International Journal of
Science and Engineering Investigations
vol. 8, issue 88, May 2019
Received on May 9, 2019
ISSN: 2251-8843

Study on the Influence of Vehicle's Dimension to Rollover

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Abstract- The roll moment is a characteristic value for vehicle instability. The roll moment includes the moment of centrifugal force and gravity force. This value is a multivariate function, dependent on the motion conditions (velocity, steering angle) and the dimension of the vehicle (height, mass). This study focused on determining the function of the roll moment, based on the motion trajectory of the center of gravity and simulated the dependence of roll moment on the vehicle's dimension parameters. The results show that when the vehicle's mass and height increase, the value of the roll moment also increases.

Keywords- *Rollover, Lateral Instability, Roll Moment, The Center of Gravity's Trajectory.*

I. INTRODUCTION

The lateral instability is the cause of traffic accidents, including lateral slip and the rollover phenomenon [1]. The rollover phenomenon is defined as a sudden displacement of the trajectory of the center of gravity [2]. For vehicles with large dimension and mass, the rollover phenomenon is at higher risk [3].

When the vehicle moves on a straight road (excluding the influence of external forces), the load of the sprung mass is evenly distributed on both sides of the wheel. In the case of the vehicle steers, the centrifugal force appears. This force tends to go out of the arc, so it will cause the roll moment M_F. The centrifugal force causes the vehicle body to be tilted, so the center of gravity also changes the position and generates the roll moment M_P [4].

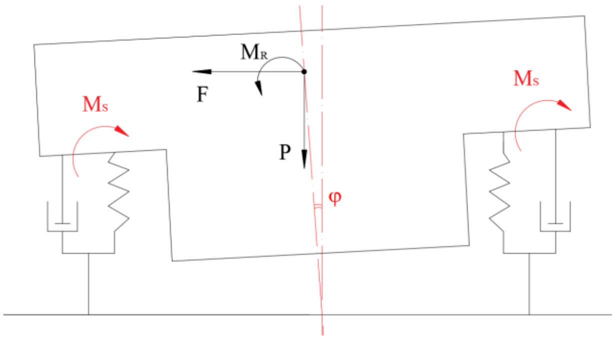

Figure 1. Roll moment of the vehicle

The roll moment is the sum of the two values above:

$$M_R = M_F + M_P \tag{1}$$

Assume that M_S is the anti-roll moment of the vehicle, if:

$M_S < M_R$: the vehicle is tilted

$M_R > M_{S,max}$: the vehicle is rollovered

The roll moment is a multivariate function, depending on the lateral acceleration and the sprung mass. For large-sized vehicles, the distance from the center of gravity to the roll center is increased, which greatly affects the value of the roll moment M_R.

II. DETERMINE THE ROLL MOMENT

A. *Establish the function of roll moment*

From Figure 2, the roll moment M_R can be defined as follows:

$$M_R = Px_0 + Fy_0 \tag{2}$$

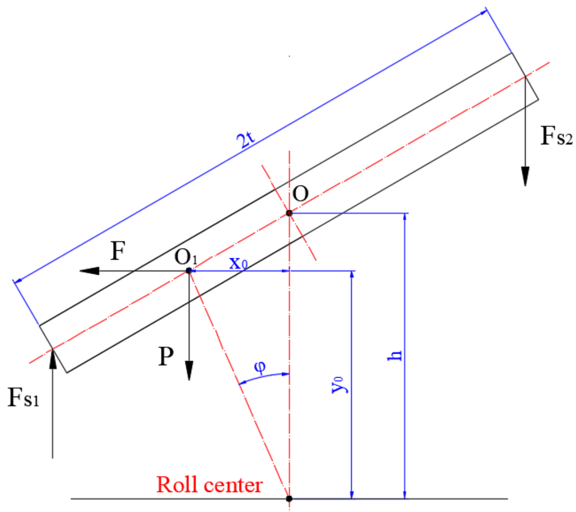

Figure 2. The diagram to determine the roll moment

Where:

P: Gravity force, P = mg

F: Centrifugal force, F = ma_y

m: Sprung mass; a_y: Lateral acceleration

To determine the value of the roll moment M_R, it is necessary to determine the distances x_0 and y_0.

At equilibrium, the center of gravity at O_1 position. When the vehicle body is tilted around the roll axis, the position of the center is at points O_2, O_3, O_4,... The set of the above positions constitutes the motion trajectory of the center of gravity, this trajectory is in the form of an arc with the radius being the distance from the center of gravity to the roll center (Figure 3).

Assume that position O_1 is the origin of the coordinates, the equation that describes the motion trajectory of the center of the gravity is of the form:

$$x^2 + (y + h)^2 = h^2 \quad (3)$$

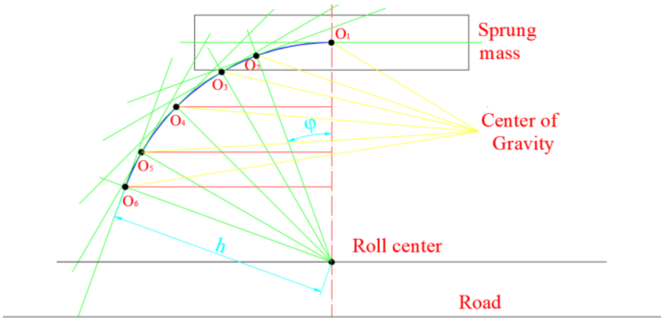

Figure 3. The motion trajectory of the center of gravity

With the above diagram, the value of x_0 and y_0 can be determined as follows:

$$x_0 = h\sin\varphi \quad (4)$$

$$y_0 = h\cos\varphi \quad (5)$$

From (3), (4) and (5), the equation for determining the value of the roll moment M_R has the form:

$$M_R = mh(g\sin\varphi + a_y\cos\varphi) \quad (6)$$

The equation (6) shows the dependence between the roll moment M_R on the sprung mass and the distance from the center of gravity to the roll center. This result is similar to the results of other studies [5, 6], but it is more complete and clear.

B. Simulate the dependence of roll moment on height and sprung mass of the vehicle

Using the established dynamic model vehicle [7], the dependence between the roll moment on the sprung mass and height of the vehicle is given as shown in Figure 4.

From the graph in Figure 4, it can be seen that:

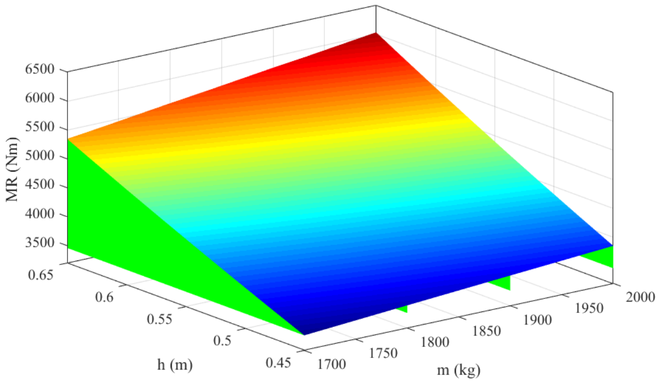

Figure 4. Dependence between roll moment on dimension parameters

In the case that the distance from the center of gravity to roll center unchanged, the value of the roll moment increases almost linearly according to the sprung mass. If the sprung mass increases by 1%, the value of the roll moment increases by 21.9 (Nm).

In case the sprung mass unchanged, the value of the roll moment increases almost linearly according to the distance from the center of gravity to the roll center. If the distance increases by 1%, the value of the roll moment increases by 42.6 (Nm).

Therefore, the increase in the value of the roll moment due to the distance has a greater effect than the mass.

In Figure 4, the set of values in the form of an inclined plane is limited by simulating conditions.

$$A_1 m + A_2 h + A_3 M_R = 0 \quad (7)$$

Where: A_1, A_2, A_3 is the ratio coefficient.

III. CONCLUSION

When the vehicle body is tilted, the trajectory of the center of gravity is an arc.

The roll moment M_R is a characteristic value for vehicle safety when moving. If this value is greater, it means that the vehicle is in danger of losing safety. The value of the roll moment M_R depends on the distance from the center of gravity to the roll center and the sprung mass. Therefore, large-dimension vehicles often lose stability when steering at high speeds.

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How to Cite this Article:

Tuan, A. N. & Thang, B. H. (2019) Study on the Influence of Vehicle's Dimension to Rollover. International Journal of Science and Engineering Investigations (IJSEI), 8(88), 62-64. http://www.ijsei.com/papers/ijsei-88819-11.pdf