International Journal of Scientific Engineering and Science
Volume 7, Issue 5, pp. 98-101, 2023. ISSN (Online): 2456-7361

Research on the Effects of Central of Center of Vehicles on Auto Vibrations

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Abstract— *As people's needs in life increase more and more, automobile has become the means of transport that is being popularly used in their daily activities. In addition to cost and form, ride and handling is among the important criteria for modern automobiles; and the vibration level of a vehicle directly affects its smoothness level. Nowadays, digital simulation is being widely used in studying the mechanical system of an automobile, more than that, the simulation process has proven its preeminence as it can depict the nonlinear system when simulating the vibration level of an automobile. Basing on mentioned requirements, the research team has simulated the oscillation system of an automobile while taking nonlinear factors into consideration by setting reasonable structural parameters with a view to ensure smooth ride and handling for coaches. In this article, they will clarify the impact of structure on the smoothness of coaches and how to select a suitable structure for each type of coach.*

Keywords— *Coach, Nonlinear, Oscillation, Simulation.*

I. INTRODUCTION

Vietnam's auto industry is on its way to become the country's leading industry. However, in order to attain that goal, there was a lot of work needed to be done, one of which was to do deeper study on oscillation, ride and handling, as well as the quality of the vehicle's kinematics and dynamics to optimize its properties.

Based on the mentioned facts, there have been a few researches in the automotive industry that refer to the vibration of automobile. In this study, the research team builds an oscillation model for a 16-seat Mercedes sprinter. The sprinter's body and frame are a solid block on which they install suspension systems, the front suspension follows McPherson type, the rear suspension is a dependent suspension system [4,5]. The space model consists of masses bound together by the constraining force.

On the basis of the oscillation model, they apply D'Alambe principle so as to set up a system of differential equations representing the oscillation. The system consists of 7 differential equations which represent the oscillations [2].

II. BUILD THE MODEL AND ESTABLISH A SET OF DIFFERENTIAL EQUATIONS REPRESENTING THE OSCILLATION

Set up differential equations.

In accordance with D'Alambe's principle: $\vec{F} + \vec{F}_{qt} = 0$

$\vec{F}\_$ is the total external pressure acting on an object.

$\vec{F}_{qt}\_$ is the total fictitious pressure acting on an object.

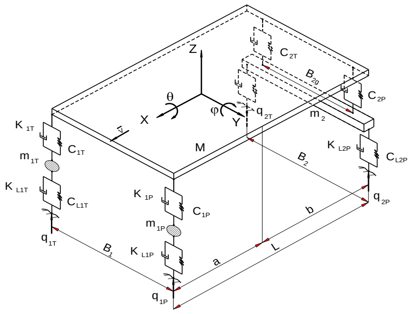

Figure 1: Oscillation model of coach

⇒ The set of equations consists of 7 differential equations, with 7 unknowns as: $\xi_{1T}; \xi_{1P}; \xi_2; \theta; \theta_2; \varphi; Z.$ using Matlab - Simulink to solve the set of differential equations with a view of simulating the vibration of vehicle bo dy [2].

$$\begin{cases}
-m_{1T}.g - m_{1T}.\ddot{\xi}_{1T} + F_{1T} + F_{L1T} = 0 \\
-m_{1P}.g - m_{1P}.\ddot{\xi}_{1P} + F_{1P} + F_{L1P} = 0 \\
-m_2.g - m_2.\ddot{\xi}_2 + F_{2T} + F_{L2T} + F_{2P} + F_{L2P} = 0 \\
-J_{2X}.\ddot{\theta}_2 + \dfrac{B_{2g}}{2}(F_{2T} - F_{2P}) + \dfrac{B_2}{2}(F_{L2T} - F_{L2P}) = 0 \\
-M.g - M.\ddot{Z} - F_{1T} - F_{1P} - F_{2T} - F_{2P} = 0 \\
-J_y.\ddot{\varphi} - a(F_{1T} + F_{1P}) + b(F_{2T} + F_{2P}) = 0 \\
-J_X.\ddot{\theta} - \dfrac{B_1}{2}(F_{1T} - F_{1P}) - \dfrac{B_{2g}}{2}(F_{2T} - F_{2P}) = 0
\end{cases}$$

III. SIMULATION OF OSCILLATION

From the Simulink library, we get the block-diagram simulator.

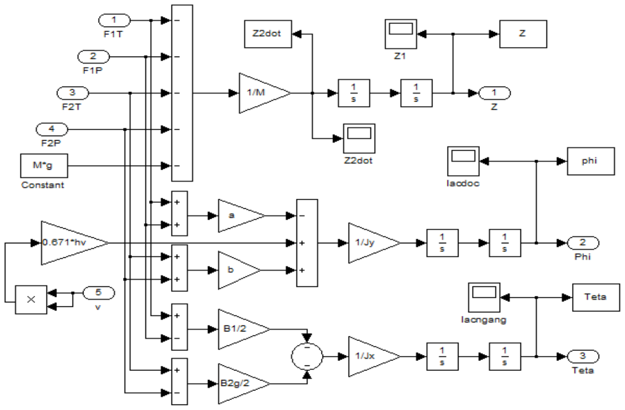

Figure 2: Oscillation general diagram [3]
- Vehicle body.

The car body is determined by three parameters, which directly affect the smoothness of the car body and its vibration.

+ Z- block: describes the vertical vibration of the vehicle's center of gravity G, determined by a differential equation.

$$-M.g - M.\ddot{Z} - F_{1T} - F_{1P} - F_{2T} - F_{2P} = 0$$

+ φ- block": Describes the oscillation around the horizontal axis of the vehicle, determined by a differential equation.

$$-J_y.\ddot{\varphi} - a\left(F_{1T} + F_{1P}\right) + b\left(F_{2T} + F_{2P}\right) + F_v = 0$$

+ Teta-block": Describes the oscillation around the vertical axis of the vehicle, determined by a differential equation.

$$-J_X.\ddot{\theta} - \frac{B_1}{2}\left(F_{1T} - F_{1P}\right) - \frac{B_{2g}}{2}\left(F_{2T} - F_{2P}\right) = 0$$

Therefore, the general diagram has met the requirements of accurate and scientific vehicle vibration simulation.

IV. SIMULATION REPORT

4.1 Parameters included in the calculation

The specifications of suspension system are based on the 16-seat Mercedes sprinter. The set of parameters listed below includes parameters both measured and calculated in accordance with the documents [4,5].

4.2 Simulation report

4.2.1. Oscillation simulating results

When the vehicle runs at the speed of 60 km/h for a test distance of 01 km, the total time is 60 seconds.

- Oscillation coordinate Z and oscillating acceleration of the vehicle body center of gravity:

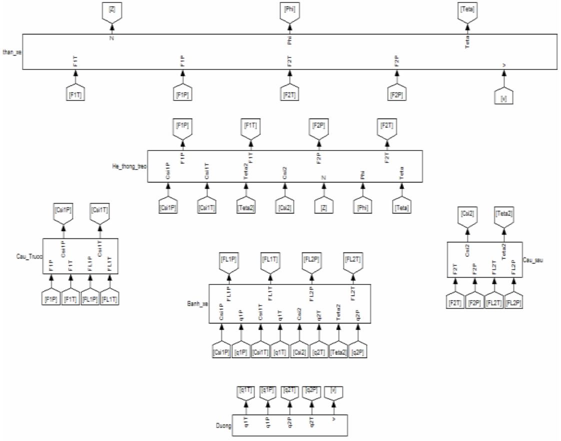

Figure 3: Vehicle body

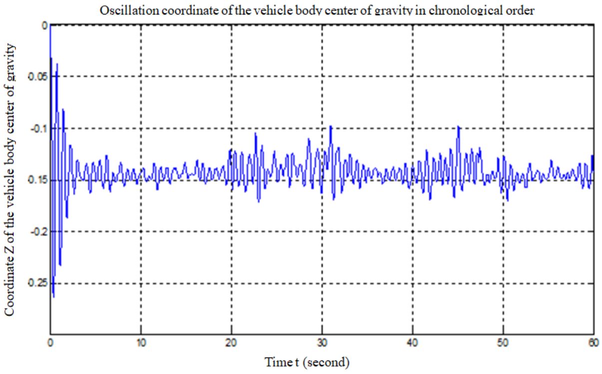

Figure 4: Oscillation coordinates of the vehicle body center of gravity Z

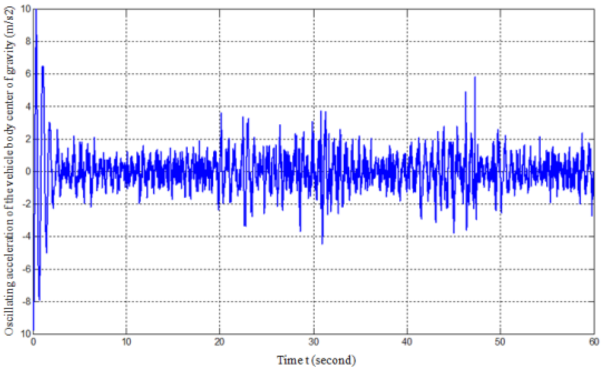

Figure 5: Oscillation coordinates of the vehicle body center of gravity in chronological order

Based on the diagrams in Figures 5, we can see that the vehicle body steadily oscillates around the equilibrium position Z_{cb} = -0.14m and stabilizes after about 2 seconds.

- Longitudinal pitch angle (Theta) and horizontal roll angle (Phi) around the axles of the vehicle body and passing through the vehicle body center of gravity:

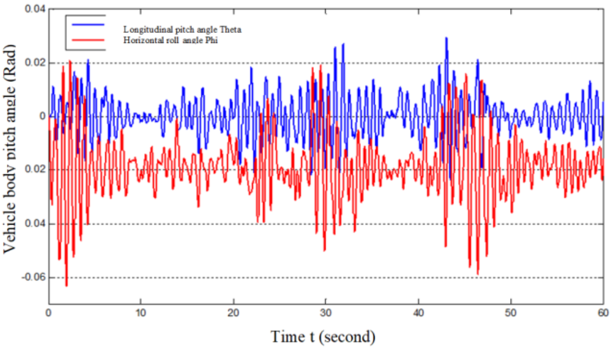

Figure 6: Longitudinal pitch angle and horizontal roll angle of vehicle body

The pitch angle along the longitudinal axis of the vehicle (Theta angle) in Figure 6 oscillates around point 0, and is smaller in amplitude than the roll angle along the longitudinal axis of the vehicle (Phi angle).

4.2.2 The impact of parameters on vehicle vibration

4.2.2.1 The impact of vehicle velocity:

The vehicle speed is modified from 10 to 100 km/h on the actual road 1km long from Hanoi to Lang Son under uniform speed motion.

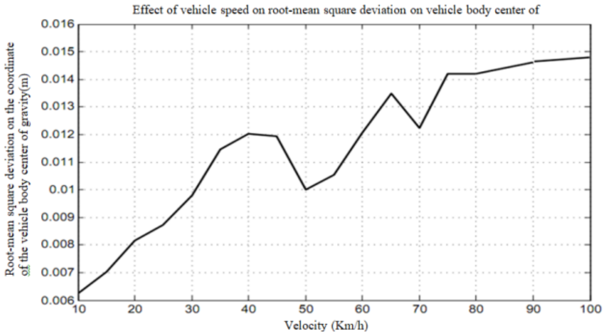

Figure 7: Root-mean square deviation D_φ with velocity

The root-mean square deviation on the coordinate D_Z of the vehicle body center of gravity gradually rises as engine speed is increased.

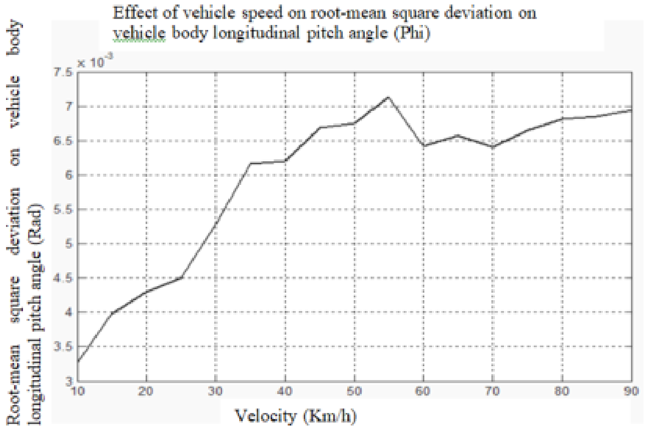

Figure 8: Root-mean square deviation on vehicle body pitch angle D_φ based on velocity

- The effect of vehicle speed on root-mean square deviation on the vehicle body center of gravity:

- The impact of vehicle speed on the root-mean square deviation on vehicle body pitch angles D_{Phi}, D_{Theta} (Rad), the vehicle's bridge axle center of gravity D_{Csi1T}, D_{Csi1P}, D_{Csi2}:

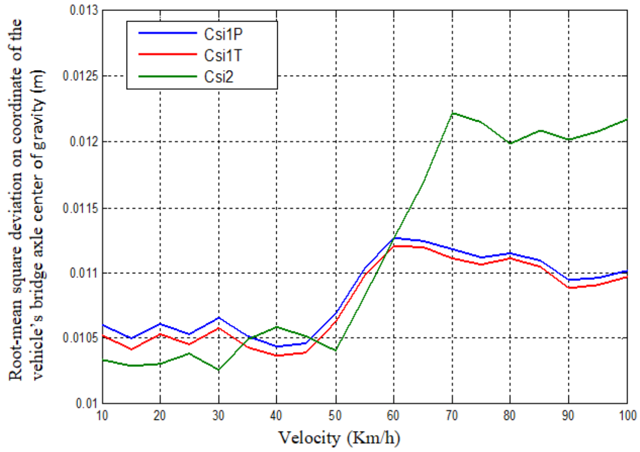

Figure 9: Root-mean square deviation on coordinate of the vehicle's bridge axle based on velocity

4.2.2.2 Effect of damping damping coefficient

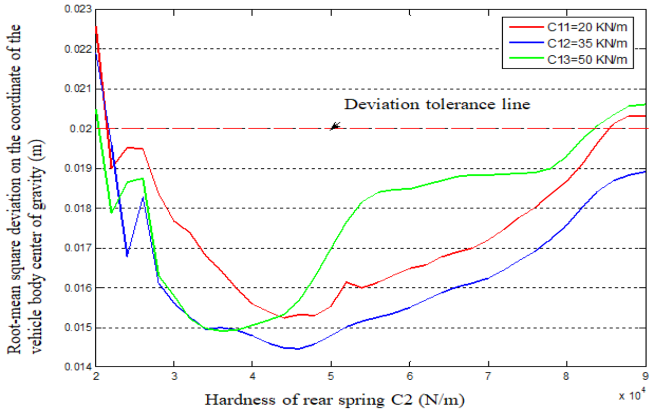

Figure 10: The impact of Square deviation of body center of gravity coordinates DZ when spring stiffness C1 and C2 change

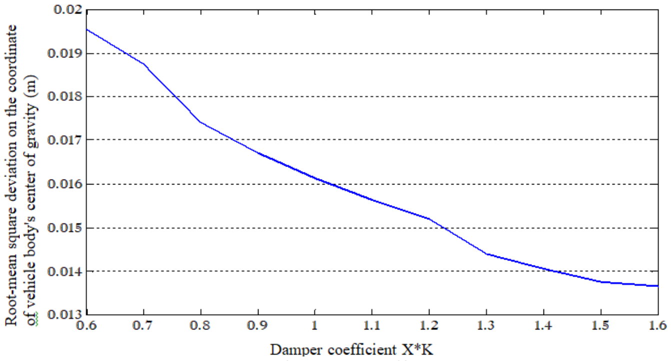

Figure 11: The impact of damper coefficient on root-mean square deviation on the coordinate DZ of the vehicle body center of gravity

Based on two mentioned diagrams, we can clearly see that both D_Z and $D_{\ddot{Z}}$ decrease when the damper coefficient is increased; thus, when we increase the damping level, the smoothness of ride and handling increases.

4.2.2.3 The impact of tire hardness:

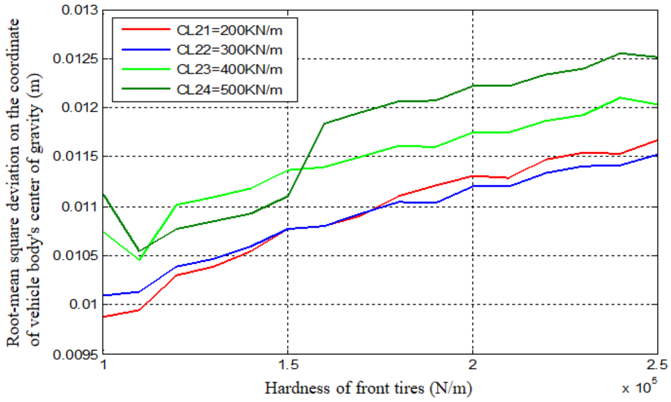

Figure 12: The impact of tire hardness on root-mean square deviation on the coordinate of the vehicle body center of gravity DZ

As we can see, the deviation D_Z and $D_{\ddot{Z}}$ increase as tire hardness is increased. However, the values of D_Z and $D_{\ddot{Z}}$ do not increase too much, not exceeding the tolerance.

4.2.2.4 The impact of vehicle body mass and hardness of horizontal stabilizer bar:

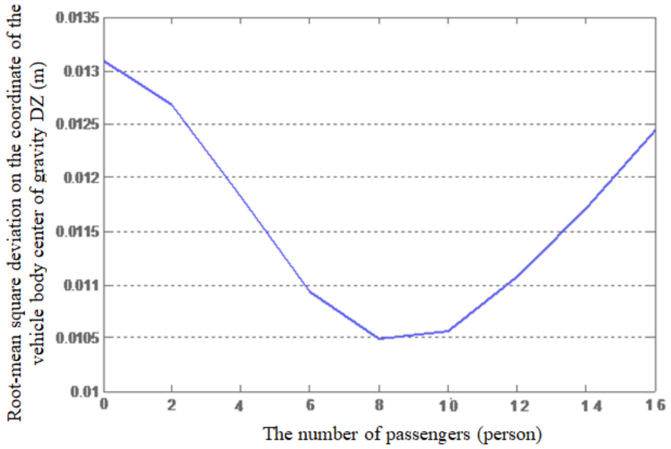

Figure 13: The impact of suspension mass on root-mean square deviation on the coordinate of the vehicle body center of gravity DZ

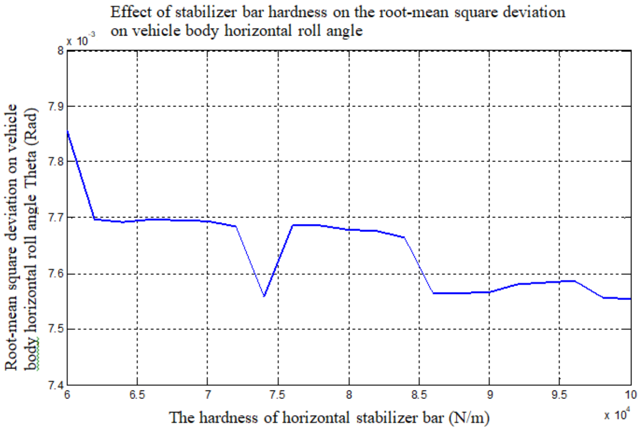

Figure 14: Effect of tire stiffness on the square deviation of the vehicle's center of gravity coordinates DZ

We can see that D_Z decreases when we increase the number of passengers and reaches the minimum value when n = 8 people, then it increases again. However, D_Z is still within the tolerance level.

Again, we see that $D_{\ddot{Z}}$ decreases as the number of passengers is increased and reaches the minimum value at n = 16 people, $D_{\ddot{Z}\min}$ = 1 m/s2. However, even when $D_{\ddot{Z}}$ reaches the maximum value, $D_{\ddot{Z}\max}$ does not exceed the tolerance.

The Root-mean square deviation on vehicle body horizontal roll angle slightly changes and tends to decrease when we change the anti-torsion hardness C_{od}.

V. CONCLUSION

In this study, we have built a space oscillation model for a 16-seat coach, obtained results include:

The car body oscillates around the equilibrium position Zcb = -0.14m and stabilizes after around 02 seconds; the longitudinal pitch angle and horizontal roll angle of the vehicle body are around point 0; vehicle body center of gravity Csi = -0.2-0.2 during the process; the vehicle body oscillation changes from 0.01 to 0.125 when the tire hardness changes from 200KNm to 500KNm; vehicle body center of gravity ranges from 0.0105 to 0.013 when changing the number of passengers on the vehicle; the horizontal roll angle ranges from 7.5 to 7.9Rad when changing the anti-torsion hardness of the stabilizer bar; acceleration of body oscillation from 1.1 to 1.8m/s2 when changing the number of passengers on the vehicle; the vehicle body center of gravity ranges from 0.015 to 0.022 when changing the spring hardness; and it fluctuates from 0.014 to 0.019 when changing the damper coefficient from 0.6 to 1.6; the vehicle's center of gravity ranges from 0.006 to 0.015 when the speed changes from 10 to 100km/h; the rear horizontal roll angle ranges from 0.0095-0,-0135 when the vehicle speed changes from 10 to 100km/h; oscillation of the body horizontal roll angle is from 3 to 6Rad when vehicle speed changes from 10 to 100km/h.

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