International Journal of Scientific Research in Mechanical and Materials Engineering
© 2023 IJSRMME | ISSN : 2457-0435

The Vehicle Suspension Parameters System Analysis - A Review

Shashank Sagar[1], Ajai Singh[2] Vikash Dwivedi[3]
[1]M.Tech Student, B.N. College of Engineering and Technology, Lucknow, India
[2,3]Assistant Professor, B.N. College of Engineering and Technology, Lucknow, India

ARTICLEINFO

Article History:

Accepted: 01 June 2023
Published: 22 June 2023

Publication Issue
Volume 7, Issue 3
May-June-2023

Page Number
41-50

ABSTRACT

Methods for changing the driving behavior of passenger vehicles using active control strategies have been highlighted recently. In specific, the study concentrated on active suspensions to improve the comfort of the ride, while some attention was given to using the same to improve the behavior of the car. The reduction of body roll during a handling maneuver was subjectively assessed as very useful in exercise. It seems that an active suspension can be used to decrease the movement of the vehicle's body roll during maneuvers without sacrificing the comfort of the ride. This characteristic offers a benefit over passively suspended vehicles that have to compromise ride and handling. Analysis of functional controllability is used to demonstrate that achievable roll stability is eventually restricted by suspension travel, even with perfectly effective anti-roll bars. A method is submitted to identify critical axles, the lift-off of which determines the roll stabilization limit. The highest possible control goal for optimizing roll stability is to combine the uniform load transfers at all critical axles while taking the largest inward suspension roll angle to the highest permissible angle. Because of its energy regeneration, large bandwidth, easier design, versatile and precise power control, better handling performance as well as drive characteristics, it is found after a thorough examination that car suspensions should be designed using the electromagnetic active suspensions

Keywords : Passive Suspension System, Active Suspension System, Rollover Dynamics, Roll control, Actuators

I. INTRODUCTION

The majority of studies on semi-active suspensions used a two-degree-of-freedom (2DOF) model to depict single suspensions. There haven't been many studies into single-degree-of-freedom (SODF) systems [1-4]. The possibility of using semi-active suspensions to control the dynamics of an entire automotive model. This chapter will cover the literature on roll control. Most current cars come equipped with safety features like ABS and ESP, which are utilized to restrict roll in order to prevent vehicle rollover [5-7]. In numerous cutting-edge vehicles, an active suspension system has been included, mostly to lessen body roll. A higher maximum cornering speed and improved directional stability are the results, particularly while performing emergency evasive manoeuvres [8].

Rollover Dynamics

During a corner, the roll moment is caused by the lateral tyre forces from the ground counterbalancing the lateral inertial force acting at the centre of gravity of the vehicle. The moments of the vertical forces balance this instant [10].

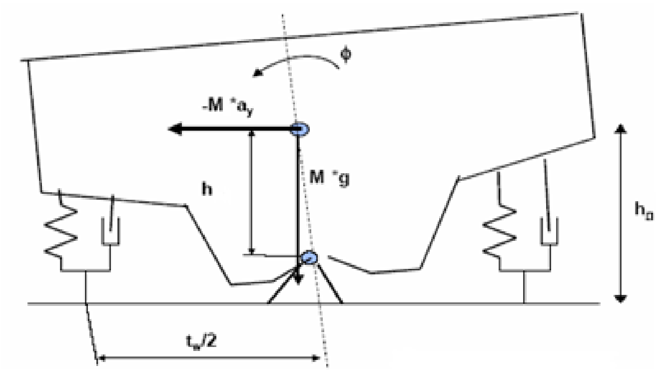

Figure 1: A simple model of vehicle roll motion [10].

Considering the centre of the outside tyres' contact patches and assuming minimal roll angles yields:

$$\sum T = \frac{mgt_w}{2} - ma_y h_0 - F_{zi} t_w \quad (1)$$

where m is the vehicle's mass, g is its acceleration due to gravity, t_w is its track width, a_y is its lateral acceleration, h_0 is its height above the ground, and F_{zi} is the total normal load placed on the inner tyres. The front and rear axle tracks are the same in this straightforward model. The usual load, F_{zi}, is zero at the rollover threshold (limit cornering situation). Therefore, the lateral velocity is equal to [11] at the rollover threshold:

$$a_{y\,lim} = \frac{gt_w}{2h_0} = g.\text{SSF} \quad (2)$$

where the commonly used static stability factor (SSF) is defined as t_w / (2h0). Automobile rollover tendency has long been described using the static stability factor. The SSF grade effectively identifies a vehicle's top-heavyness. The vehicle is more secure and has a lower danger of rolling over when the SSF score is higher. While larger C.G vehicles like SUVs, pick-up trucks, and vans have an SSF value of 1.00-1.30, most sedans and coupes have a safety rating of 1.30-1.50. Figure 2 provides an illustration of how SSF is described in automobiles and higher C.G. vehicles [12-14].

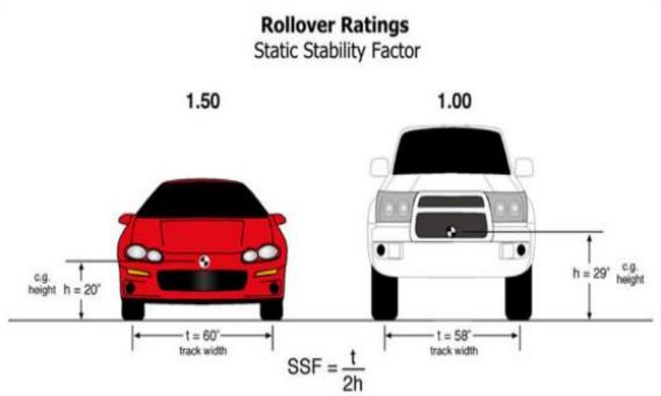

Figure 2: Illustration describing SSF in cars and higher C.G vehicles like trucks [15].

Literature Review of Roll Control

Instead of eliminating body roll, roll control in literature generally focuses on preventing vehicle rollover. In contrast to body roll removal, which aims to maximize tire-road contact and hence enhance a vehicle's cornering capabilities, rollover prevention aims to prevent this very specific sort of accident [12]. Generally speaking, there are two distinct circumstances in which rollover may occur. The first instance is a rollover brought on by rapid, excessive movement on a level surface. The second type is a "tripped rollover," in which the car has already started to slide and flips over when one of the wheels strikes an obstruction or soft ground. technologies for controlling the dynamics of modern vehicles, such as the Electronic Stabilisation Programme.

A mathematical model of a restricted bandwidth hydro-pneumatic suspension was created by Shuttlewood et al. [16] and integrated into a vehicle handling model. A viable control approach for reducing body roll throughout a cornering manoeuvre is evaluated using the combined model. The roll control plan was developed with the idea of using motion feedback measurements that don't interfere with ride control. A study on the impact of the body movement feedback transducer's position on the system's ability to eliminate body roll is presented. Sharp [18] showed that a car equipped with an active suspension system has negligible body roll angle compared to one with a passive..

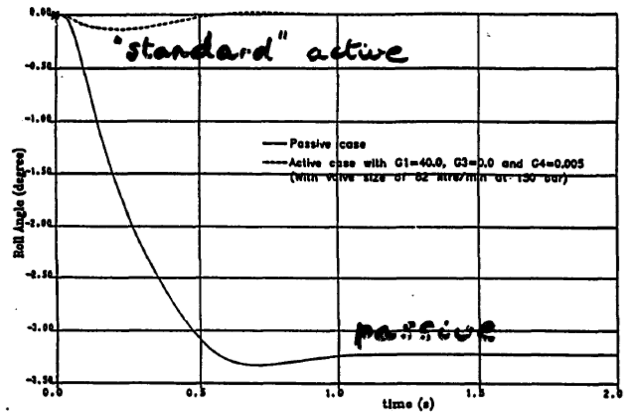

Figure 3: Comparison of roll angles between a car with active and passive suspension systems [18].

Martens [17] looked into how several active safety features, including ESP, active steering, active suspension, and active roll control, affected a vehicle's stability. If an unanticipated departure from the vehicle's intended yaw rate happens, these systems respond quicker and are more precise and adaptable than the driver. Since it uses the Anti-Lock Braking System (ABS) found in the majority of modern automobiles, the ESP system doesn't need much more hardware. The steering has a considerably quicker effect on roll dynamics than brakes do. Implementing a suspension system with active roll control that can reduce rapid load transfer in the roll direction due to slaloming will increase vehicle stability, and the conclusion is that a vehicle equipped with all of these features will be more stable.

A control approach using braking forces was given by Schofield et al. [19] that ensures exponential tracking of a yaw rate standard while restricting the roll angle, hence preventing rollover. On automobiles with ABS, the system is simple to use. Since it appears to the periodic answers of the roll angle and roll rate to the front direct angle that these results exhibit substantial phase delay in the frequency band of interest for emergency lane change manoeuvres [19], Takano and Nagai hypothesised that directly measuring the vehicle's roll angle or roll rate might not be suitable for predicting rollover. Since they do not display this behaviour, yaw rate and lateral velocity are better candidates for rollover prediction. Commercial vehicles, which have a high centre of gravity.

Slow continuous suspension control has been proposed by Van der Westhuizen and Els [20] to reduce body roll. They contend that decreasing the vehicle's body roll angle will promote load transfer and, as a result, lessen the lateral forces produced by the tyres. The car may slide instead of rolling over as a result of this reduction in lateral force.

Roll Control in Practice

A luxury car's suspension is typically built with comfort in mind [12]. The car will roll excessively during turning as a result of the associated soft suspension settings, which will diminish comfort and reduce tire-to-road contact. As a result, the majority of luxury automakers have created a suspension system that can minimize or even completely remove body roll. In order to improve the car's comfort, this technique can also be utilised to remove pitch.

1) Hydraulic and Pneumatic Suspension Systems

Pneumatic or hydraulic components are frequently added to the conventional suspension system by automakers that want to lessen or completely eliminate body roll [21]. Citroen's Hydractive suspension system, which was first used in the XM in 1989, is arguably the most well-known of these systems. It is modelled after the business's conventional "Hydro-pneumatic suspension," which places a sizable sphere atop each of the four suspension struts. As seen in Figure 4, each sphere has two compartments that are divided by an elastic membrane. Compressed gas is housed in one compartment, and high-pressure fluid is housed in the other. Road irregularities create shocks that are conveyed into the gas through the fluid and membrane [22]. The gas chamber acts like a spring, storing and then releasing the energy.

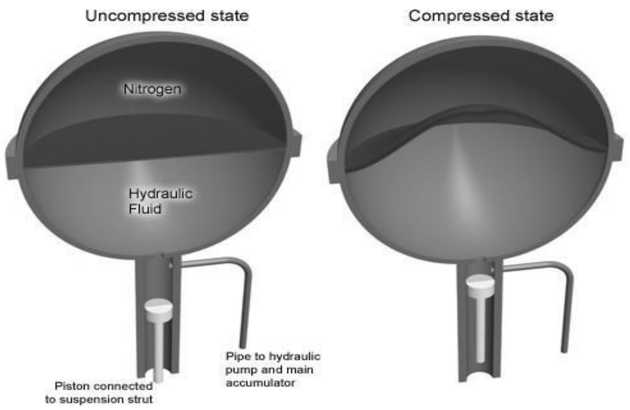

Figure 4: Hydropneumatic spheres [22].

While still using spheres at every angle, the advanced Hydractive suspension now uses an additional sphere in the middle of each axle [22]. The fluid between the left and right spheres is connected by the two central spheres, which are likewise connected to one another. As a result, high-pressure fluid connects each of the four corner spheres to the others. These middle spheres increase the total amount of gas and fluid that one-wheel experiences, resulting in softer spring and damper characteristics and a more comfortable ride overall. The valves on the central sphere will close if it is necessary to reduce body roll or pitch while turning or braking. As a result of the decreased effective volume of gas and fluid, springs are now stiffer.

Citroen created an extra anti-roll feature and integrated it into its Xantia: the Xantia Activa is shown in Figure 5. This function was created to totally prevent body movement when cornering [22]. In this design, the anti-roll bar has an additional gas-filled spherical in the centre. Without the additional sphere, the anti-roll bars would be very stiff; when the valves are opened, the sphere serves as a cushion. To avoid gearbox vibrations from one tyre to the other, the anti-roll bar operates as a very soft one. Body roll is sensed while cornering, and the anti-roll bar sphere's valves are closed to reduce the cushioning effect and improve stiffness. In addition, the anti-roll bar is adjusted using a separate hydraulic ram.

Figure 5: Cornering in a Xantia Activa and a normal Xantia [23].

'Active Body Control,' or ABC, is another hydraulic system Mercedes utilizes to reduce body roll [21]. In contrast to Citroen's Hydractive or Active, it may change the spring rate but not damping. Each wheel is supported by a substantial strut that functions as both a spring and a damper in one piece. The coil spring surrounds the damper, which is located in the centre of the strut. A fluid chamber sits on top of the coil spring. The suspension strut's length stays the same. The fluid chamber is emptied in as the springs on the inside of the corner are stretched.

Figure 6: Stabilizing effect of Active Body Control [21].

BMW also created the "Dynamic Drive" hydraulic body roll control system [12]. Each side of the anti-roll bar receives torque from a hydraulic coupling component. Similar to Citroen's active anti-roll bar, when travelling straight ahead, the two wheels are detached. This prevents vibrations from spreading between the two connected wheels and guarantees a smooth ride. As shown in Figure 7, the hydraulic element joins the two sides of the anti-roll bar during turning and applies a stabilising torque to lessen body roll.

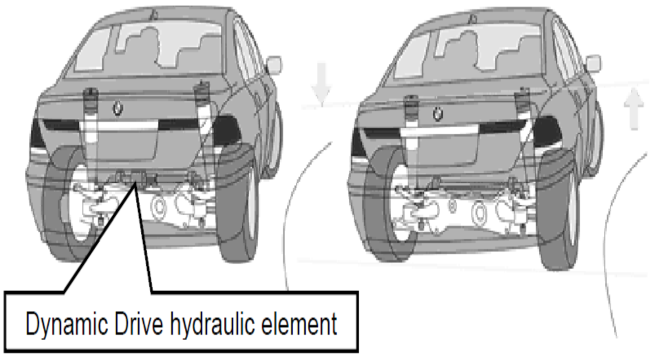

Figure 7: Body roll elimination (BMW)

2) Electromagnetic Suspension Systems

These hydraulic systems are referred regarded as active suspension systems because they are employed in the BMW Dynamic Drive, Mercedes ABC, and Citroen Xantia Activa. This kind of hydraulic active suspension arrangement has a serious drawback in that a powerful, energy-guzzling hydraulic pump is necessary to keep the hydraulic actuators operating at an acceptable pressure and to make up for pressure losses that cannot be avoided in the hydraulic system. The better ride comfort and decreased roll and pitch do, however, come at the cost of greater energy consumption. One benefit of the linear motor versus a hydraulic suspension with active suspension is its dual function as a generator. In situations where the motor needs to generate a force that travels in the reverse direction of its speed, energy is now able to be recovered where it would frequently be wasted by a typical damper. In Figure 9, the body roll reduction of a 1996 Lexus 400 LS equipped with this active suspension technology is depicted.

Figure 8: Bose suspension front module [22].

Figure 9: Body roll reduction (Bose).

3) Adaptive Damping (Semi- Active Suspension)

Adapting dampers can be used to lower the rate when roll or pitch occurs by altering the damper's parameters [12]. This can be accomplished using a magnetorheological fluid, that's viscosity can be altered by altering the electromagnetic field. The number of channels that the oil must pass through, the total area of the valves within the shock absorber, or the total area of the gates in the shock absorber can all be altered to alter the viscosity of the fluid. Long turns will eventually require this technology to support body roll. However, behaviour can be substantially improved during quick direction changes by increasing the damper qualities. The suspension system simply needs minimal adjustments, with the adaptive dampers replacing the conventional ones. As a result, this approach is frequently used to improve. Additionally, to increase the range of tuning choices for the handling characteristics, this system is typically used in conjunction with multiple active components. It can also be utilized to lessen wheel load variations and improve comfort. As our final example, let's look into the Active, Hydractive, and Adaptive suspension designs. The responses of Active suspension, Hydractive suspension, and Adaptive damping to road irregularities are all very different [21]. Once the system has experienced a few shocks, adaptive damping slowly starts to work. When the system encounters a bump, the adaptive damping begins to change the suspension, although the hyperactive suspension performs marginally better because it can respond quickly.

High and low bandwidth active vehicle suspension systems

The actuator's wavelengths (that is, its frequency range of action) are influenced by the spatial relationship between the spring, damper, and actuator. Two configuration types were found to be often discussed in the literature, per a survey.

4) High Bandwidth (HB):

Broad bandwidth is another name for HB. In these systems, the body and the wheel are directly connected by a double-acting actuator. The actuator is said to be fully loaded if it can support every ounce of the sprung mass. If a spring or damper is perpendicular to the actuator, the system is partial. Following are some benefits of partially loaded systems over completely loaded systems. (A) The spring keeps the weight of the vehicle fixed. (b) The spring and damper serve as a passive suspension system in the event that the actuator malfunctions.

Table 1: Summary of modelling complexity and analysis-type restrictions for several automobile suspension system models

Item	Quarter-Car Suspension Model	Half-Car Suspension Model	Full-Car Suspension Model
Mathematical Modelling Complexity	Low	Medium	High
Heave Acceleration [1]	Single wheel only	Half vehicle	Full vehicle
Pitch Angular Acceleration [1]	-	Model Dependent	Full vehicle
Roll Angular Acceleration [1]	-	Model Dependent	Full vehicle
Road Holding Analysis	Single wheel only	Either front and rear or left and right wheels depending on the model	All wheels
Suspension Travel Analysis	Single wheel only	Either front and rear or left and right suspension workspace depending on the model	All suspension workspaces

Narrow bandwidth is another name for LB. The literature has discussed two distinct versions of this system. The Low-Frequency type-1 (LB1) of the first consists of a spring and an actuator connected in sequence and positioned parallel to a damper (if one is present). The second configuration, known as Low Bandwidth type-2 (LB2), entails connecting the actuator in series with a number of springs and dampers. The system that emerges achieves the benefits mentioned for HB AVSS which is partially loaded. In LB AVSS, single-acting actuators are employed.

The variations within the LB1 and LB2 AVSS. Due to its wider frequency working range, HB AVSS necessitates big bandwidth controllers, actuators, and sensors, which raises the cost of these components. According to Williams, the application of variable damping may lead to energy savings in both HB and LB AVSS. This was verified. The results of the simulation demonstrate that changing the passive damper to a variable damper can extend the LB1 AVSS's working range and get it near to the HB AVSS's. Williams examines the effectiveness of both the HB and LB AVSS and identifies their benefits and drawbacks. The operating range of an HB suspension system will be extensive.

Actuators in active vehicle suspension systems

In contrast to PVSS and SAVSS, AVSS uses force-introducing actuators to improve performance. The following is a list of some actuators from the literature: First, hydraulic two categories have been established for these actuators. Electromagnetic motors come in two different varieties: An electromagnetic rotary motor actuator. To create linear motion, these actuators use rotational electrical motors connected to gearboxes or ball screws. These actuators use continuous electromagnetic motors instead of their rotary counterparts, eliminating the need for a gearbox. However, these devices usually generate too much power and weigh more than hydraulic actuators. Hybrid Actuators, for instance, are actuators that combine an electromagnetic rotary motor and a ball-screw hydraulic damper. The following characteristics of servo-hydraulic actuators make them popular choices for use in AVSS. Compact in size, with a high power-to-weight ratio, inexpensive, with stuffiness, and with continuous production of force without overheating. Servo-hydraulic actuators had been chosen for this project as a result.

The need for actuator force feedback

In the past, the majority of AVSS research has concentrated on developing an external control loop that selects the perfect actuator control force. Based on measurements or predictions of the vehicle states with the outside interference from the road, this force is estimated. This method has limited the quantity of laboratory verification that can be done because it ignores the actuator's dynamics. Hydraulic actuators are susceptible to chattering in AVSS applications because of their severe nonlinearity. Additionally, the close coupling among hydraulic forces generated and the movement of the vehicle's frame, resulting in backpressure, makes it difficult to provide the required force. In order to ensure the pumping mechanism is stabilized as well as the proper forces are generated to enhance ride comfort, actuator force feedback is necessary. Because of this, the majority of the material now in circulation focuses either on constructing the inner force loop for control in conjunction with the outer planned force generation loop or just the inner loop. A PI inner force management loop and a state feedback outer loop, which is as well as a combination of numerous outer loops employing skyhook control with an inside control loop, are examples of works where both control loops are built using Model Reference Adaptive Control (MRAC).

II. CONCLUSION

The response to a bump can be used to compare the Active, Hydractive, and Adaptive suspension systems. An adaptive damping system responds slower as it starts its action after the system is affected by some disturbances. The hyperactive suspension responds slightly faster than an adaptive damping system responds slower as it starts its action after the system is affected by some disturbances. The hyperactive suspension responds slightly faster than the adaptive damping; the response starts as the system hits the bump but the process is slow, and for a small bump, it cannot adjust quickly. The active suspension responds fast and corrective action is taken nearly immediately to damp the disturbance. The electromagnetic suspension system consumes lower energy than a hydraulic system, though not insignificant. It was also presumed that the suspension and tires were linear in operation. Modeling should be used to design cars with non-linear suspensions. Most driving circumstances, particularly rollover, are essentially non-linear in nature, so an effort could be made to model the non-linear conduct during a rollover.

III. REFERENCES

[1]. Akcay, H. and Turkay, S. (2008). RMS performance limitations and constraints for quarter-car active suspensions, Proceedings of the Mediterranean Conference on Control and Automation, MED'08, Ajaccio, France, pp. 425 - 430.

[2]. Akcay, H. and Turkay, S. (2009). Inuence of tire damping on mixed H2=H1 synthesis of half - car active suspensions, Journal of Sound and Vibration 322(1- 2): 15-28.

[3]. Al-Holou, N., Lahdhiri, T., Joo, D. S., Weaver, J. and Al-Abbas, F. (2002). Sliding model Neural Network inference fuzzy logic control for active suspension system, IEEE Transactions on Fuzzy System 10(2): 234-245. A

[4]. nakwa, W. K. N., Thomas, D. R., Jones, S. C., Bush, J., Green, D., Anglin, G. W., Rio, R., Sheng, J., Garrett, S. and Chen, L. (2002). Development and control of a prototype pneumatic active suspension system, IEEE Transactions on Education 45(1): 43 -49.

[5]. Astrom, K. J. and Hagglund, T. (2004). Revisiting the Ziegler-Nichols step response method for PID control, Journal of Process Control 14(6): 635-650.

[6]. Ballo, I. (2007). Comparison of the properties of active and semiactive suspension, Vehicle System Dynamics 45(11): 1065 - 1073.

[7]. Beale, M. H., Hagan, M. T. and Demuth, H. B. (2010). Neural Network ToolboxTM 7 User's Guide, The MathWorks, Inc., Natick, MA.

[8]. Bemporad, A., Morari, M. and Ricker, N. L. (2011). Model Predictive Control ToolboxTM User's Guide, The MathWorks, Inc., Natick, MA.

[9]. Bessa, W. M., Dutra, M. S. and Kreuzer, E. (2010). Sliding mode control with adaptive fuzzy dead-zone compensation of an electro-hydraulic servo-system, Journal of Intelligent and Robotic Systems: Theory and Applications 58(1): 3 -16.

[10]. Bouazara, M., Richard, M. J. and Rakheja, S. (2006). Safety and comfort analysis of a 3-D vehicle model with optimal non-linear active seat suspension, Journal of Terramechanics 43(2): 97-118.

[11]. Buckner, G. D., Schuetze, K. T. and Beno, J. H. (2000). Active vehicle suspension control using intelligent feedback linearization, Proceedings of the American Control Conference, Vol. 6, Chicago, IL, USA, pp. 4014 -4018.

[12]. Burns, R. S. (2001). Advanced control engineering, Butterworth-Heinemann, Oxford, Boston. Canale, M., Milanese, M. and Novara,

C. (2006). Semi-active suspension control using fast model-predictive techniques, IEEE Transactions on Control Systems Technology 14(6): 1034-1046.

[13]. Cao, J., Liu, H., Li, P. and Brown, D. (2008). State of the art in vehicle active suspension adaptive control systems based on intelligent methodologies, IEEE Transactions of Intelligent Transportation Systems 9(3): 392-405.

[14]. Chantranuwathana, S. and Peng, H. (2004). Adaptive robust force control for vehicle active suspension, International Journal of Adaptive Control and Signal Processing 18(2): 83-102.

[15]. Chen, H., Liu, Z. Y. and Sun, P. Y. (2005). Application of constrained H1 control to active suspension systems on half-car models, Journal of Dynamic Systems, Measurement and Control, Transactions of the ASME 127(3): 345 -354.

[16]. Chen, H. and Scherer, C. W. (2004). An LMI based model predictive control scheme with guaranteed H1: Performance and Its Application to Active Suspension, Proceedings of the American Control Conference, Vol. 2, Boston, MA, United states, pp. 1487 - 1492.

[17]. Chen, P. C. and Huang, A. C. (2005a). Adaptive multiple-surface sliding control of hydraulic active suspension systems based on the function approximation technique, Journal of Vibration and Control 11(5): 685-706.

[18]. Chen, P. C. and Huang, A. C. (2005b). Adaptive sliding control of non-autonomous active suspension systems with time-varying loadings, Journal of Sound and Vibration 282(3-5): 1119-1135.

[19]. Chien, T. L., Chen, C. C., Chiu, H. C., Cheng, H. W. and Chen, Y.-C. (2008). Almost disturbance decoupling control of nonlinear MIMO uncertain system and application to half-car active suspension system, International Journal of Vehicle Design 46(4): 367 -392.

[20]. Dahunsi, O. A. and Pedro, J. O. (2010). Neural Network-based identi_cation and approximate predictive control of a servo-hydraulic vehicle suspension system, Engineering Letters 18(4): 357-368.

[21]. Dahunsi, O. A., Pedro, J. O. and Nyandoro, O. T. (2009). Neural Network-based model predictive control of a servo-hydraulic vehicle suspension system, Pro- ceedings of the International IEEE Africon 2009, Nairobi, Kenya, pp. 1-6.

[22]. Dahunsi, O. A., Pedro, J. O. and Nyandoro, O. T. (2010). System identi_cation and Neural Network based PID control of servo-hydraulic vehicle suspension system, SAIEE Africa Research Journal, Research Journal of the South African Institute of Electrical Engineers 101(3): 93-105.

[23]. Deng, J., Becerra, V. and Stobart, R. (2009). Input constraints handling in an MPC/Feedback Linearization Scheme, International Journal of Applied Math- ematics and Computer Science 19(2): 219-232.

[24]. Du, H. and Zhang, N. (2007). H1 control of active vehicle suspensions with actuator time delay, Journal of Sound and Vibration 301(1-2): 236-252.

[25]. Du, H. and Zhang, N. (2008). Designing H1=GH2 static - output feedback controller for vehicle suspensions using linear matrix inequalities and genetic algorithms, Vehicle Systems Dynamics 46(5): 385-412.

[26]. Du, H. and Zhang, N. (2009). Fuzzy control for nonlinear uncertain electrohydraulic active suspensions with input constraint, IEEE Transactions on Fuzzy Systems 17(2): 343-356.

[27]. Du, H., Zhang, N. and Lam, J. (2008). Parameter-dependent input-delayed control of uncertain vehicle suspensions, Journal of Sound and Vibration 317(3-5): 537-556.

[28]. Elizer Jr., R. M. (1993). Guidelines for the design and application of speed humps, ITE Journal (Institute of Transportation Engineers) 63(5): 11-15.
[29]. Farong, K. and Zongde, F. (2007). An experimental investigation into the design of vehicle fuzzy active suspension, Proceedings of the IEEE International Confer- ence on Automation and Logistics, ICAL 2007, Jinan, China, pp. 959- 963.
[30]. Fateh, M. M. (2010). Robust impedance control of a hydraulic suspension system, International Journal of Robust and Nonlinear Control 20(8): 858-872.
[31]. Fateh, M. M. and Alavi, S. S. (2009). Impedance control of an active suspension system, Mechatronics 19(1): 134{140.

Cite this article as :

Shashank Sagar, Ajai Singh, Vikash Dwivedi, "The Vehicle Suspension Parameters System Analysis - A Review",International Journal of Scientific Research in Mechanical and Materials Engineering (IJSRMME), ISSN : 2457-0435, Volume 7 Issue 3, pp. 41-50, May-June 2023.
URL : https://ijsrmme.com/IJSRMME237212