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RIDE TEST ON VEHICLES TRAVELLING OVER SPEED BUMPS: SIMULATION WITH CARSIM SOFTWRE

Adetia Lenahatu[1*], *Mohamad Yamin*[2]

[1]Industrial Technology, Depok, INDONESIA
[2]Industrial Technology, Depok, INDONESIA

Abstract

This research aims to analyze the vehicle's response when passing over speed bumps using computer simulations utilizing Carsim software. Six key parameters were explored in this study: vertical forces on the suspension, vertical acceleration of the center of gravity, damping forces, suspension characteristics, as well as the pitch and roll angles of the suspended masses. The results and discussions of each of these parameters provide deep insights into how vehicles respond to road obstacles. The vertical forces experienced by the vehicle's suspension while crossing speed bumps allow us to assess the physical impact of these road obstacles on the vehicle. Similarly, the vertical acceleration of the center of gravity provides an indication of how harshly the vehicle is jolted when navigating speed bumps, which is closely related to passenger comfort and vehicle stability. Damping forces within the suspension system are also of utmost importance as they indicate the extent to which the dampers can mitigate vibrations and shocks when encountering speed bumps. Suspension characteristics, such as the compression force response when traversing obstacles, aid in understanding how the suspension responds to rough road conditions. Furthermore, the pitch and roll angles of the suspended masses provide insights into how the vehicle responds to changes in vertical and lateral velocity when crossing these obstacles. By analyzing these parameters, this research provides valuable information for vehicle developers and road planners. This data can be utilized to enhance vehicle designs, including dampers and suspensions, as well as road elements like speed bumps, to achieve better levels of comfort and performance. Moreover, this study highlights the significant value of simulation technology in comprehending vehicle responses in various road scenarios. Thus, this research not only offers a profound understanding of vehicle responses to speed bumps but also lays the foundation for substantial improvements in vehicle design and road infrastandaructure, ultimately aiming to enhance the driving experience and road safety.

Keywords: Carsim Simulation, Speed Bumps, Vehicle Response, Suspension Characteristics, Road Comfort

*Corresponding author: Tel. +62 81 11789989
E-mail address: mohay.info@gmail.com

1. Introduction

CarSim is a software tool developed by Mechanical Simulation Corporation to simulate the dynamic behaviour of passenger vehicles and light trucks[1], [2]. It is designed to provide an accurate, detailed, and efficient method for simulating vehicle performance[3]. CarSim is widely used in the automotive industry and is considered the "company standard" vehicle dynamics simulation software[4]. CarSim is part of the standard VehicleSim structure, which includes other products such as TruckSim and BikeSim[5]. CarSim runs on Windows OS and most real-time systems[6].

Vehicle ride testing is one of the most important aspects of motor vehicle development and improvement. When vehicles traverse different types of road obstacles, such as speed bumps, ride quality becomes a crucial factor in driver experience and passenger comfort. This quality can also affect the overall safety and performance of the vehicle.

$$F_{total} = ks.\Delta s + Cs\frac{d\Delta s}{dt} + ms.\frac{d2\Delta s}{dt2} \quad (1)$$

Suspension model This equation is a basic representation of the total force on the suspension system. Ftotal is the total force on the suspension, ks is the spring constant, cs is the damping coefficient, ms is the mass of the suspension, and Δs is the displacement of the suspension[7].

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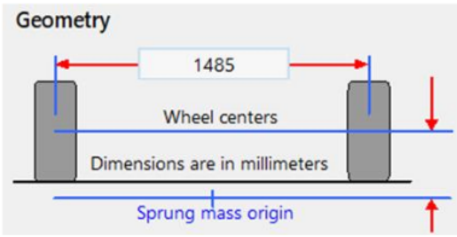

Fig. 1. Geometry interface in CARSIM Software

Vehicle geometry addresses crucial dimensions such as wheelbase, wheel width, wheel diameter and more, which affect vehicle performance. Wheelbase and wheel width play an important role in stability, while wheel diameter and wheel centre to road surface distance affect stability and ground clearance. both wheelbase and wheel width are key factors in determining vehicle stability.

$$r^{\cdot} = \frac{a \cdot u - b \cdot \delta^{\cdot} f}{Iz} \qquad (2)$$

This equation describes the rate of roll (r˙) at a constant speed state. a and b are the distances of the vehicle's centre of mass to the front and rear axes, δ˙f is the rate of change of the front steering angle, and Iz is the vehicle's moment of inertia about the vertical axis[8].

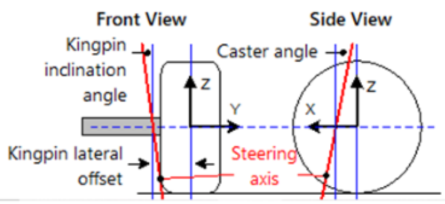

Fig. 2. Wheel axis and wheel thickness

Wheelbase and wheel width are the main factors in determining vehicle stability, these two geometry dimensions play a key role: a longer wheelbase provides better stability, but can make the vehicle difficult to control, while a wider wheel width also improves stability, but can make it difficult to control the vehicle[9].

$$m.ay = -Cf.\delta f - Cr.\delta r - m.u.r \qquad (3)$$

The equation of lateral motion describes the lateral acceleration ay of the vehicle. Cf and Cr are the front and rear friction forces, δf and δr are the front and rear steering angles, m is the mass of the vehicle, u is the vehicle speed, and r is the roll rate[7].

Such as wheelbase, wheel width, wheel diameter, and wheel centre to road surface distance, have a significant impact on vehicle performance. For example, a longer wheelbase and wider wheel width can improve stability, but also make the vehicle difficult to control due to the greater moment of inertia. On the other hand, a larger wheel diameter improves stability, but can make the vehicle more unstable. A higher wheel centre to road surface distance increases ground clearance, but can make the vehicle more prone to roll over due to a smaller moment of inertia. Therefore, vehicle designers need to carefully consider the geometry of the vehicle to achieve the optimal balance in performance[10].

Therefore, ride tests have become an important focus in the automotive industry and vehicle engineering. Ride tests are based on the ISO 2631 standard[11], which defines the sensitivity of the human body to vibration. The Ride Test in CarSim software uses the following equation to calculate the ride comfort index:

$$RCI = \frac{1}{T}\int_0^T \sqrt{\frac{1}{n}\sum_{i=1}^{n} a_i^2 \, dt} \qquad (4)$$

Equation RCI is the ride comfort index, T is the test duration, N is the number of vibration measurements, a is the acceleration in the i-th direction[12].

Speed bumps are a type of road obstacle often found in urban areas. They are designed to reduce vehicle speed and improve road user safety. However, they can also affect travelling comfort and require proper suspension design to be effectively handled by vehicles[13]. Speed Bump Height: 5 cm (five centimetres) to 9 cm (nine centimetres), Total width: 35 cm (thirty-five centimetres) to 39 cm (thirty-nine centimetres), Highest clearance: 50%[14].

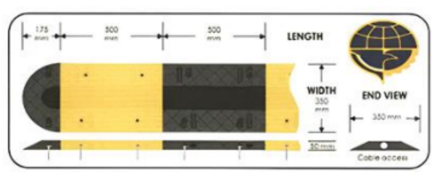

Fig. 3. Speed bump obstacles[14]

In an effort to understand and improve vehicle performance when travelling over speed bumps, this research proposes the use of computer simulation using Carsim Software[1]. This simulation allows us to carefully analyse the vehicle's response to such obstacles by utilising parameters that can be adjusted as required. The results of these simulations can

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provide valuable insights in designing and optimising vehicle suspensions[15].

The purpose of this study is to investigate the response of a vehicle when crossing speed bumps obstacles with the help of Carsim Software simulations[16]. I will analyse various parameters, such as vehicle height change, vertical acceleration, and forces acting on the vehicle during the ride test[17]. The results of this research are expected to provide important guidance to the automotive industry in designing vehicles that are more comfortable and safe for road users[18].

In other words, this research will focus on the vital aspects of ride testing and explore the potential of using Carsim Software simulation technology in the development of better vehicles.[19] Through a deeper understanding of vehicle responses when crossing speed bumps, we can improve the ride quality of vehicles and optimise rider comfort[20].

2. Experimental and Procedures

The method used in this research is simulation using Carsim software. This research tries to replicate the real conditions when vehicles cross speed bumps. The data obtained from these simulations can provide a better understanding of how vehicles respond to these obstacles, including changes in comfort levels, stability, and other parameters.

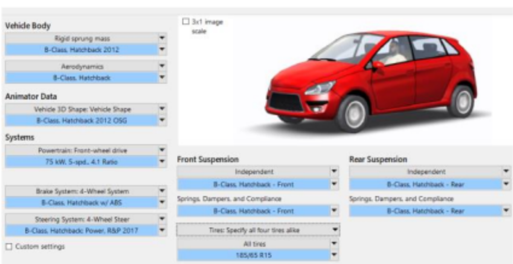

Fig. 4. Car model setup

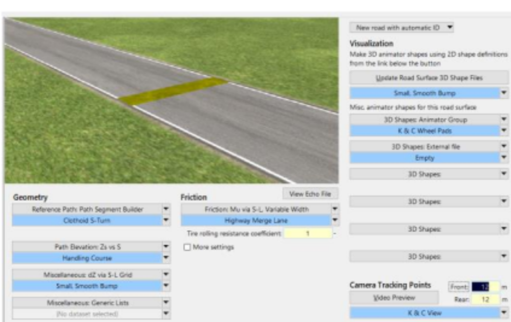

Fig. 5. Speed bumps setting

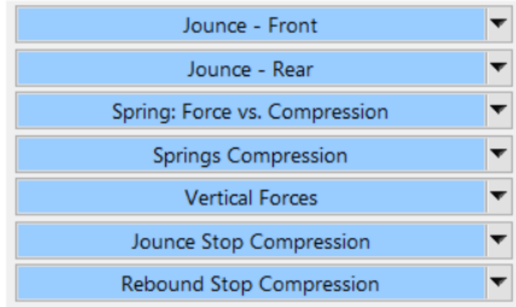

Fig. 6. Parameters viewed in carsim software simulation

3. Results and Discussion

3.1 Jounce – Front

"Jounce – Front" refers to measuring the vertical movement of a vehicle's front wheels. Jounce itself refers to a change in the vertical position of the wheel suspension, or in this context, the front wheel suspension. So, "Jounce – Front" in Carsim measures the extent to which the vehicle's front wheels move up or down (compression) during a particular movement or test.

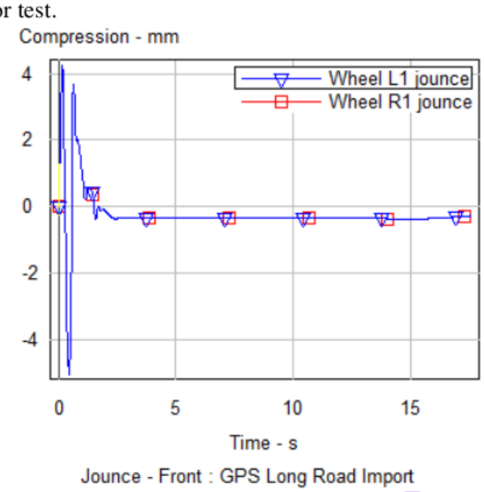

Figure 7. Jounce – Fornt plot

In Figure 7, the Ride Test graph uses the X axis (time in seconds) and Y axis (compression in mm) at a speed of 10 Km/hour showing front wheel compression (left and right). The level of driving comfort is considered quite good because wheel compression is relatively low (under 4 mm) during testing. The difference in compression between the left front wheel and the right front wheel is visible, where the left wheel has slightly higher compression. Factors that might influence this difference include uneven road conditions or differences in tire pressure. Vehicle stability can be inferred from small wheel

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compression fluctuations during testing, indicating a fairly stable vehicle. These results can be used as a contribution to evaluating the performance and comfort of driving at a speed of 10 Km/hour in the journal.

3.2 *Jounce – Back*

"Jounce – Rear" in Carsim Software refers to measuring the vertical movement of the vehicle's rear wheels. In this context, "Jounce" still refers to a change in the vertical position of the wheel suspension, but this time in relation to the rear wheel suspension.

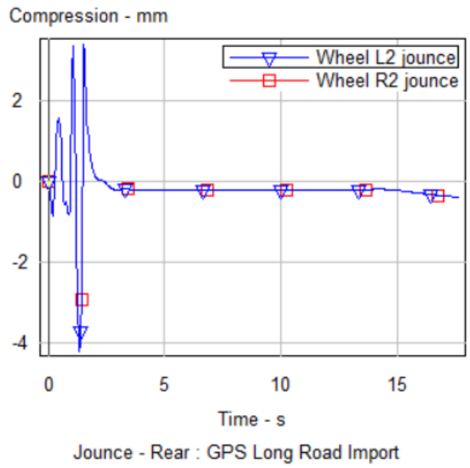

Figure 8. Jounce – Back Plot

In Figure 8, the results of the Jounce - Rear test at a speed of 10 km/hour using Carsim software reveal the difference in compression between the left rear wheel (Wheel L2 Jounce) and the right rear wheel (Wheel R2 Jounce). The graph shows that the rear wheel compression is lower than the front wheel, especially seen from the red line which is below the blue line. Further analysis shows that the rear wheels experience double compression when passing speed bumps at around 0.5 seconds and 1.5 seconds. The level of driving comfort at the rear is considered lower than at the front, due to lower rear wheel compression. In conclusion, the test results recommend increasing the level of driving comfort at the rear by considering modifications to the rear suspension, such as replacing the shock absorber or installing stiffer springs.

3.3 *Spring: Style vs. Style Compression*

The "Spring: Force vs. Compression" plot in Carsim Software visualizes the correlation between the force (force) produced by a spring and the level of spring compression in a vehicle's suspension system. The Analysis of this graph provides deep insight into the elastic characteristics of suspension springs

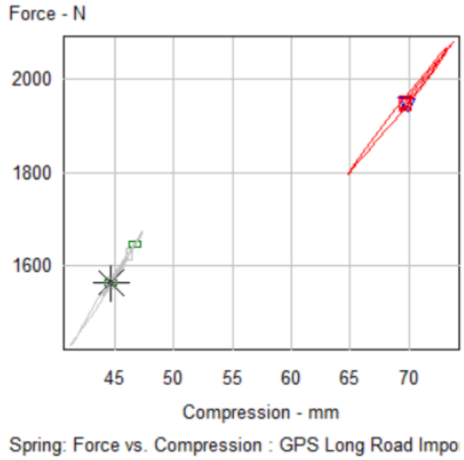

Figure 9. Spring: Force vs. Pressure Plot Compression

In Figure 9, the graphical analysis of "Spring: Force vs. Compression" in the driving comfort test at a speed of 10 km/hour using Carsim software shows the relationship between spring force and spring compression level. The X-axis of the graph reflects the compression rate of the spring in millimeters, while the Y-axis shows the spring force in Newtons. The analysis results reveal that the spring force increases as compression increases, indicating that the spring becomes stiffer when compressed. Peak spring force occurs at approximately 70 mm, indicating the spring's maximum compression limit. The level of driving comfort at the rear is considered lower than at the front, due to the high spring force. In conclusion, the test results recommend modifications to the springs to improve ride comfort, with the suggestion of replacing the springs with softer ones as a potential solution.

3.4 *Spring Compression*

"Springs Compression" refers to the testing and analysis of spring compression in a vehicle's suspension system. Springs Compression allows users to visualize and understand the extent to which springs within a vehicle's suspension experience compression during various driving conditions.

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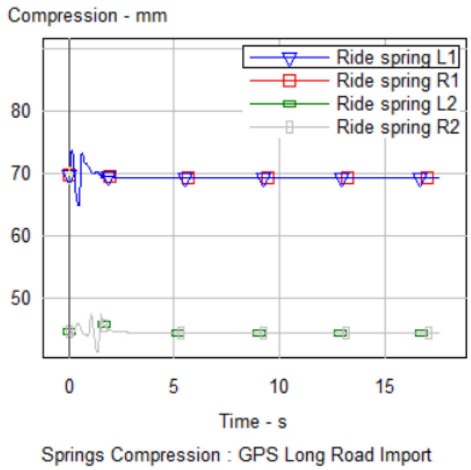

Figure 10. Spring Compression Plot

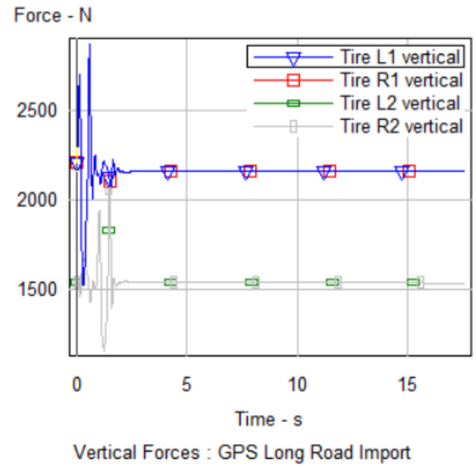

Figure 11. Vertical Force Plot

In Figure 10, analysis of the "Springs Compression" graph in the driving comfort test at a speed of 10 km/hour using Carsim software reveals the difference in compression between the left rear wheel (Wheel L2 Compression) and the right rear wheel (Wheel R2 Compression). The X-axis of the graph represents time in seconds, while the Y-axis reflects the wheel's compression level in millimeters. Observation of the graph shows that the rear wheels have lower compression compared to the front wheels, as can be seen from the position of the red line which is below the blue line. Further analysis revealed that the rear wheel compression peaks occurred at approximately 0.5 seconds and 1.5 seconds, indicating twice the compression when passing speed bumps. The level of driving comfort at the rear was rated lower due to lower rear wheel compression, and testing recommended modifications to the rear suspension, including the option of replacing the shock absorber or installing stiffer springs to increase the level of driving comfort.

3.5 Vertical Strength

The “Vertical Forces” plot refers to the vertical forces that occur on the vehicle during the simulation. These forces include all forces related to vertical movement, including forces arising from suspension response, wheel interaction with the road surface, and overall vehicle dynamics. Vertical Forces analysis in Carsim helps understand how a vehicle's suspension responds to pressure and vertical forces originating from various road conditions or driving situations.

In Figure 11, analysis of the "Vertical Forces" graph in the driving comfort test at a speed of 10 km/hour using Carsim software reveals the difference in vertical forces acting on the front and rear wheels. The X-axis of the graph represents time in seconds, while the Y-axis reflects the vertical force in Newtons. On the graph, the blue line representing Wheel L1 Vertical is above the red and green lines (Wheel R1 Vertical and Wheel R2 Vertical), indicating higher vertical forces on the front wheels. The peak vertical force on the front wheels occurs at around 0.5 seconds and 1.5 seconds, indicating two shocks when passing speed bumps. In contrast, the rear wheel peaks at around 0.75 seconds and 1.75 seconds. Evaluation of the level of driving comfort shows that the front has a lower level of comfort, caused by higher vertical forces. Therefore, the test results recommend modifications to the front suspension with the option of replacing the shock absorber or installing stiffer springs to increase the level of driving comfort.

3.6 Jounce Stop Compression

The "Jounce Stop Compression" plot refers to the compression or compression of the upper limit (stop) of the vehicle's suspension travel or movement. The jounce stop itself is a suspension component designed to prevent excessive movement or compression of the suspension during certain situations, such as when the vehicle crosses an obstacle or when the suspension reaches its upper travel limit.

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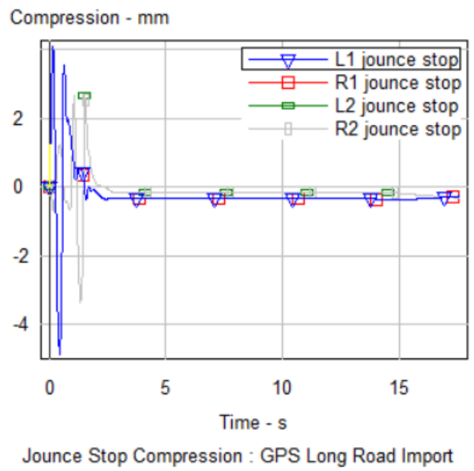

Figure 12. Jounce Stop Compression Plot

In Figure 12, analysis of the "Jounce Stop Compression" graph in the driving comfort test at a speed of 10 km/hour using Carsim software reveals that all four wheels experience compression when passing speed bumps. In the graph, the front wheel compression (L1 and R1) looks higher than the rear wheel compression (L2 and R2), indicating higher front suspension stiffness compared to the rear suspension. The front wheel compression peaks occur at around 0.25 seconds and 1.25 seconds, while the rear wheels reach peak compression at around 0.5 seconds and 1.5 seconds. The level of driving comfort at the front is rated lower due to higher front wheel compression, which can be felt as a harder shock by passengers. In conclusion, the test recommends modifications to the front suspension, such as replacing the shock absorber or installing stiffer springs, to increase the level of driving comfort.

3.7 Compression Stops Rebound

"Rebound Stop Compression" in Carsim Software is a parameter used to simulate suspension compression when the wheels return to the ground after passing over a bump or hole in the road. This parameter is important for determining the level of driving comfort and vehicle stability.

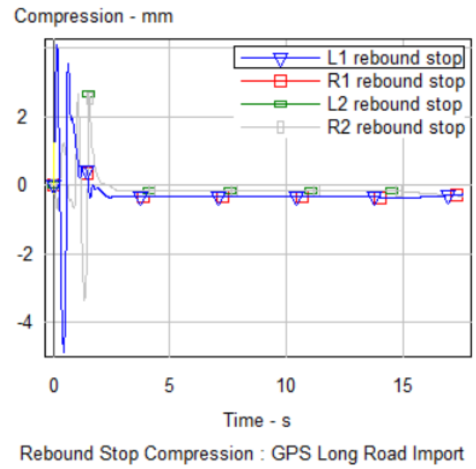

Figure 13. Rebound Stop Compression Plot

In Figure 13, analysis of the "Rebound Stop Compression" graph in the driving comfort test at a speed of 10 km/hour using Carsim software reveals that all four wheels experience compression when passing speed bumps. In the graph, front wheel compression (L1 and R1) looks higher than rear wheel compression (L2 and R2), indicating higher front suspension stiffness compared to the rear suspension. The front wheel compression peaks occur at around 0.25 seconds and 1.25 seconds, while the rear wheels reach peak compression at around 0.5 seconds and 1.5 seconds. The level of driving comfort at the front is rated lower due to higher front wheel compression, which can be felt as a harder shock by passengers. In conclusion, the test results recommend modifications to the front suspension, such as replacing the shock absorber or installing stiffer springs, to increase the level of driving comfort.

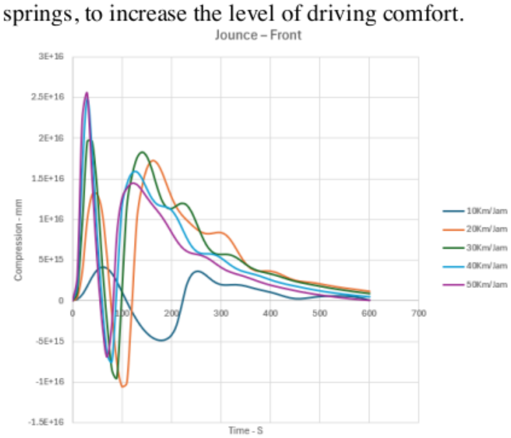

Figure 14. Combined Jounce – Fornt Plot with speed variations

The graph shows the performance of the Jeep

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Compass front suspension at various speeds. The higher the speed, the harder the suspension works to maintain stability and handling, but this can result in a harsher ride for passengers. This chart helps evaluate the performance of the Jeep Compass suspension and compares it to other vehicles.

By using a combination of these plots, we can understand how a vehicle responds to speed bumps and whether extensions to the suspension system or other changes are needed to improve ride comfort when going over obstacles such as speed bumps. By analyzing these parameters, I can better understand the complexity of the vehicle's response when going over speed bumps. By analyzing these parameters, I can better understand the complexity of the vehicle's response when going over speed bumps. This information can help in the development of better vehicles, more efficient suspension designs, and optimization of vehicle characteristics to achieve desired levels of comfort and performance.

4. Conclusions

Based on the measurements and analysis performed on various parameters such as vertical force on the suspension, vertical acceleration of the centre of gravity, damping force, per compression characteristics of the suspension, and pitch and roll angles of the mass connected to the suspension when passing over speed bumps, we can understand how the vehicle responds to speed bumps obstacles. This information has important value in the development of better vehicles, the design of more efficient suspensions, and the optimisation of vehicle characteristics to achieve the desired level of comfort and performance when encountering road obstacles such as speed bumps. By analysing these data, this research has provided valuable insights into the complexity of vehicle response to obstacles, opening up opportunities for significant improvements in the driving experience.

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Book Chapter

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