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Experimental Study of Fluctuations, Parameters and High-Order Values of Velocity in Wake Region of a Model Car

V. Barzanooni, A. Bak Khoshnevis*

Mechanical Engineering Department, Hakim Sabzevari University, Sabzevar, Iran

ABSTRACT: In this study, an experimental analysis is conducted to explore effects of placement distance of a model trailer on dynamics of flow as well as the higher-order parameters of velocity including flatness and skewness in wake region of a Notch back model car. In addition, variation trend of Strouhal number and mixed length scale are depicted. All the experiments are conducted in the aerodynamic laboratory of Hakim Sabzevari University. In order to measure property of the flow, the researchers have made use of a wind tunnel and hot wire anemometer produced by Farasanjesh-e-Saba company. The results indicate that the values of skewness in the lower heights (near to ground) are less than their values in the upper heights (near to roof of model). This behavior is inversed as the distance from the car increases. The values of flatness, also gradually decrease by an increase in the distance from the car. The Strouhal number often reduces by increase in the distance of the car from trailer and the mixed length scale in the width of trailer often has one or two maximum peaks. The wake of trailer in positions near the car is not effective in the formation of maximum peaks of mixed length scale sites.

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1- Introduction

In spite of the fact that turbulence is one of the very old issues in fluid mechanics, it has been remained unresolved. This phenomenon generally exists in most of the issues related to energy transformation, fluid flow, transmission systems, etc. [1]. The possible method for description of turbulence, with the help of general laws of continuum mechanics, was established by Reynolds at the end of the previous century. In this method, the field velocity of turbulence is decomposed into two main components; one is related to the average motion and the second, to the time-dependent fluctuations of fluid velocity. The higher level co-relational functions including skewness and flatness, lead to the improvement of comprehensiveness of the specific turbulent model in terms of statistics.

Homogeneous Isotropic Turbulence (HIT) with a negative skewness determined in the velocity differentiation of $(\partial u_i/\partial x_i)$ in which u_i is the fluctuating component of velocity across x_i. Skewness is defined as follows [2]:

$$S_u = 1/N\sum_1^N \frac{\left(u(n)-\overline{U}\right)^3}{\sigma_u^{\,3}} \tag{1}$$

The theoretical predictions for skewness and its dependency to turbulent Reynolds' number defined as $\lambda u'/v$ in which u' is fluctuation of velocity, λ is micro-scale of tailor and v is kinematic viscosity, have been widely considered in the past. While Kolmogrov [2] has argued that S should be kept constant, other researchers based on the subsequent discussions of Kolomogrov [3], have maintained that with an increase in Re, there should be an increase or decrease in S [4].

There has been a lot of experimental and numerical researches on different models of cars so far. Ahmed et al. [5] considered a simple model car, experimenting different models with different angles of the behind mirror. Precise experiments on this model are conducted in other studies [6-7].

Turbulence will be distributed by pressure fluctuations and velocity in the field. Statistical properties are sensitive to anisotropy and for the analysis of this anisotropy we can make use of statistical quantities. This anisotropy can be related to the turbulence and therefore with an increase in the mixture, the anisotropy increases and some flow parameters like the third and fourth normal statistical moments (skewness and kurtosis) increase as well. In the present study, the existing statistical parameters between the higher order velocity values are investigated.

2- Methodology

Measuring the characteristics of flow in this experimental endeavor was performed by using hot wire anemometer in a low velocity wind tunnel. The wind tunnel had a test section with a length of 168 cm and a width and height of 40 cm. The appropriate design of the tunnel leads to the creation of free flow turbulence intensity of about % 0.1 in the direction of the flow and the intended device has a high accuracy. Maximum velocity is 30 m/s and inflow is 10 m/s in this experiment. The experimented models were a simplified model of a Notch back car model and an eight class trailer model without accessories like mirrors, antenna, wheels, etc. Considering the blockage coefficient of determination is the first point in creating the model. In order to ignore the effect of fluid flow on the lateral walls of the test section on the surface of model, the suggested values for the blockage coefficient were in a range of 0.05 to 0.1. In this research, the selected value for this coefficient, based on the experimental conditions and the wind tunnel, is 0.09 based on which the scale of models

Corresponding author, E-mail: khosh1966@yahoo.com

is 1:75. In these experiments, at first, the model car was independently exposed to the flow and then it is positioned in distances of 0.01, 1, 2, 3 and 4 times the length of trailer and behind it. In each case, data gathering is conducted in the distances of 0.01, 0.25, 0.50, 0.75, 1, 1.25 and 1.75 times the length of the car at its behind.

3- Results and Discussion

In Fig. 1, at the *x/l*=0.01, anisotropy in the instantaneous velocity of flow in the lower part of the vehicle and output flow is very high. The skewness curve has a minimum. With increase in height from the ground, the skewness values are positive, reaching to the maximum. In this position, with increasing distance from the end of model cars, anisotropy values and the maximum peaks of skewness increases are transferred to the higher parts. By increasing distance of the vehicle from the model trailer, at position *X/L*=1, the anisotropy is much less in the lower position, Skewness in the initial position is zero but in other positions, it is positive. Instantaneous velocity, in the position close to the ground, is at the average speed range. In addition, the fluctuations and frequency are very low in this region. It can be concluded, that with increasing car distance from the model trailer, and in this position, mixing layer and output flow from model trailer beneath is led to the upper position. And after dealing with model car, passes from the upper part of the model and causes severe anisotropy in the upper part of the wake vehicle. In areas that the flatness value is less than 3, almost all the instantaneous velocity is lower than the average velocity. As seen in the skewness diagram, in the first position placement of the vehicle on the wake of model trailer, there exist the effects of anisotropy in the upper part of the model roof that are due to the shear layer separated from the roof of the trailer and entry the vortex to this area. In this area the flatness values are positive (greater than 3), and reflects the anisotropy and severe fluctuations in the instantaneous velocity in this region that away from the trailer, these effects are low.

4- Conclusion

In the present study, the existing statistical parameters between the higher order velocity values, namely skewness and flatness coefficients, in the behind wake of a model car are investigated.

Some of the findings of the present study are:

1. Large changes in the higher order moments close to the Gaussian values statistically leads to higher complexity of the wake flow arrangement compared to the free jet flow and other limited flows.
2. There are maximum points of skewness in the lower and upper heights of the wake and in these parts, the extent of mixture is higher.
3. In most of the cases, increase in the height of the wake of the car results in a decreasing skewness level.
4. In other cases, with an increase in the height, the kurtosis values have a downward decreasing trend and the probable density distribution curve becomes closer to the Gaussian density curve. At x/l=0.01 the process is the reverse, and in the lower heights the density distribution curve is equal to the Gaussian density distribution curve and with an increase in the height, the curve becomes more stretched and gets away from the Gaussian.

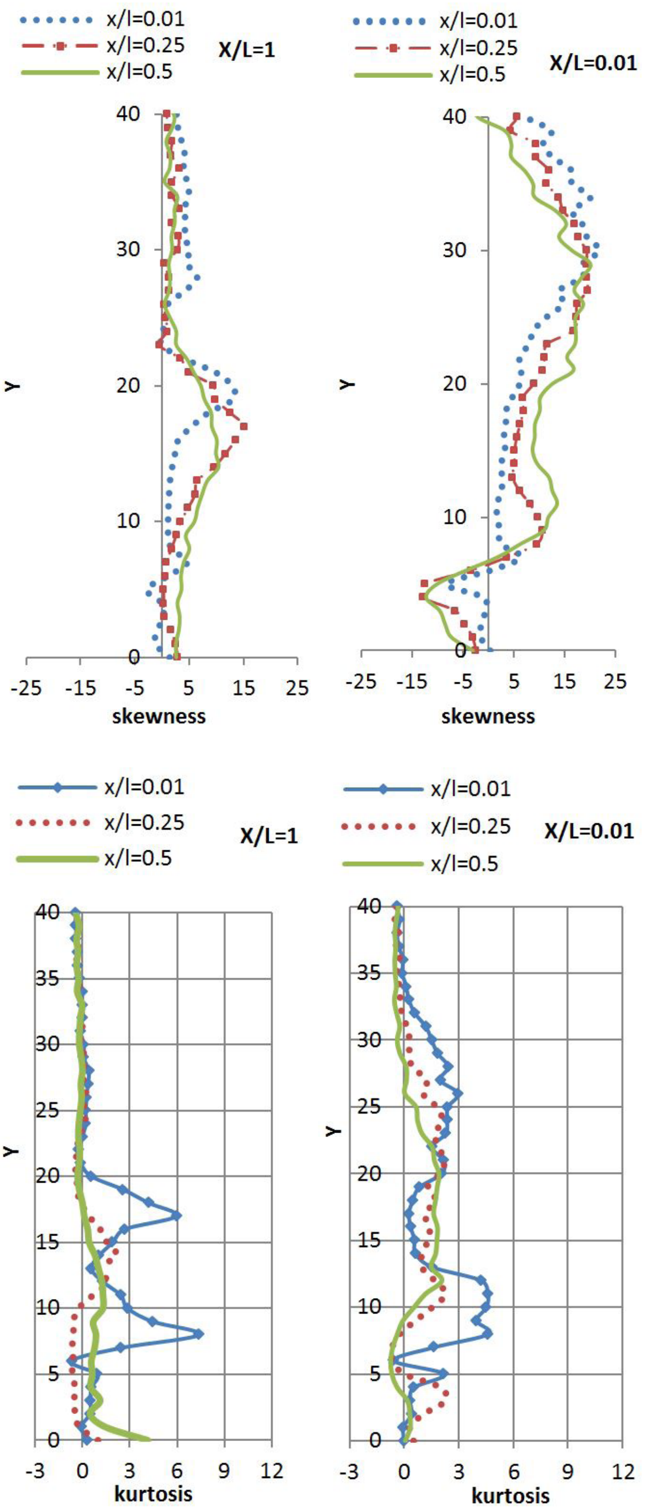

Figure 1. The process of change in skewness and flatness for different positions of car in the flat wake of the trailer

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