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Design and Development of a Jet Wind Turbine for Domestic Application

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ABSTRACT

Through the coming several decades, renewable energy technologies, thanks to their continually perfecting performance and cost, and growing recognition of their Environmental, profitable and social values, will grow decreasingly competitive with Traditional energy technologies, so that by the middle of the 21st century, renewable Energy, in its colourful forms, should be supplying half of the world's energy requirements. This project encompasses the design and development, of a Jet wind turbine for domestic application characterized by a tapered cowl and four cambered aerofoil blades. The tapered cowl is engineered to streamline airflow, enhancing the velocity of incoming wind and optimizing the performance of the turbine in high-speed jet conditions. The cambered blades are designed to maximize lift while minimizing drag, utilizing advanced aerodynamic profiles to ensure efficient energy conversion. The study focuses on optimizing balance between energy capture and structural integrity This research aims to advance the development of jet wind turbines, providing a sustainable energy solution that harnesses high-velocity wind resources effectively.

INTRODUCTION

The growing global demand for clean and sustainable energy has highlighted the importance of optimizing renewable energy technologies, especially in the wind energy sector. Despite its widespread adoption, conventional wind turbines often face significant challenges in low wind-speed regions, where energy capture and efficiency are substantially reduced. This limitation has driven the exploration of innovative designs that can harness wind energy more effectively under such conditions.

A jet engine-type wind turbine offers a promising solution by incorporating a ducted design, which accelerates airflow and optimizes the interaction between wind and turbine blades. Unlike conventional open-blade turbines, the jet engine-type turbine employs a Cowl to align and smooth the airflow, reducing turbulence and enhancing energy conversion efficiency. This approach is particularly advantageous in low wind-speed regions, where conventional designs struggle to maintain effective power generation.

This study focuses on the design, analysis, and optimization of a small-scale jet engine-type wind turbine. By leveraging advanced aerodynamic principles and efficient airfoil profiles, the proposed design aims to maximize power output at wind speeds as low as 3–5 m/s. Key parameters such as rotor dimensions, tip speed ratio, and blade dimensions configuration are evaluated to ensure optimal performance. The research emphasizes practical

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applications for decentralized power generation in rural and urban settings, contributing to the broader goal of sustainable energy solutions.

Fig: 1 Jet Wind Turbine

LITERATURE GAP ANALYSIS

Despite advancements in jet-inspired wind turbine designs, significant gaps remain in the research. Most studies focus on performance under moderate wind speeds, with limited exploration of their efficiency in extremely low wind conditions typical of urban and suburban areas. Structural analyses often neglect the long-term durability of materials under variable wind speeds and environmental factors such as humidity and temperature. Additionally, performance validation largely relies on computational models, with minimal experimental testing in real-world residential settings. Furthermore, while power optimization is a common focus, little attention is given to integrating turbines with domestic power systems or addressing energy storage challenges, which are critical for consistent household energy supply.

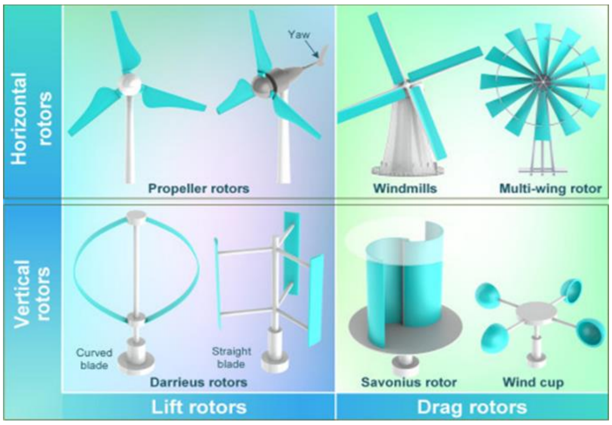

Fig: 2. Different types of Wind turbines

METHODOLOGY

The jet-engine inspired Wind Turbine, as shown in Figure 3, was employed as the baseline model for the research analysis and designed using Computer Aided Design Commercial Software. The Wind Turbine was composed of a rotor, a curly shroud (Mixer), cambered blade, and a base frame. The curly shroud was designed in such a way that it has capability to enhance the performance of the Wind Turbine due to the vortex formation at the back of the Wind Turbine.

Fig: 3 Jet-engine inspired Wind Turbine

Design of Aerofoil Blade-The image shows a cross-sectional view of an airfoil. The airfoil has a curved upper surface and a flatter lower surface, which creates lift when air flows over it. The dimensions shown indicate the chord length(250mm), thickness(10.6mm) and camber (7.53mm)of the airfoil,

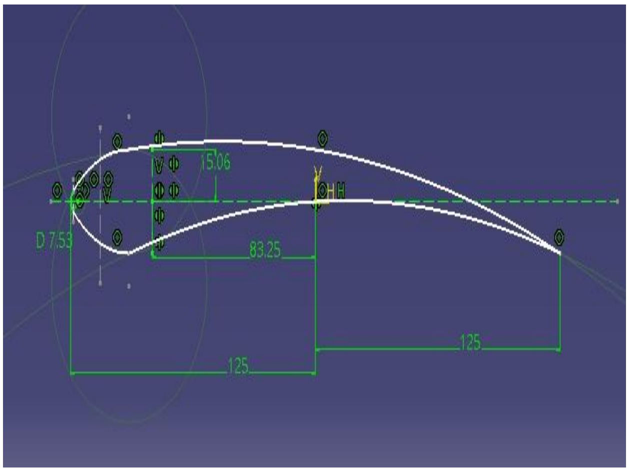

Fig: 4, Design of Cambered blade

Components of the Jet Wind Turbine :-

Tapered Cowl: The cowl is designed to direct and accelerate the incoming wind onto the blades, enhancing the turbine's efficiency by reducing turbulence and maximizing flow speed.

Cambered Blades: Four cambered aerofoil blades are mounted on the rotor. Their aerodynamic shape allows for increased lift generation and reduced drag, crucial for optimal performance in high wind conditions.

Shaft: The blades are connected to a central shaft, which converts the rotational motion of the blades into mechanical energy.

Bearings: Bearings support the shaft, allowing it to rotate smoothly while minimizing friction. Proper bearing selection is essential for the turbine's longevity and performance.

Dynamometer: A dynamometer is connected to the shaft to measure the torque and power output generated by the turbine, providing data for performance evaluation and optimization.

CALCULATIONS

Summary of Parameters and Assumptions

Number of Blades: 4

Diameter (D): 400 mm (or 0.4 m) overall diameter including 4 blades

Blade Radius (R): 0.2 m (half of the diameter)

Blade Material Sheet metal Thickness: 1 mm

Wind Speed (V): 5 m/s

Air Density (ρ): 1.225 kg/m³

Turbine Efficiency (η): 60%

Tip Speed Ratio (TSR): 5

1: Swept Area and Power Output

$P = \frac{1}{2} * \eta * \rho * A * V^3$

Where:

P is the target power output (5 watts).

η is the efficiency (assumed to be 60%, or 0.6).

A is the swept area of the turbine, $A = \pi \left(\frac{D}{2}\right)^2 \, OR \, A = \pi * (R^2)$.

V is the wind speed (assumed to be 5 m/s).

$\rho \text{ is Air Density in } Kg/m^3$

$A = \pi * (R^2) = \pi * (0.2)^2 = \mathbf{0.1256\ m^2}$

$P = \frac{1}{2} * 0.6 * 1.225 * 0.1256 * (5^3)$

$\boldsymbol{P = 5.76\ W}$

2: Chord Length Calculation

The chord length (c) for each blade is calculated using the formula:

$C = \frac{8 * \pi * R}{n.TSR}$

Were,

1. TSR is Tip Speed Ratio (TSR): 5
2. R is Blade Radius (R): 0.2 m (half of the diameter)
3. n is the number of blades (4),

$C = \frac{8 * \pi * 0.2}{4 * 5}$

$C = 0.251\ m = \mathbf{251\ mm}$

POSSIBLE OUTCOME

The implementation of a jet wind turbine with a cambered aerofoil blade design is expected to yield several positive outcomes, significantly enhancing energy efficiency and performance. The cambered shape of the blades allows for improved lift generation, effectively capturing energy from high-velocity wind streams while minimizing drag. This aerodynamic advantage can lead to higher power output compared to traditional flat-blade designs, making the turbine more effective in diverse wind conditions. Additionally, the optimized blade design may contribute to reduced noise levels and lower maintenance requirements due to smoother airflow and less turbulence. The innovative use of materials and construction techniques could also result in a lightweight yet robust turbine, facilitating easier installation and potentially lower overall costs. Overall, these advancements position the jet wind turbine as a promising solution for harnessing renewable energy, supporting efforts to transition to sustainable power generation and reduce reliance on fossil fuels.

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