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Study on the Load Distribution of the Vehicle when Steering at Different Velocities

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Abstract: - The centrifugal force causes the vehicle body to tilt. Therefore, the load on both sides of the wheel will change. The load change value is a nonlinear function depending on the values of the fixed parameters (mass, dimension) and the change of the input values (velocity, steering angle). The increased load change value means that the vehicle is unstable. If this value approaches the limit value, the vehicle is in danger of being rollovered. The study focused on modeling and simulating the change of load distribution at different velocity and height values. The results show that when the velocity or height increases, the load on both sides of the wheel will be more different, thereby increasing the risk of instability. Some electronic control systems can be used to support vehicle stability and balance when moving.

Keywords:- *The Load Distribution, Lateral Instability, Rollover, Modeling And Simulating.*

I. INTRODUCTION

When the vehicle steers, the centrifugal force will appear [1]. The centrifugal force tends to go out of the rotating arc, this force causes the roll angle of the vehicle. The value of the roll angle is proportional to the value of the centrifugal force, this force depends on the mass of the vehicle [2] and the movement condition [3]. The centrifugal force can be determined through the expression:

$$\vec{F} = m\vec{a}_y \qquad (1)$$

Where:
m: Sprung mass.
a_y: Lateral acceleration.

In case the vehicle is tilted, the load distributed on both sides of the wheel will change. One side will reduce the amount of load ΔF_1, one side will receive the additional load ΔF_2 such that $\Delta F_1 = \Delta F_2$ [4, 5]. If the value of the roll angle is greater, the change in load ΔF will also be greater, therefore causing a risk of rollover.

The load distribution value is a nonlinear function, depending on the change of input parameters such as velocity v, steering angle δ.

$$\Delta F = f(v, \delta) \qquad (2)$$

This research focused on modeling and simulating the dependence between the load distribution and the vehicle's velocity, height.

II. ESTABLISHING THE LOAD DISTRIBUTION WHEN STEERING

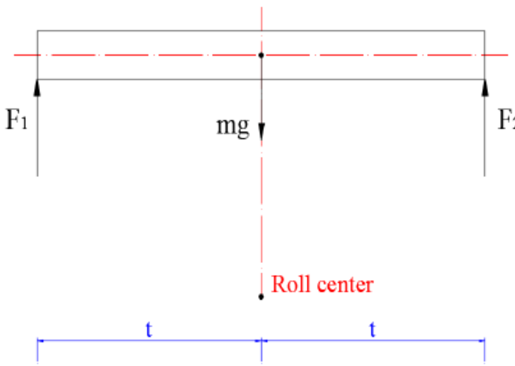

Fig 1:- The Vehicle Body at Equilibrium

At equilibrium, when the roll angle $\varphi = 0^0$, the center of gravity at position O, the load of the vehicle is evenly distributed on both sides ($F_1 = F_2$).

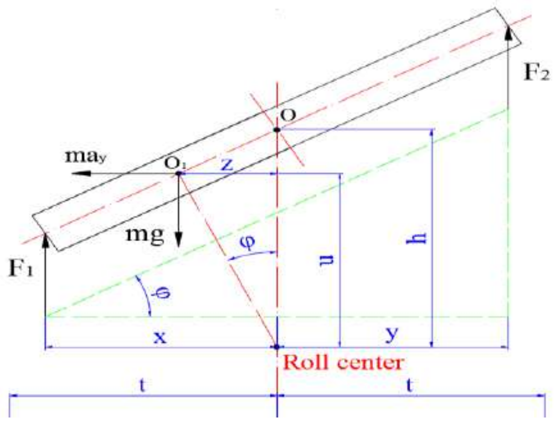

Fig 2:- The Vehicle Body is Tilted

When the vehicle body is tilted, the center of gravity changes to position O_1. At this time, the load on both sides of the wheel will change ($F_1 > F_2$).

The value of load changes when the vehicle body is tilted:

$$\Delta F = \left| F_i - \frac{mg}{2} \right| \qquad (3)$$

From Figure 2, the equations for determining the load on both sides in the form:

$$\begin{cases} F_1 + F_2 = mg \\ -F_1 x + F_2 y + mgz + ma_y u = 0 \end{cases} \quad (4)$$

Since the vehicle is symmetrical across the longitudinal plane, it can be considered as:

$$\begin{cases} x + y = 2t\cos\varphi \\ x - y = 0 \end{cases} \quad (5)$$

The trajectory of the center of gravity is in the form of an arc. Therefore, it is easy to identify the above unknowns:

$$\begin{cases} z = h\sin\varphi \\ u = h\cos\varphi \end{cases} \quad (6)$$

From (3) (4) (5) and (6), the load change value can be determined as follows:

$$\Delta F = \frac{mh(g\tan\varphi + a_y)}{2t} \quad (7)$$

The volume of the value ΔF will increase depending on the roll angle φ and lateral acceleration a_y.

$$0 < \Delta F < \frac{mg}{2} \quad (8)$$

If the volume of the value ΔF is close to the value $\frac{mg}{2}$, it means that the vehicle tends to be unstable. When the volume of the value ΔF reaches the limit value, the vehicle is rollovered.

III. SIMULATION

A. Simulation Conditions

The parameters of the vehicle as Table 1.

Description	Symbol	Value	Unit
Sprung mass	m	2500	kg
Distance from the center of gravity to the front axle	l_1	1300	mm
Distance from the center of gravity to the rear axle	l_2	1700	mm
Distance from the center of gravity to the roll center	h	700 – 900	mm
Half the track width	t	800	mm

Table 1:- Vehicle Specifications

Assume that the vehicle moves steadily at velocity values v = {60; 80; 100} km/h, distance from the center of gravity to the roll center h = {700; 800; 900} mm and Fishhook steering angle as shown in Fig. 3 [6]. Ignore the effects of road surfaces and external factors.

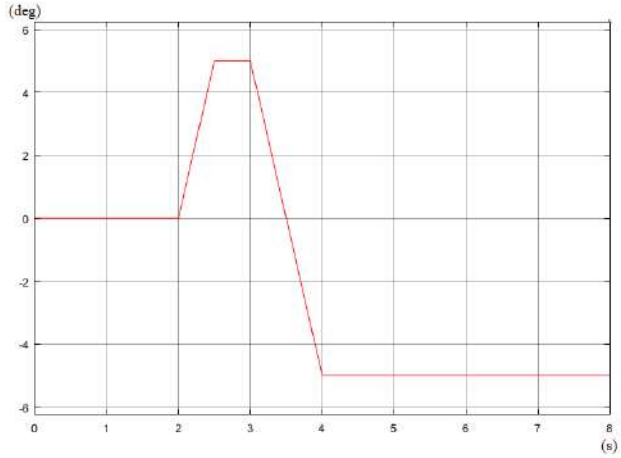

Fig 3:- Steering Angle

B. Simulation Results

Use the dynamic model vehicle established in the study [7, 8] and the motion conditions above. The graph shows the load distribution at the front axle of the vehicle (h = 700 mm) when driving at different velocities as shown in Fig. 4.

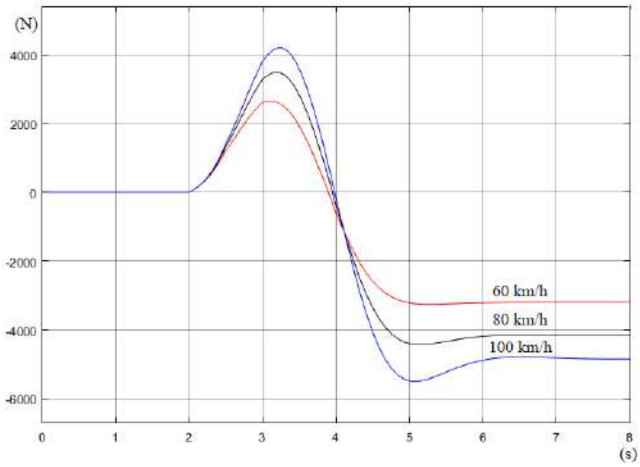

Fig 4:- The Load Distribution at the Front Axle at Different Velocities

The load distribution depends not only on the velocity but also on the distance from the center of gravity to the roll center. The graph in Fig. 5 clearly shows this dependence (v = 60 km/h).

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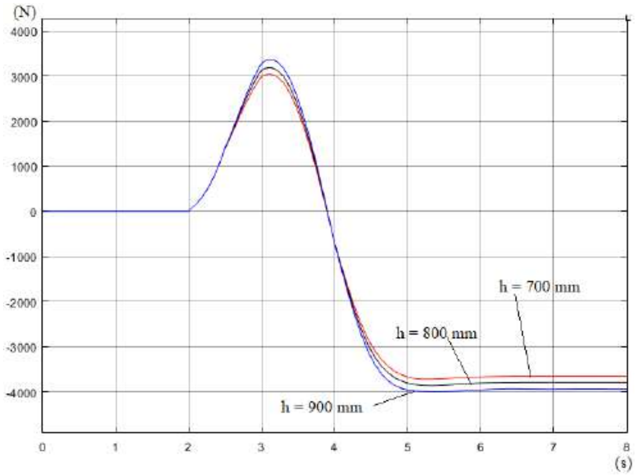

Fig 5:- The Load Distribution at the Front Axle at Different Heights

From the graph, it can be seen that:

- ➢ The steering angle increases, the load change also increases.
- ➢ The velocity increases, the load change also increases.
- ➢ The height increases, the load change also increases.
- ➢ The greater the load difference, the vehicle is unstable.

IV. CONCLUSIONS

When steering, under the influence of centrifugal force will change the position of the center of gravity. At this time, the load on both sides of the wheel will change. The load difference value ΔF depends on the input parameters.

If the velocity or the height of the vehicle increases, the difference in load between the two wheels also tends to increase, causing instability when moving. If the difference is close to the limit, the vehicle can be rollovered.

Should be equipped with the active stabilizer bar, the electronic stability program (ESP), the dynamic stability control (DSC) to increase the stability of the vehicle when steering.

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