International Journal of Advanced Science and Technology
Vol. 29, No. 9s, (2020), pp. 7932-7942

Coupling the Effect of Wind and Pavement Dynamics in Longitudinal Dynamics of Twin Track Vehicle

Dr. K M Jagadeesha[1], Mr. Gopalareddy[2]

[1]*Professor and Head of the Department, Department of Automobile Engineering, PES College of Engineering Mandya, Mandya-401 [2]*

[2]*Assistant Professor, Department of Mechatronics Engineering, Acharya Institute of Technology Bangalore-107*

[1]

[1] kmjagadeeshmys@gmail.com,

[2]

2 gopalreddykonkal@gmail.com

Abstract

Vehicle Performance, stability and control is not only depending on vehicle parameters like center of gravity location, vehicle speed and tire-parameters, it of an extent influences by many other parameters like wind, pavement and driver inputs. The wind–pavement-vehicle dynamics analysis plays a dominant role in Vehicle Performance, stability and control and it has been considerably developed in the past decades. In this work, much attentiveness hasbeen agreed towards the effect of aerodynamic forces on acceleration and rakingperformance, on the twin track vehicles, comparing the acceleration and braking performance of two different models under different conditions (considering the lift and neglecting the lift) by considering the coefficient of adhesion, aerodynamics characteristics and location of center of gravity.For the purpose of study two different car models were considered namely model-1 and model-2 and they were modeled using modeling software CATIA V5. Attention is given only to the external design of the cars, while the interiors were not modeled. Further, analysis has been carried out using ANSYS-Fluent to determine the aerodynamic characteristics like drag coefficient (Cd) and coefficient of lift (Cl). With the help of flatbed tire testing machine, the coefficient of adhesion has been experimented on various pavement types and conditions by changing the inflation pressure and vertical load on tires.In the results it has been observed that model-1 has better acceleration and braking performance than the model-2 comparatively. Acceleration and braking performance are more in the condition of neglecting the lift and comparatively less in the condition of considering the lift. Acceleration of ground vehicles decreases with increase in lift force. Also, the braking performance of vehicles decreases with increase in lift force.

1 Introduction:

Modern automobile industries are giving more importance to safety, handling and ride comfortness of vehicles, where Ground vehicle dynamics plays a paramount role. Ground vehicle dynamics is improving since past few decades. In modern ground vehicles coupling dynamics i.e., wind-pavement-vehicle dynamics is very important consideration.

Acceleration/braking are critical aspect of longitudinal vehicle dynamics which directly affects the economical operation and safety of an automobiles. The longitudinal dynamics characteristics of road vehicles depends on wind-pavement-vehicle dynamic parameters. Handling and the longitudinal dynamics characteristics of untracked road vehicles are greatly enhanced in recent decades through the

ISSN: 2005-4238 IJAST

electronic gadgets. There are many autotronic devices like traction control systems and Anti-lock braking systems that have been designed to avoid wheel lock-up and skidding, which improves the longitudinal dynamics along with vehicles directional stability notably on wet or icy pavements. These autotronic devices fulfil their functionality when certain parameters, like vehicular velocity, weight of the vehicle, roll angle, yaw rate, and sideslip angle are familiar. Alteration in vehicle's weight, the position of the Center of gravity, road grade, road irregularities, road loads and load shift alter the ground vehicle dynamic behavior both longitudinal and lateral.

For analysis purposes the center of gravity is the virtual point to consider the vehicle weight, inertial load, aerodynamic load, and also centrifugal forces when the vehicle negotiating the curve, accelerating or decelerating on a level road and while moving up or down the hill. Whitehead, et al. [3] reviewed the effect of varying center of gravity location (both vertically and horizontally) on rollover propensity of a ground vehicle. Chainani. A, et al. [4] study reveals that aerodynamic drag force greatly affects the vehicular forward motion and that there's a difference with in the pressure between the air flowing above and below the car. G.Shiva et al. [5] performed a comparative study on aerodynamic characteristics like lift, down force and drag using ANSYS fluent and concluded that by decreasing the drag entire car performance, speed can be increased with the reduction in fuel consumption.

Tire-road adhesion is the one the most dominant parameter, that influences braking distance and acceleration with safety. Friction between pavement surface and tire prevents relative movement between a tire and pavement surface. V V R L S Gangadhar et al. [6] made an analysis and suggested that the rolling loss will be higher for overloading than the specified load and the fuel consumption will likewise be more. A possible method of optimizing fuel consumption by adjusting tire operating load pressure is suggested. T.J.W. Leland, et al. [7] investigated the influence of load, inflation pressure and surface texture upon both wet and dry surface braking performance of aircraft tires, and they observed that in dry surfaces there is no significant difference in friction between different surfaces. Tire-road adhesion decreases with increasing speed and vertical load, in just slightly wet surface even a very thin film of water can cause a large decrease in tire-road adhesion. A tread pattern improves wet traction on surfaces having a smooth macrotexture, but has little or no effect on rough surfaces on which the asperities provide sufficient drainage [8]. In point of fact, on very rough surfaces, a smooth tread tire is often somewhat superior [9]. However, at high speeds (80 mph or higher), coarse surface texture as well as tread pattern is essential [10].

From the above note, here examination is performed to consider the impact of wind and asphalt dynamics in longitudinal acceleration and braking of ground vehicles.

Defınıtıon of problem and methodology.

As discussed earlier, to study the longitudinal acceleration and braking of ground vehicles the two car models were considered and created all the surfaces using CATIA v5R20® software using Freestyle Sketching function and Fill Surface Definition tool as shown in Fig.1 (a) and (b).

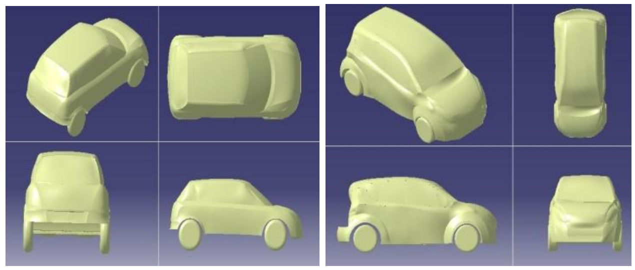


Fig.1(a) Fig.1(b)

Fig.1(a) Multi Views of model-1 and (b) Multi Views of model-2**.**

The created car models were subjected to CFD analysis in ANSYS FLUENT® to simulate the coefficient of drag and coefficient of lift. In the time of meshing, sizing functions were used wherever necessary so as to get accurate lift/drag parameters. The mixed element mesh was used for generating mesh and the fine mesh was considered for good results. The whole number of elements obtained was 4.835 million as shown in Fig.2.

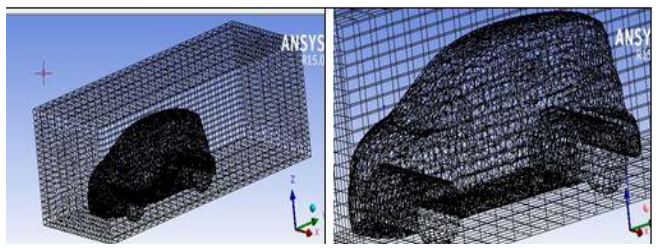


Fig.2 FEA model of considered car**.**

The final solution was obtained by performing the iterations in three different stages utilizing higher-order equations. The Pseudo Transient Scheme was selected to quicken the convergence.

The final drag coefficients are obtained for different speeds of 40kmph, 60kmph, 80kmph, 100kmph and 120kmph respectively for model-1 & 2 is shown in Fig.3. Similarly, the final lift coefficients are obtained for the different speeds of 40kmph, 60kmph, 80kmph, 100kmph and 120kmph respectively for model-1& 2 is shown in Fig.4.

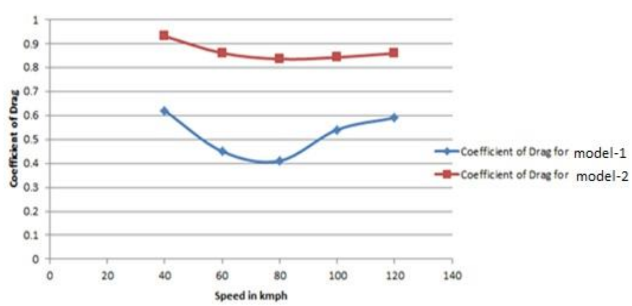


Fig.3 Coefficient of Drag (Cd) fomodel-1 & 2.

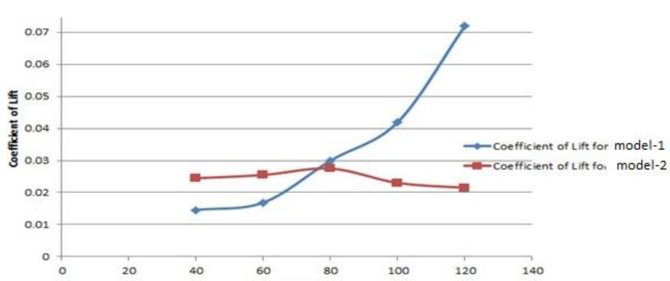


Fig.4 Lift Coefficient (Cl)for model-1& 2**.**

International Journal of Advanced Science and Technology
Vol. 29, No. 9s, (2020), pp. 7932-7942

Measurement of Coefficient of Adhesion **(μ)**

There are large number of experimental approaches are available and used to quantify the adhesion coefficient between the tire and pavement surfaces. In our work flatbed type tire testing machine was used to measure the coefficient of adhesion for different pavement type and obtained results are as shown in Fig.5 & 6.

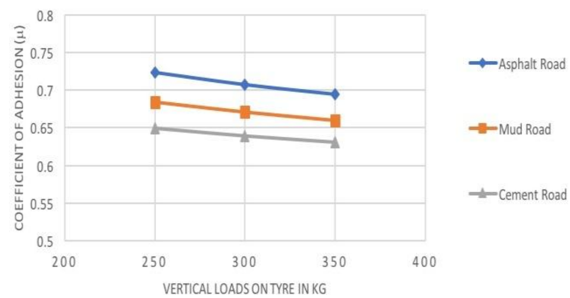


Fig.5. Variation of μ vs Vertical Load on Tire for model-1

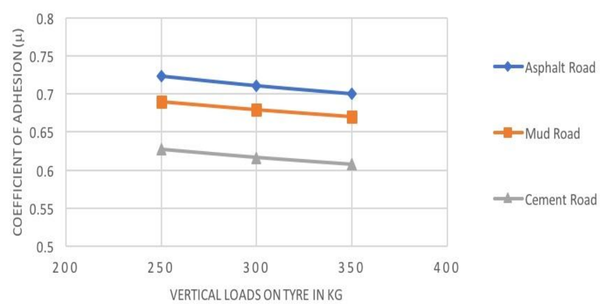


Fig.6. Variation of μ vs Vertical Load on Tire for model-2

Measurement of Vehicle Center of gravity Location

In this work to locate the virtual position of Center of gravity of the vehicle in horizontal and vertical direction, the analytical method is used as it's the only technique which provides the virtually exact location of Center of gravity and it's the straightforward procedure.

ISSN: 2005-4238 IJAST

Fig.7. Weighing the Front Tire Contact Forces on Horizontal Surface using weighing bridge.

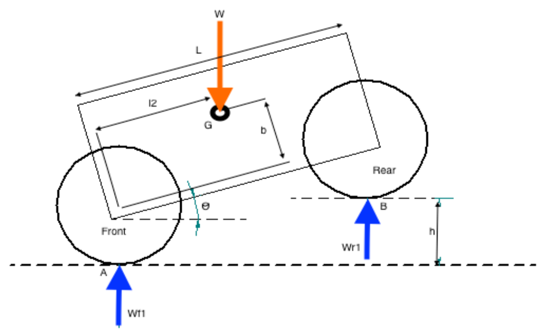


Fig.8. Force body diagram on inclined surface**.**

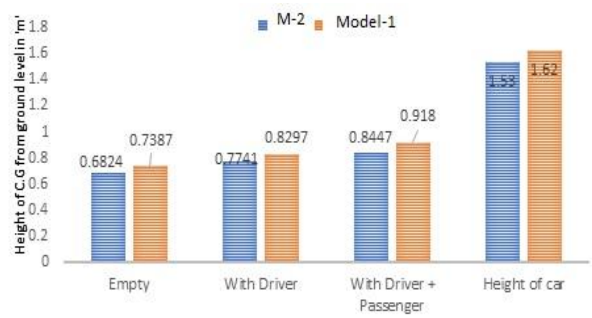


Fig.9. Comparison of Variation of Height of Center of gravity from Ground Level**.**

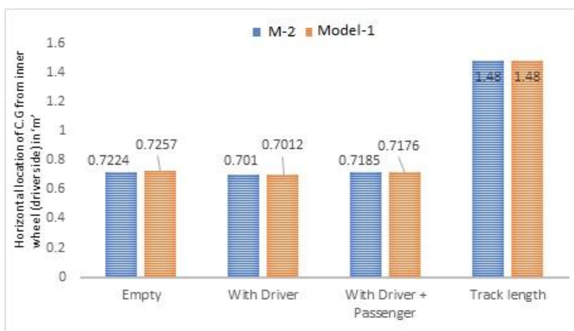
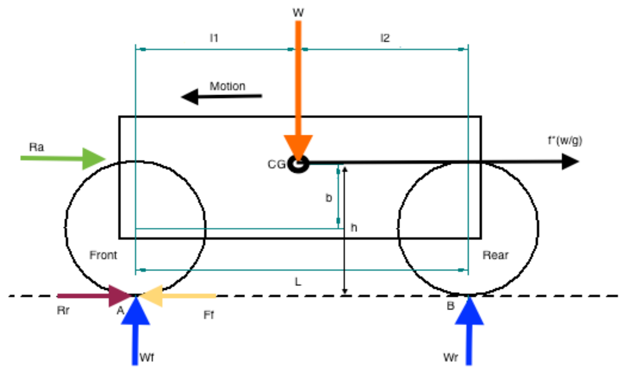


Fig.10. Comparison of Variation in Horizontal Location of Center of gravity from Inner Wheel (Driver Side).

2 Equatıons governıng acceleratıon and brakıng performance for untracked ground VEHICLES.

In this study, analytical method is selected to delve into the acceleration and braking performance. The acceleration and braking performance of the vehicle are frequently surveyed by considering numerous conditions like vehicle cruising on a level street, climbing the slope, and descending the slope. However, in this work just cruising on level street condition is considered.

Governing Equation: Maximum Achievable Acceleration (Neglecting the Lift force**)**



$$\frac{f}{g} = \left[\frac{\mu l_2}{(L+\mu h)} - \frac{(R_a+R_r)}{W}\right] \qquad (1)$$

Fig.11. Force body diagram of car for Maximum Achievable Acceleration (Neglecting the Lift force**).**

Governing Equation: Maximum Achievable Acceleration (Considering the lift force)

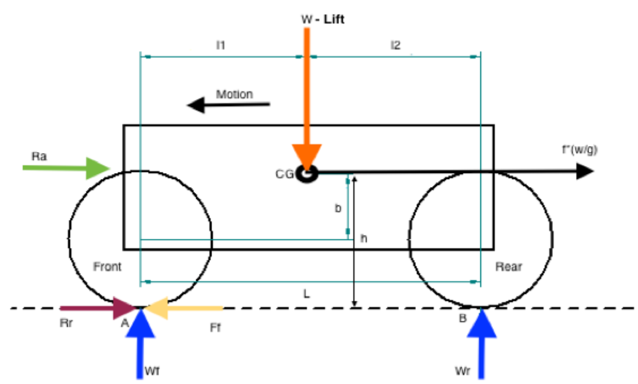


Fig.12. Free body diagram of car for Maximum Achievable Acceleration (Considering the lift force).

$$\frac{\mu l_2(W-Lift)}{W(L+\mu h)} - \frac{(R_a+R_r)}{W} \qquad (2)$$

Governing Equation: Maximum Achievable Braking (Neglecting the lift force)

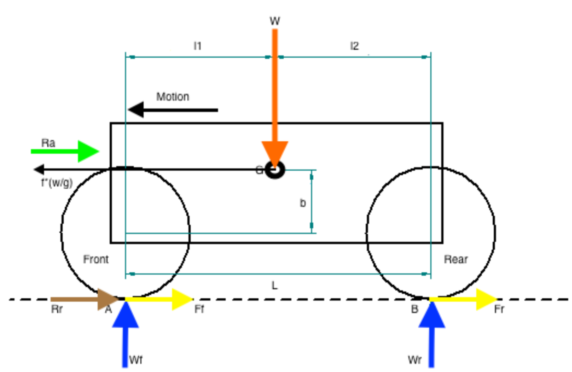


Fig.13. Free body diagram of car for Maximum Achievable Braking (Neglecting the lift force).

$$\frac{f}{g} = \mu + \left[\frac{R_a + R_r}{W}\right] \quad (3)$$

Governing equation: Maximum achievable braking (Considering the lift force)

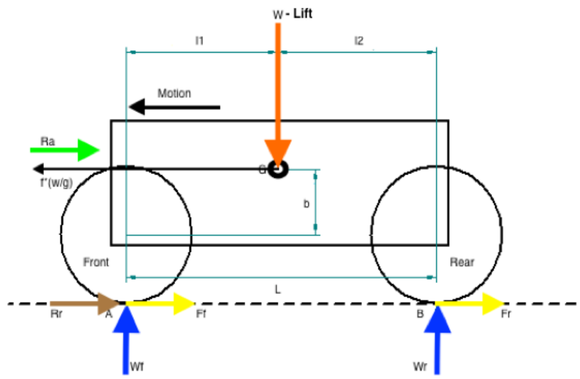


Fig.14. Free body diagram of car for Maximum Achievable Braking (Considering the lift force)**.**

$$\frac{f}{g} = \mu\frac{(W - Lift)}{W} + \left[\frac{R_a + R_r}{W}\right] \quad (4)$$

3 RESULTS AND DISCUSSION

In this study, the variables affecting the vehicular acceleration and braking performance are determined with the assistance of numerical conditions. Within the subsequent sections, the main points of the experimental outcomes acquired for the above variables are discussed.

Maximum achievable Acceleration performance without considering lift force.

In this section, the primary concerns of the examinations were talked about. The acceleration timings are determined during acceleration the vehicle from 0-60 kmph without tire slip. during this computation, the aerodynamic lift force has been disregarded.

Effect of Coefficient of Adhesion on Maximum Achievable Acceleration for Different Road Condition

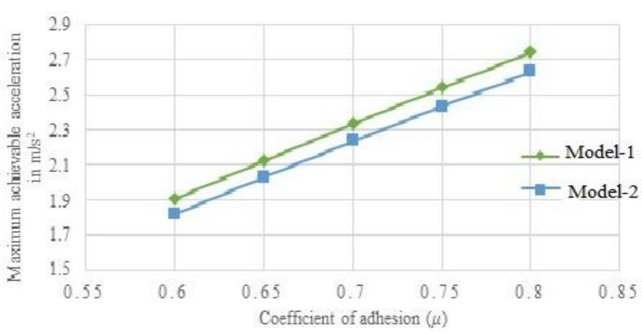


Fig.15. Variation of Maximum Achievable Acceleration vs Adhesion Coefficient on a Level Road**.**

From the Fig.15, it can be clearly observed that increasing the coefficient of adhesion between tire and road increases the maximum achievable acceleration and model-1 shows better acceleration performance than the model-2.

Outcome of vertical distance of center of gravity from ground level on maximum attainable acceleration

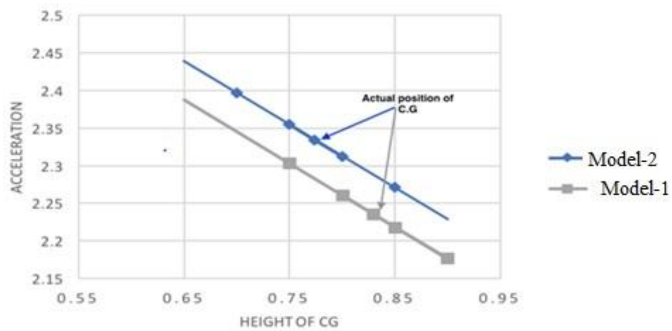


Fig.16. Varying maximum attainable acceleration(m/s^2) vs vertical distance of Center of gravity from ground level in "m"

From Fig.16, it can be noticed that as the center of gravity from the ground level increases, the greatest attainable acceleration up diminishes and expands the time taken to accelerate.

Effect of horizontal Distance of the center of gravity from Rear Wheel on Maximum Achievable Acceleration.

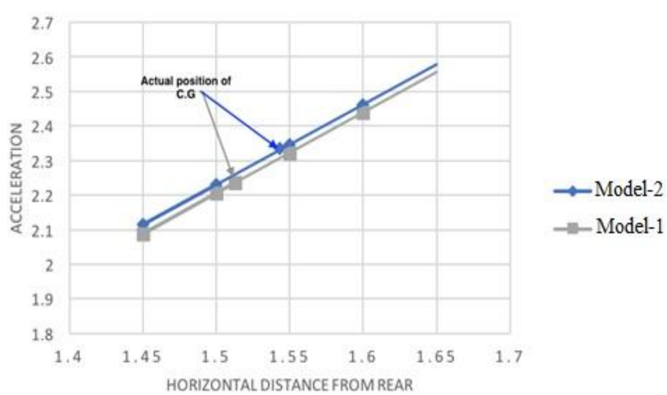


Fig.17. Varying maximum achievable acceleration(m/s^2) vs horizontal distance of Center of gravity from rear wheel in "m"

From Fig.17, we can see that the vehicular acceleration highly reliant on the horizontal distance of the Centre of gravity from the rear axle. The maximum achievable vehicular acceleration increases as Centre of gravity distance from the rear axle increases, and lessens the time taken to accelerate on a flat road.

Maximum achievable braking performance without considering lift force.

In the succeeding section, the details of the outcomes acquired are explained. The vehicle stopping distance is determined to stop the vehicle from 60-0kmph without tire slip on pavement.

Effect of Coefficient of Adhesion on Stopping Distance

For Different Road Condition

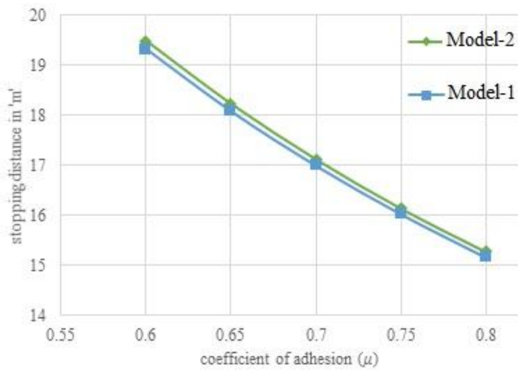


Fig.18. Variation of Stopping distance vs Coefficient of adhesion on level road**.**

From Fig.18, it's often clearly observed that as the tire-road coefficient increases the vehicular stopping distance decreases. Model-2 has comparatively less stopping distance than Model-1.

Effect of change in aerodynamics lift force on acceleration and Braking Performance of ground vehicles.

Aerodynamic lift force is a vertical force component which acts perpendicular to oncoming flow of fluid when a vehicle cruising on road. To study the effect of lift on acceleration and braking, co-efficient of adhesion of asphalt road and actual C.G location of vehicle is considered. In the following section the effect of aero-dynamic lift on acceleration and braking are discussed. Table 1 and Table 2 shows Coefficient of Lift (C_l) and Lift Force in 'N' for model-1 and model-2 respectively.

Table 1. Coefficient of Lift (C_l) and Lift Force in 'N' of Model-1

Speed in kmph	Coefficient of Lift	Lift Force in 'N'
40	0.0146	2.472
60	0.0169	6.435
80	0.03	20.32
100	0.042	44.43
120	0.071	108.21

Table 2. Coefficient of Lift (C_l) and Lift Force in 'N' of Model-**2**

Speed in kmph	Coefficient of Lift	Lift Force in 'N'

40	0.0245	3.963
60	0.0255	9.277
80	0.029	18.76
100	0.0233	23.55
120	0.021	30.57

Effect of Variation of Lift on Acceleration Performance:

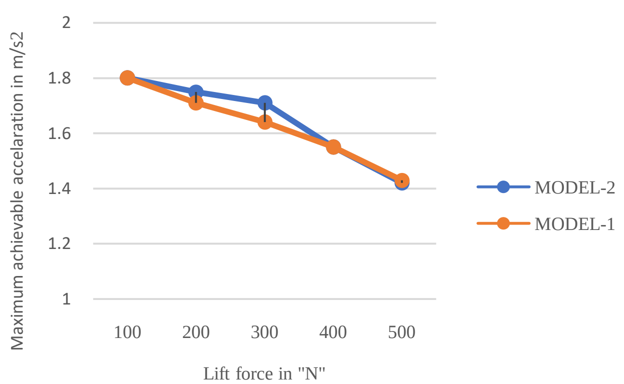


Fig.19. Effect of Lift force on acceleration of the vehicle cruising on level road.

From the above Fig.19. we can say that increase in lift force decreases maximum achievable acceleration of the ground vehicle. The variation of maximum achievable acceleration has not much variation over the range of lift force.

Effect of Variation of Lift on Braking Performance:

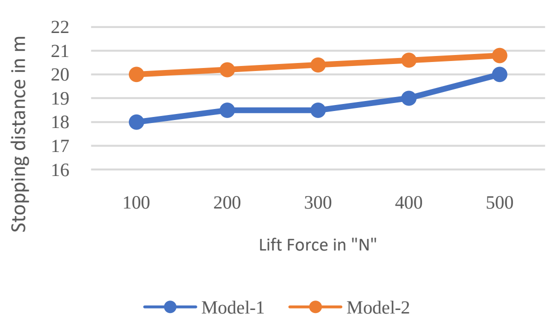


Fig.20. Effect of Lift force on braking performance of the vehicle cruising on level road and both the wheels are braked

From the above Fig.20, we can say that the vertical lift force affects the vehicle stopping distance. As the lift force increases vehicle stopping distance increases, i.e., braking performance of the vehicle decreases in both the models.

4 Conclusion

Coupled vehicle dynamic parameters greatly influences the longitudinal dynamics of ground vehicle performance i.e. the acceleration and braking performance. Coefficient of adhesion influences both braking and acceleration performance. As the coefficient of adhesion increases, the longitudinal dynamic performance increases. From the obtained the results it is clear that model 1 shows better acceleration and braking performance comparatively.

The vehicle parameter which is location of center of gravity in both vertical and horizontal direction affects the longitudinal dynamic performance. As the position of the center of gravity along the horizontal direction from the rear axle increases, longitudinal vehicular acceleration also increases. The acceleration performance of ground vehicles decreases as the vertical distance of center of gravity increases from the ground level.

The considered aerodynamic parameter in this work is vertical lift force due to in flow of wind. When the vehicle is cruising on road, which affects longitudinal performances of ground vehicles adversely, i.e. as the lift force increases both acceleration and braking performance of both the considered models decreases.

References

1. Germann, S. and Isermann, R., 1994. “Determination of the centre of gravity height of a vehicle with parameter estimation”. In IFAC Symposium on System Identification, vol.1, pp. 563-568,
2. Solmaz, S., Akar, M. and Shorten, R., 2006. “Online centre of gravity estimation in automotive vehicles using multiple models and switching”. In Proceedings of the 9th IEEE International Conference on Control, Automation, Robotics and Vision, Singapore.
3. Whitehead, R., Travis, W., Bevly, D. M. and Flowers, G., 2004.“A study of the effect of various vehicle properties on rollover propensity”. SAE Technical Paper - 2004-01-2094.
4. Chainani. A, Perera. N “ CFD Investigation of Airflow on a Model Radio Control Race Car’’ Proceedings of the World Congress on Engineering 2008 Vol II WCE 2008, July 2- 4, 2008, London, U.K
5. G. Siva, V. Loganathan, “Design and Aerodynamic Analysis of a Car to Improve Performance”, Middle-East Journal of Scientific Research, 2016, pp.133-140.
6. Dr. V V R L S Gangadhar. “Effect of tyre over load and inflation pressure on rolling loss” Professor, Department of mechanical engineering, Princeton college of Egg. & tech, Hydrabad, Telangana, INDIA.”
7. T.J.W. Leland, T. J. Yager, and U.T. Joyner "Effects of Pavement Texture on Wet Runway Braking Performance” NASA Technical Note D-4323, 1968.
8. Giles, C. G. And Lander, F.T.W., "The Skid Resisting properties of Wet Surfaces a t High Speeds: Exploratory

ISSN: 2005-4238 IJAST