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Dinamo em turbina de tesla, à base de materiais recicláveis, para geração descentralizada de energia e recarga de baterias

Dynamo in tesla turbine, based on recyclable materials, for decentralized energy generation and recharge batteries

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Resumo: Atualmente a busca por novas formas de geração de energia é um dos grandes desafios da humanidade. A produção descentralizada de energia bem como a reciclagem de materiais, a fim de obter ganhos ambientais de baixo custo, são pontos de extrema importância, pois são questões que devem ser avaliadas paralelamente ao desenvolvimento sustentável, sendo extremamente discutidas e divulgadas pela sua relevância e importância, pois o foco central certamente corresponde a preservação ambiental do planeta. Diante desse tema, no presente trabalho foi construído um protótipo utilizando turbina Tesla e um dínamo acoplado, visando o modelo descentralizado de geração de energia, para recarga de baterias de chumbo-ácido concomitante ao desafio de se chegar a um dispositivo inovador e inédito com ganhos econômicos e ambientais. O sistema desenvolvido foi feito e estruturado desde a fabricação de diversos acessórios obtidos a partir de materiais recicláveis fixados em sua estrutura, passando pelo aprimoramento do modelo físico durante sua fabricação até a realização de testes experimentais investigando sua funcionalidade. Os resultados mostram que o sistema projetado respondeu significativamente ao que foi proposto, onde o dínamo gerou corrente para o sistema, fornecendo 12 V no modelo físico, recarregando a bateria. Diante dos resultados obtidos, acredita-se que o protótipo tenha grande potencial, em uma linha e direção característica, onde com o aprimoramento da estrutura e diversificação de componentes seja possível tornar-se uma nova proposta, ou seja, um dispositivo inovador que atende às expectativas a um preço acessível, sendo um modelo descentralizado de geração de energia e ecologicamente correto.
Palavras-chave: energia descentralizada, protótipo, desenvolvimento sustentável, baterias chumbo-ácido.

Abstract: *Nowadays the search for new forms of energy generation is one of the great challenges of humanity. Decentralized energy production as well as material recycling, in order to obtain low-cost environmental gains, are extremely important points, as they are issues that must be evaluated in parallel with sustainable development, being extremely discussed and disseminated for their relevance and importance, since the main focus certainly corresponds the environmental preservation of the planet. In view of this theme, in the present work, a prototype was built using Tesla turbine and a dynamo couplet, aiming at the decentralized energy generation model, for the recharge of lead-acid batteries concomitantly with the challenge of reaching an innovative and unprecedented device with economic and environmental gains. The developed system was made and structured from the manufacture of various accessories obtained from recyclable materials attached to its structure, through the improvement of the physical model during its manufacture until the performance of experimental tests investigating its functionality. The results show that the projected system responded significantly to what was proposed, where the dynamo generated current for the system, providing 12 V in the physical model, recharging the*

battery. In view of the results obtained, it is believed that the prototype has great potential, in a characteristic line and direction, where with the improvement of the structure and diversification of components it is possible to become a new proposal, that is, an innovative device that meets expectations at an affordable price, being a decentralized model of energy generation and environmentally friendly.
Keywords: decentralized energy, prototype, sustainable development, lead-acid batteries.

1. Introduction

Macroeconomic development is an important indicator of a nation, being dependent on economic resources and energy infrastructure. Energy, in addition to being a sign of development, is today a cause for concern since most of the sources used for its generation are not renewable. It is becoming increasingly clear that the lack of studies and planning on their uses, in a sustainable manner, ecologically correct and using alternative sources, brings the imminence of an energy blackout.

The development of renewable energy sources is necessary, given the increasing increase in global energy consumption. The crucial point is the search for investments, especially in countries with great potential in energy production and which are still in the group called underdeveloped, as is the case in Brazil. Underdeveloped countries seek to boost economic growth and compete with other countries. To this end, all options for economic growth include increasing energy consumption as cheaply as possible, however, in most cases more polluting.

Energy consumption in industrialized countries is projected to increase by only 1% per year in the coming decades, while in developing countries it will be approximately 3% per year. If such projections become reality, developing countries will be consuming more energy than industrialized countries by 2025 (Hinrichs et al., 2015).

Today the global concern is to encourage the creation of new efficient forms of energy generation that seek to prevent or reduce the occurrence of environmental degradation factors in an ecologically sustainable and economically viable way (Portal Energia, 2012). In the specific case of the electricity sector, a new concept of electric power generation has been highlighted, the so-called decentralized production, which has been gaining prominence and strength in the world and in Brazil, being the target of great interest and studies, in order to try to answer energy needs, since this type of technology is associated with a reduced cost and a high benefit (Delgado, 2014).

Decentralized energy production, known as the "Third Industrial Revolution", constitutes in the fact that each individual can assume the role of inventor of energy microgeneration, that is, it is the energy that is being produced close to where it will be used. This type of production is receiving more attention in the planning and implementation of energy systems, as it produces cleaner energy from renewable resources and is able to avoid significant energy losses during the transfer. Other advantages of decentralization include: reduction of transmission losses, reduction of carbon emissions, security of remote plants, more competitive prices, low environmental impact and faster service to consumers (Gaspar, 2015; Ramos, 2015; Wen et al., 2019 and Yue et al., 2019).

Decentralized energy is suitable both for stand-alone and grid-tied applications. When operated in stand-alone, they could provide electricity for non-grid connected homes (Akinyele, et al., 2014). Technological advances have shown that it is possible to produce energy on a small scale, usually from 1 to 10 thousand kW, using renewable sources, such as solar, hydraulic, wind and biomass (Ramos, 2015 and Wen et al., 2019). In the decentralized production category, the use of Tesla turbines (Cairns, 2003; Couras, 2009; Batista, 2009; Ho-Yan, 2011; Reis, 2011; Bonzanini, 2012; Freitas, 2017; Harris, 2019 and Schulza et al., 2020) powered by compressed air, capable of generating energy, stands out as a topic of great interest in the scientific community.

Associated with the issue of energy generation, we have the issue of solid waste generation on the planet. The increasingly unrestrained use of materials causes an accumulation of waste where recycling is often not carried. In this context, increasing the life cycle of products constitutes a path capable of contributing to sustainable development, in a more eco-efficient way. The environmental issue linked to the solid waste generation and its disposal in the environment, has increasingly driven industries and companies to adapt to the new procedures and standards imposed by organs responsible bodies, in the search for obtaining and guaranteeing their certifications. In the case of automotive batteries such as lead-acid, for example, during the recycling process, waste (slag) is generated which, if randomly discarded into the environment, cause precipitation, adsorption and transport of the various elements, mainly lead, residing in a great environmental problem, since lead is one of the greatest contaminants in the environment (Fernandes, 2011). Increasing the life cycle of this product, that is, with its reuse after recharging, extending its usage time, are certainly procedures that contribute to reducing the environmental impact. Innovative approaches are needed to address the needs of the 1.3 billion people lacking electricity, while simultaneously transitioning to a decentralized energy system (Peter et al., 2015; Wadim, 2019). With particular focus on the energy needs of the underserved, in the present work a prototype was built using a Tesla turbine with recyclable materials, having a bicycle dynamo in its structure, which is its great differential. Operating parameters and structural characteristics for greater performance were evaluated, in the search for a device low-cost, capable of recharging lead-acid batteries through energy generation in a decentralized manner, as well as being able of increase the useful life of products, as in the case of recharging batteries, aiming at environmental preservation and sustainable development.

2. Methodology

2.1 Materials used to build Tesla turbine prototype

To obtain the prototype designed for the tesla turbine and to ensure the study focused on possible decentralized power generation, the materials described in Table 1 below were used.

Table 1. List of materials used.

Acrylic plates measuring 250 mm x 250 mm and 15 mm thick.
Bearings SKF 6301-2ZC3.
Nylon tube 80 mm long, 180 mm outside diameter and 90 mm inside diameter.
Stainless steel discs 95 mm outside diameter, 25 mm center hole and 1.5 mm thick.
225 mm x 180 mm x 0.8 mm thick stainless steel plate for making 20 spacers with 44 mm outside diameter and 25 mm center hole.
44 mm diameter solid shaft with 200 mm length.
Threaded bar 5/8 ’’ for 1 m in length.
BL Lamp 12V, 6W.
Compressed air compressor to generate the necessary fluid to guarantee the operation of the turbine.
12 V dynamo.
Lead-acid battery, responsible for providing the 12 V load.
Charge inverter, which turned 12 V into 220 V, providing 2000 W for consumption.

2.2 Programs used for making technical drawings and making graphics

For the elaboration of the technical drawings, the free program SOLID EDGE 2009 ST9 was used, belonging to the Paulista University, Campus-São José do Rio Pardo-SP. For the construction of the graphics, we used free version programs: Excel and Origin 8.1.

2.3 Measuring machinery and instruments

For making parts and system analysis, the following instruments and machines were used: (a) lathe: for making parts was used a model Romi P400 II belonging to DBL Industrial Machining, located in the city of Tambaú-SP; (b) Milling machine: for making parts of a Kondia Powermill model, belonging to DBL Industrial Machining Company, located in the city of Tambaú-SP; (c) multimeter: to collect the respective voltages, an MD-380 Instrutherm model was used, one belonging to the Mechanical Engineering Laboratory of UNIP-Rio Pardo and another multimeter belonging to Eletrocar; (d) digital tachometer: a model of the Politerm model POL-19 was used to monitor the rotations generated by the turbine at an interval of every 5 seconds, in a stipulated time of 65 seconds.

The data collection took place in an interval of 0 to 65 seconds, in order to analyze the performance of the turbine in relation to its rotation and voltage generated in the dynamo.

2.4 Dynamo support bases fabrication processes

Two support bases were tested for the dynamo, in order to alleviate the vibration in the system, thus increasing the rotation attached to the dynamo, increasing its capacity to generate tension. The following manufacturing processes were performed: i) Base 1: A flat iron 25 mm wide, 168 mm long and 3 mm thick was cut. The flat iron was bent at a distance of 63 mm from one end. Two holes with a diameter of 9 mm were made in the lower base for fixation. At a distance of 85 mm from the lower base, a hole with a diameter of 9 mm was made to fix the dynamo. To finish, the other end was rounded with a radius of 12.5 mm; ii) Base 2: 4 $^1/_2$” x 4$^1/_2$” gusset with 5 mm thickness and 40 mm length, with dimensions referring to the ends of the order of 75 mm and 100 mm; 75 mm x 85 mm plate with 5 mm thickness welded on the side.

2.5 Dynamo used in the present work

The dynamo used in the present work corresponds to one of 12 V and 6 W, Chinese model, Owlet brand, used in a bicycle old.

Figure 1. Dynamo used to generate current in the Tesla turbine.

2.6 Compressors

Two compressors have been used for the tests. The technical characteristics are illustrated in the Table 2, below.

Table 2. Technical characteristics.

Parameter	Compressor I	Compressor II
MODEL	CSL20BR/200L- 2 stages Bravo Shulz	WTV 20N/350- 2 stages
pés^3/min	20	20
l/min	566	566
lbf/in^2	175	175
barg	12	12
Reservoir	183L and 4’25’’(filling time)	254L and 367L; 6’15’’ and 8’40’’, respectively (filling time)
rpm	970	750
Pulley (mm)	124	50HZ (220) and 60HZ(185)
Belt	1-A	2-A
Electric motor	5HP; 3.70kW; 50Hz; voltage 380V	5HP; 3.75kW; voltage 220V/380
Lubricant	1000mL / Ref. MS LUB SCHULZ	2000mL / Ref. WAYNOIL (Wayne)
Weight with engine	158kg	-----------------

Source: Adapted from technical catalogs.

The model CSL 20BR/200L, referenced in the work as compressor I. This model has a volume of 183 L, a pressure of 175 lbf/in² and a power of 5HP, or 3.70 KW. The other model, a WTV - 20N / 350 (compressor II), has a volume of 367L, a pressure of 175 lbf / in² and a power of 5HP, or 3.75 KW. This compressor has 2 reservoirs of the same capacity, doubling its volume to 734L. Because the compressor has 2 reservoirs, the existing flow in the compressor increases. With the increased volume released, the maximum speed achieved for the 65-second interval was 5529 rpm at 50 seconds, providing a voltage of 10.43 V.

2.7 Lead-acid battery and power inverter

Batteries, also called energy accumulators, have as their main function the accumulation of energy to be used by their consumers, being responsible for converting energy released in a chemical reaction, into electrical energy. The battery used in this work was an MBR7-BS model, generally used in motorcycles (Figure 2a). One power inverter was used in the prototype structure (Figura 2b).

Inverters are static circuits (ie, they have no moving parts) that convert DC power to AC power at the desired frequency and output voltage or current. Batteries provide low continuous voltages, making it impossible to use them to power devices that are connected to the power grid. DC/AC inverters are devices that convert low battery voltages (usually 12 V) into an alternating voltage (usually 110 or 220 V), (Silva, 2017).

(a) (b)

Figure 2. (a) MBR7-BS model battery, and (b) Power inverter.

Like all batteries, this one has a specific voltage and amperage, which are crucial in the project's working process. In Table 3 below, are the technical data for the battery used.

Table 3. Technical data for battery model MBR7-BS.

Product details	
Brand	Pioneiro
Model	Mbr 7-bs
Voltage	12 V
Amperage	7ah
Battery Type	sealed
Application	motorcycles
Size (w x w x h)	114 v 71 x 131 mm
Model reference	8003
Supplier warranty	6 months
Approximate net weight of product	2.5 kg

Source: Adapted from technical catalogs.

It is important to note that the battery's power supply capacity is quite limited. For example, if a battery supplies a maximum current of 10 amps (A) with 12 volts (V), its maximum power will be 120 watts (W), that is, if 12 V of the battery is converted to 120 V, the current theoretical maximum will be 1 A and no device greater than 120 W can be powered, taking into account that 100% of the energy can be converted, which does not occur in practice.

2.8 Experimental procedure for monitoring lead-acid battery recharge

In order to monitor the recharge of the battery, four tests were carried out, lasting 120 seconds each, where the instant the release of the fluid output, that is, the compressed air responsible for ensuring the operation of the turbine, was turned on a SKIL 9003 sander that needs 720 W to work, to the charge inverter connected to the battery, thus making it possible to evaluate the functionality of the prototype, performing the following experimental steps: a) The time for the start of release of the compressed air system was timed to make the turbine work and at the same time a 720 W sander was connected to the inverter, powered by the battery; b) The sander was turned on uninterruptedly for 120 seconds of the tests; c) For the stipulated time of 120 seconds, measurements were taken of how many volts the dynamo made available at an interval of 30 seconds; d) Before starting each test, that is, releasing the compressed air output, the voltage available in the battery was measured; e) At the end of the tests, new measurements were taken from the voltage existing in the battery. It is noteworthy that with the existence of rotation in the turbine shaft, ensuring battery recharge, the sander was kept on for a period of 120 seconds.

3. Results

3.1 Construction processes

The construction of the Tesla turbine prototype using HDD disks was performed based on illustrations described by Sbtroy (2006). All other procedures, parts dimensions and structuring of the proposed turbine, as well as the assembly as described, with the dynamo attached to the system, were developed and tested by the work team of the present project. The disks used as the turbine blades and separators were extracted from discarded hard drives from unused computers.

This equipment has as its operating principle the adherence of the working fluid to the disc wall. On the surfaces of the discs, where the fluid slides, the phenomenon of boundary layer formation becomes responsible for impelling the axis, with the tendency of the discs to assume the same fluid velocity. The flow through the discs causes momentum in the discs and therefore produces torque and power in the rotor shaft. Although the Tesla turbine is a well-known device in the academic world, it is not yet a product developed to the point of industrialization and, in fact, little is known about the phenomena that occur in the disc flow (Warren 1991; Schmidt, 2002; Sbtroy, 2006; Bonzanini, 2012; Rocha et al., 2013 and Gaspar, 2015). Aiming at greater adherence of the fluid to the surface of the discs that make up the turbine blades, it was necessary to create a radius oblong on the surface of the turbine in order to improve the efficiency of the boundary layer. Fluid flows between the separately disposed rotor discs, and when this occurs, the fluid adheres to the surface of the discs causing the rotor shaft to begin to rotate at a certain speed and may gain speed over the flow. Regarding the rotation of the rotor axis caused by the boundary layer principle, it can be stated that the higher the flow pressure the greater the generated rotation (Warren, 1991). Unlike conventional ones, the Tesla-type turbine features a rotor shaft made up of crimped parallel rotational discs. These disks placed spaced along the axis enable the system, providing excellent power-weight ratio (Schmidt, 2002; Bonzanini, 2012).

In the turbine rotor assembly, the discs were equally separated by spacers. The pieces were made in laser cutting. In Figure 4, illustrates finished stainless steel disc, after the laser machining process, where burrs were removed and polished on their surface.

(a) (b) (c)

Figure 4. (a) Front of reused HD; (b) HD disassembled and (c) Illustrates Finished stainless steel disc.

A 44 mm diameter solid shaft was used for rotor production. Firstly, this shaft went through a cutting process, leaving it in a size suitable for machining, in order to reduce the production time, having little material to be removed. Regarding the fastening of the discs to the rotor shaft, a washer was made whose function is to be threaded at the end of the shaft, securing the discs and separators by compression. The shaft and lock washer were produced using the conventional lathe. Having the shaft, the discs, the spacers and the washer already manufactured, the turbine rotor was assembled, placing the discs in the shaft through the 25 mm hole, being spaced by the spacers, which would be locked by the washer fixing. With the rotor assembly, it was possible to dimension the turbine body, in which it was made of nylon, referring to the total size of the discs and spacers deposited on the rotor shaft.

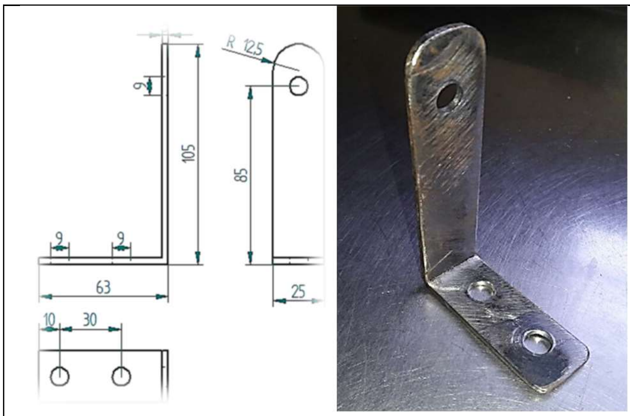
To fix the rotor shaft to the turbine body, it was necessary to plug the ends of the 98 mm bore of the body by acrylic sheets containing a bearing fixed on its surface. The machining of the acrylic sheets was performed using the conventional lathe and milling machine. With all the parts produced, the rotor was fitted into the turbine body and then the two ends of the shaft fitted into the bearings coupled to the acrylic sheets. Finally, the system was locked with the four screws produced. Figure 5 below illustrates the final assembly of the turbine frame, using all parts made to their respective dimensions.

Figure 5. Mounted turbine.

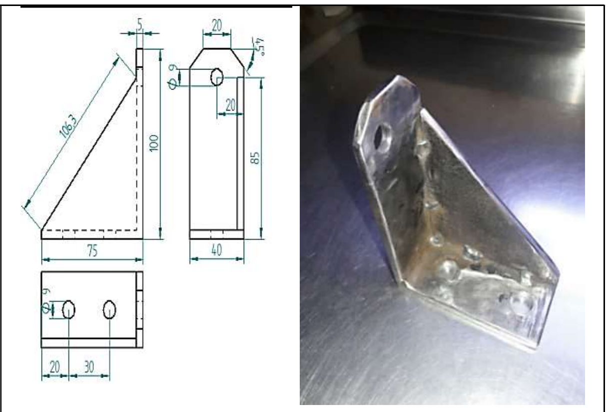
3. 2 Support base for dynamo

Two support base for the dynamo were tested in order to soften the vibration in the system, thus increasing the rotation adhered to the dynamo and, consequently, increasing its capacity to generate tension.

The base was fixed to the system by means of an M8x20 hex bolt and then the dynamo was fixed, thus ensuring that it was positioned specifically, in the position referring to the center of the turbine's output shaft. Figure 6 illustrates the final pieces, used as a dynamo support base.



(a)



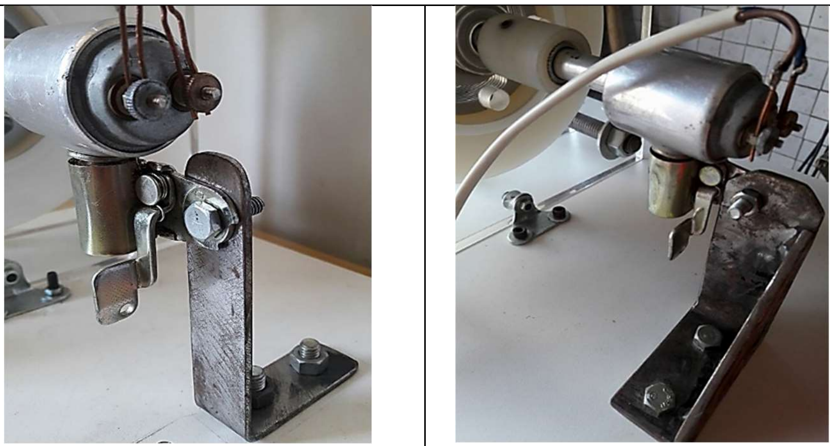
(b)

Figure 6. (a) Base 1: The technical-mechanical design and Ready support base, for the dynamo and (b) Base 2: The technical-mechanical design and Ready support base, for the dynamo.

3.3 Process of manufacturing the interconnect fitting between dynamo and turbine shaft

With the dynamo fixing base already manufactured, it was necessary to design an accessory to interconnect the dynamo to the turbine shaft. For the manufacture of this accessory the following procedures were performed: 30 mm diameter x 45 mm long nylon shaft with through hole in the center of the 12 mm diameter shaft and 40 mm long; recessed ends 18.3 mm in diameter by 13 mm deep; shaped corners with proper profile finish; 4 mm diameter hole located 13.5 mm away from the opposite end of the recess in order to obtain a 5 mm thread to ensure locking of the attachment with the turbine shaft. Having completed the interconnect fitting and the dynamo support base, it was possible to establish the connection between the dynamo and the turbine shaft.

Through the 12 mm hole in the interconnect fitting, it was coupled to the turbine shaft and fixed by means of the 5 mm thread to prevent rotation between its coupling. At this stage, the dynamo was tightly fixed to the recess in the interconnecting fitting, which ensured that there was no rotation between the fitting and the dynamo. Thus, the only rotation in the system was between the turbine shaft and the dynamo. With the dynamo attached to the turbine shaft, it was coupled to its respective mounting base by means of a M8x20 hex bolt. It is noteworthy that there was no specific design for fixing regarding the turbine and the base, because the entire procedure was dimensioned at the time of final assembly. Figure 7 below illustrates the axis and interconnection between dynamo and turbine axis, respectively each support base.



(a) (b)

Figure 7. Fixing the dynamo on its support base. (a) Base 1 and (b) Base 2.

Because the dynamo provided a pre-set voltage of 12 V, corresponding to a corresponding rotation, a battery was interconnected to the dynamo to ensure recharge and keep the available voltage constant. With this voltage present in the battery available for consumption, a charge inverter was used, which corresponds to an accessory capable of converting these available 12 V into a voltage of 220 V, to ensure the connection to the battery by means of a cable and to provide approximately 2000 W of power from the inverter. With all the connections established, the complete prototype assembly was completed, where through the use of compressed air it is possible to guarantee the operation of the designed tesla turbine, adhering work to its output shaft, which was connected to the dynamo, which through this connection was responsible for providing the voltage of 12 V.

3.4 Comparison of data referring to rotations, for the different compressors and support bases

Figure 8a and Figure 8b shows a comparison between bases 1 and 2. Figure 8c shows a comparison between compressors I and II referring to the rotations achieved, using the support base 2 of the dynamo.

It is possible to observe in Figure 8a, that in both assemblies and, using the compressor I, the system rotation reached a peak around 30 s, resulting in a rotation of 3608 rpm, referring to the first dynamo support base, while it stops the second was of the order of 3720 rpm, for the same time interval. Note that after 30 s, rotation decreases with time, to a value of 1343 rpm, using the assembly, referring to the first support base, while for the second, it was around 1825 rpm. Thus, for both dynamo support bases, and using compressor I, the system responded in an equivalent way, presenting a rotation peak in 30 s and a decrease in it, after the interval of 65 s. In Figure 8b, it is possible to observe that in both support bases, there is a tendency for rotation stabilization, after 30 s of operation. However, with the use of the second support base, the system rotation reached the value of 6571 rpm at 65 s, while with the use of the first support base, the value was 5442 rpm in the same interval.

These results show that the second dynamo support base, which was made to reduce the high vibration of the system (observed with the use of the first support base), contributed to a significant increase in the rotation adhered to the dynamo and, successively increasing its capacity in generating voltage, with an increase in the order of 1149 rpm. It is noteworthy that this result shows that the system reached 12 V at 65 seconds, with no drops in production until this period, so the power generation capacity using the second support base, is in fact more productive compared to the first.

Analyzing the data in Figure 8c, which shows the rotation generated in the turbine for both compressors and, using the second support base, it is observed that for compressor I, the maximum rotation reached was 3720 rpm. This value corresponded to 4 rpm to more than for the first base (data not shown). In addition, there was an increase in the rotation present in the turbine up to 30 seconds and after this period there was a drop in the generated rotation, ending with a rotation of 1825 rpm, that is, it ended with 482 rpm more, when compared with the data obtained in the first base (data not shown).

For compressor II, it is observed that for the period from 0 to 65 seconds, the maximum rotation reached was 6571 rpm, presenting an increase of 1042 rpm, when compared to the maximum rotation reached in the first base. It can be said that there was a significant increase in the rotation generated without any peak moment and at the end of 65 seconds the rotation present in the turbine was 6571 rpm, with an increase of about 1129 rpm in relation to the final rotation at 65 seconds, observed for first base of support. According to the data obtained, there was a significant increase in the rotation of the system, between 5s and 65s, going from 1308rpm to 6571rpm, respectively, generate a load of 12 V. For the evaluation of the system's performance in relation to the rotation as a function of time, it was observed that after 40 s, the curve tends to stabilize, with a brief increase in the interval from 40s to 65s.

After several tests performed, it was found that the Base 2 model provided greater stability to the system, therefore opting to direct the construction and assembly of the prototype with this model. It was observed that after reaching the maximum rotation, it remained constant, with a small oscillation until the end of the time stipulated for the measurements.

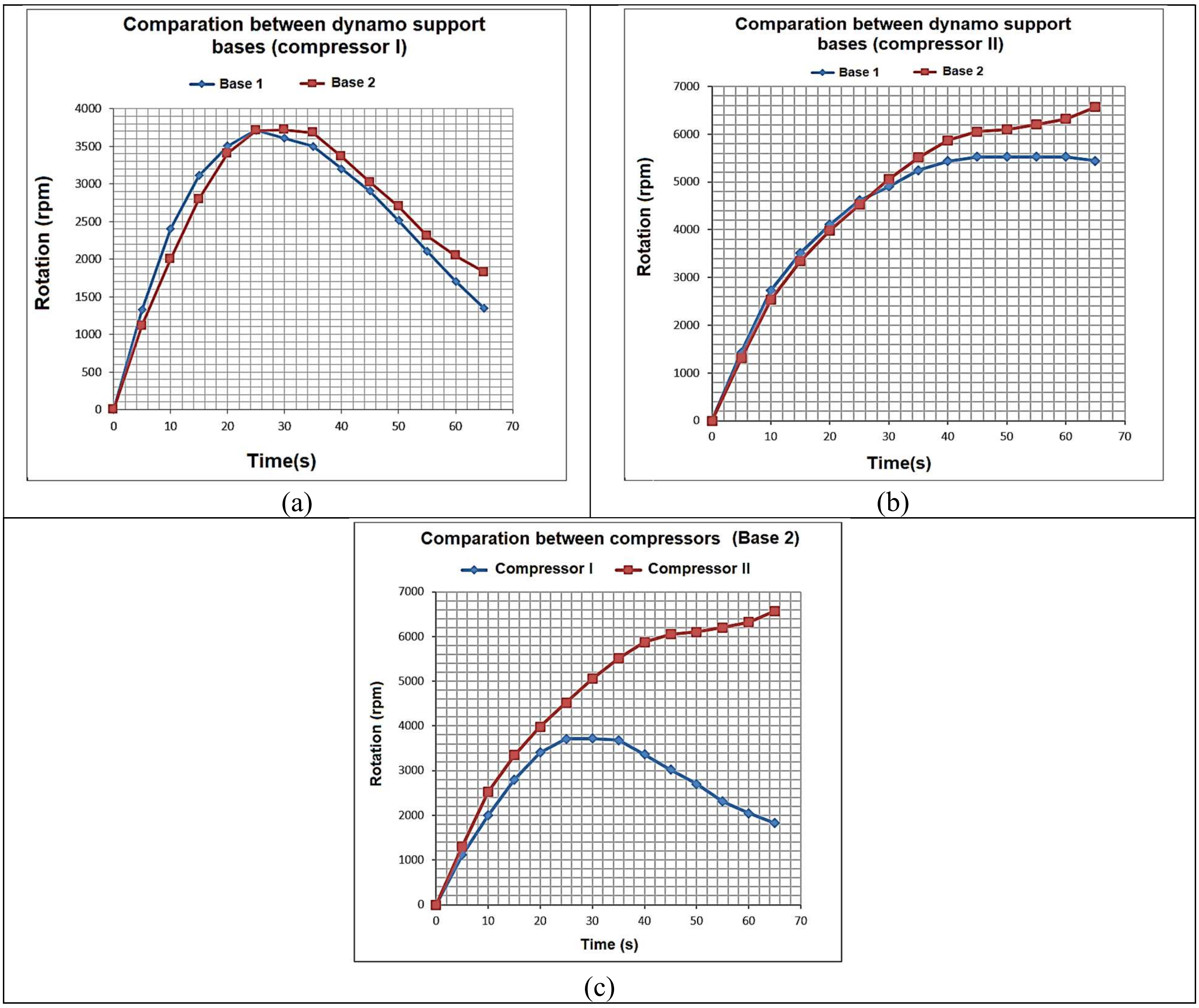


Figure 8. (a) Comparison between bases, (b) Comparison between the compressors, having as a response pattern the variation of the rotation as a function of time, obtained using the second support base of the dynamo.

Compressor II therefore presented better performance compared to compressor I and, in addition, base 2 was the most efficient of the processes. It was observed that after reaching the maximum rotation, it remained constant, with a small oscillation until the end of the time stipulated for the measurements. After several tests performed, it was found that the Base 2 model provided greater stability to the system, therefore, opting to direct the construction and assembly of the prototype with this model.

3.5 Mounted Prototype and Function Tests

Figure 9 below illustrates one of the tests performed, among the various, where it is possible to observe the peak moment in the voltage, when the system starts rotating, because it is coupled to the compressed air compressor. The operation of the lamp notes the power generated by the system, where it is observed that the dynamo generated current, converting mechanical energy into electrical energy, through electromagnetic induction.

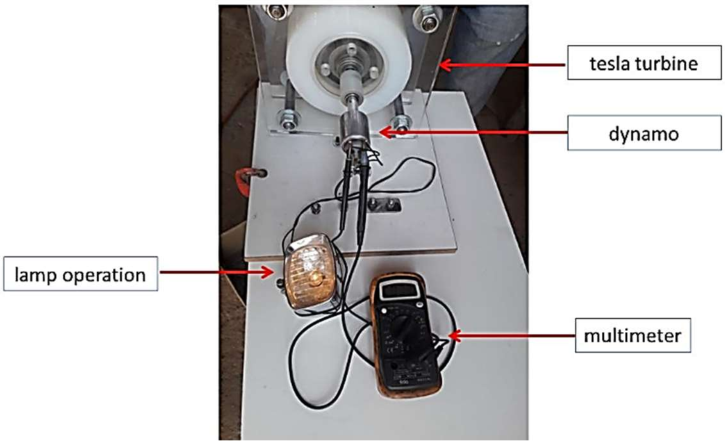


Figure 9. Verification test of the system operation using the compressor.

Figure 10 below, illustrates a comparison between voltage and rotation, obtained from the support base 2, using the compressor II. It is possible to observe that the voltage compared to the rotation presented excellent linear correlation between the variables, obtaining a correlation coefficient of the order of R = 0.9995.

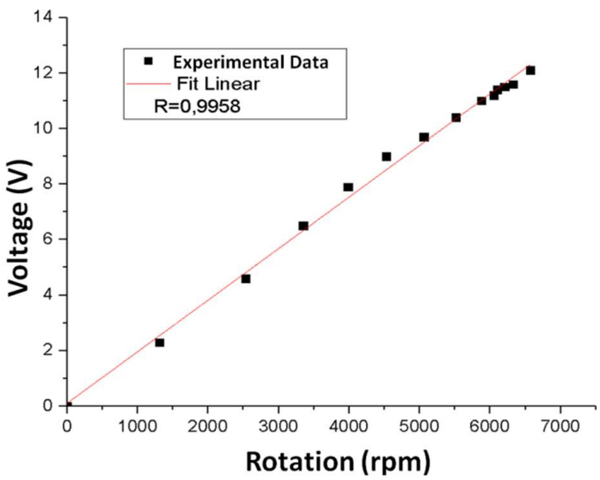


Figure 10. Comparison between voltage versus rotation, obtained using the system coupled to the compressor.

As for the variation in voltage as a function of time, a tendency towards stabilization was observed, which demonstrates that the system tends to preserve the 12V load. Thus, it can be seen that there was a significant increase in energy production without occurring an immediate drop.

3.6 Lead-acid battery charge assessment and monitoring

The dynamo provides a pre-set voltage of 12 V, referring to a corresponding rotation. For the tests on the lead-acid battery, this was connected to the dynamo, in order to ensure its recharge, as well as to maintain constant voltage available. With this voltage present in the battery available for consumption, a charge inverter was used, which corresponds to an accessory capable of converting these 12 V available into a voltage of 220 V, ensuring the connection to the battery, through a cable, to provide a power of approximately 2,000 W, which is supplied by the inverter.

Figure 11 below illustrates the finished prototype, already with coupling between turbine and dynamo, dynamo and battery, and the battery to the inverter, using the second dynamo support base.

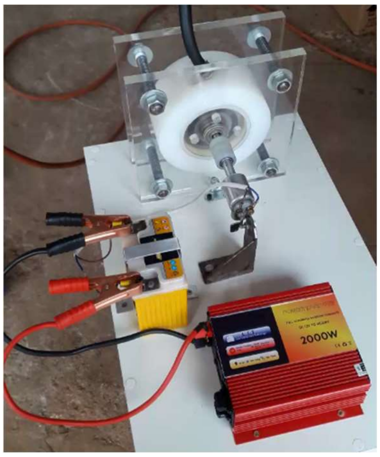


Figure 11. Completed battery coupled prototype.

Table 5 below illustrates the results obtained for the lead-acid battery recharge test, using the tesla turbine dynamo prototype, developed in the present work. According to the data presented, it can be seen that the dynamo generated the 12 V to ensure battery recharge and, as the duration of each test was 120 seconds, after 480 seconds, equivalent to 8 minutes, there was a drop in charge of the 0.3 V battery, this being due to the fact that after the end of each test, the released compressed air output was not maintained, i.e., the battery was not receiving a charge during the interval between the completion of the execution of a test and start another one, since the Tesla turbine was not being powered by compressed air and thus the dynamo was not generating energy. For the analysis of the dynamo's recharging capacity in front of the battery, after carrying out the recharging tests, only the turbine was kept working, thus enabling the dynamo to supply charge to the battery. At this stage, the battery was at 12.3 V. We kept the system on, recharging as described above, that is, for 4 minutes. According to the results, it was possible to verify that the battery returned to a charge of 12.44 V, that is, 0.14 V was recharged. The system therefore responded satisfactorily and fulfilling the function for which it was designed, that is, charging a lead-acid battery.

Table 5. Data obtained during battery recharge monitoring test.

Time (s)	Dynamo voltage (V)			
	Test 1	Test 2	Test 3	Test 4
0	0	0	0	0
30	11.00	8.00	8.00	12.30
60	11.50	11.80	12.70	13.80
90	12.00	12.20	12.30	12.60
120	13.20	12.30	12.60	13.80
Initial battery voltage (system off)	12.90	12.50	12.44	12.41
Final battery voltage (system off)	12.50	12.44	12.41	12.30

4. Conclusion

In the present work, a prototype was developed using a Tesla turbine a dynamo, aiming to recharge a lead-acid battery, in order to minimize environmental impacts, prolonging the product's life cycle, in the expectation of decentralized production of energy generation. Were carried out the construction, assembly and verification of the prototype using recyclable materials for its manufacture, having as a differential a dynamo coupled, verifying its functionality and analyzing its performance parameters and its operating structure, using driven compressed air flow between the discs deposited on a rotor shaft. At this point the boundary layer principle is initiated by the adhesion between fluid and the disc surface, where observed the capacity and efficiency of its use aiming at decentralized energy generation and recharging a lead-acid battery; (i) It was found that the architecture of the support base for the dynamo, as well as the type of compressor used, influence the performance of the system; (ii) The voltage compared to the rotation presented excellent linear correlation between the variables; (iii) As for the variation in voltage as a function of time, a tendency towards stabilization was observed, which demonstrates that the system tends to preserve the 12V, being possible to observe that there was a significant increase in energy production; (iv)New material combinations where tested, as well as improvements to the physical model by assembling the turbine and the interconnection between the dynamo and its axis, where it was possible to ensure sustainable energy generation through the dynamo-generated current because the turbine rotation, as well as the battery recharging; (v) The prototype responded satisfactorily and significant for the purpose for which it was designed, showing itself highly promising.

Much effort and research are still needed to solve technological challenges and thus allow these potentialities to become a reality. New physical parameters will be tested in a second stage, as well as the system's energy efficiency calculations will be presented. Certainly with new evaluations and changes in the structure, it may be possible to achieve more accentuated results, in a system where the tested assembly aimed at the generation of energy in decentralized production, in order to contribute to the sustainable development and environmental preservation of the planet.

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