Wind Turbine Powered Car Uses 3 Single Big C-Section Blades

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Abstract— The blades of a wind turbine have the most important job of any wind turbine component; they must capture the wind and convert it into usable mechanical energy. The objective of this work is to determine the mechanical power of single big C-section of vertical wind turbine for wind car in a two-dimensional model. The wind car has a vertical axis with 3 single big C-section blades mounted at an angle of 120°. Moreover, the three single big C-section blades are directly connected to wheels by using various kinds of links. Gears are used to convert the wind energy to mechanical energy to overcome the load exercised on the main shaft under low speed. This work allowed a comparison of drag characteristics and the mechanical power between the single big C-section blades with the previous work on 3 C-section and 3 double C-section blades for wind car. As a result obtained from the flow chart the torque and power curves of each case study are illustrated and compared with each other. In particular, drag force and torque acting on each types of blade was taken at an airflow speed of 4 m/s, and an angular velocity of 13.056 rad/s.

Index Terms-- Blade, vertical wind turbine, Drag characteristics, mechanical power

I. INTRODUCTION

Wind energy is playing a critical role in the establishment of an environmentally sustainable low carbon economy. Wind energy or wind power describes the process by which wind is used to generate mechanical or electrical power. Wind energy is harnessed as mechanical energy to help of wind turbine [1]. A wind turbine is a device that extracts kinetic energy which acts on the rotor blade from the wind and converts it into mechanical energy or torque. Rotational energy is used either by generating electricity or directly moves machines or equipment such as mills or water pumps or wind car. [2, 3]

As an example Technical University of Denmark – DTU – has used wind energy to operate wind car [4]. A team of German students of Stuttgart University’s Team InVentus has built the Ventomobile, a three-wheeled "car" which features a 2 meter diameter two-bladed rotor mounted on top. [5, 6]

At New Jerusalem in Tracy, California, US, wind powered car, Faster than the Wind, was constructed by Rick Cavallaro, an, and which called Blackbird. It reached a top speed of more than 2.85 times faster than the wind blowing at the time (13.5 mph) powered by the wind itself. Also, the car has a passing resemblance to a Formula 1 racing car [7]. Along the dry plains of Ivanpah Lake in Nevada, Wind-powered vehicle or Wind powered Greenbird reached speeds of 126.1 mph (202.9km/h). [8]

Wind Explorer, Wind-powered car, has created by two German inventors that recharges the battery through a wind turbine carried in the car. To test the vehicle, the duo recently completed a 3,100-mile trek across Australia. [9, 10]

In general, there are two main categories of wind turbines: Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT) [11]. Although HAWT designs are widely used, they have the disadvantage that they have to be positioned perpendicular to the wind direction. VAWT has the advantage that they are independent of wind direction for their operations. Today researches are stating that the main types of vertical-axis wind turbine are Savonius turbine, and Darrius. Savonius turbines are usually mounted on a short tower, and the generator shaft is positioned vertically with the blades pointing up. Also, it uses drag, like a cup anemometer, to produce torque. Whereas, the generator shaft of Darrius turbine is positioned vertically with the blades pointing up, and the blades use the lift design. The aim of this work presented in this paper is to compare the mechanical power of single big C-section with the previous work on 3 C-section and 3 double C-section blades wind car results by using the wind energy. The data are presented through graphs using Microsoft Excel.

II. Theory

A. Drag force

Drag is the component of force acting on a body that is projected along the direction of motion [12]. A total drag force on a body comes directly from the action of pressure and viscous stresses on the body. The viscous stress, particularly that part due to viscous shear, is referred to as the skin friction component of the drag force. The portion due to pressure is variously referred to as the form drag, shape drag, or just pressure drag. Particularly when flow separation occurs, leading to the formation of a wake, the pressure difference across a body can mean that form drag is the principle portion of the drag force. The drag coefficient, \( C_D \), for steady flow with no free surface effects was defined as

\[
C_D = \frac{F_D}{\frac{1}{2} \rho U_e^2 A}
\]

Where \( F_D \) is the drag force, \( U_e \) is the speed of the fluid; \( A \) is projected area in the direction of \( U_e \), and \( \rho \) the density of the fluid [13]. Drag coefficient for an object depends on the shape of the object and on the Reynolds number [14]. The drag coefficients for selected objects are given in table 1.

1 Drag coefficients for two-dimensional shapes \((10^4 < Re < 10^6)\). The drag coefficients in all cases are based on the projected area [13].
B. Mechanical Power

A wind turbine consists of rotor, which catches the energy from wind and concentrates it on the shaft, and the generator, which receives the mechanical energy from the shaft (usually through the gearbox) and converts it to electrical energy. Mechanical power is “power” defined in terms of mechanical parameters such as force, speed, torque, and the like. Compare mechanical power to electrical power, which is defined in terms of voltage, current and so on.

a. Power in linear motion

Fig. 1 shows an object that is under the effect of a force. It is assumed that the force passes through the object mass center and causes the object to move along a straight path with a constant velocity. In such a case, the object receives power to maintain its motion. In other words, in order to maintain the motion at the same speed, some power must be provided to the object. This power can be defined as

\[
\text{Power} = \text{Speed} \times \text{Force} \tag{2}
\]

This expression for power is in terms of the speed and the force, both of which are mechanical parameters related to motion. Note that the force has the same direction as the motion (velocity). [15]

![Fig. 1 An object under the effect of a force](image)

b. Power in rotational motion

The object in Fig. 1 has a translational motion. A turbine shaft has a rotational motion. Similar to speed and force in translational motion, in rotational motion one has “angular speed” and “torque”. [15]

For a shaft that, under the effect of torque, rotates with a constant angular speed, the power is

\[
\text{Power} = \text{Angular speed} \times \text{Torque} \tag{3}
\]

III. RESULTS AND DISCUSSIONS

In this work, the three blade wind car and the direct connection is used via various links and gear. A vertical wind turbine is mounted on the chassis are shown in Fig. 2. The turbine captures wind and moves due to the presence of pressure drag force which cause it to rotate about it fix axis.

![Fig. 2 Set up (front view of the wind car with scale is 1mm=10cm).](image)

Fig. 3 shows the free stream velocity $U_\infty$, the direction of the speed of the blades ($\omega R$), the position of the blades with angle $\gamma$, and the direction of rotation of the blades for single big C-section blade.

![Fig. 3 Schematic diagram of three-blade rotor for single big C-section blade](image)

During the rotation, the free stream velocity $U_\infty$ has two components. First component, it is directed along with the velocity direction. It is used to calculate the skin friction drag force. The second component is directed perpendicular to the velocity direction and used to calculate the pressure drag force. Since the speed of the blades affects both surfaces of the C-section, and at the same time we have the free stream velocity effect on the upper or lower surface which depends on the location of the profile, the free stream velocity is added to or subtracted from the speed of the blades ($\omega R$), which depends on the direction of the velocity as shown in Fig. 4.

![Fig. 4 Schematic diagram of one-blade rotor for single big C-section](image)

The flow chart of single big C-section blade wind car below represents the way to calculate the drag force and torque.
Using the flow chart of the single big C-section blade, the drag force can be calculated for one blade. The total forces and the torque for three blades can be also calculated using the same flowchart. Fig. 5 shows the change in torque for a single big C-section blade of diameter 1 m with angle of rotation. Also, Fig. 6 illustrates the variation in power of the single big C-section blade of diameter 1 m with angle of rotation. It shows the maximum power which produced by single big C-section blades is just over 11 kW.

\[ \text{Torque}^* \text{ is dimensionless. Torque}^* \text{ is based in the maximum torque} \]

\[ \text{Power}^* \text{ is dimensionless. Power}^* \text{ is based in the maximum power} \]

**IV. CONCLUSIONS**

In this paper a model for the evaluation of energy performance and aerodynamic forces acting on a different type of blade for vertical axis wind turbine which are depending on the blade geometrical section has been developed. This study consists of a detailed analysis of different blade testing methods and improvements to a novel concept for vertical-axial testing of wind turbine blades. The work demonstrated that Double C-section blade of a wind turbine with diameter 0.3 m can enable to produce more mechanical power than any other blade in the lower wind speeds. Mechanical power and torque for single big C-section was calculated and the result was compared with C-section blades. It was revealed that single big C-section has a...
maximum torque and mechanical power compared to C-section blades.

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REFERENCES


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