EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 22, No. 1, January 2025, pp. 47 - 54 **ISSN 2090 - 5882**
(Received October 25. 2024, Accepted in final form December 25. 2024) **jest.journals.ekb.eg**

Evaluation of the change of weight on the performance of the Front and Rear suspension system by Using Matlab Simulink

Hamdy Abo El Daheb[1], Mohamed Ali Hassan[2] and Sabreen A. Abdelwahab[3]

[1]Automotive Technology Department, [2]Production Technology Department,
Faculty of Technology and Education, Sohag University, 82524, Sohag, Egypt.
[3]Production Technology Department, Faculty of Technology and Education,
Helwan University, Cairo, EGYPT.

ABSTRACT
There are different types of transportation, including sea, air, and land. Therefore, vehicles are essential for road transportation, providing mobility to passengers and goods. However, when roads are poorly paved, the design and performance of a vehicle's suspension system become critical. So, suspension system design is at the center of designers' attention because it plays a crucial role in improving ride quality, road handling, and ensuring the vehicle's stability while driving and the comfort of passengers. In this paper, Matlab Simulink has been used to construct a simplified half-car model and study the effect of the weight change on the rear and front suspension systems. The vertical displacement, vertical velocity (bounce), pitch angular displacement, pitch angular velocity, and upward force on the body from front and rear have been simulated. The Simulink results show when the weight increases the rear and front force increase but the increase in pitch is very small.

KEYWORDS
Suspension system, Matlab, pitch angular, and vertical velocity.

INTRODUCTION
Vehicles are essential for land transportation, providing the ability to move passengers and goods. For vehicles to do this, they rely on many systems such as the braking system, steering system, suspension system, and other systems. Each system of the vehicle performs the specific functions for which it was designed. When the roads are unpaved, the suspension system plays its role. Suspension is the term given to the system of springs, shock absorbers, and linkages that connect a vehicle to its wheels. The suspension system converts the forward energy generated by bumps in the road into vertical energy that is transmitted to the vehicle's frame. Suspension components, such as coil springs and shock absorbers, help mitigate this road force.

The functions of the suspension system are to improve the ride quality and handling of the road and ensure the stability of the vehicle while driving and the comfort of

passengers. The suspension system consists of a group of mechanical components to perform these tasks.

The types of suspension are non-independent suspension and independent suspension, the first type non-independent suspension. It has both right and left wheel attached to the same solid axle. When one wheel hits a bump in the road, its upward movement causes a slight tilt of the other wheel. Anther Independent suspension, independent suspension is a broad term for any automobile suspension system that allows each wheel on the same axle to move vertically independently of each other.

Several research papers have addressed the types of suspension systems. Ufuk Demircioğlu et al., [1], focused on optimizing the suspension system. They used the MSC Adams View software and the Monte Carlo Simulation method with a uniform distribution to evaluate the approach and improve the car's ride comfort and road-holding capacity. The technique relies on setting variables and objectives without requiring the development of a mathematical model. The optimization process was carried out over 2000 trials. According to the results, the proposed method was significantly effective for the optimization process.

Jacob Kwaku Nkrumah et al., [2], presented a review of vehicle suspension control and simulated passive, semi-active, and active suspension systems using quarter-vehicle models with the help of Matlab software. Matlab Simulink has been used to compare the ride quality of passive, semi-active, and active suspension systems based on the defined parameters. According to the comparison of the suspension deflections of the three systems under the same road conditions, the semi-active suspension system exhibited the least suspension deflection compared to the passive and active suspension systems.

Teshome Kumsa Kurse et al., [3], used a technique MATLAB Simulink to create and simulate a half-car model, and various figures were devised to analyze the suspension's behavior. According to the simulation results, the Fuzzy-PID controller outperforms other controllers in terms of response amplitude, settling time, overshoot, steady-state precision, and dynamic performance.

Mahesh Nagarkar et al., [4], used the MATLAB/Simulink environment to create a mathematical model of a nonlinear quarter-car suspension system, which they then developed and simulated for control and optimization. One of the control techniques they employed was Fuzzy Logic Control (FLC) to manage the active suspension system. The results showed that the optimized passive suspension system closely mimicked the original FLC-based active suspension system. Additionally, when compared to other suspension systems, the optimized FLC system produced better results based on health criteria, proving to be more effective in terms of performance. Mahesh P. Nagarkar et al., [5], implemented a nonlinear quarter-car suspension–seat–driver model for optimal design. The model, which includes a nonlinear quarter-vehicle system with four degrees of freedom (DoF) for the driver, was developed for optimization and analysis. It accounted for both quadratic tire stiffness and cubic

stiffness in the suspension spring, frame, and seat cushion. The simulation results showed that the optimal design outperformed traditional designs in terms of ride comfort and health, providing better performance in both aspects.

Rabie Abd-Elwahab M. et al., [6], used MATLAB/Simulink to simulate a quarter-car suspension system, modeling it as a two-degrees-of-freedom system. They designed the passive suspension parameters using various optimization techniques, including Taguchi, Genetic Algorithms (GA), and Simulated Annealing (SA). The results showed that the GA and SA methods were effective in determining the optimal suspension system design parameters, which led to a reduction in the root mean square (RMS) value of vertical vibrations, improving the overall performance of the system.

Ahmad O. Moaaza et al., [7], used MATLAB/Simulink to study the vertical vibration response of a passive suspension system and a semi-active suspension system under random road excitations. They also explored the performance of three different controllers: skyhook, groundhook, and hybrid control. The study found that, compared to the skyhook and groundhook suspension systems, the hybrid-controlled semi-active suspension system offered improvements in suspension performance. Furthermore, when compared to passive suspension, the hybrid, skyhook, and groundhook control methods all resulted in enhanced suspension performance.

Shinde et al., [8], focused on improving the performance of a half-car suspension system using various optimization techniques, including hybrid genetic annealing (a combination of genetic algorithms and simulated annealing), simulated annealing, and genetic algorithms. The main objective was to enhance ride comfort by reducing the accelerations experienced by the vehicle, particularly in the passive suspension system.

Hada M. K. et al., [9], conducted a study that used genetic algorithms to optimize the suspension system parameters. The goal was to achieve an optimal balance between ride comfort, handling quality, and suspension stroke under random road conditions. The results showed that genetic algorithms outperformed traditional methods, offering superior performance in terms of the suspension system's overall effectiveness.

Kuznetsov et al., [10], presented a study focused on optimizing a quarter-car model coupled with a driver. They developed a 3-degrees-of-freedom (DoF) model, consisting of a 2-DoF quarter-car system and a 1-DoF driver model. The optimization process was guided by ride comfort criteria specified in ISO 2631-1 and used the Algorithm for Global Optimization Problems (AGOP) to achieve the desired results. This approach helped improve the overall performance and comfort of the driver during vehicle operation.

In the present work, a simplified half-car model by Matlab Simulink has been applied to study the influence of the weight change on the rear and front suspension systems.

THE SUSPENSION MODEL

Figure 1 shows the suspension system which is divided into two subsystems, the front, and the rear suspension. Figure 2 shows the vehicle suspension model. This model explains the operation of the suspension system which consists of two subsystems, the front suspension and the rear suspension. Two suspensions depend on equations to create the Simulink model.

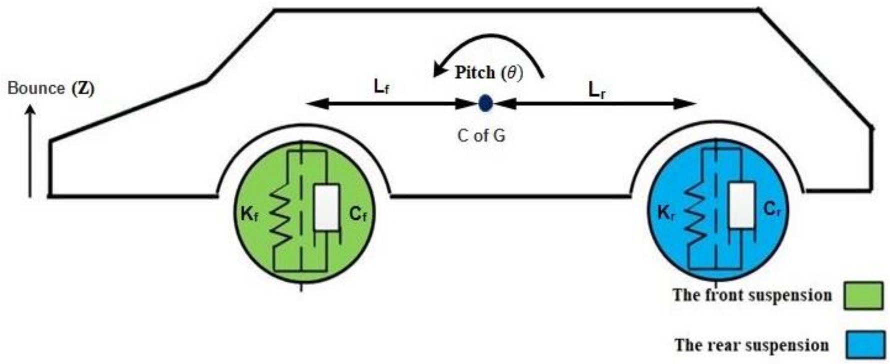

Fig. 1. The front and rear suspension system.

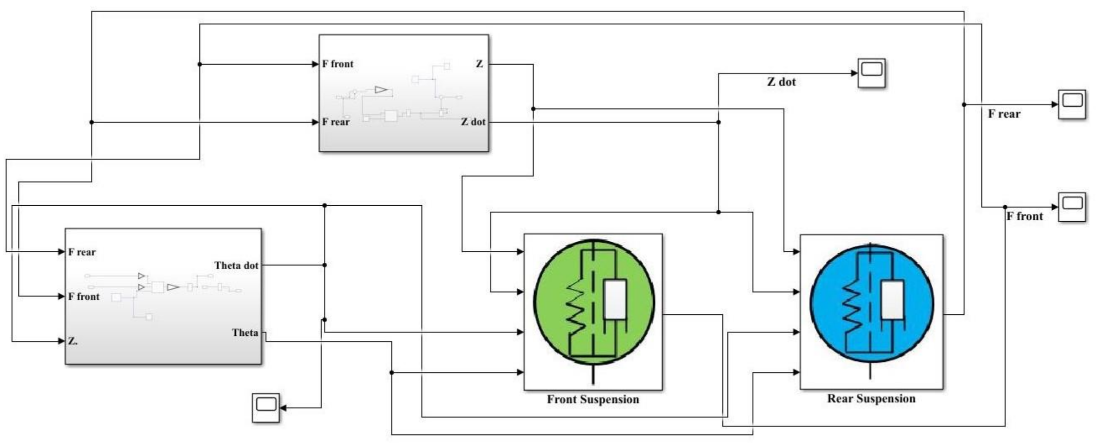

Fig. 2 The vehicle suspension model.

The vehicle suspension model has been created in two steps, the first step creates the front suspension and anther create the rear suspension. The front suspension influences the bounce, or vertical degree of freedom, according to the relationships, [6].

$$F_f = 2K_f(L_f\theta - Z) + 2C_f(L_f\dot{\theta} - \dot{Z}) \qquad (1)$$

Where

F_f = Upward force on body from front suspension.

K_f, C_f= Suspension spring rate and damping rate at each wheel.

$\dot{\theta}$, θ = Pitch (rotational) angle and rate of change.

Z, $\dot{Z}$= Bounce (vertical) distance and velocity.

L_f =Horizontal distance from body center of gravity to front suspension.
The moment due to front suspension calculated by [6] [7] [10]

$$M_f = -L_f F_f \quad (2)$$

For the rear suspension

$$F_r = -2K_r(L_r\theta + Z) - 2C_r(L_r\dot{\theta} + \dot{Z}) \quad (3)$$

F_r = Upward force on body from rear suspension.
K_r, C_r= Suspension spring rate and damping rate at each wheel.
L_r =Horizontal distance from body center of gravity to rear suspension
The moment due to rear suspension calculated by

$$M_r = -L_r F_r \quad (4)$$

The forces and moments result in body motion according to Newton

$$M_v\ddot{Z} = F_f + F_r - M_v g \quad (5)$$

Where
M_v = Body mass
g = The gravitational acceleration

$$I_{yy}\ddot{\theta} = M_f + M_r - M_y \quad (6)$$

Where
I_{yy} = Body moment of inertia about center gravity.
M_y = Moment introduced by vehicle acceleration

SIMULATION AND RESULTES

MATLAB is a suitable environment for simulating linear and nonlinear mechanical systems. Therefore, MATLAB was used to simulate the suspension system of a half-vehicle, which consists of a front suspension system and a rear suspension system. The effect of changing weights on the suspension system was studied using three weights: 1000, 12000, and 14000 kg. At each weight, both the rear force, the front force, vertical velocity (bounce), and pitch have been calculated. Figure 3 shows the rear force at three weights, Fig. 4 shows the front force at three weights, Fig. 5 shows the vertical velocity at three weights, and Fig. 6 shows the pitch at three weights.

The results showed that with increasing weight, the vertical velocity (bounce) increases. Also, the increase in the rear force is greater than the front force. As, with increasing weight, the change in pitch is very small.

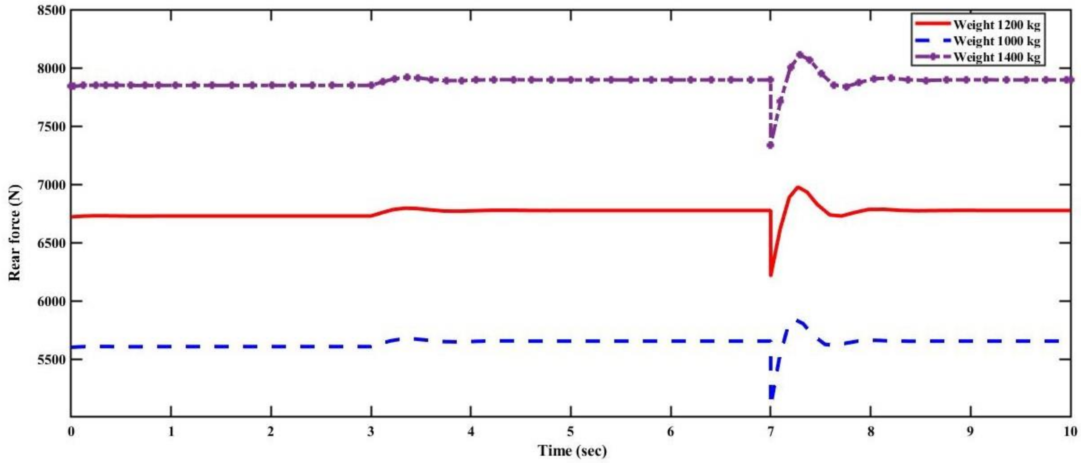

Fig. 3 The upward force on body from the rear suspension.

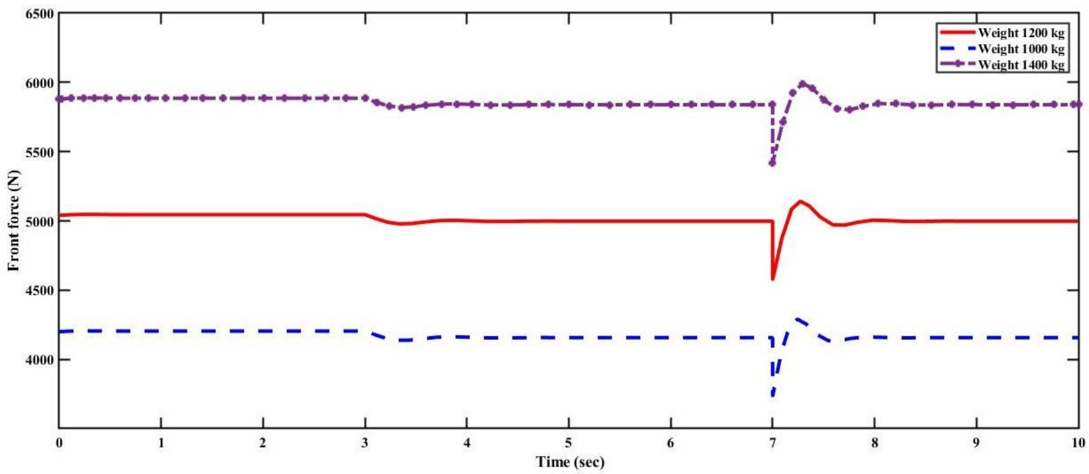

Fig. 4 The upward force on body from the front suspension.

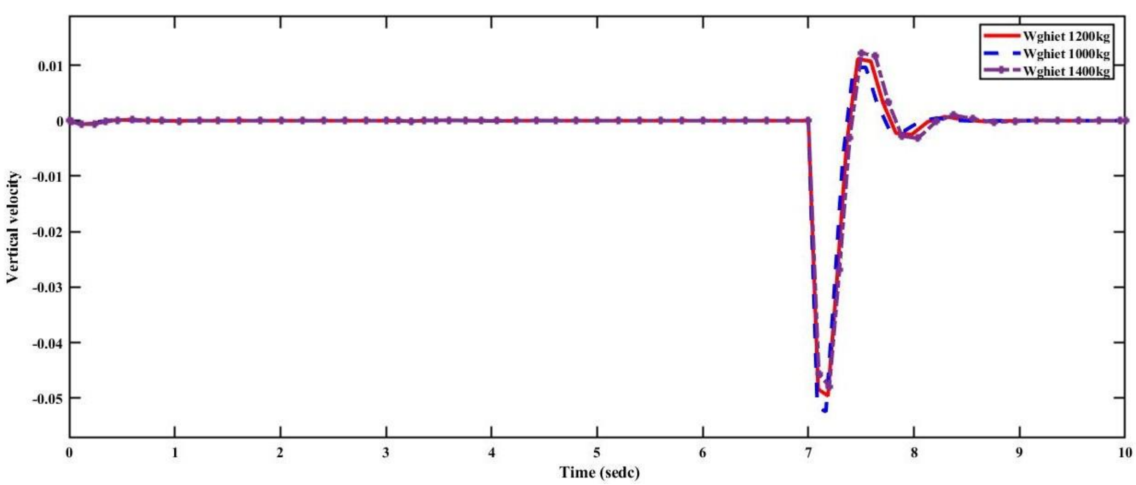

Fig.5 The vertical velocity (bounce).

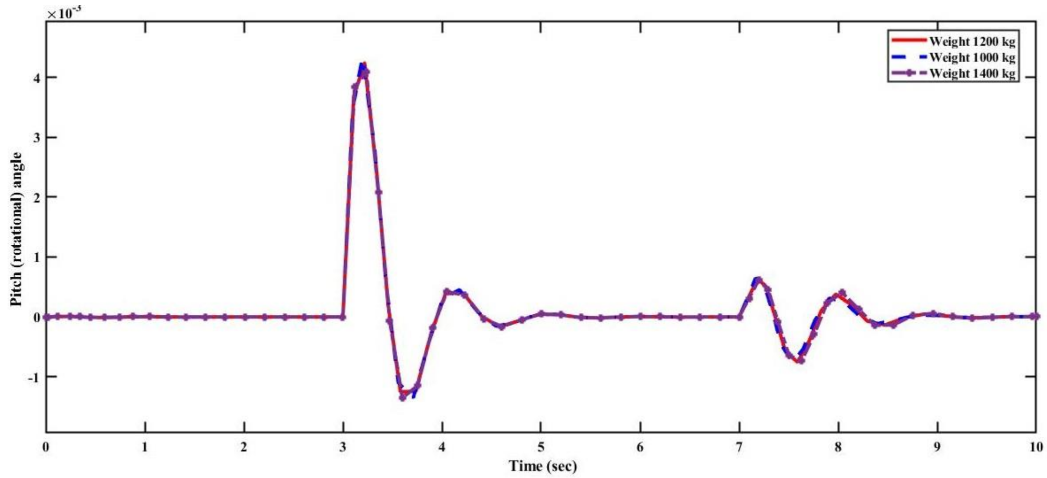

Fig. 6 The pitch (rotational) velocity.

CONCLUSIONS

The suspension system is considered one of the important systems in vehicles as it plays an effective role in improving ride quality, and road handling, and ensuring the vehicle's stability while driving and the comfort of passengers. There are several different types of suspension systems used in vehicles such as active suspension systems and semi-active suspension systems. The suspension system consists of mechanical components that enable the suspension system to perform the tasks for which it was designed efficiently. In this research, Matlab Simulink has been used to create the Simulink suspension system in addition to evaluating the performance of this system at three different weights. The results can be drawn:

1. When weight increases the rear and front force increase, but the rear force increases more than the front increase.

2. The change of the pitch with change weight is small.

3. With a weight increase, the vertical velocity (bounce) increases

4. The pitch occurs after the vertical velocity (bounce).

REFERENCES

1. L. Asif and W. Malik, "2nd International Conference on Engineering, Natural and Social Sciences Effect of Marble Powder on Concrete: A Review," no. April, pp. 166–171, (2023).

2. J. K. Nkrumah, Kwabla Sherry Amedorme, Baba Ziblim, and David Inusah Offei, "Review of Suspension Control and Simulation of Passive, Semi-Active and Active Suspension Systems Using Quarter Vehicle Model," Am. Acad. Sci. Res. J. Eng. Technol. Sci., vol. 90, no. 1, pp. 144 - 160, (2022), [Online]. Available: https:// asrjetsjournal.org/index.php /American_Scientific Journal/article/view/7452.

3. T. Kumsa, "Transport Engineering and Applications A General Review of the Fundamentals of MATLAB Vehicle Passive Suspension System Simulink Model", July, (2023), doi: 10.37591/TTEA1.

4. M. Nagarkar, Y. Bhalerao, D. Bhaskar, A. Thakur, V. Hase, and R. Zaware, "Design of passive suspension system to mimic fuzzy logic control active suspension

system," Beni-Suef Univ. J. Basic Appl. Sci., vol. 11, no. 1, (2022), doi: 10.1186/s43088-022-00291-3.

5. M. P. Nagarkar, G. J. Vikhe Patil, and R. N. Zaware Patil, "Optimization of nonlinear quarter car suspension–seat–driver model," J. Adv. Res., vol. 7, no. 6, pp. 991–1007, (2016), doi: 10.1016/j.jare.2016.04.003.

6. M. R. Abd-Elwahab, M. M. Makrahy, N. M. Ghazaly, and A. O. Moaaz, "Optimization and Analysis of the Quarter Car Passive Suspension Using Taguchi, Genetic Algorithm, and Simulated Annealing Approaches," Int. J. Transp. Dev. Integr., vol. 8, no. 3, pp. 383–392, (2024), doi: 10.18280/ijtdi.080302.

7. A. O. Moaaz, A. S. Ali, N. M. Ghazaly, and M. M. Makrahy, "Performance Evaluation of Semi-Active Suspension for Passenger Vehicle through Skyhook, Groundhook and Hybrid Control Strategies," Int. J. Veh. Struct. Syst., vol. 14, no. 5, pp. 572–579, (2022), doi: 10.4273/ijvss.14.5.04.

8. Shinde, D., Mistry, K.N., Jadhav, G., Singh, H. Optimization of automobile suspension system using hybrid GSA algorithm. IOP Conference Series: Materials Science and Engineering, 377: 012149, (2018). https://doi.org/10.1088/1757-899X/377 /1/ 012149.

9. M. K. Hada, A. Menon, and S. Y. Bhave, "Optimisation of an active suspension force controller using genetic algorithm for random input," Def. Sci. J., vol. 57, no. 5, pp. 691–696, 7, (200), doi: 10.14429/dsj.57.1806.

10. Kuznetsov A, Mammadov M, Sultan I, Hajilarov E. Optimization of a quarter–car suspension model coupled with driver biomechanical effects. J Sound Vib; 330: pp 2937–46, (2011).