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# Design and Fabrication of Omni Directional Turbine.

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**ABSTRACT**

The Archimedes Wind Turbine is a small and efficient solution for wind power that can transform as much of the wind energy into electricity. It has low noise operation, efficient operation at low wind speeds, and compact design, thus ideal for urban and domestic application. Despite all these benefits, it is constrained by limitations like high aerodynamic drag and wind-direction sensitivity, which deteriorate its performance when operating in different environmental conditions. In order to address these issues, the project deals with re-engineering the structure of the turbine and blade geometry for greater aerodynamic efficiency and omnidirectional wind capture. CFD analysis has been conducted to investigate airflow behaviour and optimize the design with minimal drag. According to these findings, the model is manufactured, followed by static structural analysis and fatigue life analysis in order to determine strength and durability. Rotational energy of the turbine will be translated into electricity through Faraday's Law of Electromagnetic Induction.The primary goal of the project is to create a wind turbine that maintains the original Archimedes advantages, low noise, and compactness while eliminating its drawbacks. The final design is intended to provide a universal, omnidirectional, and clean energy solution that can operate efficiently in various wind conditions, making it ideal for extensive clean energy applications.

**Keywords:** *Archimedes Wind Turbine, CFD Analysis, Omnidirectional, Aerodynamic Optimization, Faraday's Law*

## 1. Introduction

The global energy demand has increased significantly due to population growth. Traditional fossil fuel-based energy sources contribute to environmental issues such as greenhouse gas emissions and air pollution, and therefore, a shift toward renewable energy is required. Wind energy, being clean and sustainable, has gained prominence as an alternative source of energy. Conventional turbines like the Archimedes wind turbine provide efficient energy generation but face issues such as drag and directional sensitivity. An omni-directional wind turbine is developed to address these problems, hence providing an improved, adaptable, and efficient renewable energy solution.

## 2. Objectives

- Design an omni-directional wind turbine that captures wind from every direction.
- Reduce drag and increase aerodynamic performance.
- Create a lightweight prototype from 3D printing with PLA material.
- Electrify mechanical rotation with neodymium magnets and copper coils.
- Create a compact, efficient, and silent renewable energy source for city use.

## 3. Literature Survey

The work draws from several studies on innovations in wind turbine design, bearing optimization, 3D printing technology, and AI-based design processes for sustainable energy. Suprihatiningsih et al. investigated the performance and design of a three-blade spiral horizontal-axis wind turbine (TASH) and showed that the addition of a planetary gearbox enhanced the power coefficient and torque output of the turbine when working under low winds, thereby making it more suitable for microgeneration systems. To complement this, Szweda et al. suggested hybrid bearing systems for vertical-axis wind turbines, which enhance operational performance by shifting from rolling to sliding elements, lowering resistance when starting and providing quiet operation. All these ideas are directly indicative of the mechanical versatility of omni-directional systems.Intelligent manufacturing was highlighted by Ravi and Chacko as they merged AI and machine learning into 3D printing to ensure greater precision and material optimization of parts. Leong et al. added value through the investigation of bio-based polymers for 3D printing, which provide sustainable options with adequate mechanical strength, encouraging greener practice in turbine prototyping. These methods highlight the application of harmonizing design intelligence with sustainable material selection .Ravinthiran et al. developed an omni-directional wind turbine with epoxy and E-glass fiber, combining horizontal and vertical axis design features for applicability in urban settings. ANSYS Fluent simulations aided aerodynamic performance under different boundary conditions. Likewise, Patil et al. applied Fibonacci spiral geometry to their HAWT design, testing conical helix blade performance through SolidWorks simulation for effective low-height deployment, achieving up to 71.38% efficiency under urban wind flow conditions. Sapkota et al. presented an Archimedean spiral-type HAWT that optimized pitch and opening angles to improve power coefficients, reaching 0.25 at a tip-speed ratio of 1.5. Their CFD analysis established operational viability across low-to-medium wind speeds. Shahrubudin et al. provided a broader review of 3D printing, highlighting its transformative role across multiple sectors, while Attene proposed a topological STL repair method to improve printability—an essential step for ensuring integrity in rapid prototyping of aerodynamic blades.Rakesh et al. investigated the Lucid Spherical Turbine in gravity-fed pipelines, demonstrating its flexibility and power output of up to 1 MW, confirming off-main-stream uses of turbine technology beyond wind sources only. Chasalevris and Dohnal investigated improving rotor stability through variable journal bearings, incorporating vibration-damping arrangements which assist in design flexibility under high speeds.Shahzad et al. emphasized the immediacy of shifting to renewables, placing wind energy as part of the larger global energy sustainability agenda. Cheng and Zhu discussed innovative wind energy conversion systems (WECS), specifying drivetrain configurations, MPPT controls, and generator technologies as critical for effective wind harnessing. Kim et al. investigated the Archimedes spiral blade using both CFD and PIV methods, which showed a large power coefficient ($Cp \approx 0.25$) and excellent aerodynamic performance confirmed by the use of flow visualization tools.Xie and Billinton proposed the Equivalent Capacity Ratio (ECR), which helps properly match turbines with site-specific wind characteristics, a measure that guarantees efficiency as well as reliability. Ni et al. used MATLAB and finite element software to design an optimal 20 kW HAWT blade with actual-world manufacturability based on composite materials. Iancu et al. also pointed out STL file format limitations for 3D printing and proposed developing more sophisticated formats for complex geometries. Jung et al. investigated NACA 6409 aerofoil performance with ground effect, verifying that endplate and aspect ratio modifications substantially enhance lift-to-drag ratio—implications that were directly borne out by the aerofoil choice and validation procedures applied to this research.

Collectively, these works form a basis for the aerodynamic modeling, structural optimization, and design validation approaches taken up in the development of the omni-directional wind turbine considered in this study.

## 4. Design Methodology

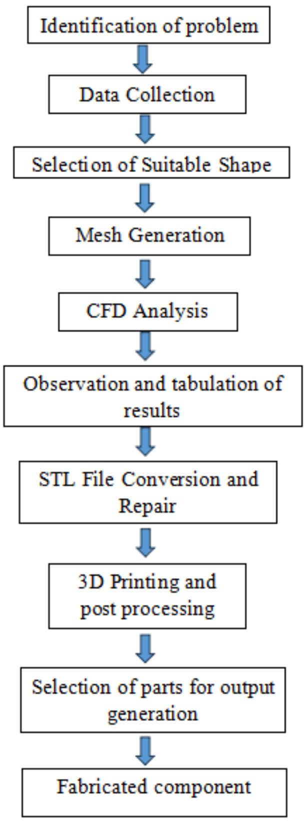


**Figure 1:** Methodology followed for Design and Fabrication of the turbine

### *4.1 Conceptual Design and Aerodynamic Simulation*

We designed a split-rotor omni-directional wind turbine utilizing helical 5-blade profiles to optimize wind capture in all directions. The blade profiles were optimized employing the NACA 6409 airfoil that has desirable lift-to-drag ratios.

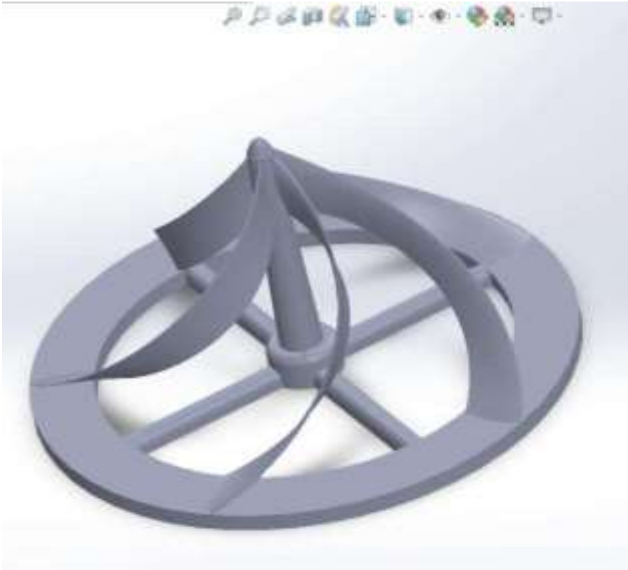

**Figure 2:** Left hemisphere of the Turbine

Aerodynamic performance analysis was carried out using SolidWorks Flow Simulation and assessing lift and drag forces as a function of wind speeds.

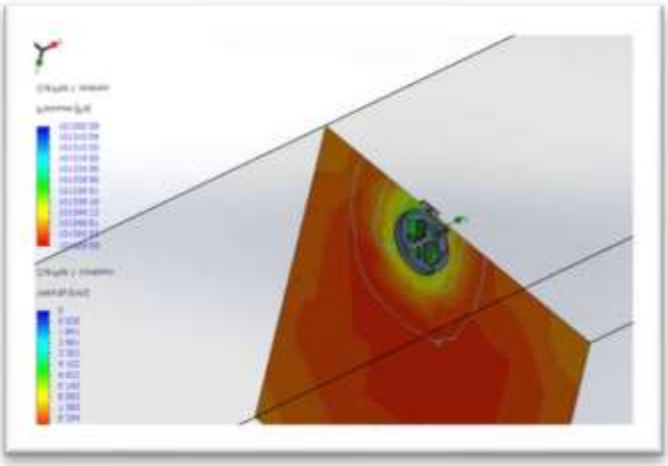

**Figure 3:** Flow Simulation Velocity Cut Plot

### *4.2 3D Printing*

PLA was chosen for prototype printing via Fused Deposition Modeling (FDM) due to its affordability and simplicity of printing. STL files were created, preceded by pre-print mesh repair and wall thickness checks to guarantee print quality and structural integrity.

**Figure 4:** 3D Printed LHS Rotor

### *4.3 Energy Conversion*

Arranged neodymium magnets (10 mm × 3 mm) along the rotating rotors and positioned an 18 SWG copper wire coil at the center to capture EMF generated by relative motion. The output voltage was determined through experimental setup based on Faraday's law using mutimeter.

**Figure 5:** Prototype Generating AC Voltage

### *4.4 Structural and Fatigue Analysis*

After 3D printing, SolidWorks structural and fatigue analyses validated the turbomachinery's resistance to wind loads (10–25 m/s) and $10^6$ cycles and with durability and location of high stress areas for design improvement.

**Table 1:** Stress results obtained against Wind speeds

| **Wind Speed (m/s)** | **Pressure (Pa)** | **Von Mises Stress (N/m²)** |
|---|---|---|
| **10** | 61.25 | $4.07\times10^{-2} \rightarrow 1.529\times10^{6}$ |
| **15** | 137.81 | $9.246\times10^{-2} \rightarrow 3.454\times10^{6}$ |
| **20** | 245 | $1.633\times10^{-1} \rightarrow 6.141\times10^{6}$ |
| **25** | 383 | $2.57\times10^{-1} \rightarrow 9.650\times10^{6}$ |

## 5. Results and Discussion

The following results were obtained from the simulation between Archimedes(A) and Omni directional (O) wind turbines.

**Table 2:** Comparison of Lift and Drag coefficients of the turbines

| S.No | Velocity (m/s) | Coefficient of Lift (CL) [O] | Coefficient of Drag (CD) [O] | Coefficient of Lift (CL) [A] | Coefficient of Drag (CD) [A] |
|---|---|---|---|---|---|
| 1 | 3 | 0.02529 | 1.6654 | 0.01347 | 3.7029 |
| 2 | 5 | 0.03101 | 1.6737 | 0.01124 | 3.7312 |
| 3 | 8 | 0.01600 | 1.6102 | 0.01343 | 3.5682 |

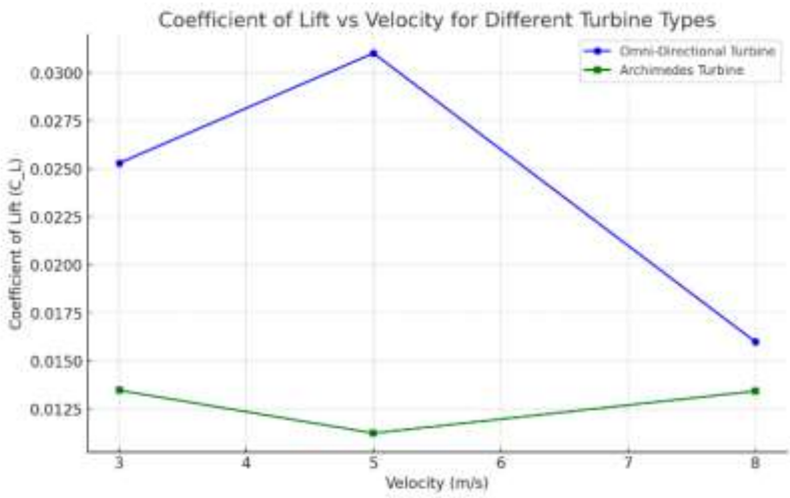


**Figure 6:** Graph drawn for Coefficient of Lift [CL] and Velocity [V] between both the turbines

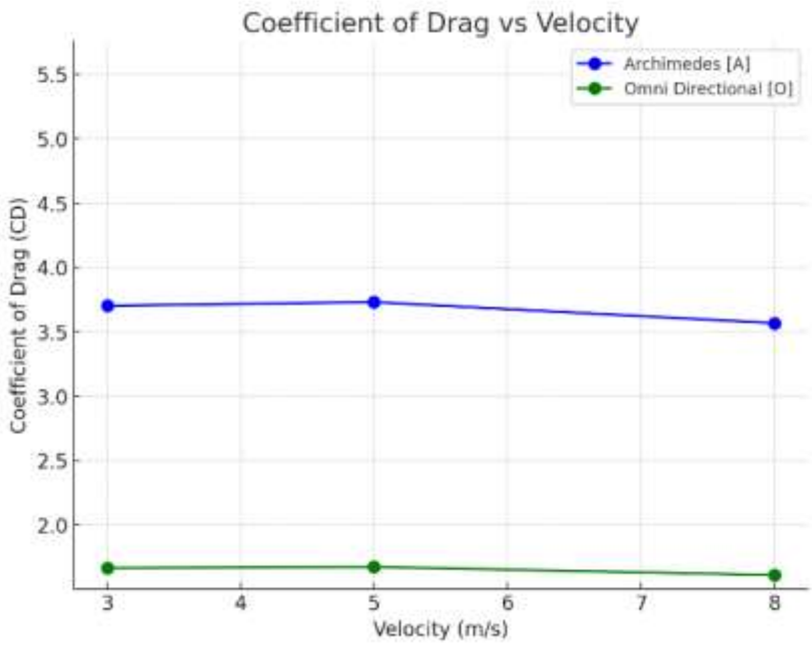


**Figure 7:** Graph drawn for Coefficient of Drag [CD] and Velocity [V] between both the turbines

Based on the observed results, a multi-directional wind turbine capable of efficiently capturing wind from varying directions was designed. The aerodynamic improvements incorporated into the design have resulted in a significantly lower drag coefficient for the Omnidirectional wind turbine making it a more versatile and sustainable solution for renewable energy generation.

After fabrication, the prototype was tested under controlled wind velocities. The following voltage output readings were taken:

• **At 4 m/s wind velocit**y: 23.68 mV AC

• **At wind speed of 6 m/s:** 38.30 mV AC

## 6. Conclusion

Drawing upon the results as observed, we have been able to design a multi-direction wind turbine that efficiently harvests winds from multiple directions. The redone turbine offers solutions to some of the original spiral wind turbine's main disadvantages, specifically the high drag coefficient. The added aerodynamic measures in the redesign have made it possible to design an omnidirectional wind turbine with a lower drag coefficient when compared to an Archimedes wind turbine.This drag reduction further improved the efficiency of the turbine as a whole so that it could produce more uniform power output under turbulent or changing wind conditions. The optimized design is not only an improvement in performance but also provides higher reliability and less mechanical stress, and thus it is a more viable and sustainable option for renewable power production.Additionally, viable 3D printing and proof testing of the prototype also reaffirmed the feasible applicability of the design with quantifiable AC voltage production under different wind velocities. Experimental tests substantiated predictions made during simulations and validate the use of adopting such configurations within real-life projects. Upgrades in the future could focus on using lighter materials, increased scaling for power applications, as well as connectivity into smart controls in order to better optimize the harvesting of energy.

## 7. Future Scope

The omni-directional wind turbine includes enhancing its electrical output by integrating amplifiers and DC-DC converters, which can efficiently regulate and boost the voltage generated through Faraday's Law. Moving beyond traditional electromagnetic induction, the system can be further advanced by incorporating dual-axis motors that allow better adaptability and energy harvesting from variable wind directions. These turbines also hold great potential for large-scale deployment in high-wind regions such as highways, coastal areas, and elevated terrains, contributing significantly to decentralized and sustainable energy generation.

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