Applied Mechanics and Materials Vol. 660 (2014) pp 689-693
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doi:10.4028/www.scientific.net/AMM.660.689

Submitted: 24.07.2014
Revised: 11.08.2014
Accepted: 13.08.2014

An Evaluation of Drag Coefficient of Wind Turbine System Installed on Moving Car

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Keywords: Aerodynamic performance, Moving vehicle, Wind turbine system, CFD Simulation, ANSYS FLUENT.

Abstract. This study presents a simulation result of an evaluation of the aerodynamic performance of a moving car with a wind turbine system. Sedan type cars (approaching the size of Proton Wira car) were modeled using the SolidWork software and simulation was done by ANSYS FLUENT software. Three car models with different wind turbine system positions (in front of the front bumper, on top of the hood and on top of the roof) plus one model without the wind turbine system were simulated. The study proved that the position of the wind turbine system installation will change the characteristic of the air flow around the car body and affects the aerodynamic performance of the car. Extended front bumper of a car is not significantly affecting the aerodynamic performance of the car. This extended bumper seems to be the suitable area to install a wind turbine system and the investigation shows that the aerodynamic performance of the car improved due to lower drag coefficient, C_{d}..

Introduction

New inventions and researches have been done lately relating to the idea of mounting a wind turbine for power generating system in vehicles. A wind turbine is a device that converts kinetic energy from the wind, also called wind energy, into mechanical energy; a process known as wind power. [1].

Based on existing inventions and previous researches, this study is interested in several issues regarding to the idea of electrical vehicle with a wind turbine system. An electric vehicle (EV), also referred to as an electric drive vehicle, uses one or more electric motors or traction motors for propulsion. Three main types of electric vehicles exist, those that are directly (1) powered from an external power station, (2) powered by stored electricity originally from an external power source, and (3) powered by an on-board electrical generator, such as an internal combustion engine (hybrid electric vehicles) or a hydrogen fuel cell [2].

The appropriate position for the installation of wind turbine system will reflect on other factors that should also be considered. Beside the appearance factor, the most interesting factor to be discussed is the drag force of the car. How far the wind turbine system effects the drag of the car will be investigated. This study will give important insights on the advantages of wind turbine installed in front of the car.

This study looks into the matter of how the attached wind turbine installed in different positions on the vehicle will affect the aerodynamic performance of the car and also the drag force. Last but not least, the most important point of all to be highlighted is whether this idea is practical to be implemented or not.

Aerodynamic Drag. Drag is usually an undesirable effect, like friction, and it is best to minimize it. The drag and lift forces depend on the density ρ of the fluid, the upstream velocity *V*, and the size, shape, and orientation of the body, among other things, and it is not practical to list forces for a variety of situations. Instead, it is more convenient to work with an appropriate dimensionless number are the drag coefficient C_d, and the lift coefficient C_l, defined as

Drag coefficient: $$C_d = \frac{F_d}{\frac{1}{2}\rho V^2 A} \quad (1)$$

Lift coefficient: $$C_l = \frac{F_l}{\frac{1}{2}\rho V^2 A} \quad (2)$$

Where A is ordinarily the frontal area which is the area projected on a car normal to the direction of flow of the body.

Car manufacturers try to attract consumers by pointing out the low drag coefficients of their cars as lower drag leads to higher fuel efficiency. The drag coefficients of the vehicles range from about 1.0 for large semitrailers to 0.4 for minivans and 0.3 for passenger cars. In general, the more blunt the vehicle, the higher the drag coefficient. [3]

Vertical Axis Wind Turbines. Wind turbines can be classified into two general types: horizontal axis and vertical axis. Savonius type rotor blade is one of the vertical axis wind turbines (VAWT). Savonius type rotor blade is a simple wind turbine that operates based on drag concept. The working principle of Savonius rotor resembles a cup anemometer. The low efficiency of VAWT limits its usage in large power production. The most apparent advantage of VAWT is that it can operate in all wind directions and thus are built without using any yaw mechanism [4]. Other advantages include low noise and simplicity. Fig 1 shows the design of the Savonius type rotor blades used in this study. The whole body size of the system is set to be 0.1m in height and 1m width (0.1 m^2 front area).

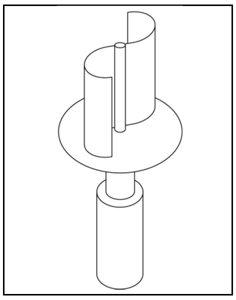

Fig.1 Savonius type rotor blade

Wind turbine position. Three different models were used to evaluate the best postion to mount wind turbine on a vehicle which is (1) at the front of the bumper, (2)on top of the car hood and (3)on the car roof as shown in Fig.2 below. The size of the car models are 4.2 m long, 1.7 m width and 1.8 m in height. The front area for the wind turbine system is set to be 0.2 X 0.75 meter square for each model. In this case, the boundary size to be used is 15 m x 15 m square inlet and outlet area with 30 m length. All three models will be simulated under similar parameters where velocity inlet is 25 m/s (90 km/hr) to determine the drag coefficient C_d and lift coefficient C_l.

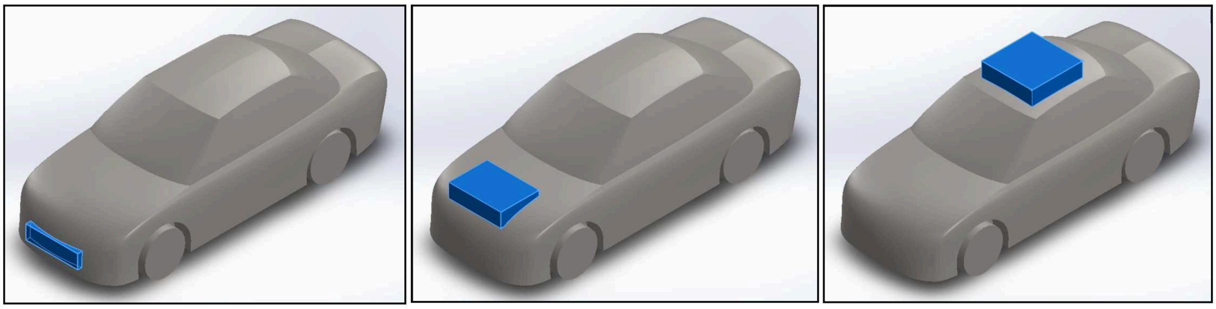

Fig.2: Three car models with different position of wind turbine.

Results and Discussions

Drag Coefficient. The model will be simulated by using the ANSYS FLUENT Software to obtain the C_d value. For this simulation, the car is assumed to be travelling at 25m/s (90km/hr). We will investigate the characteristics of the external flow around the car body in order to evaluate the aerodynamic performance of the car when the wind turbine system is mounted in different position of the car body. The distribution of velocity contour around the car model is shown in Fig.3 to 6. Based on the result shown, different position of the wind turbine mounted on the car body will affect the distribution of air velocity around the car while it moves with a certain speed.

Fig.3 shows the distribution of air velocity around the car without any wind turbine system installation. It is clearly shown that the highest velocity is on the top or on the roof of the car. This proved the reason why most design by inventors based on this idea will place the wind turbine system on the roof of the car. The idea is that high wind speed velocity in that area will help to rotate the turbine blade with maximum speed and thus generate more electricity.

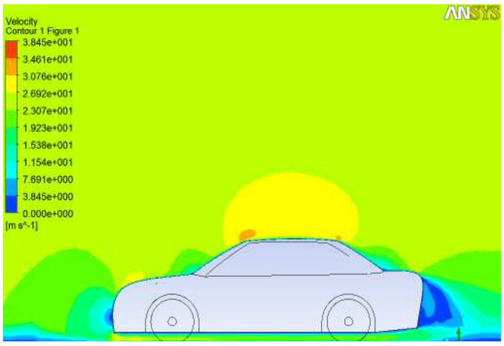

Fig.3 Distribution of velocity of air around car without wind turbine system.

The distribution of the air velocity around the car with the wind turbine mounted in the front bumper of the car is shown in Fig.4. This closely resembles the air velocity distribution shown in Fig.3. It means that the installation of the wind turbine in front of the car bumper does not really affect the aerodynamic performance of the car.

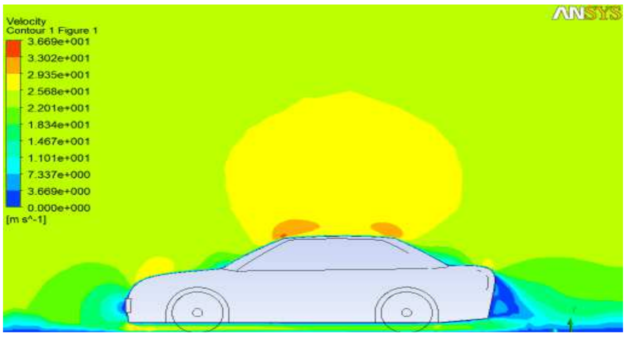

Fig.4 Distribution of velocity of air around car with wind turbine in front of the front bumper.

The installation of the wind turbine on the top of the hood and on the top of the roof of the car showed significant changes in aerodynamic performance of the car. Installation of the wind turbine system in both places has caused a change in the velocity distribution around the car as shown in Fig.5 and Fig.6. Based on the result shown in the figure, the low velocity area around the car body increased and this means that the pressure on the surface of the car body is expanded.

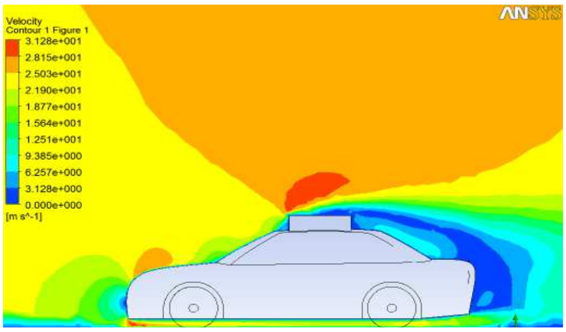

Fig.5 Distribution of velocity of air around car with wind turbine on the roof top.

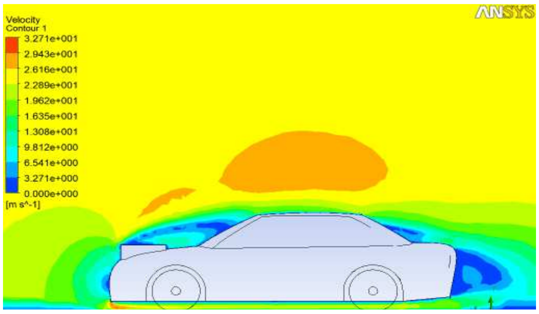

Fig.6: Distribution of velocity of air around car with wind turbine on the hood.

Table 1 shows the simulation result of drag coefficient of each model with different wind turbine system position. As shown in the table, there are no changes in the drag coefficient if the wind turbine is installed in front of the bumper compared to when there is no wind turbine system. Meanwhile, the drag coefficient for the simulation of the car model with wind turbine mounted on the top of the hood and on the top of the roof shows obvious changes.

Table 1 Drag Coefficient of Car Model with Different Wind Turbine position

Position	No wind turbine	Front	Hood	Roof
C_d	0.39	0.39	0.45	0.51

Referring to equation (1), the Drag Force, F_d is proportional to the Drag Coefficient, C_d. The higher the value of C_d, means the higher the value of the drag force of the car. Because of this, the drag force of the car becomes higher when the wind turbine is installed on the top of the hood or on the top of the roof of the car. Based on the study of other researcher, the value of drag coefficient C_d is to be around 0.38 for sedan car [5]. This is proven by this simulation where the drag coefficient of a car without the wind turbine is 0.39. Furthermore, besides the two major factors (the car and its travelling speed) that will influence the drag coefficient, any changes added to the car body, such as the installation of wind turbine on different area of the car will also affect the C_d value of the car.

Conclusion

The aerodynamic drag and air velocity characteristics around the sedan car with a wind turbine system were numerically investigated. Three car models with different wind turbine system position were simulated by ANSYS Fluent software to study the air flow characteristic around the car body and to determine the drag force of the car at a certain speed. A standard k-ε model was selected as the turbulence model for numerical simulation.

In this study, three positions of the wind turbine system were presented, namely the front bumper, on top of the car hood and car roof. Installing the wind turbine system in front of the front bumper will not affect the aerodynamic performance of the car significantly, but the issue of whether the system will work efficiently due to low wind velocity in that section should also be taken into account. Installation of the wind turbine system on top of the car roof is a good idea as there is a high wind velocity in the area, but obviously it will also change the aerodynamic performance of the car. An increased in the drag force of the car will theoretically consume more power to move the car.

Several matters should be taken into consideration in realizing the idea for the design of the wind turbine system on a vehicle in the future. The efficiency of the system is the main concern because it will influence the electric power generation. In terms of power generation, the focus should be on how the system can produce power great enough to be used in the car system.

Besides that, the position to install the wind turbine system as performed in this study will also affect the aerodynamic performance and the power consumption. The installation of the system in any area of the car body should also consider its suitability because it may affect other system of the vehicle. Last but not least, the aesthetic value also should be taken into account. The installation of wind turbine system on the car body will affect the appearance of the car.

Acknowledgement

The present work has been supported by Ministry of Education Malaysia under Exploratory Research Grant Scheme (Vote No. E034).

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