International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

A CFD Investigation into the Flow Distribution on a Car passing by a Truck

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Accepted 10 January 2014, Available online 01 February 2014, **Special Issue-2, (February 2014)**

Abstract

The flow distribution occurring on a car when it is passing by a truck is investigated using three dimensional (3D) Computational Fluid Dynamics. The free stream velocity over the vehicles was varied keeping the relative velocity of the vehicles equal to zero. This approach assumes that the relative velocity of the vehicles has a negligible effect on the flow distribution. The overtaking manoeuvre is analysed with the vehicles at three different static positions, with unsteady flow conditions. As the car passes the truck during an overtaking manoeuvre the flow around the two vehicles interact generating pressure variation over the car, this leads to adverse effect on the car handling and stability.

Keywords: *overtaking manoeuvre, pressure variation, car handling and stability.*

1. Introduction

As the car passes the truck during an overtaking manoeuvre the flow around the two vehicles interact generating pressure variation over the car. This pressure variation may lead to adverse effect on the car handling and stability (Corin, *et al*, 2008). This case is somewhat similar to the study of cross wind problems on vehicles. Sudden change of wind velocity in the wake of the truck causes rapid change of the Aerodynamic forces acting on a passing by car. This sudden change causes difficulty in controlling the vehicle which may result in miss-steering and an accident (Charuvisit, *et al*, 2004). To avoid such accidents, the behaviour of the light vehicle to such disturbances created by the heavy/large vehicle is difficult to evaluate and are still not clear (Charuvisit, *et al*, 2004). This paper is to investigate that how a car (light vehicle) passing by a truck (heavy/large vehicle) is affected by the flow disturbances created by the heavy vehicle.

The transient aerodynamic forces acting on a vehicle model overtaking another vehicle model was studied by Corin, *et al* (2008). However, the study considered was only two dimensional and the vehicle models overtaking each other were both similar.

The impact of the ratio between the relative velocity and the overtaken vehicle velocity ($k = V_r/V$) is an area of some debate (Corin, *et al*, 2008). Yamamoto, *et al* (1997) conducted a dynamic study on scale models and concluded that, for a velocity ratio of k<0.25 dynamic effects could be neglected and the problem could be modelled statically. Similarly, Telionis, *et al* (1979) conducted tow tank analysis on a greater range of velocity ratios and suggested that dynamic effects were insignificant upto k<0.4.

However, in the present study the velocity ratio considered is zero i.e., k=0. Since, the relative velocity between the vehicles is zero. This simplifies the problem and static analysis can be done. So, the dynamic effects can be neglected. Thus, the present study aims to clarify the characteristics of the Aerodynamic forces acting on a car passing by a truck using CFD for free stream velocities which are of typical motorway driving conditions. The overtaking manoeuvre is analyzed with the car at three different static positions.

2. Computational Parameters

Various parameters such as the free stream velocity (V_∞) and the position of the car (Δx, Δy) along the truck were considered. Three different free stream velocities (V_1=16 m/s, V_2=19 m/s, V_3=22 m/s) and three different positions of the car model (Δy_1, Δy_2, Δy_3) along the length of the truck were considered which are of typical motorway driving conditions.

Δx = lateral spacing between the vehicles
Δy = longitudinal spacing between the vehicles

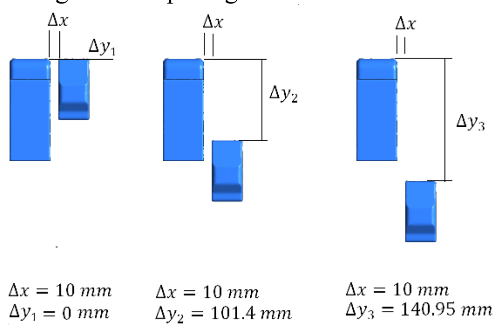

Fig.1 The three different Positions of the car

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3. Governing equations

Navier Stokes dimensionless form for Newtonian Viscous fluid is,

$$\frac{\partial u}{\partial t} + u.\nabla u + \nabla \mathrm{p} - \frac{1}{Re}\nabla^2 u = 0, \qquad \nabla. u = 0$$

For turbulent kinetic energy k,

$$\frac{\delta(\rho k)}{\delta t} + \frac{\delta(\rho k u_i)}{\delta x_i} = \frac{\delta}{\delta x_j}\left[\frac{\mu_t}{\sigma_k}\frac{\delta k}{\delta x_j}\right] + 2\mu_t E_{ij}E_{ij} - \rho\epsilon$$

For dissipation ϵ,

$$\frac{\delta(\rho\epsilon)}{\delta t} + \frac{\delta(\rho\epsilon u_i)}{\delta x_i} = \frac{\delta}{\delta x_j}\left[\frac{\mu_t}{\sigma_\epsilon}\frac{\delta\epsilon}{\delta x_j}\right] + C_{1\epsilon}\frac{\epsilon}{k}2\mu_t E_{ij}E_{ij} - C_{2\epsilon}\rho\frac{\epsilon^2}{ku_i}$$

u_i represents velocity component in corresponding direction

E_{ij} represents component of rate of deformation

μ_t represents eddy viscosity

$$\mu_t = \rho C_\mu \frac{k^2}{\epsilon}$$

4. Computational Setup

Commercially available CFD package was used for the analysis. The models were created using CATIA V5. The meshing and solving was done using ANSYS Workbench (Fluent).

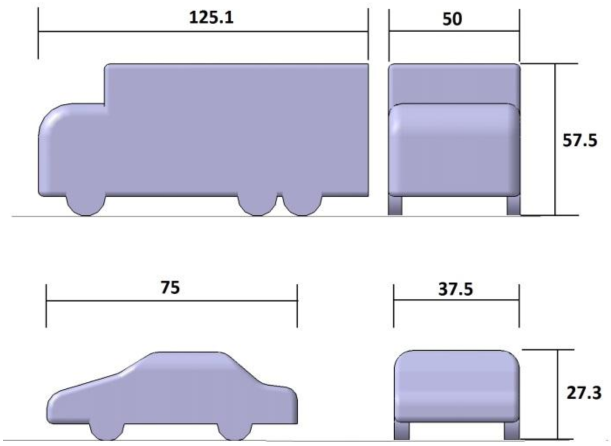

Fig.2 Dimensions of the car and truck models in mm

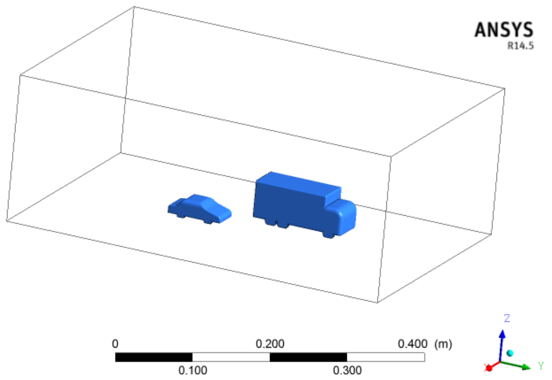

Fig.3 Computational domain for Δy_3 position of car

The computational domain size was slightly varied for the three different positions of the car. The minimum domain was set to 3 times the length of car along the width and 4 times the length of car along the length. A fine mesh was generated around the models.

Pressure based solver, 1st order Implicit Unsteady formulation with Green-Gauss cell based Gradient option was set, standard k-epsilon (2 equation) model with default values.

5. Results and Discussion

Figure 4 shows the Pressure distribution on the front side of the car at various positions (Δy_1, Δy_2, Δy_3) and for various free stream velocities (V_1, V_2, V_3).

A, E, I are the pressure distributions without the truck for V_1, V_2, V_3 respectively.

B, F, J are the pressure distributions at the position Δy_1 for V_1, V_2, V_3 respectively.

C, G, K are the pressure distributions at the position Δy_2 for V_1, V_2, V_3 respectively.

D, H, L are the pressure distributions at the position Δy_3 for V_1, V_2, V_3 respectively.

Fig.5 shows the Pressure distribution on the side of the car towards the truck which is most influenced by the truck for various positions (Δy_1, Δy_2, Δy_3) and for various free stream velocities (V_1, V_2, V_3).

a, e, i are the pressure distributions without the truck for V_1, V_2, V_3 respectively.

b, f, j are the pressure distributions at the position Δy_1 for V_1, V_2, V_3 respectively.

c, g, k are the pressure distributions at the position Δy_2 for V_1, V_2, V_3 respectively.

d, h, l are the pressure distributions at the position Δy_3 for V_1, V_2, V_3 respectively.

Fig.7 shows the graph for change in Coefficient of Lift (C_L) at various positions. The C_L is maximum at Δy_1 and it is clear that there is no significant variation for different velocities on coefficient of lift, as more the velocity more is the lift coefficient.

Fig.8 shows the graph for change in Coefficient of Drag (C_D) at various positions. When the car is at Δy_1 position there is a significant drag on the car and at Δy_3 there is a drop in the drag Coefficient.

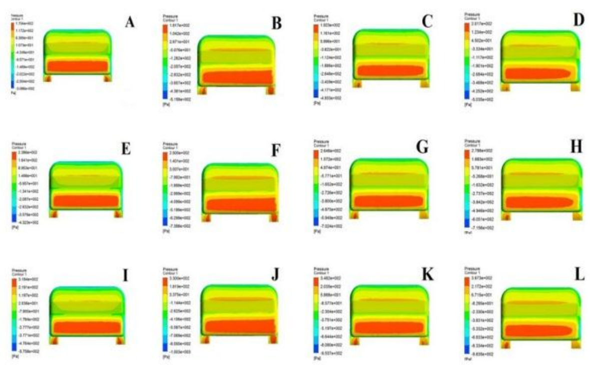

Fig.4 Pressure distribution on the front side of the car at various positions

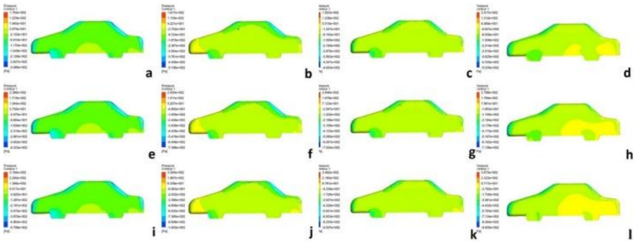

Fig.5 Pressure distribution on the side of the car towards the truck

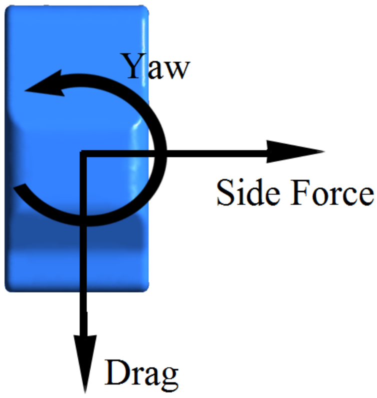

Fig.6 Representation of forces and Yaw moment on car

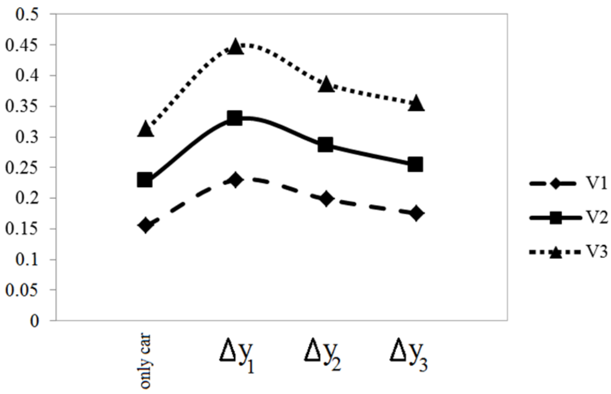

Fig.7 Coefficient of Lift (C_L) at various positions

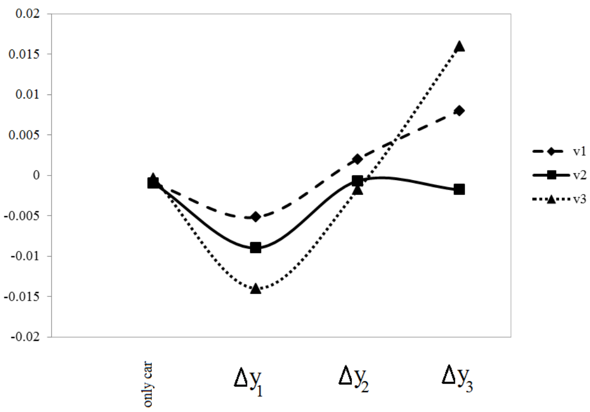

Fig.8 Coefficient of Drag (C_D) at various positions

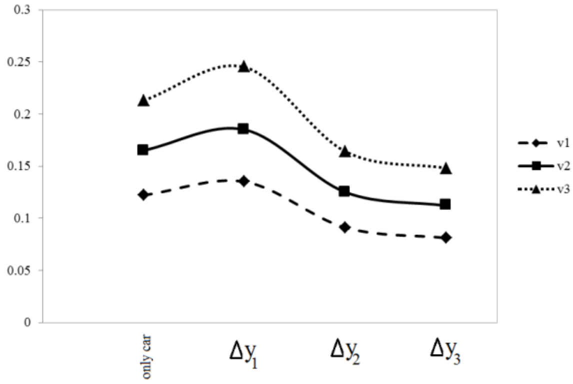

Fig.9 Coefficient of Side Force (C_{SF}) at various positions

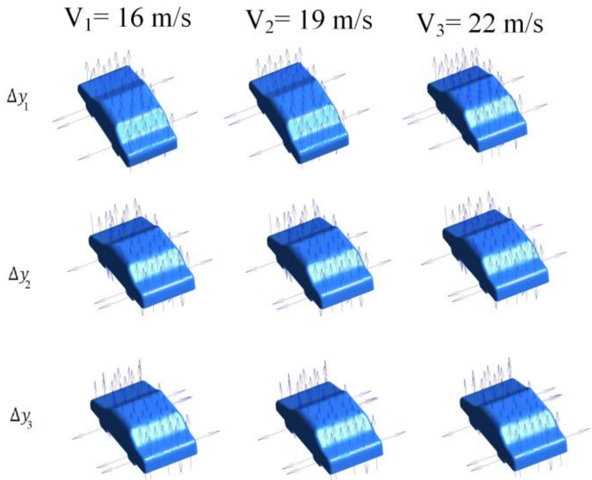

Fig.10 Normal forces for different Velocities and positions

Figure 9 shows the graph for change in Coefficient of Side Force (C_{SF}) at various positions. There is a significant change in the values of C_{SF}, at Δy_1 it is in negative direction and approaching to zero at Δy_2 and moving in positive direction at Δy_3. The increase of C_{SF} is observed with increase in free stream velocity.

Figure 10 shows the Normal forces for different Velocities and positions. At Δy_1 the forces acting on the car are tending to turn the car towards the truck generating an Anti-clockwise yaw. The direction of yaw is shown in Fig.6. At the position Δy_2 the forces acting on the car result in a yaw in Clockwise direction. At Δy_3 the forces result in an Anti-clockwise yaw.

6. Conclusion

The car when in an overtaking manoeuvre passing by a truck is constantly undergoing a yaw moment which is changing its direction. This may lead to adverse effect in car handling. The magnitude of the yaw moment may be small but, with the effect of cross wind the magnitude may be much larger. Analyzing the Aerodynamic forces on a car overtaking a heavy vehicle in the presence of cross wind is needed to understand to avoid car handling issues.

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