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A review of truck seat suspension system

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Abstract
This review will explore and analyze the characteristics, advantages, disadvantages, limitations and applications of each type of truck seat suspension system. Then go deeper into analyzing the development trends and future directions of various types of truck seat suspension systems.
Commercial truck driving can be a grueling task if the vehicle isn't optimized for drivers. The long hours on the road, combined with unpredictable terrains, make comfort and safety paramount. An easily overlooked yet critical component of a trucker's comfort is their seat suspension system. Whether you're driving on bustling freeways or winding country roads, a comfortable seat can make the difference between a satisfying day's drive and an uncomfortable experience. So, what are the types of seat suspension systems? Explore each type to learn how critical the right seat suspension is to a driver's success [1].
Keywords: *vehicle, truck, seat suspension system*

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I. INTRODUCTION

The suspension system is a combination of tires, springs, shock absorbers, and connectors that connect the vehicle to its wheels, allowing the vehicle to travel reasonably well. Suspension systems are essential for both handling and consistency of travel [3]. The suspension system is a system of springs, safeguards and associations between the vehicle and its wheels. It is a process that physically separates the car body from the car wheel. The suspension system generally consists of three main components: a structure that maintains the vehicle's weight and determines the suspension geometry, a spring that transforms kinematic energy into potential energy; or vice versa; and a shock absorber, a mechanical device designed to dissipate kinetic energy [4]. The predominant role of the vehicle suspension system is to reduce the vertical acceleration that is transmitted to the vehicle body (indirectly to passengers or loads), ensuring comfort directly in the lane. Therefore, The purposes of the suspension system are: to prevent the road shocks from being transmitted to the components of the vehicle; to protect the resider from road shocks; to maintain the vehicle's stability during pitching or rolling while the vehicles are in motion [5].

Figure 1: An illustration of a shock absorber used in automobiles [5]

The increasing demands on the overall dynamics and stability of vehicles, as well as the rapid development of hybrid and electric passenger cars, could contribute to the implementation of several controlled suspension systems and their integration into the overall control of passenger vehicles. Several scientists have paid great attention to car suspension system like how to ensure the stability of suspension systems and how to improve the required suspension performance, namely driving comfort, road handling, and suspension deflection. Until now, many vehicle suspensions models have been proposed. Modifying the suspension requires a deep understanding of car suspension networks and vehicle dynamics. Keeping the wheel in contact with the road is essential for the safety of the vehicle movement, since the total load of the car is lies through the contact surfaces of the tires [6].

II. PASSIVE SUSPENSIONS SYSTEM

At their core, these systems utilize metal springs and a variety of damping devices to absorb shocks and vibrations. When your truck hits a bump, the mechanical suspension's springs flex, and accompanying shock absorbers quell the oscillation, leaving you feeling more like you're rocking in a cradle than serving as a crash test dummy. Mechanical suspensions offer a proactive response to road conditions. Each unit can be manually adjusted to a driver's weight and ride preference, ensuring a custom tailoring to their form and driving style. While they provide a robust and adjustable ride, they tend to lack a critical design factor – comfort [1].

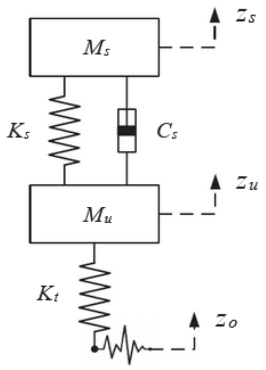

Figure 2: A passive suspension model [7]

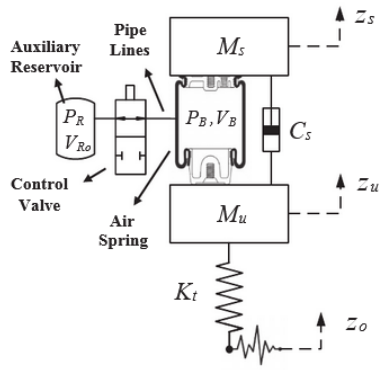

Figure 3: The physical model of air spring [7]

The ride comfort and road holding responses for quarter car model of air spring suspension system are studied comparatively with the passive suspension responses. Moreover, the parameters that influence the characteristics of the air spring are investigated through an extensive parametrical sensitivity analysis. In order to analyze the influence of the air spring parameters on the suspension system performance of passenger vehicles, the dynamic air spring suspension model is given. Quarter car model of the passive suspension system is presented and then the performance of air suspension and the passive suspension is compared under ISO-based random road input. A model of the air spring is derived according to the basis of the thermodynamic equation and the mathematical models for both air spring and passive suspension. In figure3, the influence of the air spring parameters on the suspension system performance is presented. It compares the air spring responses over the passive suspension. The air spring dynamical performance are investigated based on extensive simulations confirming which combination of the air spring parameters are best to obtain the best values of body acceleration, suspension deflection, and dynamic tire load. The following sections will show the simulation results obtained when the diff erent air spring parameters are modified, and their eff ects will be analyzed [7].

A passive suspension system is one in which the characteristics of the components (springs and dampers) are fixed. These characteristics are determined by the suspension designer, according to the design goals and the intended application. A passive suspension, such as shown in Figure 2, has the ability to store energy via a spring and to dissipate it via a damper. Figure 2 represents one-quarter of a vehicle, and therefore is commonly referred to as 'quarter-car model'. The mass of the vehicle body (sprung mass) and tire–axle assembly (unsprung mass) are defined respectively by m_b and m_a, with their corresponding displacements defined by x_b and x_a. The suspension spring, k_s, and damper, c_s, are attached between the vehicle body and axle, and the stiffness of the tire is represented by k_t. The parameters of a passive suspension are generally fixed to achieve a certain level of compromise between reducing vibrations and increasing road holding. Once the spring has been selected, based on the load-carrying capability of the suspension, the damper is the only variable remaining to specify. Low damping yields poor resonance control at the natural frequencies of the body (sprung mass) and axle (unsprung mass), but provides the necessary high-frequency isolation required for lower vibrations and a more comfortable ride. Conversely, large damping results in good resonance control at the expense of lower isolation from the road input and more vibrations in the vehicle [10].

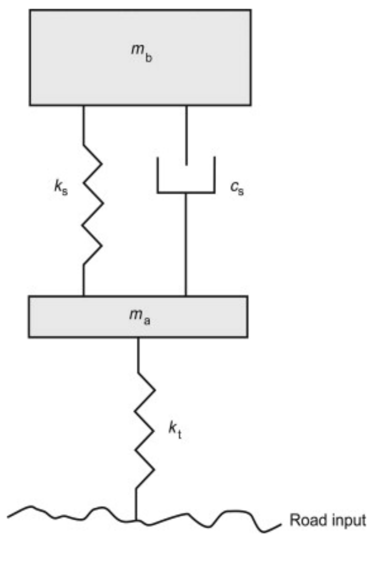

Figure 4: A model of passive suspension [10]

III. SEMI-ACTIVE SUSPENSION SYSTEM

Modern air suspension systems for truck seats prioritize strength, adjustability, and ergonomics, ensuring the drivers remain as comfortable as possible. Like a cushion of air, air suspension systems can float drivers over even the roughest roads. They are the gold standard when it comes to luxury and comfort in driver seats. Air suspension systems feature airbags and other pneumatic components connected to an air compressor and valves. For the long-haul trucker, air suspension systems provide a smooth ride and can help alleviate stress on the body over extended periods. At GRA-MAG, we carry ergonomic truck seats that utilize air suspension systems to create the most accommodating user experience [1].

The duty of a suspension system is to bear the vehicle weight, to cut off the vehicle body from road disturbances, and to preserve the traction force between the tires and the road surface. The function of uspension system is to advance the comfort of riding, road traction handling and steadiness of vehicles. Suspension systems are classified into a passive, semi-active and active suspension system. We can say ac compromise between the passive systems, and the costly higher-performance fully active suspension system is called semi active suspension system. In consideration with an active system, a semi-active system requires much less power, and is less complex and more consistent and can provide great improvement in ride quality. Karnopp introduced the skyhook control strategy, which is unquestionably the most broadly used control policy for semi-active suspension systems. The skyhook control can decrease the resonant peak of the body mass and thus achieves a good quality riding. But, to improve both the ride quality and the safety of vehicle, both resonant peaks of the body and the wheel need to be reduced. For this purpose Minimax control strategy proposed by Prof. Herman Winner and Tobias Niemz is introduced in this thesis. The models of skyhook and minimax are developed using Matlab/Simulink. The passive suspension, minimax and skyhook are compared using SILS. This paper is prepared as follows. In Section II, a two degree-of-freedom quarter car model for the semi-active suspension system is given. In Section III, on/off skyhook algorithm is introduced. Wheel load influence matrix is introduced and minimax controller is designed. In Section IV, the Simulink models are shown. In section V the performances of passive system, skyhook and Minimax strategies are compared and evaluated using SILS and the simulation results are given [11].

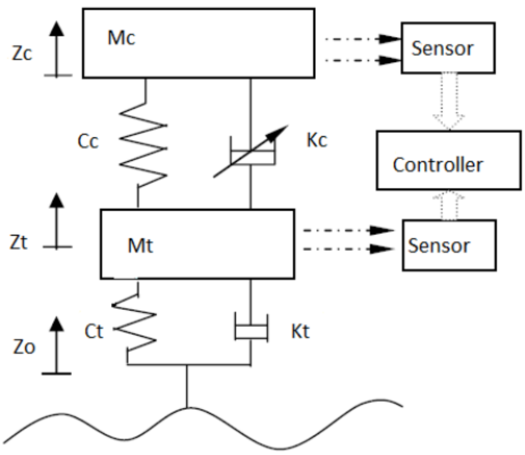

Figure 5: A 2 DOF semi active suspension system quarter car [11]

A two degrees of freedom semi-active quarter car model is shown in Fig6. It consists of sprung mass, Ms which is connected to the unsprung mass, Mu through semi-active suspension system. The semi-active suspension system consists of spring stiffness Ks ,suspension damper Cs and a MR damper placed between sprung mass and unsprung mass. The tire stiffness is represented by Kt while tire damping is neglected because of its minimum effect on final results xs, xu and xt are the sprung mass, unsprung mass and tire vertical displacement respectively. This quarter car model revels the basic properties of full vehicle model [8].

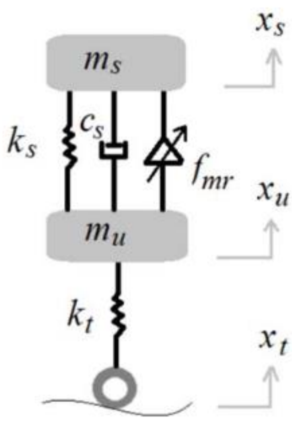

Figure 6: Semi active suspension system [8]

IV. ACTIVE SUSPENSION SYSTEM

Knowing what the different types of truck seat suspension systems are remains important because, as you can see, they both deliver reliable performance. However, the right choice comes down to determining what factors are most important to you. Mechanical suspensions reduce vibrations, but they don't enhance ergonomics for the driver. Air suspension seats, on the other hand, create a soft space for the driver to rest on and adjust while enjoying less vibrations on the road. Air suspension systems are innovative systems that use modern technology to create a workspace that your truckers can endure for long hauls. Upgrade your fleet with the right truck seat suspension systems today to create the healthiest and most productive workspace possible [1].

The active suspension system actively controls the vertical movement of the wheel-axle assembly through computer-controlled system. This suspension system offers smooth riding experience whereas in passive suspension system the condition of the road decides the entire movement. The active suspension provides freedom to adjust the entire suspension system and the control force here can be introduced locally as per the system state. The active suspension came in picture more than two decades ago. The F1's racing car lotus first employed the active suspension. That time it had numerous problems such as excessive noise, vibrations, & harshness. It also had excessive power consumption issue. Its manufacturing cost was very high at initial stages so manufacturers were not sure whether to implement this in a passenger car. The design of the active suspension system can be determined by two stages. The first stage is to construct control oriented dynamic model of a vehicle active suspension and then by choosing appropriate control strategy, which has substantial impact on the ride comfort and ride safety. [12].

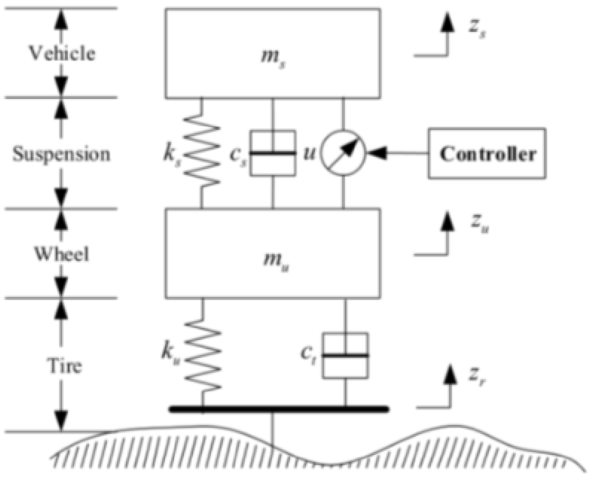

Figure 7: A model of active suspension system [12]

Several researchers have recently invested in active suspension systems to improve the stability and driving capabilities of the vehicles. To date, numerous control approaches have been utilized in the active suspension system fields, for example, Quadratic Linear Control (LQR), Quadratic Gaussian Linear Control (LQG), Slider Mode Control, Control H, Adaptive Slider, Preview Control, Neural Network Methods, Fuzzy Logic, and Optimal Control. Control methods can help improve the performance of the active suspension system [6].

V. CONCLUSION

In this article, the author introduces an overview of types of truck seat suspension systems. There are actually three types of suspension systems commonly used, Passive suspension system, Semi active suspension system and Active suspension system.

In the future, the designer should consider certain requirements while designing the vehicle suspension system like independency, good camber control, good body roll control, good structural efficiency, good isolation, low weight, long life, low cost, etc. Further research on electromagnetic active suspensions should focus on two main perspectives, namely the development of electromagnetic linear drives, as well as better system management.

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