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Wind Power Vehicle Uses 3 Double C-Section Blades

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Abstract: This paper presents a mean for calculating the torque variation during the revolution of a vertical-axis wind turbine for different types of blades for wind car. For this purpose, two dimensional model analysis have been performed on a C-section and Double C-section blades for wind car. The wind car has a vertical axis with 3-blades mounted at an angle of 120º. For these configurations a computational model has been developed to calculate the main parameters, namely the velocity profiles, drag forces, pressure distributions and finally the torque around the C-sections and NACA 0012 profile. As a result obtained from the flow chart only the torque curves of each case study are illustrated and compared with each other. Finally, the torque curve is compared for the analyzed architectures, achieving a quantification of the effect of blade shape on the overall rotor performance of wind car. The aim of the present work is to numerically analysis the aerodynamic behavior of a three bladed C-section and double C-section operating at different angle of rotation, in a constant wind speed of 4 m/s and angular velocity 13.056 rad/s.

Keywords: C- section blades, drag force, Double C- section blades, vertical blades, torque.

1. INTRODUCTION

The wind is just moving air. This mass, having a certain velocity, owns kinetic energy. The energy can be converted, through a specific device, into a more useful type. Therefore, it is possible to produce electricity, moving parts with mechanical energy, pump water or provide heat for instance.

Humans had the first approach with wind power thousands of years ago, propelling their sailboats with it. Since the 7th century AD, the wind was used by windmills to pump water or mill grains in Persia. [1]

Wind energy has been adopted for pumping water from wells for steam trains, and it is still able to provide it for isolated houses or off-grid locations. Only at the end of the 19th century the concept of modern wind turbine arises, converting the kinetic energy of the wind into electricity. As an example The solely wind-driven Ventomobile constructed by the InVentus team, a team of some 20 Stuttgart University students of Aerospace Engineering, came in first at the Aeolus Race" in the Dutch town of Den Helder last Friday. [2]

In this work, three study cases are discussed. Firstly, the case I is the C – section, case II is the double C- section with different diameters (D=0. 3 m and D=0. 15 m) and finally the third case is NACA profile 0012. For each case the velocity, drag force and torque are calculated in terms of rotational angle γ according to the flow chart presented. Since the dominant parameter is the torque, only the torque results for each case are illustrated and compared with each other.

The objective of this work is to provide a simple calculation method that shows the blade rotor designing steps, which includes configuration details and important designing parameters. The main idea of this method is to calculate the data of drag force to calculate torque to rotate the wind car.

2. THEORY

2.1. Fluid Mechanics Terminology: Drag is the component of force acting on a body that is projected along the direction of motion. Both shear forces and pressure induce drag on a body in motion. Shear forces, known as skin friction drag, are more significant in streamlined objects, while the pressure drag is more significant in blunt objects [3]. Fig. 1 shows the net drag force acting on a cylinder.

The drag force is often non-dimensioned as a function of Reynolds number. This is then referred to as the drag coefficient (Eq. 1). Similarly, the pressure acting on each different element of an object may be normalized by the dynamic free stream pressure $\frac{1}{2}\rho U_\infty^2$ to obtain the pressure coefficient (Eq.2). This quantity may also be rewritten as the reduced pressure coefficient (Eq. 3).

$$C_D = \frac{F_D}{\frac{1}{2}\rho U_\infty^2 A} \qquad 1$$

$$C_P = \frac{P - P_0}{\frac{1}{2}\rho U_\infty^2} \qquad 2$$

$$C_P = \frac{\Delta P}{q_\infty} \qquad 3$$

where C_D denotes the drag coefficient, F_D drag force, C_P pressure coefficient, P static pressure at the point of interest P_0 free stream static pressure, ρ the density of the fluid, and U_∞ the speed of the fluid.

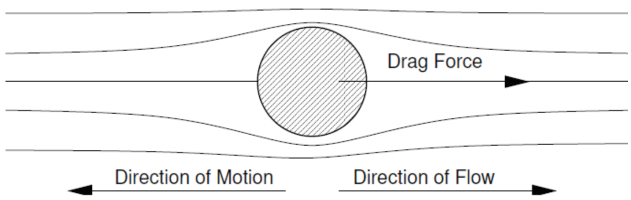

Fig. 1. Drag force on a cylinder.

The drag coefficient of flow over an immersed object usually is based on the frontal area (or projected area) of the object.

The drag coefficient for a finite plate normal to the flow depends on the ratio of plate width to the height and on the Reynolds number. The drag coefficient for all objects with sharp edges is essentially independent of Reynolds number because the separation points and therefore the size of the wake are fixed by the geometry of the object. [4]. The drag coefficient for selected objects are given in table 2.1[1]. [5],[6]

3. RESULT AND DISCUSSIONS

In this work, Fig. 2 represents double C- section blades wind car and the direct connection which is used via various links and gear. A vertical wind turbine is mounted on the chassis. The turbine captures wind and moves due to the presence of pressure drag force, which causes it to rotate around its fix axis. For the following explanations, it is assumed, that a stream of air is directed against the double C-section blades. The air is assumed to be incompressible. The viscous effects due to the surface of the airfoil at the test velocity were neglected because the surface of the C- section was smooth.

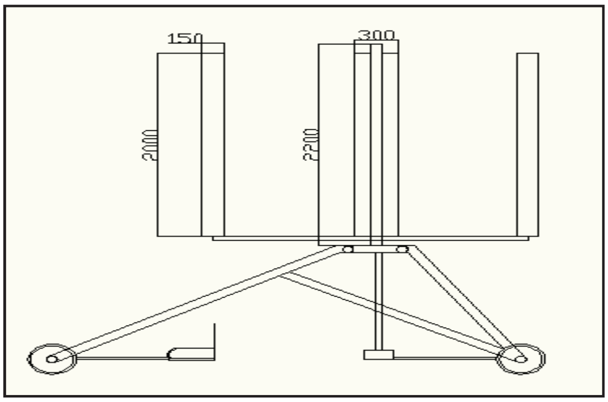

Fig. 2. Set up (front view of the wind car with scale is 1mm=10cm).

Fig. 3 shows the free stream velocity U_∞, the direction of speed of the blades (ωR), the position of the blades with angle γ, and the direction of rotation of the blades for double C-section blades.

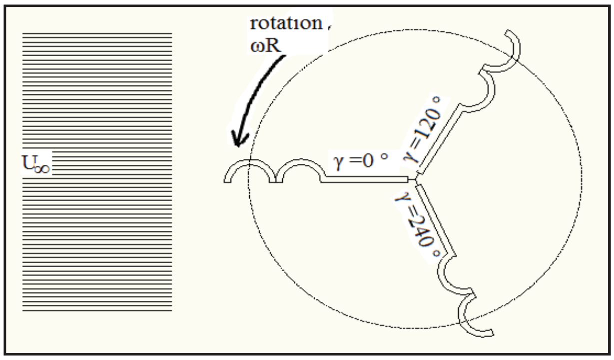

Fig. 3. Schematic diagram of three-blade rotor

During the rotation, the free stream velocity U_∞ 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 (ωR), which depends on the direction of the velocity as shown in Fig. 4.

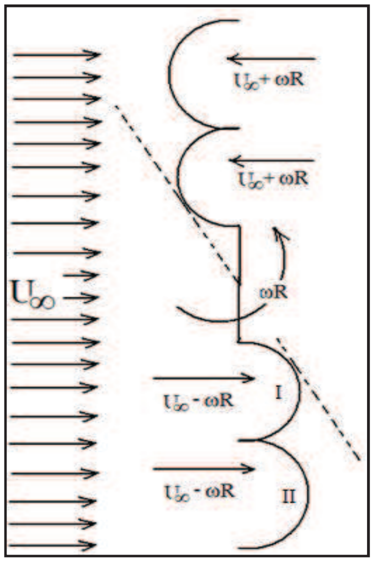

Fig. 4. Schematic diagram of one-blade rotor

The flow chart of C-section blade wind car below represents the way to calculate the drag force and torque.

[1] *Drag coefficient for selected objects (C_D) to calculate the Drag force are given in [5] and [6]*

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Where the total drag force or torque for all the double C-section blades at the same positions can be calculated by adding the drag force or torque for the first half cylinder and the second half cylinder as shown in Fig.4.

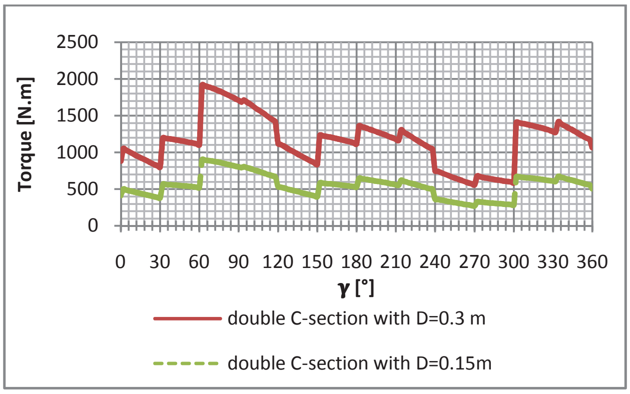

Fig. 5. Torque plot for a different diameters of double C-section

Fig. 5 represents the change in torque for different diameters of C-section blade with angle of rotation. We can easily notice that the maximum torque is produced by double C-section blade with diameter 0.3 m which is about 2000 N.m. Fig. 6 represents the change in torque for different type blades for the wind car, C-section blade at the diameter of C-section 0.3m, double C-section with different diameter is 0.15 and o.3 m for each.

4. CONCLUSIONS

The case study presented a comparison between three different blades for wind car. The results of each case are compared to gain an understanding of the capabilities of each case. This comparative study has shown that the C-section blade allowed to obtain maximum torque. The same parameter, torque, has also been determined by using the same flow chart for NACA 0012, but the results are not illustrated in the diagrams, because they are too small in comparison with the results of two other study cases. When comparing the two types of double C-section and C-section Blade considered here, the double C-section seems more advantages than the C-section and NACA 0012. Also we found the maximum torque was about 2000 N.m for double C-section blade of diameter 0.3 m. C-section blade has been shown to work better than a NACA airfoil in severe wind climates, in rotating the wind car.

5. ACKNOWLEDGMENT

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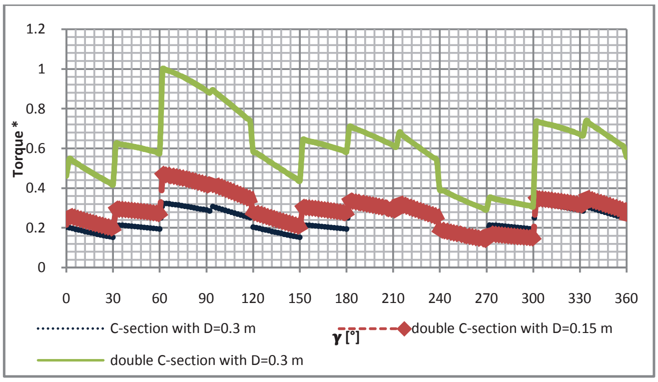

Fig. 6 Torque* plot for different type blades of C-section blades

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**Torque is dimensionless (Torque*). Torque* is based on the maximum torque*