

Vehicular air drag production at different road geometry in Palawan, Philippines

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Abstract

Vehicular air drag production is a neglected source of wind energy. One major factor that make this wind harvesting difficult is determining the proper location and time that would provide the greatest wind velocity for use in micro-wind technology harvesting. In this study, the road geometry, time of the day and the type of vehicles were considered in the vehicular air drag production and were analyzed using MATLAB Statistical tools. Results showed that these factors significantly affect the production of vehicular air drag.

Keywords: vehicular air drag, wind speed, road geometry, wind energy harvesting

1. Introduction

Harvesting wind energy is one of the most studied renewable energy concepts nowadays. The indispensable dependence of man on electricity led to the exploration of the different ways of harnessing wind. There exists another form of wind energy which is from the pressure produced by the air on the vehicles that move along the road, commonly referred to as the vehicular air drag. But a drawback of harvesting this kind of wind energy is that it is dependent on the presence of the moving vehicles. Air drag is simply defined as the resistance of the air in opposition of the moving object [1]. It is momentary and needs micro-wind technology for it to be converted and utilized. And thus, there is a need to find the optimum location and the road structure where this energy would be greatly harnessed.

One of the factors that affect the production of vehicular air drag is the speed of the vehicle. Studies found out that road geometry have a significant effect on the speed of the vehicles [2-5]. Survey conducted by [6] indicated that drivers increase speed on open straight paths as compared to horizontally or vertically curved road. Drivers have the tendency to decrease speed along curved paths and in bad weather [7].

Vehicular air drag is seen as a negative factor that slows down the speed of the vehicle and researches most often focused on reducing it [7-12]. But since the air is present everywhere, air drag could be reduced but not ultimately be avoided. The air will break and will flow to the different parts of the vehicle and will create a force, this force is felt on the side of the road where the vehicle passed, and it could be captured. The formula for the calculation of vehicle or any solid body opposition to the air can be obtained using equation (1) which is the density of air flow:

$$\rho = \frac{m}{Q} \text{ kg / m}^3 \quad (1)$$

where m = mass (kg)

Q = volume (m³)

ρ = density of air flow (kg/m³)

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Vehicular air drag produced also differs depending on the shape. Computed drag coefficient for certain shapes such as Circular disc = 1.15, cube = 1.05, 60 ° cone = 0.5, sphere = 0.47, hemisphere = 0.42, tear drop = 0.05, were used to design the body of vehicles to lessen the drag force and optimize the performance of the vehicle [8]. Equation for drag coefficient was derived to be:

$$C_D = \frac{2F_D}{\rho AV^2} \quad (2)$$

where F_D = drag force ($\text{kg} \cdot \text{m/s}^2$)

ρ = density of air flow (kg/m^3)

A = Frontal Area (m^2)

V = Air speed (m/s)

Height of the vehicle, as studied by [13] also contributes to the production of air drag of a vehicle since height determines the allowance of air passage above and underneath the body which affects force distribution of the air.

Another factor needed to be considered in vehicular air drag production is the time of harvesting. While rush hour is common to cities, rural provinces rarely have traffic issues and thus vehicles travel faster in spacious roads and thus have the potential for higher production of air drag [14]. In these places, people tend to go on the road going to work, or school, during lunch break and after work or after class. Surveys usually schedule the observation based on morning (6 – 10 am), noontime (12 – 4 pm) and evening (6 – 8 pm) [14, 15].

The objectives of the study include the determination of the effect of the road type to wind energy production; determining the time of the day where vehicular air drag would be strongest and longest; and to determine the effect of the type of vehicle in vehicular air drag velocity.

2. Methodology

2.1. Selection of road type

Straight and slope road areas were selected based from the factors considered in the previous studies [3-5]. Straight roads must not be less than 500m long, and must have no obstacles such as pedestrian lanes, houses, or stores or trees. Vertical slope roads must have an inclination of not less than 10degrees, must not be near the bridge nor any horizontal curves, and must not have any obstacles.

Eight highways were selected in the study, 4 were straight highways and 4 were sloped and all are in the southern part of Palawan.

2.2. Schedule of data collection

The windspeed created by the vehicular air drag was measured in eight (8) different locations which have two (2) types of road geometry, which is a straight stretch and a vertical curve. The observation was done in three (3) different times of the day (6-7am, 12-1pm and 5-6pm) for a span of seven (7) days. The time is selected based on [14, 15].

2.3. Data recording

Fig. 1 shows the process of data gathering. The instrument used to measure the air drag created by the vehicles is a handheld digital anemometer placed in a stand on the roadside and a camera was placed in front of the anemometer to record the values from the instrument along with the passing vehicle. The stored video was reviewed and individually encoded. The tabulated data was used in the predictive modeling of the vehicular air drag production.

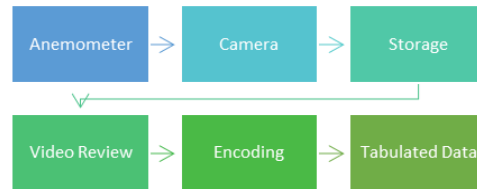


Fig. 1. Block diagram of data recording process

2.4. Data analysis

The analysis of 1370 data set was done in MATLAB and the results were used to create a predictive model for vehicular air drag production using the road geometry, time of day and vehicle type as the factors.

3. Results

3.1. Road geometry and air drag

Straight and Sloped roads positively affect the wind speed production of the vehicular air drag. Fig. 2 shows the distribution of data for the straight (blue) and sloped (green) road geometry. By observation, there are larger values of wind speed data in the straight roads, but high values of wind speed are scattered for the sloped roads. Analysis showed that higher wind speed could be produced at straight stretch of a highway as compared to the sloped vertical curvature.

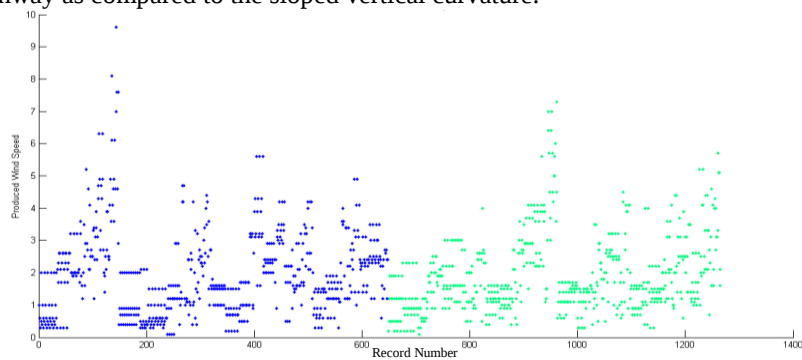


Fig. 2. Relationship between road geometry and air drag

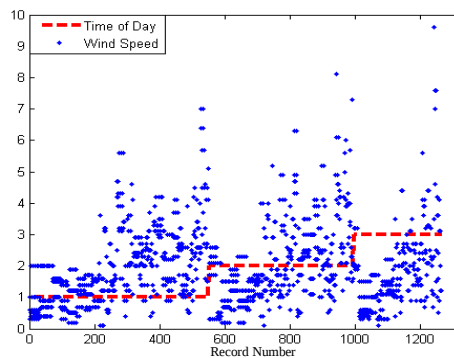


Fig. 3. Relationship between time of the day and air drag

3.2. Time of the day and air drag

Time of the day did not clearly show higher wind speed outputs as shown in Fig. 3. As it was observed that fewer vehicles were on the road during afternoon to evening, it would also indicate fewer air drag

produced during this time of the day. But the analysis of the results showed that the noon time produced the significant values of produced wind speed as compared to other time spans.

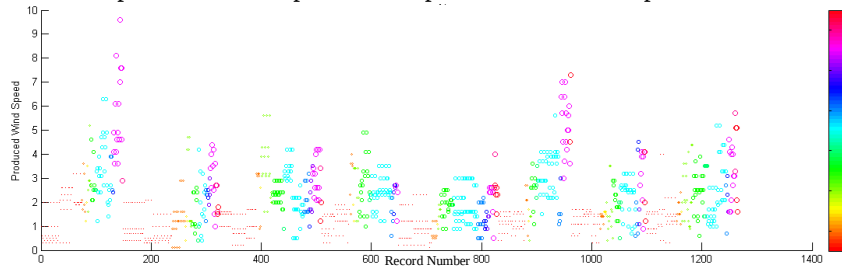


Fig. 4. Relationship between vehicle type and air drag

3.3. Type of vehicle and air drag

Fig. 4 represents the distribution of data according to the built of the vehicle. The color bar represents the built of the vehicle from smallest to largest. As was discussed earlier, the frontal area and the size of the vehicle largely contribute to air drag production. Results showed that air drag produced by large vehicles could reach as fast as 9 m/s, while faster light vehicles could produce as high as 2 m/s.

A significant effect of the body type to the produced air drag was observed and the truck, which is the largest vehicle, consistently has the highest produced air drag.

3.4. Prediction model using gaussian linear regression

1370 set of data was trained and tested using Gaussian Linear Regression Learning Model in MATLAB. Fig. 5 shows the response plot of the predicted and actual values and Fig. 6 shows the fit of the actual plot and the ideal response. The trained model was exported, and another set of data was tested in the model. The comparison of the resulting values was shown in Table 1.

The resulting equation on how the major variables affect the air drag production can be written as:

$$VAD\ production = 0.106RG + 0.263VT - 0.077TD \quad (3)$$

where: RG – road geometry

VT – vehicle type

TD – time of the day

The model can still be improved by adding other factors which are not covered in this study but are directly involved in the vehicular air drag production.

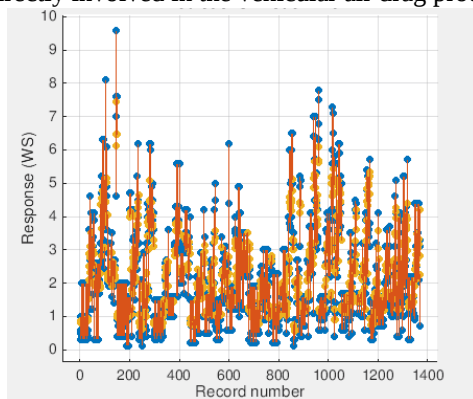


Fig. 5. Response plot of trained model

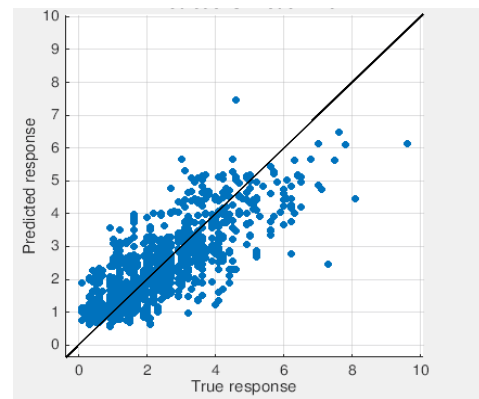


Fig. 6. Predicted Vs. actual plot of the model

Table 1. Comparison between training and testing

	RMSE	R2	MSE	MAE
Trained	0.7836	0.61	0.61416	0.58158
Tested	0.03949	1.00	0.0015595	0.0022978

4. Conclusion

Vehicular air drag production emerges to be an alternative source of wind energy affected by many factors. This study dealt with three factors that directly affects the production of the vehicular air drag.

The road type has a significant effect on the air drag production as the vehicles tend to go faster on a straight highway compared to the sloped ones. The time of the day did not increase air drag production even though the vehicles went faster during afternoon, there are less vehicles that travel during the said hour. The vehicle type positively affects the air drag production, larger vehicle produces higher air drag, but the production is also influenced by vehicle speed.

Considering only three major factors which affect air drag production could not fully define vehicular air drag production. Further study could consider the natural wind present in the area, the speed of the travelling vehicle and the number of lanes of the road.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Author A conducted the research, analyzed the data and wrote the paper, Author B edited, reviewed and proofread the paper. All authors had approved the final version.

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