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Study of Cross Wind for Heavy Vehicles and Analysis over Ahmad body

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Abstract— The vehicle in motion is affected by different aerodynamic forces and moments which affects the driving characteristics and other parameters of vehicle. Rapid rise in fuel cost made researchers to focus on reduction of drag. The aerodynamic forces and moments other than drag have high impact on lateral dynamic characteristics of vehicle. [1] In Baker and Reynolds in 1922 made a survey of wind induced accidents. This made study of crosswinds important. In these paper simulations are done on simple Ahmad body and modified Ahmad body for reduction of cross-wind effect on vehicles subjected to heavy cross-winds. The results obtained from the simulations are presented for different yaw angles, showing effect of various moments and forces acting on vehicle. Various pressure contours, velocity vectors etc. plots and graphs are plotted to closely understand effect of cross-winds on vehicle body. It was observed that yaw moment and rolling moment reduced which increases stability of vehicle with slight sacrifice of drag.

***Index Terms*— Cross wind, Aerodynamics force and moments, Ahmad body.**

I. INTRODUCTION

In Cross wind, resulting flow of air is at an angle to the direction of motion of vehicle. Figure 1 shows under yaw flow the resulting forces and moments.

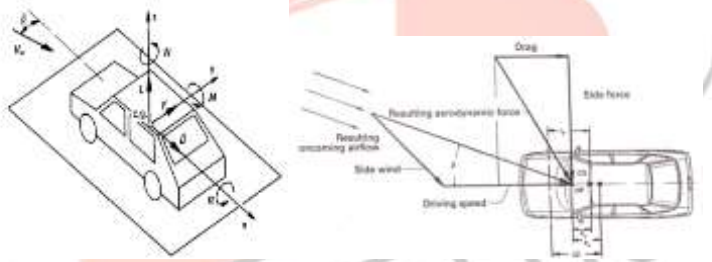
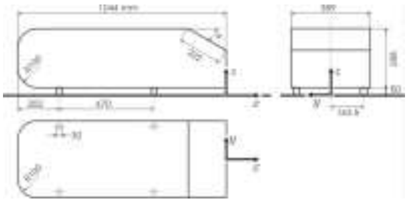


Figure 1. Resulting aerodynamic forces and moments. [8]

To satisfy the need of modern society for efficient, safe and convenient transportation systems many superways and bridges of long span have been constructed all around the world. Due to this impact of cross-wind on vehicles running on such roads is increasing continuously. This result in increased instability of vehicles and accidents occurs. According to Transport Administration of Public Security Ministry of China 2014 3.9 million accidents were occurred due to effect of cross wind on road vehicles [1]. From report of Traffic Accidents in North America it was observed that 11% of commercial vehicle accidents were related to crosswind. Also 19% of accidents were related to crosswinds in windy areas like Ontario, California, and New Mexico. Along with this Klein and Jex stated that 75% of control problems and snaking are wind related [2]. Commercial vehicles such as trucks operate significant fraction of life on highways and bridges. This concludes that heavy commercial vehicles are subjected to cross-winds. Trucks are more sensitive to cross-winds as they are lengthy than most of ground vehicles. Due to these accidents like roll-over takes place in windy areas of China, England, Germany, and North America. MacAdam et al [3] from their experiments concluded that distance between 3 points center of pressure, neutral steer and center of gravity plays a vital role to improve cross wind sensitivity. F. Cheli et al [4] measured aerodynamics moments and forces by means of six components dynamometric balance at different turbulence conditions and yaw angles. More attention was given on high-sided lorry on flat ground condition in order to understand pressure distribution on lorry surfaces and to get clear idea of flow pattern around vehicle. Finally, investigation of unsteady aerodynamic forces and moments was analyzed at different high turbulence conditions. R. Corradi et al [5] carried out wind tunnel experiments to evaluate sensitivity of different testing parameters on aerodynamic forces and coefficients of different testing parameters. The effect of the exposition (upwind or downwind), infrastructure scenario (flat ground, double viaduct, single and embankment), and of trailed unit on the aerodynamic loads acting on the vehicle was observed. David Hoyt Wafer [6] analyzed lateral response of 3-trailers using package TruckSim® the simulation Simulations were done with constant and random crosswinds aerodynamic and load configurations with several different arbitrarily defined crosswinds. From simulations it was observed that Increase in aerodynamic side-force coefficient of trailer 1 decreased the lateral displacement of the vehicle and vice-versa for both constant and random crosswinds. Increasing or decreasing the aerodynamic side-force coefficient of trailers 2 and 3 increases or decreases (respectively) the relative displacement of each trailer to its preceding unit. Takuji Nakashima et al [7] carried out simulation with conventional quasi-steady analysis and fully coupled

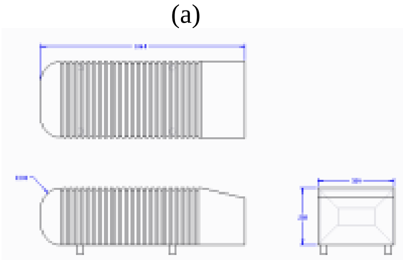
method with considering driver's reaction on truck subjected to sudden crosswind to know effects of unsteady aerodynamics on vehicle motion. From simulations authors concluded that fully coupled method is best suited for driving stability and safety analysis.
In relation with above papers, in this paper simulations are done on simple Ahmad body and modified Ahmad body for reduction of cross-wind effect on vehicles subjected to heavy cross-winds as follows

1.1Geometry



(a)

(C)



(b)

(d)

Figure 2. (a) 2D Ahmad body (b) 2D Ahmad body with Slots (c) & (d) 3D Ahmad body model.

2. CFD METHODOLOGY
CFD methodology is explained below:
2.1Mesh Generation:

A virtual wind tunnel of Width (W), Length (L), and Height (H) was created, which is shown in figure 3. The blockage ratio of 3% is assumed and Reynolds number 1.99 X10^{6} was calculated. The surface mesh is created on the body and a volume mesh is generated between surface of body and wind tunnel domain. 3 different control volumes are considered as show in figure 4. They are considered because finer mesh is required near the vehicle body and there should be smooth transition from finer mesh to coarse mesh. As air flow passes the surface it crates boundary layer. Boundary layer thickness is calculated as 22mm and there are12 prism layers with growth rate of 1.15. Number of cell counts are 1 million. The prism layers are shown in figure 5. Polyhedral type mesh is used to generate the volume mesh because of its some advantages like faster converge with less iteration, robust convergence to lower residual values, faster solution runtimes.

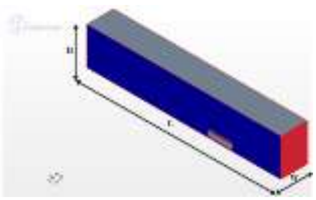


Figure 3.Vertual Wind Tunnel

Figure 4. Mesh with 3 different control voulme

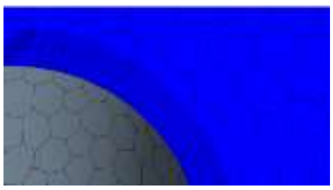


Figure 5. Prism layer

2.2. Solver Setup:

Star CCM+ CFD tool was used for this analysis.Reynold averaged navier stokes equations are used to solve for incompressible turbulent flow .A standard k-ϵ Turbulent model was used as it has advantages like robustness and easy converged. The simulation performed is steady state simulation. The solver type used was segregated flow. For one simulation CPU time Lenovo 2.8GHz windows based is approximately 12 hours. Following table, no 1shows the boundary conditions used.

Table 1. Boundary conditions

Boundary	Boundary condition	Value
Inlet	Constant Velocity Inlet, Turbulent viscosity ratio	V=27m/s I=10
Ahmad body	No slip Stationary Wall	-
Symmetry Plane	Symmetry Plane	-
Walls	Slip Stationary Wall	-
Outlet	Pressure Outlet	Constant Pressure 0 Pa

3. RESULT AND DISCUSSION

In this section the results obtained from the simulation are shown below:
The kinetic energy of air flow over an Ahmad body is converted into the pressure energy. Pressure counter shows the energy losses over body as shown in Figure 6. More resistance is observed over frontal area which offers resistance to motion of vehicle. Rear of body experiences the low pressure. The pressure difference creates the aerodynamic drag which offered resistance to motion of body.

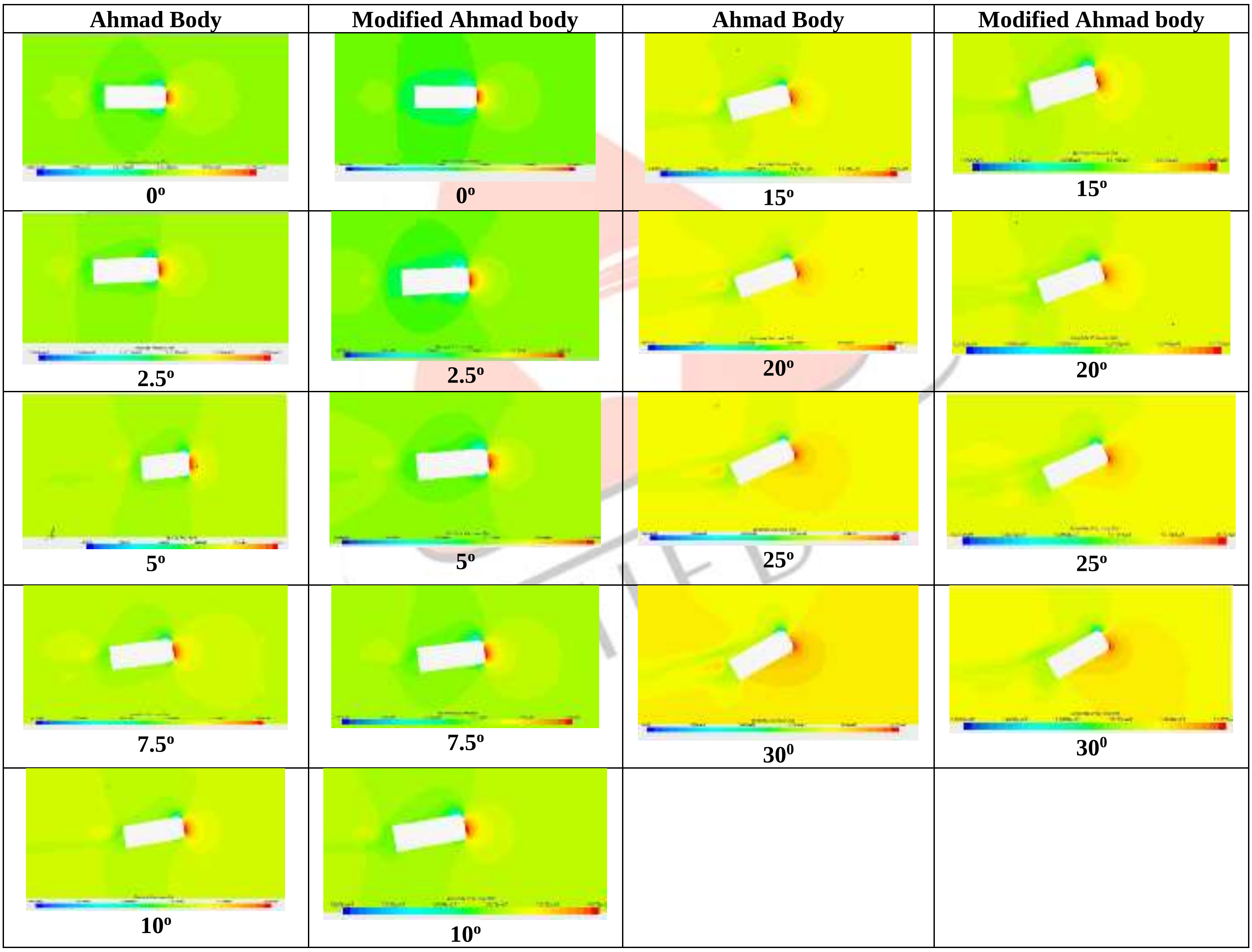


Figure 6. Absolute pressure (Pa) for different Yaw angle (°)

Because of the modified shape of the body the pressure difference between leeward side and Windward side is reduces hence the yawing moment, pitching moment, rolling moment is also reduced.

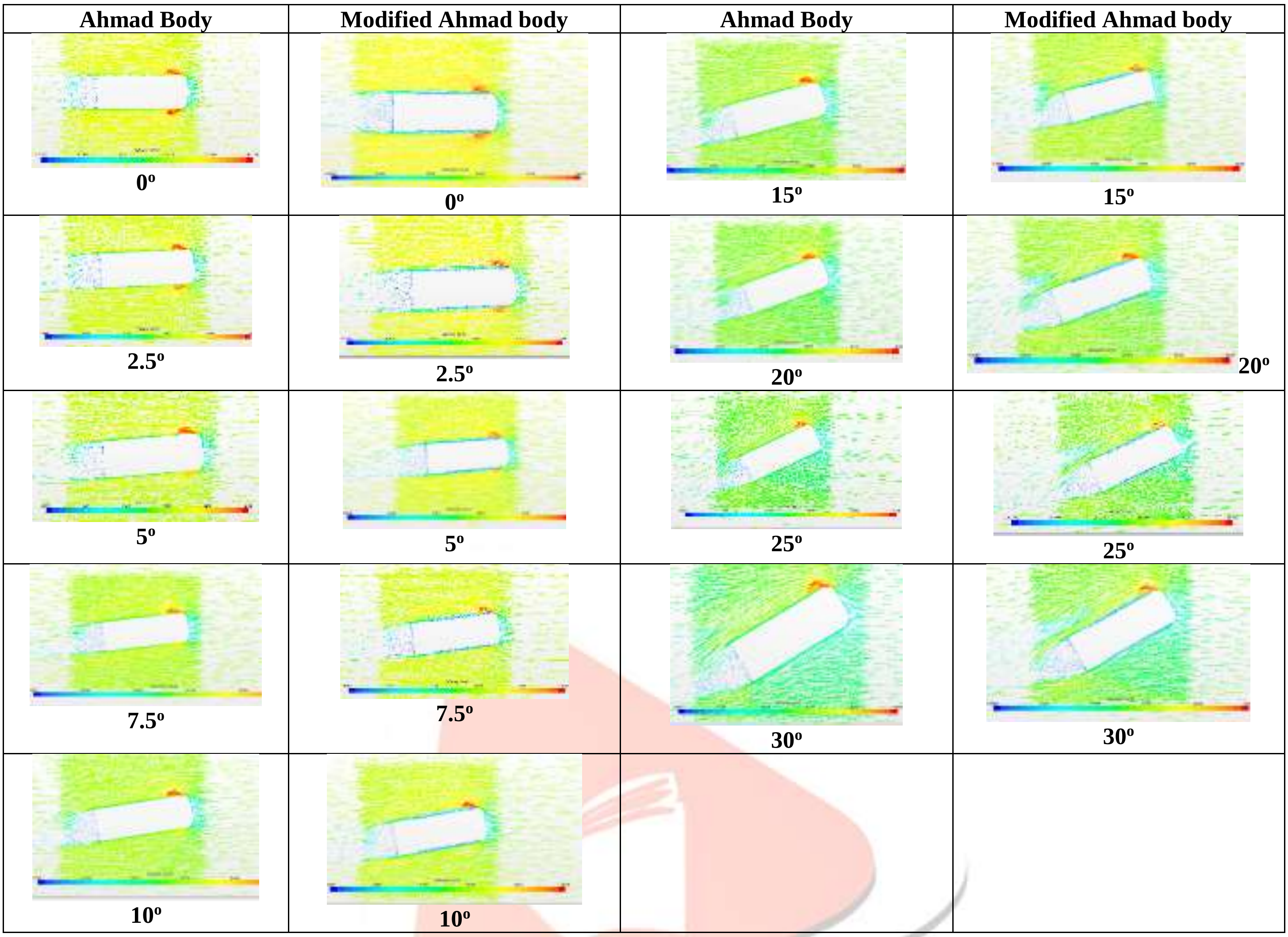


Figure 7. Velocity Vectors (m/s) for different Yaw angle (º)

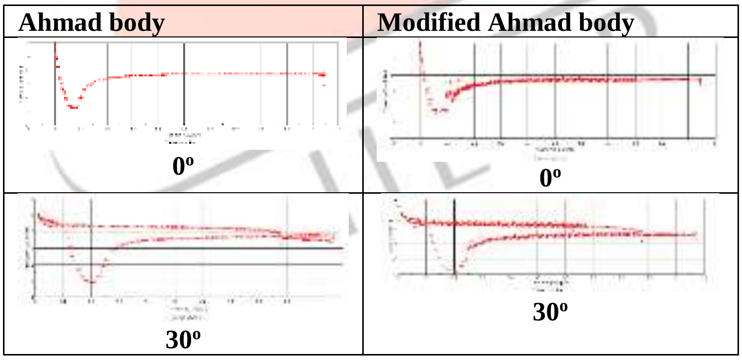


Figure 8. Pressure coefficient.

3.1 GRAPHS AND PLOTS

Formulas for different coefficients are given below [8]:

$$c_L = \frac{L}{\frac{\rho}{2} V_\infty^2 A} \quad \text{(lift)} \qquad c_D = \frac{D}{\frac{\rho}{2} V_\infty^2 A} \quad \text{(drag)}$$

$$c_M = \frac{M}{\frac{\rho}{2} V_\infty^2 A l} \quad \text{(pitching moment)} \qquad c_Y = \frac{Y}{\frac{\rho}{2} V_\infty^2 A} \quad \text{(side force)}$$

$$c_R = \frac{R}{\frac{\rho}{2} V_\infty^2 A l} \quad \text{(rolling moment)} \qquad c_N = \frac{N}{\frac{\rho}{2} V_\infty^2 A l} \quad \text{(yawing moment)}$$

Where,

C_L=coefficient of lift force (L),C_M=coefficient of pitch moment (M)
C_D=coefficient of drag force (D),C_R=coefficient of roll moment (R)
C_Y= coefficient of side force (Y),C_N=coefficient of yaw moment (N)

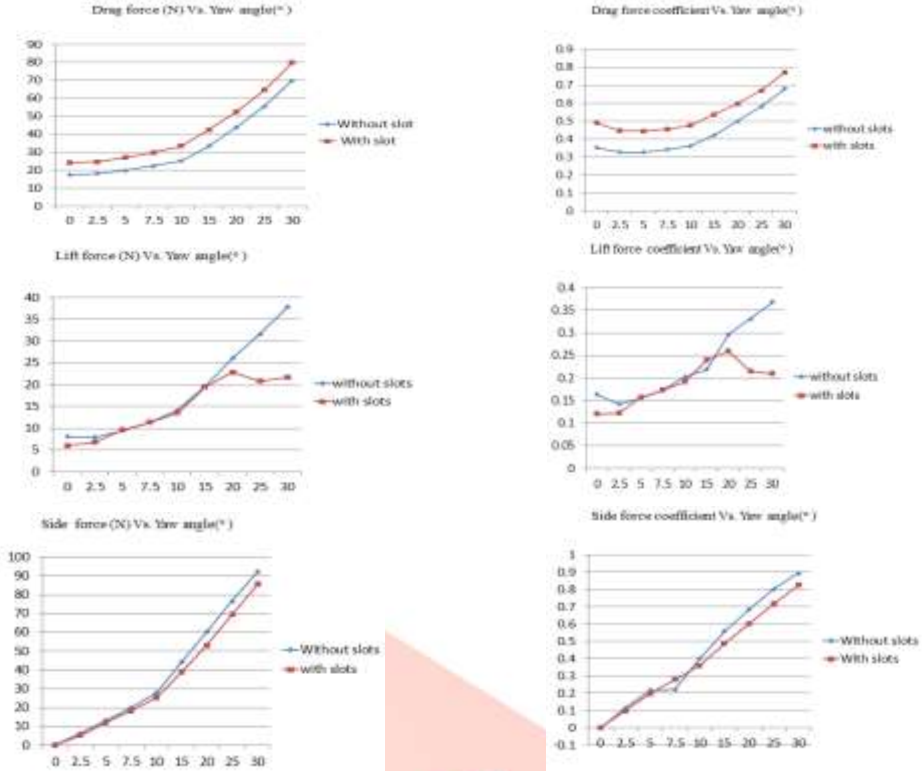


Figure 9. Aerodynamic Force (N) and Force Coefficients vs. Yaw angle (°)

Figure 9 shows that with modified Ahmad body the drag force and drag coefficient is increase but lift force, side force, lift coefficient and side force coefficient is decrease. In cross wind side force play very important role. With modification of Ahmad body side force and side force coefficient is decreasing. It helps stability of vehicle.

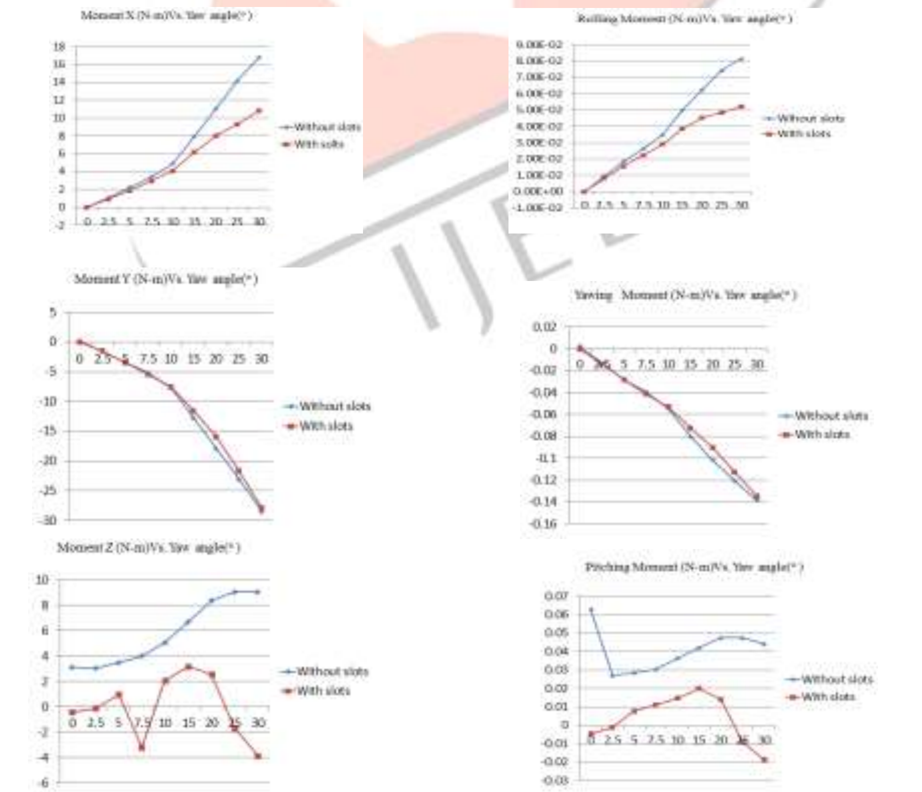


Figure 10. Aerodynamic Moment (N-m) and Moment Coefficients vs. Yaw angle (°)

Similarly, Aerodynamic Moment and Moment coefficient is decreased with modification in the Ahmad body.

4. CONCLUSION

It is found that Stability of heavy vehicle is of prime importance when subjected to cross wind. This work shows one of the ways to reduce the cross-wind effect on heavy vehicle. Simulations were performed on the Ahmad body and modified Ahmad body to understand the effect of cross wind analysis. From the results it was observed that, Lift force, side force, lift coefficient, side coefficient, roll moment (x), yaw moment (y), pitch moment (z), rolling moment coefficient, yawing moment coefficient, pitching moment coefficient were reduced because of the slots provided around the Ahmad body. This result in increase in stability and safety of vehicle subjected to cross wind with slight increase in the drag.

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