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Design of a Mini Wind Turbine for a Wind Powered Vehicle

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ABSTRACT: In an effort to align with the Global Sustainability Goals reduce the carbon footprint and environmental impact of fuel guzzling vehicles, this paper focuses on the design of a series of four mini horizontal axis wind turbine (HAWT) to power small to medium sized road vehicles. Four wind turbine rotors, each housed in a nacelle, are made using a NACA 4415 series airfoil profile. The rotor is designed using Q-Blade software and optimized to attain optimum tip speed ratio and angle of attack.

KEYWORDS: Mini horizontal axis wind turbine, Nacelle, Airfoil, Tip speed ratio, Angle of attack

I. INTRODUCTION

Wind energy is the most valuable, environmentally friendly and fastest growing non-conventional energy source and if artificially harnessed, it can be used to generate enough tractive effort to propel it. This is, theoretically, possible if a wind turbine is mounted on the vehicle and used to propel it using its relative speed to generate mechanical motion. The focus will be on designing an airfoil profile wind turbine blade to increase the efficiency of the turbine. A series of turbines will be coupled a single shaft to reduce the diameter of the turbine required and the effort needed to rotate the shaft more seamlessly and efficiently.

By implementing this technique, however, the aerodynamics of the vehicle will be upset, thus it is necessary to modify the vehicle's body shape to make it more aerodynamically efficient. The aerodynamics of the vehicle body in its entirety will be ignored as it goes beyond the scope of this paper.

II. RELATED WORK

The concept of using a series of four, small 3-blade horizontal axis wind turbines mounted atop a vehicle was coined and by Robert Yost to bypass BET limit using the principle of jet engines [1]. Moreover, propulsion mechanisms, namely lift and drag, govern the blade selection criteria for the number of blades needed on the turbine. Three blades are free from vibrations resulting from gyroscopic precession making them stable, and they also have tip speed ratios above 7 [2]. Utilizing multielement airfoil configuration in blade geometry not only increases the efficiency of the turbine, but it also results in the reduction of turbine size [3] [4]. The effects of using multielement airfoils in wind turbines can be analysed using computational fluid dynamics [5] [6] [7]. Segmenting the turbine blades make them easier to clean, replace and maintain while reducing the overall manufacturing cost of the turbine [8].

III. METHODOLOGY

NACA 4415 airfoil coordinates are imported into Microsoft Excel and used to design a wind turbine with rotor blades 120° apart with each blade having a length of 7.25cm and a hub of 1cm diameter in Solidworks. To optimize the design, the turbine dimensions were imported into Q-Blade software to determine maximum angle of attack, tip speed ratio and coefficient of lift and drag using the Blade Element Momentum Theory. Computational Fluid Dynamics was

then carried out to see the aerodynamic behaviour of the turbine as it rotates at 12m/s and at 20m/s. The wind turbine rotors will be housed in a nacelle [9] specially designed to prevent fouling and weather damage while also directing airflow towards the blades as seen in jet engines.

IV. EXPERIMENTAL RESULTS

The figures below show the designs and experimental results of the Q-Blade optimization and ANSYS Fluent Computational Dynamics of the turbine in a rotating domain.

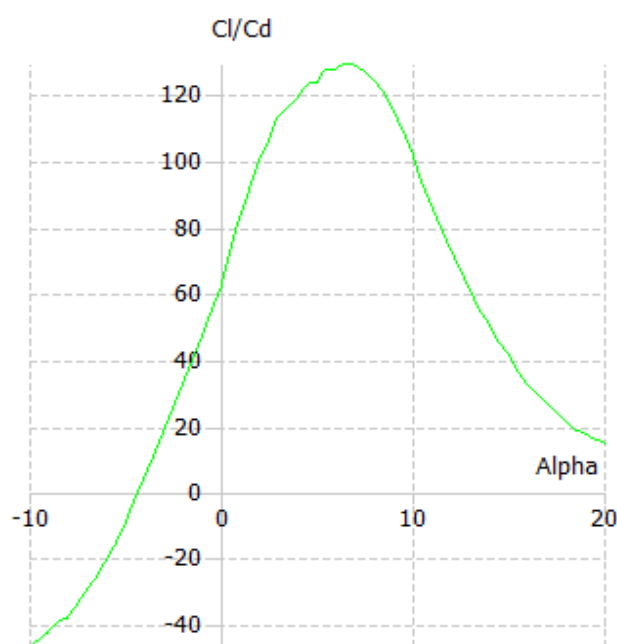


Figure 1 Coefficient of Lift /Coefficient of Drag Against Angle OF Attack Generated by Q-Blade Software

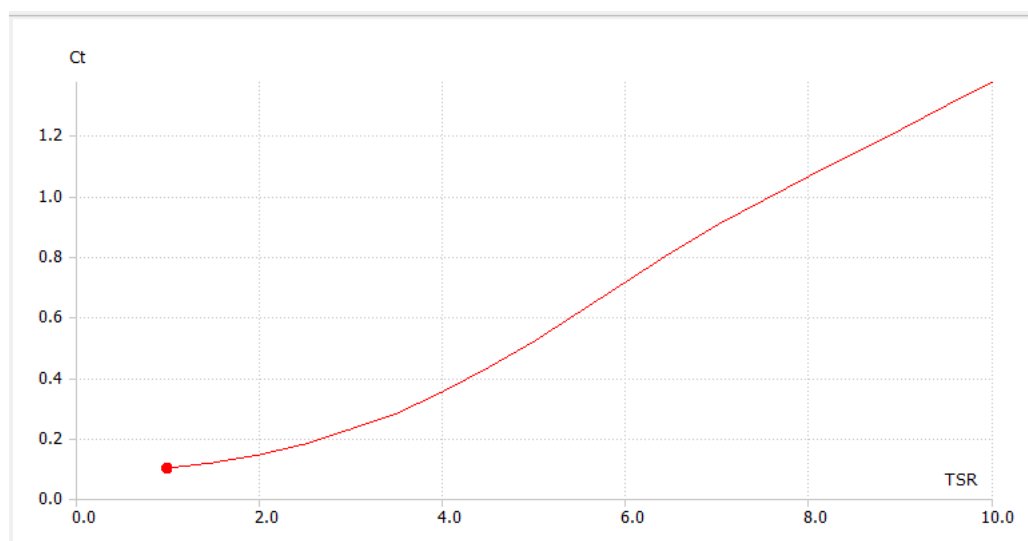


Figure 2 Coefficient of Thrust/ Tip Speed Ratio Generated by Q-Blade Software

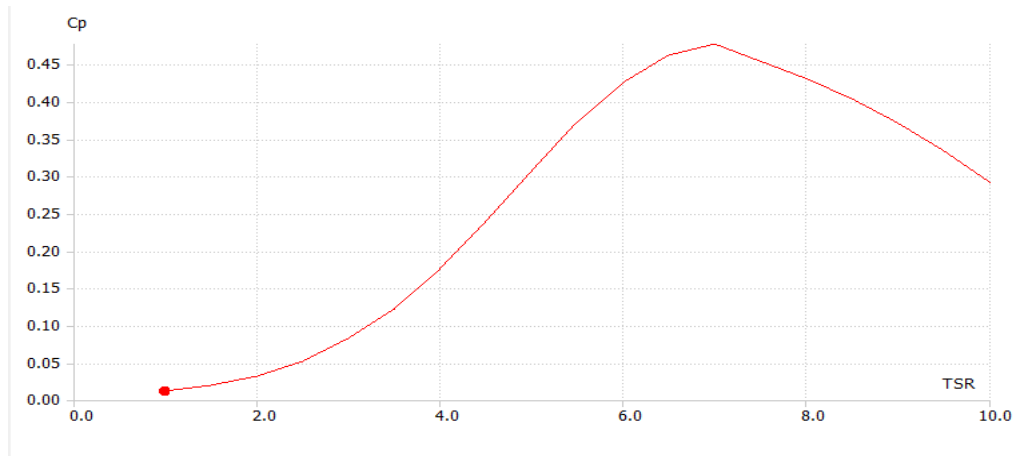


Figure 3 Coefficient of Power/Tip Speed Ratio Generated by Q-Blade Software



Figure 4 Q-Blade Optimum Rotor Design & Final Rotor Design Respectively

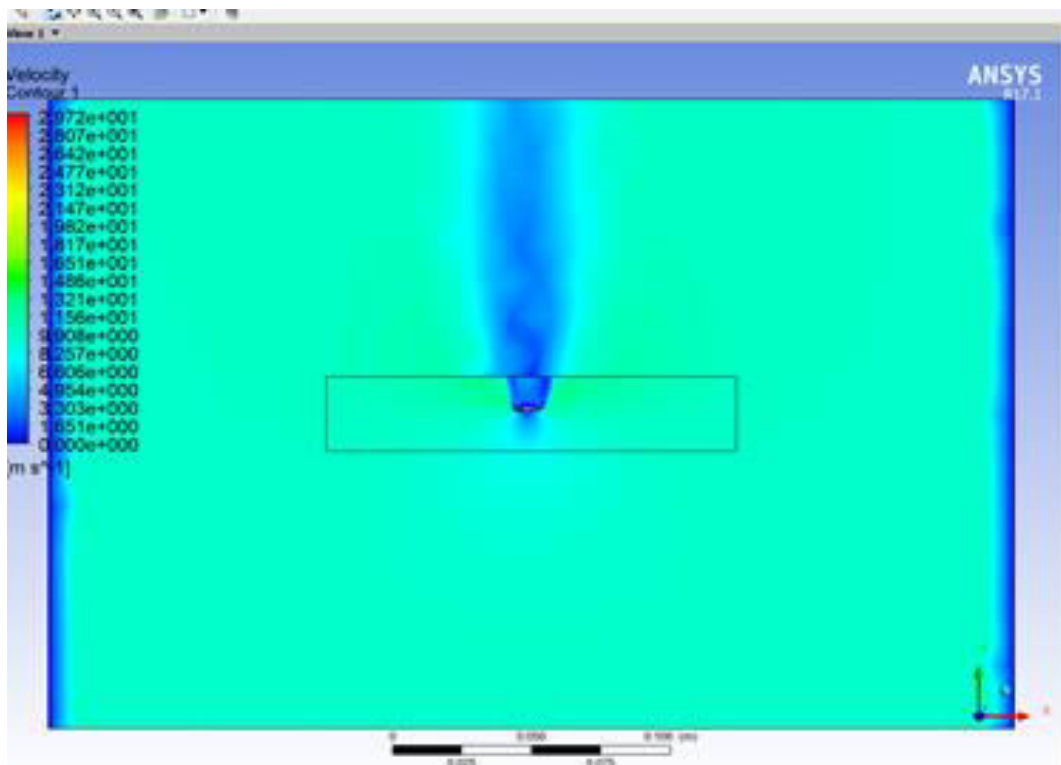


Figure 5 Velocity Profile at 12m/s

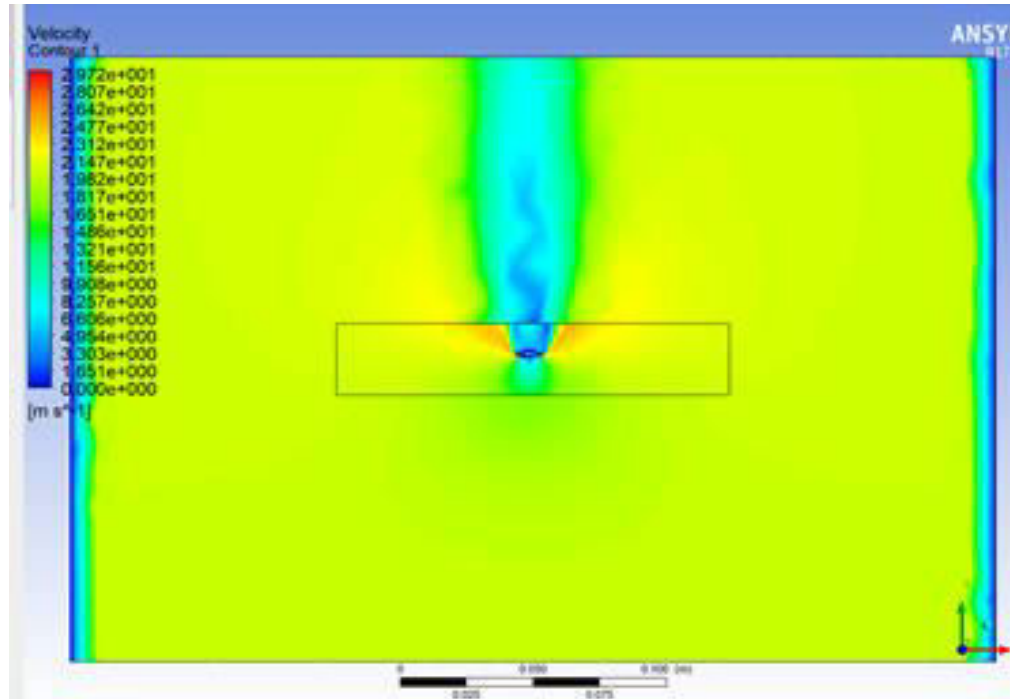


Figure 6 Velocity Profile at 20m/s

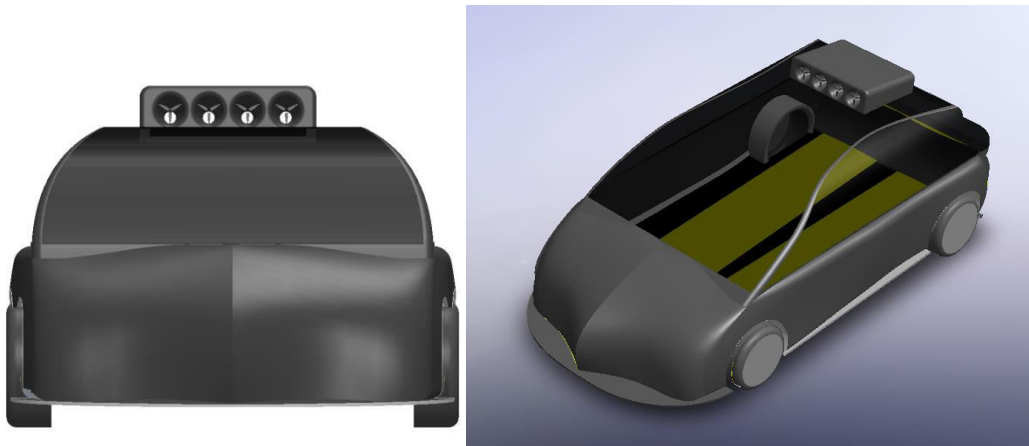


Figure 7 Proposed Vehicle Concept

V. CONCLUSION

By optimizing the rotor design in Q-Blade using blade momentum theory, the graphs show that the maximum angle attack of the turbine blades will be 6.5° and as tip speed ratio increases, so does the coefficient of thrust. The maximum coefficient of power is realized when tip speed ratio is 7 which according to literature gives the maximum turbine performance. [2] A simple rotor neglecting angle of twist and multielement airfoil configuration simplifies the design and reduces manufacturing costs without significantly affecting the overall performance of the turbine. Incorporating four turbines into the design does not necessarily increase the speed of the vehicle as they will be rotating at almost the same speed, it rather reduces the effort of the turbines, allowing them to turn a coupled shaft connected to the drivetrain more smoothly. From computational fluid dynamics, the velocity at the contact surface is lower than the velocity of the turbine at both speeds of rotation, getting higher towards the tips of the blades. This validates the fact that velocity is greater at the tips of the turbine than at the hub. The turbine is mounted atop the vehicle enclosed in a custom designed nacelle and positioned at its rear end to realize more efficiency as shown in the

proposed vehicle concept. The glass surface on the top of the concept vehicle is for turbine visibility for the benefit of this paper. The actual surface material will be the same as that of the vehicle body.

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