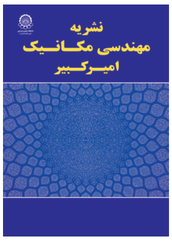

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Investigation of the Effect of Longitudinal Distance Between Two Cars on Fuel Consumption and Drag Coefficient

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ABSTRACT: According to the development of technology of automated highways, the platooning can be benefited for improvement in fuel consumption. Platooning has already been exercised in the nature and industry as an effective tool to reduce the drag coefficient. The goal of this article is to investigate the effect of longitudinal distance between two passenger cars on drag coefficient and hence the fuel consumption numerically and experimentally. It has already been shown by various investigators that a passenger car travelling in the wake of another car will experience a reduction in drag coefficient. The optimized distance and speed to attain the least drag coefficient and fuel consumption are reported. The car's speeds of 70, 90 and 110 kilometers per hour have been examined in this study. To evaluate the numerical results, some field tests are done. A device which was particularly designed and fabricated to measure the fuel consumption was installed on a sedan midsize car. The results show that the car platooning with an optimized longitudinal distance between two cars can reduce the drag coefficient by 7 percent.

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1- Introduction

The wake of the lead car can result in reduction of pressure difference between front and the back of the rear car, which causes the reduction in drag coefficient of the rear one. The development of the automated highways and using electrical automobiles provide the chance of smaller longitudinal distance between cars and yet meet the safety measures.

Wind tunnel tests have been carried out by previous investigators to study the effect of longitudinal distance between cars on the drag coefficient of each one in 2, 3 and 4 car platoons [1]. The results show that the drag coefficient of the lead car is less affected as the longitudinal distance between cars is increased. As the longitudinal distance between two cars moving in a platoon increases, the drag coefficient of the rear car increases at first but in a special distance it begins to fall and it can be lower than the drag coefficient of a single car [2].

The results of full-scale field tests showed an acceptable agreement between the field and the wind tunnel tests [3].

To enrich the available data, this study aims to numerically and experimentally investigate the effect of drag coefficient on fuel consumption of the car. A 2D simulation of single car and two cars in tandem is performed in ANSYS-FLUENT. The numerical results are related to three speeds of 70, 90 and 110 kilometers per hour and different longitudinal distances between cars. Then to evaluate the numerical results some field tests are done using a device which was particularly designed and fabricated [4] to measure the fuel consumption of the car. An appropriate distance and speed based on both lead and rear cars scoring the least drag coefficient and hence the least fuel consumption is reported by using the Artificial Intelligence MATLAB Code.

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2- Methodology

2- 1- Numerical simulation

The sedan car chosen for the numerical simulation is a Daewoo Cielo made in 2002. The 2D model of the car is imported from SOLIDWORKS into ASNSYS-FLUENT. The domain including single or two cars is 3 to 4 times greater than the dimension of the objects. The no-slip condition is established on all walls. The horizontal wall of the domain is set to be the 'Moving wall' in order to prevent the formation of boundary layer on the bottom wall and its effect on the results of drag coefficient. The mesh type used for the single car domain is 'Quadrilateral' and the one used for two car domain is the method of 'Multi-Zone' meshing in which the elements are much smaller on the walls and more important regions. The independence of the numerical results on the mesh sizes has been investigated. The turbulence model is the k-epsilon method and the error is set to be 10^{-4}.

2- 2- Field tests

The conditions in which the field tests should be done, is considered according to SAEJ1082, one of the standards of the Society of Automative Engineers (SAE). The field tests are done at 70 kilometers per hour speed for cars and a distance equivalent to twice the length of the car is set between them. According to the standard, the appropriate travelling distance is about 6.7 kilometers in these tests.

3- Results and Discussion

3- 1- Results of the numerical simulation

The drag coefficient of the single car is calculated for three speeds of 70, 90 and 110 kilometers per hour. The results for the drag coefficient of two tandem cars is reported in the form of normalized drag coefficient which is the ratio of the drag coefficient of each car to the drag coefficient of a single car in the absence of the other car at the same speed. To provide the ability for comparison, the results of wind tunnel [5] are shown in Fig. 1. For instance the result for two tandem cars at the speed of 70 kilometers per hour is shown in Fig. 2. The trend of the results obtained at other speeds is similar to the results at this speed.

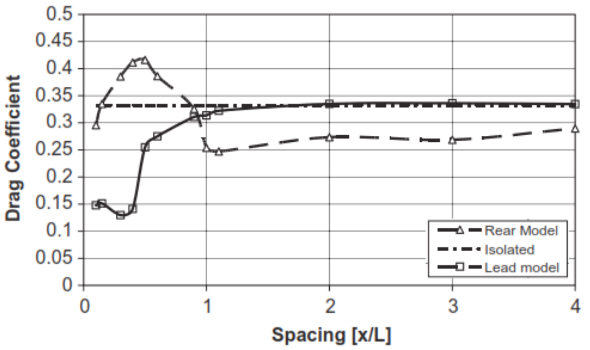

Fig. 1. Drag coefficient of two tandem Ahmed bodies in wind tunnel [5]

As can be seen from Figs 1-2, similar behavior is obtained. The only difference is in the distances in which the drag coefficient and hence the fuel consumption have the least amount.

3- 2- Optimizing the numerical results

Artificial Intelligence MATLAB Code is used to get access to drag coefficients of two tandem cars at different speeds with different distances between them. Using 70% of the data obtained from numerical solution for training, 15% for validation and 15% for test, the efficiency of the code will be 98.59%. Introducing the minimum drag coefficient for both tandem cars as the minimum of the summation of the drag coefficient of both cars, a 3D plot is generated as in Fig. 3.

In Fig. 3 the distance and speed in which the drag coefficient of both cars is minimum, will be the optimum distance between cars at the optimum speed. So the optimum distance for two tandem cars will be 1.4 car length at the optimum speed of 81 kilometers per hour. In this case 7% reduction in drag coefficient occurs.

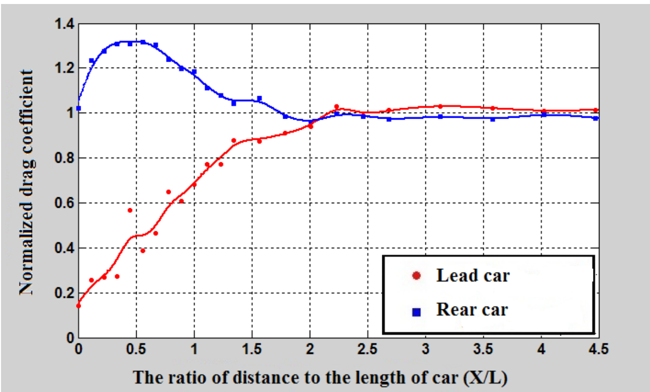

Fig. 2. Variation of the normalized drag coefficient of two vehicles in tandem with the ratio of inter-vehicle distance to the vehicle length at 70 Km/h vehicle speed

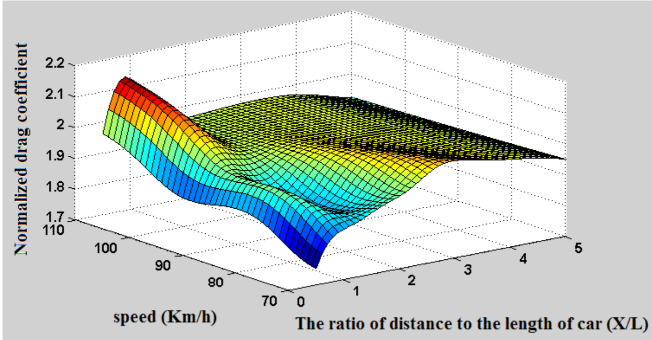

Fig. 3. Three-dimensional variation of the sum of normalized drag coefficient for both vehicles with vehicle speed and the ratio of distance to vehicle length

3- 3- Field test results

Considering the speed of 70 kilometers per hour, the distance of two car length between cars and repeating the tests for 2 or 3 times the mean fuel consumption for the single car, lead car and rear car will respectively be 291.13, 255.36 and 264.02 grams. These results show a similar behavior for the drag coefficient as the cars move in tandem.

3- 4- Comparing results of numerical simulation and field tests

The summary of the results for the speed of 70 kilometers per hour and two car length distance between the cars is reported in Table 1.

Table 1. Summary of the field test results for two vehicles in tandem with the inter-vehicle distance of two vehicle length and vehicle speed of 70 Km/h

	Single car	Lead car	Rear car
Normalized fuel consumption	1	0.88	0.91
Normalized drag coefficient	1	0.94	0.96

The results of Table 1 show that as the drag coefficient decreases while the car is moving in the wake region of the lead car, the fuel consumption reduces. This demonstrates that although many factors affect the fuel consumption of the cars, one of the important factors influencing the fuel consumption is the drag coefficient which identifies the aerodynamic condition of the car.

4- Conclusions

It can be concluded that cars travelling in tandem can effectively reduce their fuel consumption, especially for the case of automated highways in which the distances between the cars face less restrictions. The possibility of reducing the distance between cars in automated highways can increase the capacity of the highways, decrease the fuel consumption and pollution. According to the results obtained from optimizing the numerical simulation, the optimum distance is 1.4 car length at the optimum speed of 81 kilometers per hour.

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