Performance Enhancement of Tesla Turbine Pico-Hydro System Using a Plenum-Slot Nozzle Design

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Abstract - *The growing need for sustainable and efficient energy production has led to new ways of using natural resources. This study centers on the design, creation, and testing of a Tesla turbine model that includes a plenum nozzle for generating electricity. Modern production techniques such as 3D printing, machining, and laser cutting were used to build the model, with materials like ABS (Acrylonitrile Butadiene Styrene) and 0.4 mm mild steel sheet metal, as well as parts bought from commercial suppliers. The plenum nozzle was designed to ensure even flow and greatly cut down on pressure losses, reducing them from 35% in standard designs to under 1%, which allows for more effective water movement to the turbine discs. The prototype was tested at Vishwakarma Institute of Technology in Pune under three different water flow levels while keeping the water pressure constant. The findings showed that the turbine's performance improved with higher flow rates. This research supports the creation of eco-friendly energy options by improving the characteristics of how water enters the system.*

Keywords: **3D printing, ABS, Design, Efficiency, Laser cutting, Prototype, Sheet metal, Tesla turbine, Plenum nozzle.**

1. INTODUCTION

The Tesla turbine was first imagined by Nikola Tesla in 1906. In 1911, the Allis- Chalmers Manufacturing Company built one of the largest Tesla steam turbines. This turbine had a diameter of 1.5 meters, spun at 3600 revolutions per minute, and produced 500 kilowatts of power with a mechanical efficiency of 38%. However, over time, the discs of the turbine began to warp, which made it less competitive compared to traditional inertial turbines. In recent years, there has been growing interest in small-scale power generators for use in mobile, residential, and off-grid renewable energy systems. Conventional inertial turbines, such as Kaplan, Francis, and Pelton types, experience efficiency issues when made smaller. This is because the increased surface area relative to volume makes forces like surface tension, adhesion, and cohesion more influential than inertial forces, leading to lower efficiency in smaller versions. On the other hand, Tesla turbines convert flow energy into rotation by relying on the kinematic viscosity and surface effects of the working fluid, rather than inertia. This rotational energy can then be turned into electricity using generators, which makes the Tesla turbine suitable for small-scale power production. The design of the Tesla turbine relies on the sticky and thick characteristics of the working fluid to spin the tightly packed discs. A key part of the design is keeping the gaps between the discs very small, which helps create boundary layers that enhance energy transfer from the fluid, where adhesion and viscosity play the main roles. The fluid is introduced through a plenum nozzle at the outer edge, spirals inward while making many revolutions, and exits through central exhaust holes near the axle, as shown in Figure 1. The plenum nozzle ensures that water enters the rotor evenly around its circumference, avoiding high-velocity jets and pressure losses. Unlike traditional turbines, Tesla turbines do not need obstacles or vanes to generate inertial forces for energy transfer. Instead, as the fluid moves inward, it gradually transfers its momentum to the rotating discs, causing the rotor shaft to turn. Finally, the fluid exits through holes located at the central axis of the discs, completing the process of energy conversion. This paper describes the creation of a Tesla turbine integrated with a plenum nozzle for use in pico hydropower generation. Small hydropower systems are classified according to their power output: small hydropower ranges from 2.5 MW to 25 MW, mini- hydropower is less than 2 MW, micro-hydropower is under 500 kW, and pico-hydro- power is below 10 kW. The main objective of this project is to utilize the hydraulic energy from domestic water supply systems or overhead storage tanks, which are commonly installed on the rooftops of residential and commercial buildings.

The installation of the Tesla turbine is shown in Figure 2. The turbine is integrated into a PVC pipeline that transports water from rooftop overhead tanks to residential areas for regular use. A bypass system made of PVC pipes is used to maintain a constant water supply during turbine maintenance or if there is a malfunction. In these situations, valve B is closed, and valve A is opened to redirect the water flow directly to the households. During regular operation, valve A is kept closed and valve B is left open, which lets water pass through the turbine. This arrangement helps maintain a constant flow of water while also supporting the generation of energy. The electricity produced by the turbine can be used to charge different electronic devices. This paper also provides a detailed review of previous research on the subject.

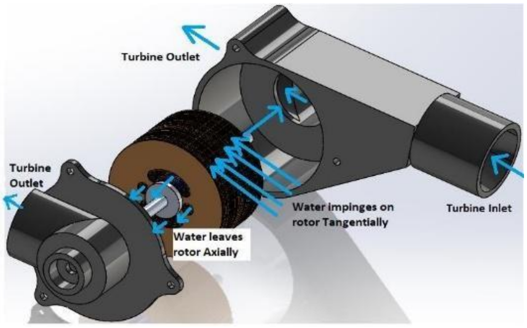

Fig-1: Inlet and outlet paths of Water in designed Tesla turbine. [1]

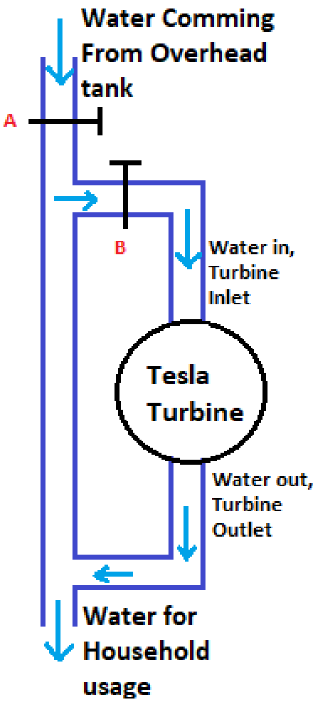

Fig-2: Bypass System. [2]

2. LITERATURE REVIEW

In this section, previously conducted research and existing literature related to mini-hydro, micro-hydro, and pico-hydropower generation systems are reviewed.

Dr. Porkumaran K and colleagues [1] have developed a micro-hydropower generation system based on LabVIEW. This system is designed to capture energy from household water supply networks. It makes use of overhead water flow and includes several key components, such as a 3D-printed micro turbine, a G 1/2 micro hydro generator, a lith- ium-ion battery, and a leakage detection system. The turbine is placed inside a 6-inch pipeline and is positioned at the best spots to work as efficiently as possible. The system also has a water level sensor that lets city officials automatically fill up storage tanks. The electricity produced is saved in batteries and can be used for different things, like lighting streetlamps and helping with home needs. Safdars I. et al. [2] did a study to check how well a pico hydro system works by looking at how the flow rate affects the turbine and generator. Their main aim was to find the best flow rate that would make the system run most efficiently. In a lab, they tested different flow rates and measured things like water flow, turbine speed, and the voltage and current from the generator. They found that as the flow rate goes up, turbine efficiency also goes up, but only until a certain point. After that, efficiency starts to drop. The turbine was most efficient at 19.7 GPM, while the generator performed best at 15.4 GPM. However, the best overall efficiency for the whole system was at 17.6 GPM, giving an efficiency of 45.5%. The researchers said that pico hydro systems can be a good way to generate electricity from small water sources, and that the efficiency of these systems depends a lot on the flow rate.

Kumano T. and their team [3] looked into using a tiny hydroelectric generator inside a building's water pipes. Their main aim was to check how well this generator works and how much electricity it can make under different conditions. They set up a system with a Pelton turbine that can normally produce 100W of power, placed inside the water pipe. They also used a device to measure water flow and another to track how much electricity is being made. Their tests showed that the generator could produce up to 102W, a bit more than its normal output. This means it works well even when the water flow and turbine speed change. The researchers found that this system can provide enough power for small offices or classrooms, and they think it could pay for itself in about five years. However, they also noted some downsides, like the system being too small for bigger setups and not considering the costs of keeping it running or fixing it when it breaks.

Márquez J. et al. [4] did a detailed study on how to model and control micro hydro power plants (MHPP). Their goal was to create a dynamic model for MHPP that can work in distributed energy systems, along with a control method to help produce power efficiently and reliably. The model combines theory with real data, looking at things like how the turbine works with water, how the generator behaves electrically, and how the control system functions. The authors suggested a three-step control method: one to keep the turbine's speed steady for consistent power output, another to adjust power based on what's needed, and a third to make sure the system stays safe. The simulation results show that all these control methods worked well to keep power production stable and efficient in different situations. However, the study has some drawbacks, like depending on simulated data, needing real-world testing, and possibly being costly to put the control methods into practice.

Mandal and their team [6] looked at how a small Tesla turbine works by using computer simulations and compared their findings with a known theory. They used special software to model the movement of air inside a tiny turbine, only a few centimeters in size. They tested the simulations at various speeds and incoming air speeds. Their results showed that how much the air slips past the blades changes in a way that matches what the theory predicted. The study found that both how well the turbine works and how much power it produces depend on how fast it spins and how fast the air comes in. They saw a maximum efficiency of 30%. The researchers also noticed that increasing the speed of the incoming air can boost the power output, but this might slightly lower how efficiently the blades spin. They suggested that these small Tesla turbines could be useful in things like tiny flying machines. However, their studies have some things to improve. They only used one design in their simulations, and they needed real experiments to confirm their computer results.

Vedavalli Gomatam Krishnan [7] wrote a dissertation that looks at making an analytical model for a small Teslaturbine, focusing on how well the rotor works and how it scales. The author made and tested several small experimental turbines with different rotor and nozzle designs to check mechanical efficiency, power density, and how well they scale. Krishnan measured the torque and speed of the turbines under different flow rates and fluid pressures and used a laser vibrometer to check the surface speed of the rotor. The results showed that small Tesla turbines can have mechanical efficiencies over 35% and power densities up to 100 watts per cubic centimeter. The research also investigated the possibility of reducing the turbine size to 1 millimeter. The study highlighted the significance of rotor design, the distance between the disks, and the input flow rate on the turbine's efficiency and power density, indicating that Tesla turbines have wide-ranging applications in fields such as microfluidics, energy harvesting, and biomedical devices.

3. OBJECTIVES

After reviewing the literature in Section 2, it was decided to use a Tesla turbine with an integrated plenum nozzle as the energy converter to transform water energy into rotational (mechanical) energy for the proposed project in this paper. Drawing from theoretical and scaling data of the cm-scale Tesla turbine from [7], the rotor design for the Tesla turbine was developed for this project. The objectives set for designing the Tesla turbine in this project are as follows:

3.1 Design and Development: To design and develop a Tesla turbine with plenum nozzle integration capable of generating electricity from the water supply system of household overhead tanks.

3.2 Optimization for Maximum Power: To optimize the plenum nozzle design and rotor to achieve maximum power generation at a given water flow rate with minimal pressure losses.

3.3 Electronics Charging: The primary goal of this project is to charge electronic devices such as mobile phones, laptops, digital watches, power banks, etc.

3.4 Bypass System Integration: To design a bypass system, as shown in Figure, to integrate the Tesla turbine into the existing water supply system without disrupting the daily water flow to households.

3.5 Manufacturing Methods: To explore new manufacturing methods to produce Tesla turbines with optimized plenum nozzles accurately and cost-effectively.

3.6 Commercialization Potential: To investigate the potential for commercializing the Tesla turbine with plenum nozzle for in-pipe Pico hydro generation. Based on these objectives, the Tesla turbine with integrated plenum nozzle design for the water supply system of household overhead tanks has been developed.

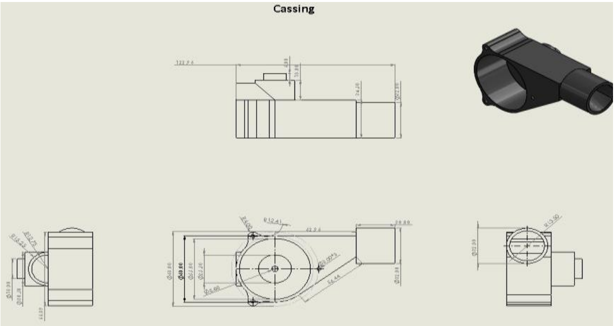

Fig-3: CAD and Drawing of Casting.

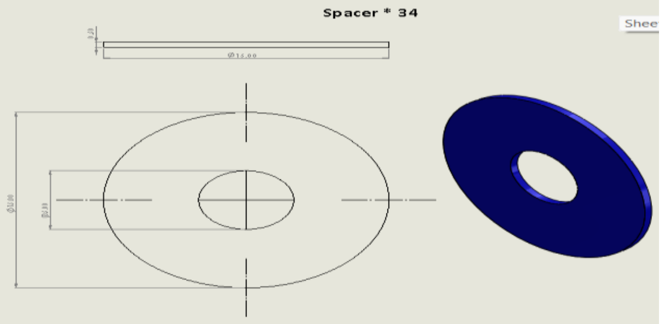

Fig-4: CAD and Drawing of Casting cover.

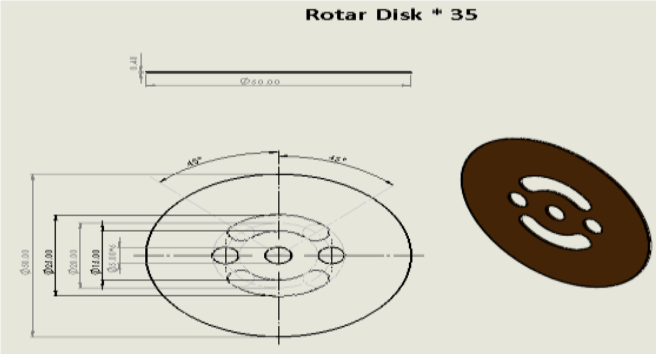

Fig-5: CAD and Drawing of Rotor discs.

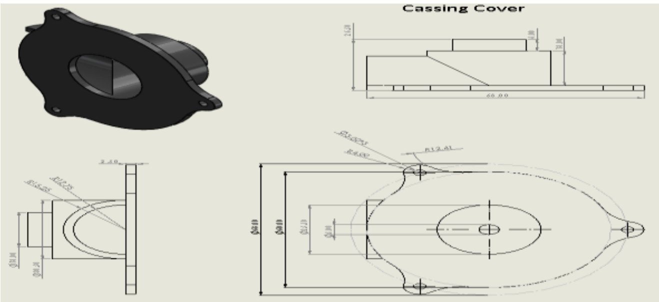

Fig-6: CAD and Drawing of Spacer.

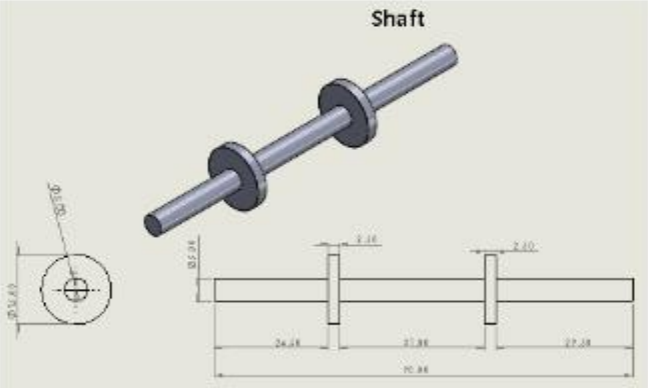

Fig-7: CAD and Drawing of Shaft.

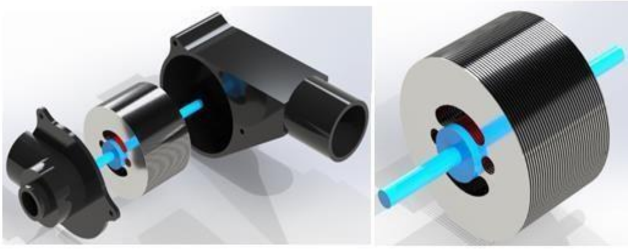

Fig-8: Exploded views of designed Tesla turbine.

Fig-9: Rendered images of designed Tesla turbine.

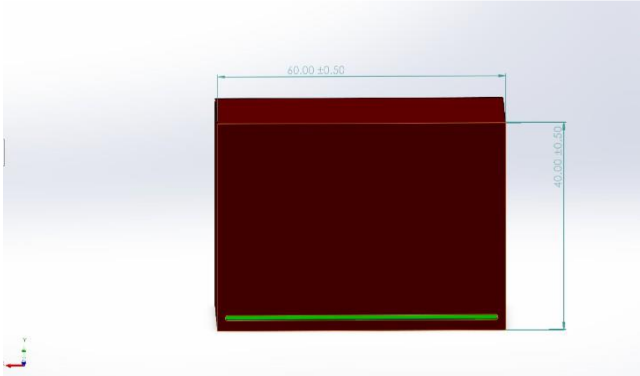

Fig-10: Plenum Nozzle Body Design.

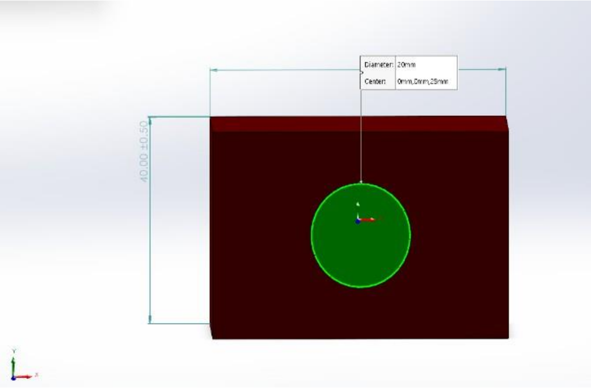

Fig-11: Plenum Nozzle Inlet.

Fig-12: Dynamo motor generator.

Fig-13: DC-DC USB voltage regulator.

Fig-14: Designed Tesla turbine Prototype.

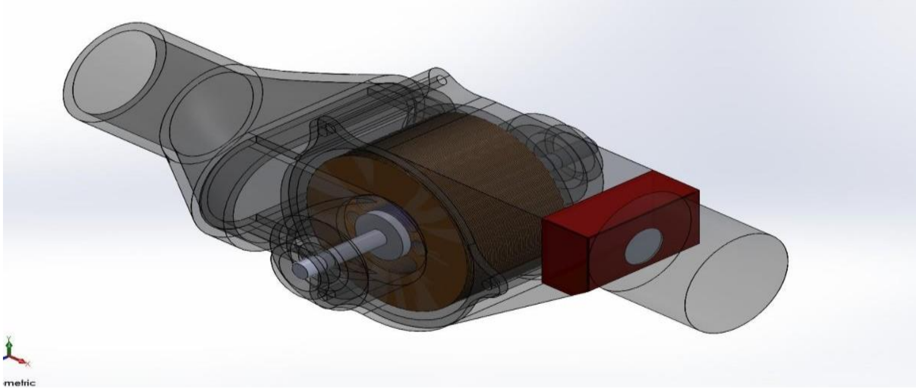

Fig-15: Design of Tesla turbine with Plenum Nozzle.

4. METHODOLGY

The methodology adopted for designing a Tesla turbine with plenum nozzle for use in household overhead tank water supply systems is outlined in detail. This process involves the design of the Tesla turbine with a plenum nozzle, identifying its parts, choosing suitable materials for each component, and creating a prototype of the turbine. Figures 3, 4, 5, 6, and 7 show the drawings and CAD models of different Tesla turbine parts, while Figure 8 provides an exploded view of the fully assembled turbine design. Moreover, Table 1 offers a detailed description of the turbine components, specifying the materials used and the manufacturing techniques applied to produce each part. The workflow is divided into five main stages:

Table-1: Components of Tesla turbine with quantity, material used and manufacturing process used to fabricate.

Sr. No.	Component	Material	Manufacturing Process
1	Housing Assembly	ABS	Additive Manufacturing
2	Housing Cap	ABS	Additive Manufacturing
3	Rotor Discs	0.4 mm MS Sheet	Laser Machining
4	Spacing Elements	0.5 mm MS Sheet	Laser Machining
5	Central Shaft	Steel	Conventional Machining
6	Rotary Bearings	N/A	Commercial Procurement
7	Dynamo Generator	N/A	Commercial Procurement
8	DC-DC USB Regulator	N/A	Commercial Procurement
9	Plenum Nozzle	ABS	Additive Manufacturing

4.1 Design Considerations

The design of the Tesla turbine is based on the literature review discussed in Section 2 and the research conducted by Vedavalli Gomatam Krishnan on small Tesla turbines [7], with important improvements made using plenum nozzle technology. The turbine was built to generate power greater than 5 watts. The design process started with a simple drawing, and then moved on to creating a detailed CAD model using SolidWorks software from Dassault Systems. The turbine design includes main parts like a casing with a built-in plenum nozzle chamber, a rotor disk, spacers, a shaft, and a casing cover. Figures 3 to 8 show the different parts of the Tesla turbine, including detailed drawings, CAD models, and an exploded view of how the parts fit together. Figure 9 shows realistic images of the assembled turbine and the rotor. As mentioned in the introduction, water enters the plenum chamber where it is spread evenly before being sent around the edge of the rotor. It then exits from the middle in a spiral motion. The plenum nozzle helps slow down the fast-moving water from the pipe into a slower, even flowing before it reaches the rotor. During this process, the water transfers its momentum to the rotor using sticky forces and friction. The rotor's rotational energy is then converted into electricity using a dynamo or electric motor generator. Since the output from the motor fluctuates, a 5V DC-DC USB voltage regulator is used to stabilize the voltage. Details of the electric motor and the voltage regulator are provided in the subsequent section.

4.2 Components

The Tesla turbine design consists of several essential parts, including the casing with an integrated plenum nozzle, casing cover, rotor discs, spacers, shaft, bearings, a DC motor, and a 5V DC-DC USB voltage regulator. Figures 10 and 11 show images of the DC motor and the voltage regulator, respectively. Each of these parts is important for assembling and operating the turbine, ensuring efficient energy conversion and com- patibility with the household water supply system.

4.3 Casing and Casing Cover with Plenum Nozzle: The casing and casing cover form the outer shell that holds the rotor discs, spacers on the shaft, and the shaft supported by bearings. The DC motor and 5V DC-DC USB voltage regulator are positioned as shown in Figure 13. The plenum nozzle is part of the casing and is designed to provide a uniform, laminar flow to the rotor with minimal pressure loss. The plenum chamberacts as a transition area where high-speed inlet flow is converted into a steady, slower moving flow across the entire rotor inlet. This design enhances energy transfer efficiency and improves the turbine's performance under different flow conditions.

4.4 Rotor of Tesla Turbine: The rotor is made up of a shaft, rotor discs, and spacers. The spacers are used to keep the right space between the discs. The design includes 35 rotor discs and 34 spacers in total. A rendered image of the assembled rotor is shown in Figure 9. As the main part, the rotor transfers power and energy. Its design is based on scaling data from [7]. The dimensions and CAD models of the rotor discs, spacers, and shaft are illustrated in Figures 5, 6, and 7.

4.5 Electricity Production Unit: The electricity production unit includes a dynamo motor generator, which acts as the power generator and produces an output voltage ranging from 4 to 12 volts. However, the output voltage varies depending on the speed of the motor, so a voltage regulator is necessary. A 5V DC-DC USB voltage regulator is used to maintain a stable output. The selected regulator has a USB port, allowing it to charge mobile phones, power banks, or other devices that require a specific power input.

4.6 Prototyping

Prototyping involves making an initial version or example of a product or process to test and confirm how well it works before investing a lot of time and resources into making it fully developed. This section offers a thorough, step-by-step explanation of the process used to prototype the designed Tesla turbine with a plenum nozzle. The prototyping process includes creating specifically designed parts for the Tesla turbine as well as obtaining standard components that are easily available. The various steps in this process are clearly described in order.

5. COMPONENTS FABRICATION

5.1 Outer Casing with Plenum Nozzle: The outer casing with integrated plenum chamber and nozzle consists of two parts: the casing and the casing cover, as illustrated in Figures 3 and 4, Figure 10 is a body of plenum nozzle. It all was fabricated using 3D printing technology, with ABS (Acrylonitrile Butadiene Styrene), a durable thermo- plastic polymer, chosen for its strength and resistance to water pressure. The plenum chamber design includes a circular inlet port with a larger cross-sectional area than the outlet, a chamber region for flow deceleration and uniform distribution, and multiple radial nozzle outlets that direct flow tangentially into the rotor region.

5.2 Rotor Discs: The rotor discs, the core components of the Tesla turbine, were produced using laser cutting technology. Mild steel sheet metal with a thickness of 0.4 mm was selected for its strength and ability to endure high rotational speeds. Laser cutting was selected to guarantee precision and accuracy, and Figure 16 provides an image of the laser-cut discs.

5.3 Spacers: Spacers are used to keep the rotor discs evenly spaced. The original plan was to use a 0.5 mm thick mild steel sheet because it is stiff and helps keep the dimensions exact. However, that material wasn't available. So, instead, 1 mm thick metal spacers with a 15 mm diameter were bought from the market for the prototype. In the end, the rotor prototype has 20 discs and 19 spacers, which is a small difference from the original design made in CAD.

5.4 Shaft: The shaft transfers the rotational movement of the turbine to the dynamo generator, enabling the production of electrical energy. In the prototype, the shaft was created through a machining process. It involved using a bolt with a standard diameter of 5 mm and a length of 100 mm. The head of the bolt was removed using a metal cutting grinder, and a 2 mm hole was drilled at one end to align with the generator shaft. Two nuts were employed to firmly attach the rotor discs and spacers to the shaft. This method of fabrication differs from the original design of the shaft, which is illustrated in Figure 7.

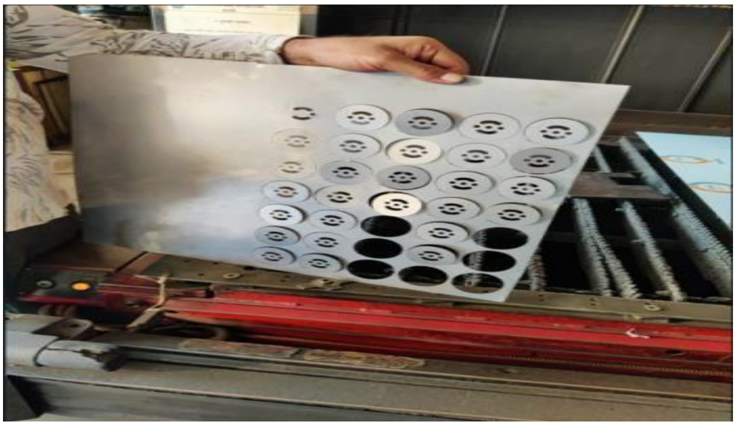

Fig-16: Lesser cutter rotor discs.

Fig-17: Designed Tesla turbine prototype testing setup.

6. COMPONENTS PROCUREMENT

6.1 Bearings: High-quality bearings were chosen and obtained from a trustworthy supplier to suit the design of the shaft and outer casing. These bearings allow the turbine shaft to rotate smoothly with very little resistance.

6.2 Dynamo Motor Generator: A dynamo motor generator capable of operating at 4 to 12 volts was purchased to transform the mechanical energy generated by the turbine into electrical energy.

6.3 DC-DC USB Voltage Regulator: A 5-volt DC-DC USB voltage regulator module was acquired to maintain a steady output despite fluctuations from the dynamo motor generator, providing a consistent 5-volt supply.

6.4 Diode: A diode sourced from the market was incorporated into the system to block back electromotive force (EMF), ensuring that the generated current flows in only one direction.

7. ASSEMBLY

The components were carefully put together following the design guidelines, with special attention given to ensuring accurate positioning of the rotor discs, spacers, and shaft. Throughout the assembly, a change was made to set up the system for testing an existing PVC connector was used to connect the turbine inlet to the water source outlet, as shown in Figure 14.

8. TESTING AND RESULTS

This section presents a testing process of designed Tesla turbines prototype with a plenum nozzle which was conducted at Vishwakarma Institute of Technology, Pune which is an engineering college. The aim of testing a designed Tesla turbine is to evaluate the performance of the Tesla turbine prototype with optimized plenum inlet flow characteristics. The testing involves measuring the turbines rotation speed in terms of RPM (Revolutions Per Minute) without load and with load, the load was given by connecting mobile phone via USB cord to DC-DC USB voltage regulator module so mobile can be charged. Along with this voltage and current readings were taken, these readings were taken for three different discharge rates: 0.2947 liters per second (LPS), 0.4545 LPS, and 0.6667 LPS.

9. EXPERIMENTATION AND EXPERIMENTAL SETUP

The fabricated Tesla turbine prototype, featuring an integrated plenum chamber, was connected into the water flow system using a PVC connector to guarantee a secure fit and efficient operation. A mobile phone served as the load, linked to the dynamo generator through a DC-DC USB voltage regulator, which helped maintain a consistent output voltage. To check the turbine's rotation speed (RPM) when it's under load and when it's not, a laser tachometer was used, giving important information to figure out how efficient the turbine is mechanically. A digital multimeter was also used to measure the voltage and current from the dynamo generator when there's no load, and these measurements were later used to calculate the turbine's overall efficiency. This configuration enabled the recording of RPM, voltage, and current values across different operating scenarios, with the collected data summarized in Table 2, offering insights into the performance of the prototype with the optimized plenum inlet flow.

Table-2: Observation Table.

Sr. No.	Time to Fill 1 Liter (sec)	Voltage (V)	Current (A)	Speed Without Load (RPM)	Speed With Load (RPM)
1	3.4	6.8	0.37	1800	1650
2	2.2	9.5	1.1	2950	2225
3	1.5	12	2	3750	2900

Table-3: Result Table

Sr. No.	Discharge (m^3/sec)	RPS Without Load	RPS With Load	Mech. Eff. Without Load (%)	Mech. Eff. With Load (%)	Overall Eff. (%)
1	0.0002942	30	27.5	15.203	11.71	8.72
2	0.0004545	49.167	37.083	43.32	18.59	23.44
3	0.0006667	62.5	48.33	60.65	28.04	36.69

10. RESULTS AND ANALYSIS

The obtained RPM, voltage and current data were analyzed to determine the turbines mechanical efficiency at without load and at with load conditions, and overall efficiency at without load condition.
Disc outer diameter
$D = 0.05$ m
D=0.05 m → radius $r = 0.025$ m

Disc gap $s \approx 0.5$ mm = 0.0005 m

10.1 Overall Efficiency:

Hydraulic power $P_{hyd} = \rho g Q H$ (1)
Electrical power $P_{elec} = V \times I$ (account for regulator losses if measured). Overall efficiency $\eta_{overall} = P_{elec}/P_{hyd}$
Overall efficiency was calculated for without load condition, and it is recorded in result Table 3.

10.2 Mechanical Efficiency:

Mechanical efficiency was calculated as the ratio of turbines rotor output power to the input hydraulic power and given as:

$$\text{Mechanical Efficiency} = \frac{Turbine\ rotor\ output\ power\ (Watts)}{Hyraullic\ input\ power\ (Watts)}$$

$$\text{Turbine rotor output power (Watts)} = 0.013 * N *(\quad) * (\text{Speed})^{2}_{\;2} \qquad (2)$$

Mechanical efficiency was calculated for without load and with load RPM values and it is recorded in result Table 3.

11. CFD SIMULATION OF PLENUM NOZZLE

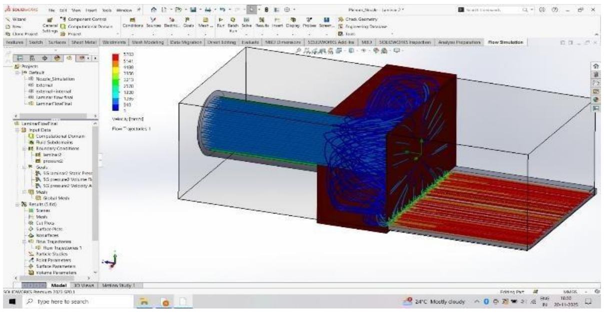

Fig-18: CFD simulation of Plenum Nozzle and Velocity Streamline flow.

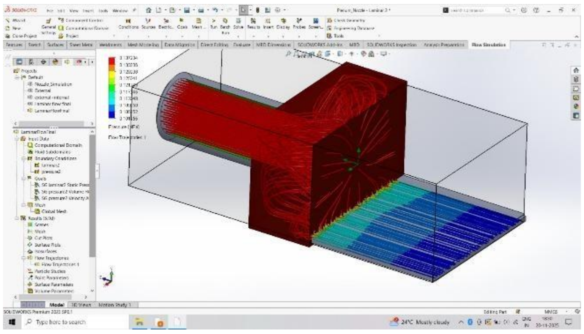

Fig-19: CFD simulation of Plenum Nozzle and Pressure Streamline flow.

11.1 Velocity Behavior in the Plenum Nozzle

In the plenum region (the large box in the center), flow enters lower velocity caused by blue streamlines. The flow recirculates and slows down inside the plenum, which is typical as the plenum's purpose is to stabilize the incoming fluid before entering- ing the nozzle. The streamlines become tangled, indicating swirling or recirculation zones.

As the flow moves toward the nozzle inlet, velocities start to increase, and streamlines get more organized, showing fluid acceleration as it is forced through a tighter space. At the nozzle exit, the flow becomes greatly accelerated and organized, as shown by the shift to yellow and red colors, which represent higher velocity levels. The stream- lines at this point are nearly parallel, showing a consistent and high-speed jet as the fluid leaves the nozzle into an area of lower pressure.

Inside the plenum chamber, the velocity is lowest, and the flow is most disordered because of the recirculation and mixing of fluid. As the fluid moves towards and through the nozzle exit region, the velocity rises sharply. Figure 18 shows the maximum velocity recorded as 5789 mm/s.

11.2 Pressure Behavior in the Plenum Nozzle

As fluid flows into the plenum from the left, it experiences the highest pressure, shown in red. This occurs because the plenum functions as a storage area for pressurized fluid. The pressure remains high and consistent across most of the plenum volume, enabling the velocity to become stable and the pressure of energy to spread out evenly. As the fluid moves toward the nozzle and speeds up, the pressure begins to drop quickly. This change is clearly indicated by the sharp shift in color from red to green and yellow. The pressure continues to decrease as the fluid exits the nozzle and enters the open space on the right side of the image, which is represented by green and blue con- tours, showing the lowest pressures in the system. The highest pressure is observed at the plenum inlet where the fluid enters. As the fluid is pushed through the narrow nozzle, the pressure decreases sharply while the velocity increases, which aligns with Bernoulli's principle. The lowest pressure is found downstream of the nozzle exit, where the fluid expands and accelerates. Figure 19 shows the maximum pressure of 0.137234 Mpa.

12. ANALYSIS

The results were analyzed by creating graphs to illustrate the performance characteristics of the designed Tesla turbine prototype with a plenum nozzle. The following graphs were produced to display the data.

a. The relationship between efficiency (including overall efficiency without load, mechanical efficiency without load, and mechanical efficiency with load) and discharge in m^3/sec, as shown in Figure 20.

b. The connection between efficiency, which includes overall efficiency without load, mechanical efficiency without load, and mechanical efficiency with load, and the rotational speed of the turbine rotor in revolutions per minute, is illustrated in Figure 21.

c. The graph showed important trends about how mechanically efficient and overall efficient the Tesla turbine prototype is, especially when the plenum nozzle was designed to work best under various conditions of discharge and turbine rotor speed. These trends gave valuable information on how the turbine operates and responds during use. From the test data and results, we can draw the following conclusions.

d. The mechanical efficiency of the Tesla turbine prototype drops a lot when a load is added, showing how much the load affects how well energy is converted.

e. Both mechanical efficiencies, whether there's a load or not, and overall efficiency without a load change noticeably when the discharge and rotor speed are adjusted, indicating that the turbine's performance is very sensitive to these factors.

f. From the graphs, it is clear that all forms of efficiency overall efficiency (without load), mechanical efficiency (without load), and mechanical efficiency (with load) show a consistent rise as the discharge rate from the water source increases and the turbine rotor speed rises. This improvement is due to the greater water flow and faster rotation, along with the even distribution of water flow achieved through the plenum nozzle, which together results in better energy conversion.

g. As the mass flow rate goes up, so does the electrical power, showing a nonlinear relationship. The system produces around 25 watts at a mass flow rate of about 0.7 kg/s, suggesting efficient momentum transfer at higher flow rates. The upward trend of the curve shows that the turbine can convert more fluid energy into electrical power as the flow rate increases.

h. As the flow rate increases, the output voltage also increases, going from about 7 volts to 12 volts when the flow goes from 0.0003 cubic meters per second to 0.0007 cubic meters per second. The curve of the graph is upward, showing that the system generates more electrical energy as the fluid speed through the turbine gets higher. This demonstrates the Tesla turbine's Sensitivity and improved efficiency with higher flow rates, which is helpful for adjusting and designing experiments.

i. Each series shows that efficiency goes up as the flow rate increases, peaking between 2.5 and 3 cubic meters per second, then starts to drop. Series3 has the best efficiency, going over 60%, while Series2 only reaches up to 40%, and Series1 remains under 20%. The bell-shaped trend shows that there's a particular flow rate that works best for the system. If the flow goes beyond that point, efficiency starts to fall because of losses.

j. The results showed that the mobile phone, acting as the load, was successfully charged at all three discharge levels, showing that the turbine can be used to power small electronic devices.

k. The plenum nozzle design removes pressure losses that usually happen with standard inlet designs, allowing the system to perform consistently under different flow conditions.

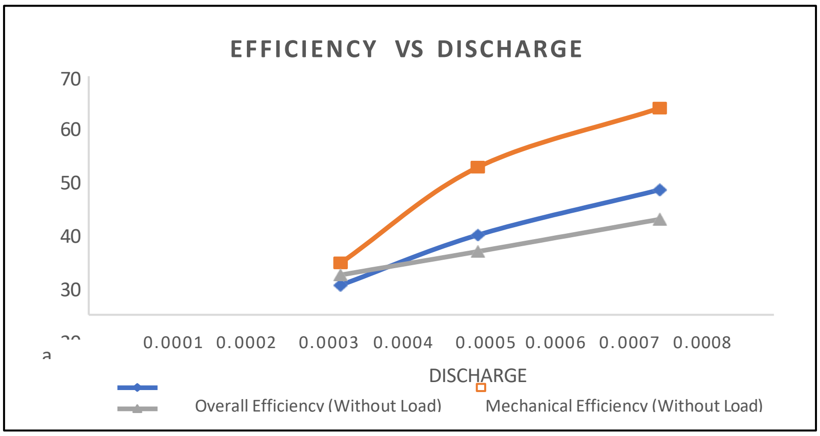

Fig-20: Efficiency (%) VS Discharge (m^3/sec).

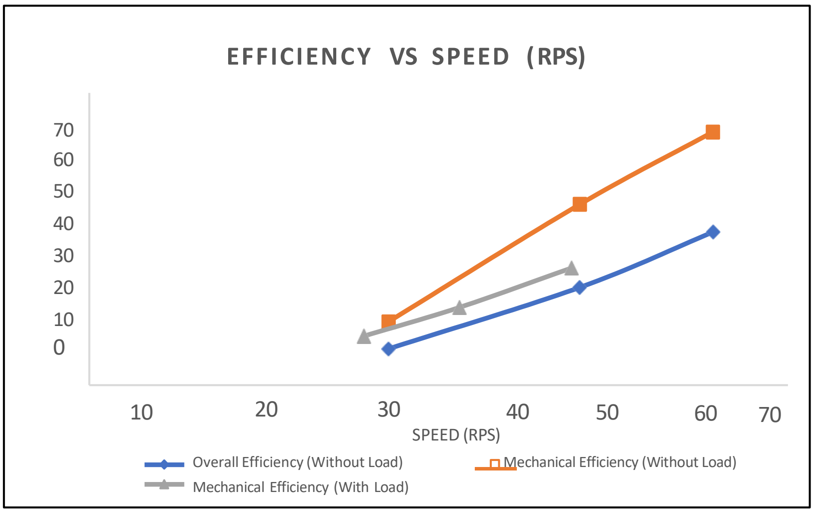

Fig-21: Efficiency (%) VS Speed (RPS)

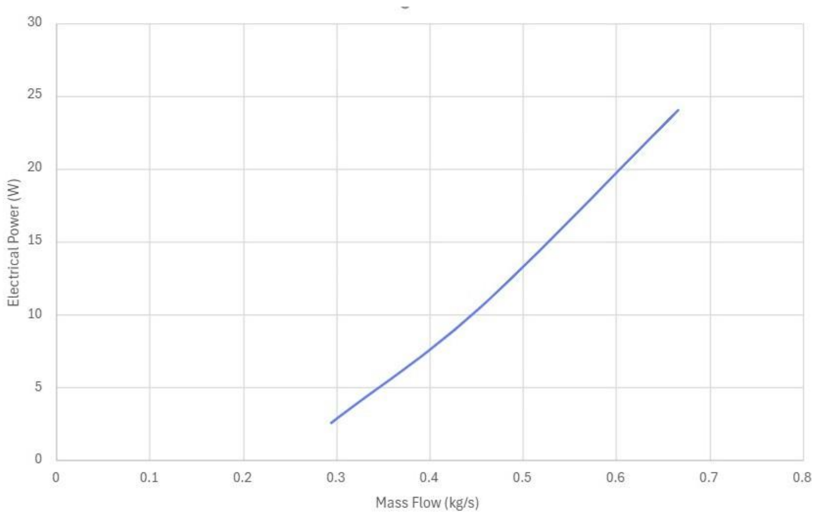

Fig-22: Electric power VS Mass Flow.

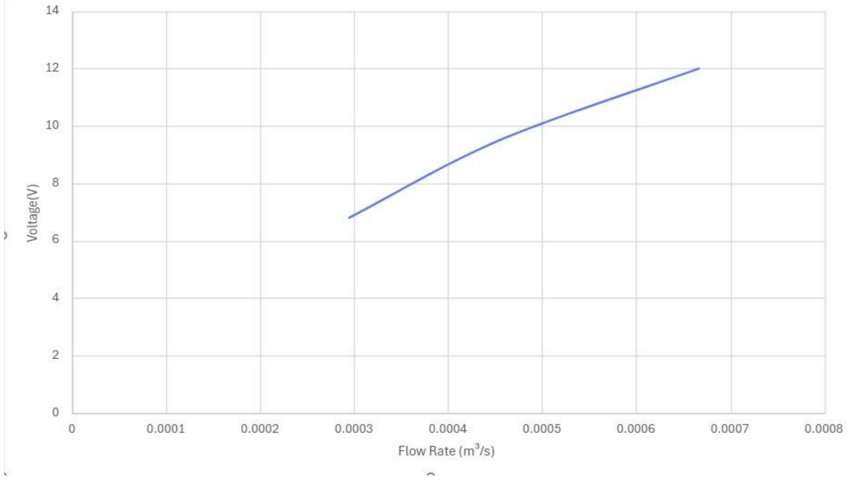

Fig-23: Voltage VS Flow Rate.

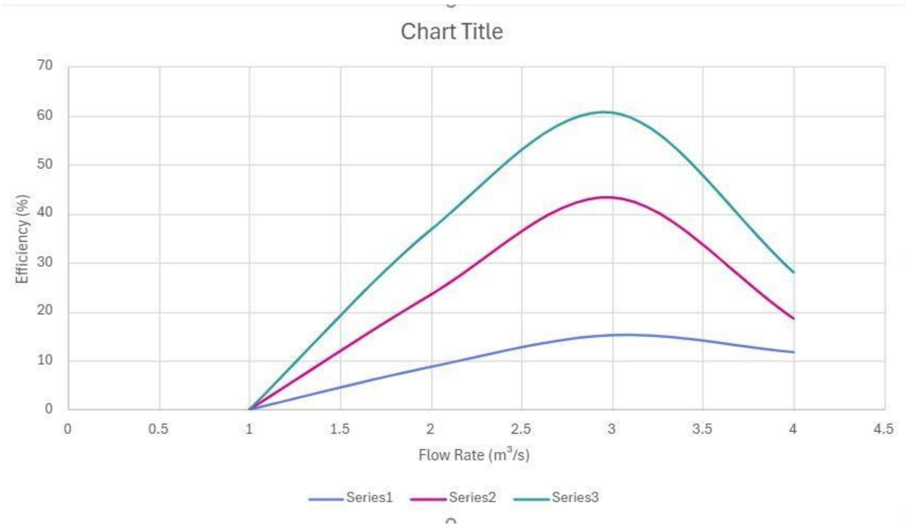

Fig-24: Efficiency VS Flow Rate.

13. CONCLUSION

The research paper introduces a project called "In-pipe energy harvesting using Tesla turbine technology with integrated plenum nozzle." The main goal of the project is to create and test a Tesla turbine that can produce electricity from the water pressure found in homes. The turbine was built to work under a water pressure of 10 meters and was tested at three different water flow rates: 0.2947 liters per second, 0.4545 liters per second, and 0.6667 liters per second. The final version of the turbine included several important parts, such as an outer casing with a built-in plenum nozzle chamber, rotor discs, spacers, a shaft, bearings, a dynamo motor generator, a DC-DC USB voltage regulator, and a modified PVC connector to attach the turbine to the water supply. The manufacturing process used various techniques, like 3D printing to make strong and accurately shaped parts with plenum nozzle designs, laser cutting for the rotor discs and spacers to ensure accuracy, and machining for the shaft and other mechanical parts. During testing, the turbine became more efficient as the water flow increased, showing that it has the potential to turn household water flow into useful electrical energy.

The plenum nozzle design worked well in reducing pressure loss and making the flow more stable. A mobile phone was used as the device to test the system, and it was able to charge successfully at all three different flow rates, proving that the design with the optimized plenum inlet is effective. While most of the project's goals were met, such as generating electricity efficiently with better inlet flow, one goal developing a bypass system to connect the turbine to existing household water systems without interrupting the water flow still needs to be worked on in future versions. Additional work will also aim to improve the turbine's efficiency by fine-tuning the plenum nozzle's design, making it work better with a wider range of water flow rates and pressure levels, and doing tests to check how long the prototype can last and how reliable it is for everyday use.

14. REFERENCES

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