International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 02, February 2016
www.ijates.com
ijates
ISSN 2348 - 7550

SUSPENSION SYSTEM WITH BROAD CLASSIFICATION AND VARIOUS MODELS: A REVIEW

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ABSTRACT

Suspension systems are important part of vehicles which provides comfort and safety to the passengers. As suspensions system design is very important factor in vehicle design, many researchers are working for the improvements in the Suspension Systems from last few years. The suspension system designs are varying according to the type of vehicle, but as the automobile industry is changing very fastly and new methodologies and designs are adopting in the industry, the design methods of suspension systems are changing and new designs and types are emerging into the automobile sector.

In this paper, a review on recent developments of automotive active suspensions system has been provided. Different suspension systems types, structures, models are enlisted and discussed in this paper. Also the characteristics, suitability of suspension system for different applications vehicles, their disadvantages and advantages are also listed in this paper. After deep and thorough review, the relation among system performance, components and analysis work has been find out and presented.

Keywords: Suspension System, Active Suspension, Quarter, Car Suspension Model.

I. INTRODUCTION

1. A car suspension system is situated between vehicle body and wheels of the vehicle; this mechanism separates the vehicle body from the lower part of vehicle. Providing comfort is the important function of the suspension system but also providing stability to vehicle, road handling and safety to vehicle parts are also other functions of suspension systems which should be accomplished by suspension system with providing comfort. Hence while designing suspension, a balanced design should be provided in order to carry out functions like road holding, load carrying and passenger comfort. The design of suspension system said to be perfect if it fulfill all above criteria.

Vehicle suspension systems have main function to provide comfort to passengers by minimizing acceleration transmitted to the users. A suspension system also separates car body from road bumps by isolating it which further leads to good road holding.

The first objective lies within the part of ride analysis and a problem of reducing a discomfort to vehicle passengers. While second objective lies in the part of providing safety and ease for the acceleration and braking [1-6]. Designing of suspension system has objective to sustain the acceleration of the car and the moving load of tire.

Any automobile travelling on road is subjected to two types of vibrations, deterministic vibration and random vibration. Out of which deterministic vibration is arises due to moving components of the car, these vibrations can be approximately predicated by numerical and method and random vibration which is caused by unpredicted loads such as wind, road irregularities etc. Due to unpredicted nature of the load the solution of these systems is very difficult to predict.

A vehicle suspension system has two objectives, first one is passenger comfort and the other one is vehicle control. When there is low damping handling then performance will be compromised and as damping coefficient increases ride/comfort will be compromised. This trade-off can be only eliminated when damping is varied according to dynamic conditions which are not possible in passive suspension system. This trade-off can be kept in controlled suspension systems. The balance in between ride comfort and vehicle stability is a measure of the good suspension system.

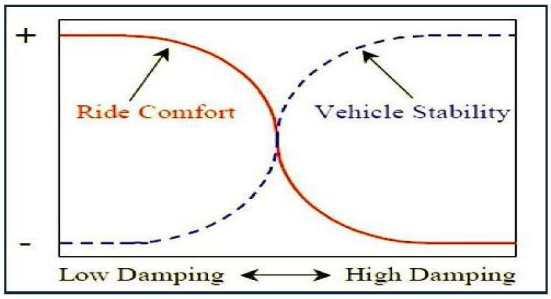

Fig 1 Compromise between Ride and Handling

The vibrations are generally caused by irregularities of the roads on which the vehicle travels. Vehicle dynamic analysis plays important role to achieve greater suspension systems and ride comfort which increases its research values. Due to this many researchers are working in the field of the vehicle dynamic analysis. From last few decades many papers are published in the field of vehicle dynamic analysis. The quarter-car model, half-car model and full-vehicle models are invented and developed by researches to improve dynamic behavior of vehicle and its vibration control.

Ride comfort is a key issue in design, development and manufacturing of modern automobiles and efforts of all designers are concentrated towards it. As confort is a main objective advanced suspension systems are emerging as a results of the efforts of modern designers. These newly developed and improved designs are capable of providing comfortable ride to the passengers by absorbing shocks and vibrations of the road. These systems provides good vehicle stability also. In last decades due to demand of automobile industry many researchers participated in the research on improved suspension systems [18].

This paper provides a review on theses improved and emerged techniques aimed to provide vehicle stability and passenger comforts in last few decades. This paper concentrated towards the characteristics of the different types of suspension systems, their advantages, disadvantages and their suitability for different type of vehicles.

II. SUSPENSION SYSTEMS

Vehicle suspensions systems are generally classified depending on their characteristics as conventional suspension and advanced suspension systems. Conventional suspension systems are generally passive suspension systems in which suspension elements i.e. spring and damper are connected to the wheel itself while

advanced suspension systems are semi-active or active suspension systems which are newly emerged system which has some advancements in the conventional type suspension systems.

2.1 Passive Suspension Systems

Conventional suspension systems are generally a passive suspension system with spring and damper attached to the wheels. The main function of spring in suspension system is to provide support to the body of a car and also to absorb and store vibration energy. In designing process, stiffness of spring is calculated. The shock absorber is a main component of the automobile suspension system used to dissipate the vibration energy stored in the spring and control the input from the road that is transmitted to the vehicle. Damping action i.e. coefficient of damping is selected at design stage and for type of vehicle performance required for ride/comfort or handling. It varies from vehicle to vehicle as requirements are changed, luxurious cars are provide great comfort hence their damper will have different characteristics than transport vehicle.

The passive suspension system actually acts as an open loop control system. The main purpose of its design is to achieve only specific conditions. The passive suspension system fixed and has no flexibility. The there is a problem in passive suspension system that if its design has high damping or too hard suspension it will transfer a most of road input or throwing the vehicle on irregularities of the road.

2.2 Semi Active Suspension System

Semi-active suspension systems are important group of the suspension system in active type. Semi-active suspension systems are very much similar to the conventional type of suspension systems. This type of suspension contains one spring and controllable damper, out of which spring stores the energy and the damper dissipates the energy. This mechanism also has a variant where damper is passive and spring is controllable because controllable damper limits to produce force to dissipate energy.

A semi-active suspension is much similar to passive suspension system having varying damping coefficient and constant spring constant one without active force sources. Damping coefficient can be controlled by remote mechanism to control damping characteristics. It can lead to the damper reaction forces. In semi-active suspension system a remote electrical switch can be used to provide soft suspension by changing damping coefficient continuously according to requirement.

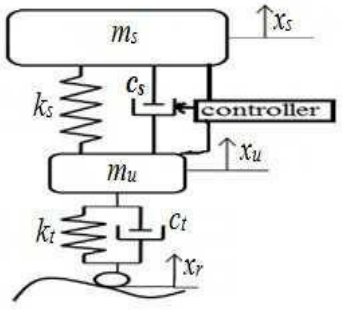

Fig 2 Semi-active Suspension System used in car

2.3 Active Suspension System

Active suspension system has two types of configuration which are depending upon the linkage in between spring and damper and controller. If controller and spring are linked parallel they can form high-bandwidth

configuration and if they are joined in series they will form low-bandwidth configuration. The high-bandwidth is more suitable and beneficial over low-bandwidth as it able to control at the higher frequency and with high-bandwidth the suspension system will work continuously as a passive suspension when an actuator work as an active part.

Patil et al [17] performed the simulation and experimental study on the vehicle suspension system. The author performed simulation of the system and he find out that the nonlinear parameters of the system also have to be considered in the system because nonlinear parameters has great impact on the results. The importance of consideration of nonlinear parameter has been shown in this work. When the performance of the nonlinear active suspension systems are compared to the linear suspension systems for the behaviour of vehicle on different types of road conditions (exitations), it is observed that behaviour of nonlinear active suspension system is much closer to the actual behaviour of the system in the experimental system as compare to the linear active suspension system.

Hence nonlinear parameters should be considered in the analysis, in order to get the actual real time result. From this work simulations also shows that active suspension system reduces the shocks, vibrations coming from road and reduces the acceleration of sprung mass and provide good ride comfort.

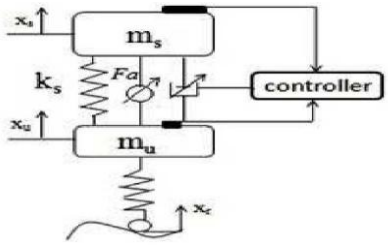

Fig 3 Quarter Car Active Suspension System

III. DIFFERENT MODELS OF SUSPENSION SYSTEM

Based on degrees of freedom, vehicle models are classified as quarter car, half car and full car models, from which half car model is further classified as Roll-Degree of Freedom and Pitch- Degree of Freedom. As shown below;

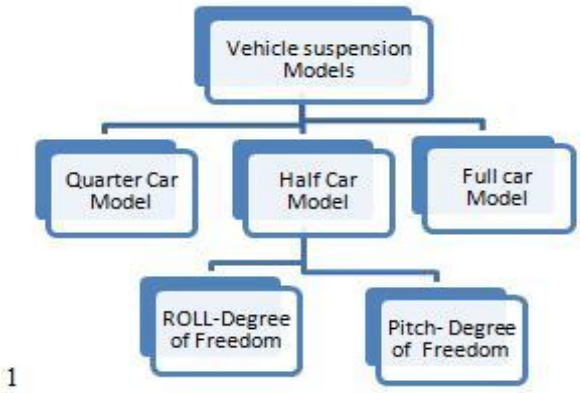

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Fig 4. Suspension Models

Suspension systems are also classified on the basis of working characteristics of suspension systems as passive suspension systems, semi active suspension system and active suspension system.

3.1 Quarter Car Model

quarter car model is used in suspension system analysis, in this a sprung mass is considered to be one fourth part of total vehicle mass. in automotive industry, single-degree-of-freedom or two-degrees-of-freedom quarter-car models of suspension systems are commonly employed in many areas like the calculate of dynamic response, identification, optimization and control of ground vehicles. as quarter car models are simple and comparatively accurate their applicability area is large. it is seen that importance of ride comfort analysis of quarter car model active suspension

system dependent on the conditions provided by the road i.e. excitations. it is also observed that the active suspension system provides vehicle more ride comfort than passive suspension system. in first intial research the linear parameter of active suspension were considered but in practice the spring also behaves nonlinearly and shows nonlinear characteristic so it is important to consider the nonlinearities of spring as well as actuator delay while designing the active suspension system. [16]

3.2 Half Car Model

In this model half car model, sprung mass considered to be halved and both halves are considered as independent. Half car model are further divided into roll degree of freedom model and pitch degree of freedom model. In Roll degree of freedom model car is considered to be halved at rolling axis of the car i.e. when disturbance or shock is acting at left wheel of front axle then reaction on right wheel of front axle is also considered, similarly in case of pitch degree of freedom where pitching axis is the point of separation. The half car model is used to analyze the dynamic response of cars in the case of road irregularities are random. In this model random variables are considered as mass of the vehicle body, mass moment of inertia of the vehicle body, masses of the front and rear wheels, distance of the front or rear suspensions location to the centre of the gravity of the vehicle body and the stiffness of front or rear tires, damping coefficient and spring stiffness of front or rear suspension etc.

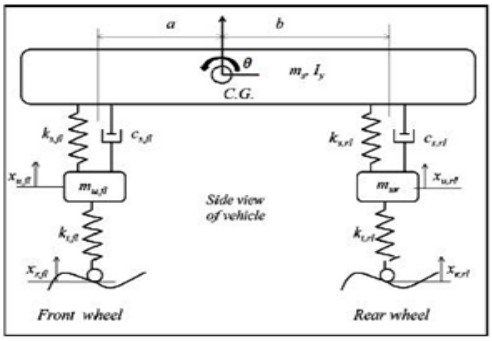

Fig 5.. Half Car Suspension Model

Half car models are further classified as roll degree model and pitch degree of suspension system each having four degrees of freedom. Out of which two are situated at the connection to unsprung masses and another two are at sprung mass. At sprung mass one angular displacement is called as roll or pitch.

3.3 Full Car Suspension Model

This type of suspension model has suspension force actuators which allows the future development of an active suspension control system which is capable of improving the passenger comfort. The popularity of types of

systems is increasing in automobile industry. These systems are highly flexible which allows them to be specifically tuned for performance or comfort, making them suitable for many applications. [11]

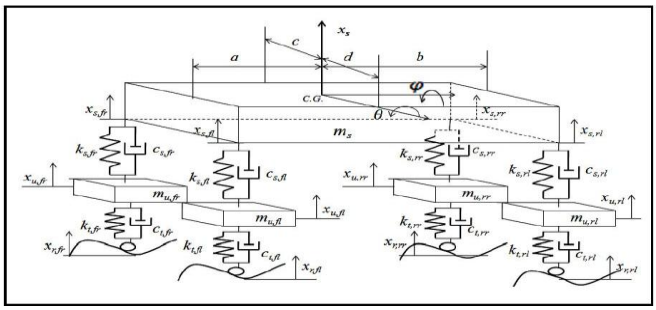

Fig 6. Full Car Suspension Model

IV. CONCLUSIONS

After reviewing important and scientific literature the relation between operating parameters and their importance has been discussed. While designing the perfect suspension system at most care should be taken as it is highly difficult characterize and predict the relationship in between system components and their response to operating parameters. Many industrial and academic researchers are working in the field of suspension system design but due to complicated nature of suspension system behavior they are facing many problems. In suspension system working, as degrees of freedom increases i.e. movement direction are increases analysis of system becomes much complex as number of variable are also increases with degree of freedom. Suspension systems having less degree of freedoms can be easy to analyze as less variables are present.

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