzle, the turbine was fed, which transformed the air flow introduced tangentially to the discs into rotary motion, engaging the highspeed brushless motor used as a generator. The three-phase alternating current, generated by the 12 triangle windings with 14 permanent magnets of the motor, was passed through the diode rectifier bridge and transformed into single-phase direct current, which fed the consumer in the system. The voltmeter gives instantaneous values of the voltage produced, and the motor speed is recorded by the digital laser tachometer on the rotor surface of the generator.
During the experiments constant values of pressure were set from the compressor, and the different parameters were recorded, as shown in table 1.

Table 1: Results of the measured and computed parameters

Nr.	p_1 (bar)	V_1 (m/s)	V_{2calc} (m/s)	n (rot/min)	P (W)
1	2	7.2	16.73	1846	0.3
2	3	8.9	20.49	3278	0.98
3	4	10.2	23.66	6843	1.8
4	5	11.5	26.45	8739	3.22
5	6	12.5	28.98	10886	4.95
6	7	13.6	31.30	13479	6.82
7	8	14.5	33.46	15834	8.85
8	9	15.4	35.49	16628	10.98
9	10	16.2	37.41	17434	12.2
10	11	17.0	39.24	17812	13.23
11	12	17.7	40.98	18187	13.44

The experimental results were transposed into graphs (figures 7 and 8) showing the dependence of different parameters: the increase of nozzle outlet velocity with the inlet pressure; the rotational speed of the turbine with respect to the inlet pressure, and the electric power produced, with respect to the rotational speed. It can be seen that the rotational speed tends to reach a maximum and will not increase much if the inlet pressure goes over 10 bar. On the other hand, the electric power tends to increase exponentially for rotational speeds over 15000 rot/min.

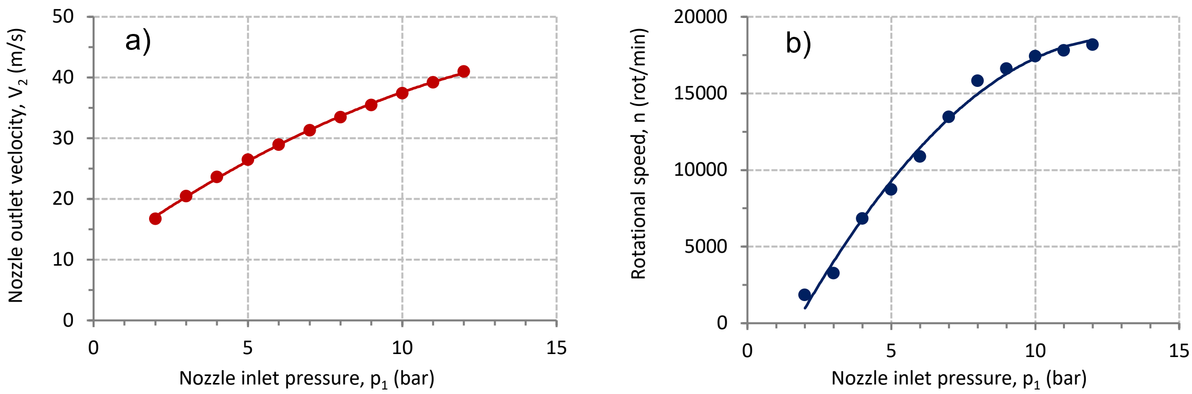

Fig. 7. Graphs with measurement results: nozzle velocity function of pressure (a) and turbine rotational speed function of pressure (b)

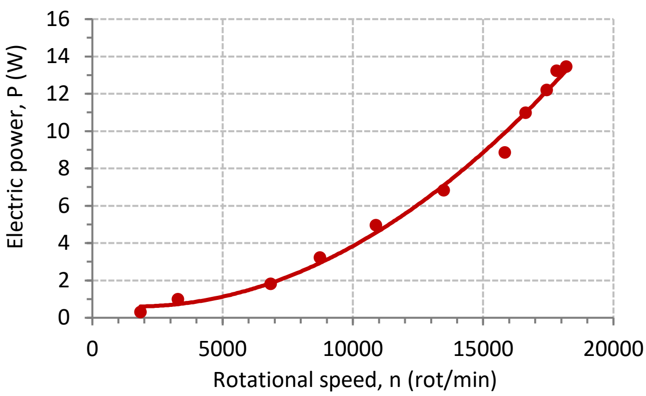

Fig. 1. Electric power produced by the turbine, function of rotational speed

The experimental measurements within the current study, corroborated with other results on the same topic from the literature, show that Tesla turbines of small and medium sizes can prove their usefulness in applications related to green energy storage. A proposed storage energy scheme is depicted in figure 9. It consists in a compressor that uses the excess energy from renewable sources such as solar or wind, a hydraulic accumulator to store the energy and a Tesla kinetic turbine with electric generator that converts the hydraulic energy to electricity, when required.

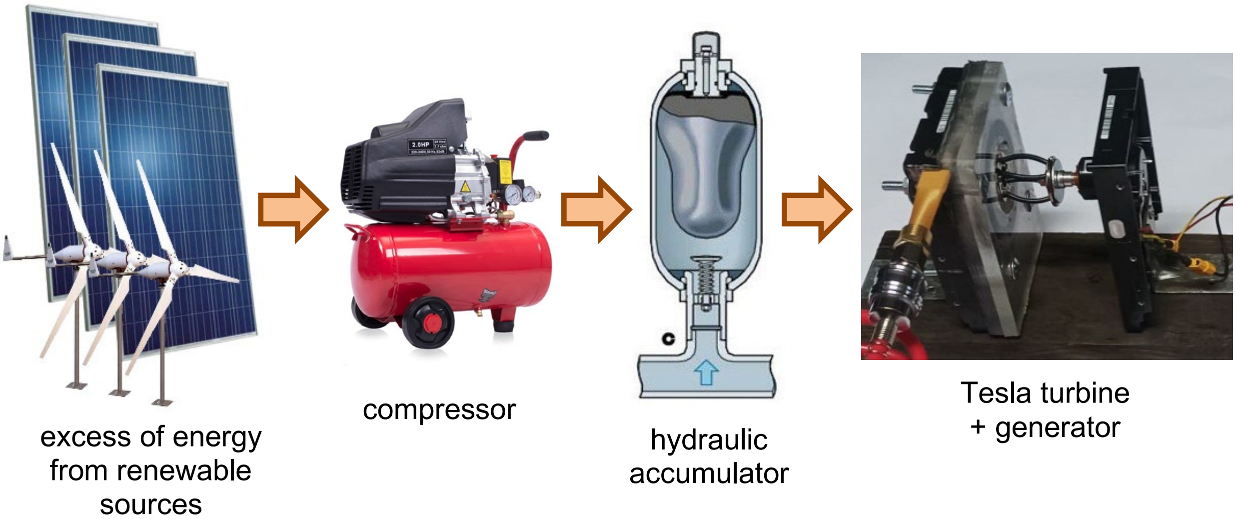

Fig. 2. Renewable energy storage scheme using a Tesla turbine

4. Conclusions

Within the current research, a small-scale experimental set-up was designed and built, consisting of a Tesla turbine and electric generator, with casing, consumer and measurement devices. Experiments were then carried out and relevant mechanical and electrical parameters were measured and computed. The results were presented and discussed.
The simplicity of construction and use of Tesla turbines, shown by their lightweight construction, for example from recyclable materials, recommends them for a variety of applications.
A disadvantage is that for high efficiencies, the rotational speed should be high (in the range of 10000…30000 rot/min), that can bring deformations of the discs, bearings, shaft. But the current study showed that, thanks to modern technology and materials, such a device can be realized and used with higher potential, especially in local micro-applications. The authors conclude that this unconventional type of turbine deserves much more study and research.
Such an energy conversion device has environmental potential in self-sustainability applications for homes and other micro-industrial and niche applications. A renewable energy storage scheme using this sort of bladeless turbine was proposed.

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