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A Review on the Performance of a Vibration Absorber in an Active Suspension System

G.Hima Bindu
Asst. Professor, Department of Mechanical Engineering
MLR Institute of Technology, Dundigal, India
gadehimabindu.24@gmail.com

Dr.A.Siva kumar
Professor & HOD, Department of Mechanical Engineering
MLR Institute of Technology, Dundigal, India

Abstract— Active suspension system is to isolate a vehicle body from road irregularities to maximize passenger ride comfort and retain continuous road wheel contact in order to provide road holding with the help of roll and pitch as well as torsion modes. In advance active suspension concepts, damped vibration absorbers, may be fitted to the axles to control wheel hop oscillations. The optimal turning and damping ratio for the vibration absorber to minimize wheel bounce on a random road are computed for a linear two-degree-of freedom system as function of the relative tyre damping rate and mass ratio. The adaptive suspension controllers provide superior passengers comfort over the whole range of road condition. In this connection an attempt is made to explain in detail about suspension system, springs, vibrations and results obtained of different researchers in their experimental investigation.

Keywords— Active Suspension; spring; Vibrations and Quarter car model.

I. INTRODUCTION

Shock absorber or a suspension damping system is a device for reducing the effect of a sudden shock by the dissipation of the shock's energy. On an automobile, springs and shock absorbers are mounted between the wheels and the frame. When the wheels hit a hole or a raised spot on a road, the springs absorb the resultant shock by expanding and contracting. To prevent the springs from shaking the frame excessively, their motion is restrained by shock absorbers, which are also known by the more descriptive term dampers. The type of shock absorber found on automobiles is usually a hydraulic type that has a casing consisting of two tubes, one telescoping into the other. On some automobiles a type of hydraulic suspension is used to function both as a spring and as a shock absorber. It comprises a sealed spherical container filled with equal volumes of hydraulic fluid and gas under pressure. The compression of the gas, which absorbs the shock, is supplied by the vehicle's engine.

II. REVIEW ON SUSPENSION SYSTEM

a) literature review

The review of literature is discussed to focus on an active suspension system in a passenger car. The analysis of leaf spring and vibrations of the suspension system is discussed in the following sessions.

Rahul N. Sandage et.al [1] has investigated about the ride comfort of the passengers by studying the performance of suspension system. For this a quarter car model with two degree of freedom has been used for checking the performance of semi-active suspension system. To improve ride comfort many analytical and experimental studies on semi-active suspension have been performed at the same time Fuzzy-PID controller work better than the PID controller having fixed gain parameters have been studied. Yahaya Md. Sam et.al [2] studied about the new strategy by which the active suspension system can be controlled. The strategy utilized the proportional-integral sliding mode control scheme. the study is been carried on a quarter-car model and the performance of the controller is compared to the linear quadratic regulator and with the existing passive suspension system. A simulation study is performed to prove the e7ectiveness and robustness of the control approach. Ayman A. Aly et.al [3] has studied why semi-active and active systems are being developed. This study states that due to increased competition on the automotive market has forced companies to research alternative strategies to classical passive suspension systems. To simulate the actions of an active vehicle suspension system a quarter-car 2 degree-of-freedom (DOF) system is designed and constructed on the basis of the concept of a four-wheel independent suspension. The main aim of this study is to illustrate the application of intelligent technique to the control of a continuously damping automotive suspension system. Zhang Jin-qius et.al [4] have investigated how the considerable energy is been wasted in the form of heat due to mechanical

vibrations of a conventional vehicle suspension. In recent years for the improvement of vibration attenuating performance as well as the reduction of energy dissipation the regenerative suspensions have attracted much attention. In this investigation the amount of energy dissipation and the potential of energy regeneration are discussed, then the research and development of regenerative suspension is reviewed, and the energy harvesting schemes and their characteristics are summarized and remarked. A. Aldair et.al [5] have studied how to reduce the road roughness in order to give comfort to the passengers and at the same time increase the ride handling associated with the pitching and rolling movements which can be done by designing a robust controller for a vehicle suspension system. This necessitates a very fast and accurate controller to meet as much control objectives, as possible. In this study to design a robust controller to meet the control objective an artificial intelligence Neuro-Fuzzy (NF) technique is been used. The vibrations on each corner of vehicle is been minimized by the proposed controller supplying control forces to suspension system when travelling on rough road. The other purpose for using the NF controller for vehicle model is to reduce the body inclinations that are made during intensive manoeuvres including braking and cornering. A full vehicle nonlinear active suspension system is introduced and tested. Suleiman Abu-Ein et.al [6] have developed a control system and the implementation technology of the controllers and the subsequent experimental study are used for suspension system in automobiles. This development is been done for safe, and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations. In this study it is been found that active suspension system improves ride comfort even at resonant frequency by the simulation and analytical methodologies which is used to analyze the suspension system. For step input of 0.08 m, the sprung mass displacement has been reduced by 25 % which shows the improvement in ride comfort and sprung mass acceleration reduced by 89. 93% .The suspension travel has been reduced by 74.64% and tire deflection has reduced by 89.73%. Sheilza Jain et.al [7] has studied that the suspension system is designed, where a ¼ model of bus is used to simplify the problem to a one dimensional mass spring-damper system. In this study the open-loop performance on the basis of time response is observed which depicts that the bus suspension has oscillations with large settling time. To overcome this problem, closed-loop system is used. Despite continuous advancement in control theory, Proportional –Integral (PI) and Proportional-Integral Derivative (PID) Controllers are the popular technique to control any process. In this paper, Proportional-Integral (PI) and Proportional-Integral-Derivative (PID) controllers are used to control the vibrations to give smooth response of the bus suspension system and carry-out their comparison on the basis of time and frequency using Matlab environment. The simulation and implementation of the controller is done using Matlab/Simulink. C. Poussot-Vassal et.al [8] have studied how the frequency modulation at mid and high frequency can be trade-off to overcome the optimal control of damping and how the best performances in terms of comfort are reflected in terms of handling and vice verse. In this a semi-active suspension system is described as a quarter car model, equipped with a controllable damper, providing an effective representation of the semi-active suspension dynamics. The main aim of this study is to propose a methodology allowing for evaluation of handling and comfort lower theoretical filtering bounds, which can be used as a benchmark for any semi-active control design.

Ammar A. Aldair et.al [9] has developed the design of a robust controller for full vehicle nonlinear active suspension systems which is used to control and handle the nonlinearities faster than other conventional controllers. Neural controller are devised to adjust the hydraulic actuators which forces to minimize the vertical displacement at each suspension point when travelling on rough roads and to reduce the inclination of the vehicle during sudden manoeuvres such as sharp bending and braking. The robustness of the proposed controller is being assessed by comparing with Fractional Order PID (FOPID) controller. To validate the robustness of the proposed approach, the cases with six types of disturbances will be investigated. The results show that intelligent neural controller have improved dynamic response measured by a decreased cost function. Kommalapati. Rameshbabu et.al [10] have studied about the shock absorber which is used to reduces the effect of travelling over rough ground, leading to improved ride quality , and increase in comfort. In this a shock absorber is designed and a 3D model is created using Pro/Engineer. The model is also changed by changing the thickness of the spring. Structural analysis and modal analysis are done on the shock absorber by varying material for spring, Spring Steel and Beryllium Copper. The analysis is done by considering loads, bike weight, single person and 2 persons. Structural analysis is done to validate the strength and modal analysis is done to determine the displacements for different frequencies for number of modes. Comparison is done for two materials to verify

best material for spring in Shock absorber. Faraz Ahmed Ansar et.al [11] have constructed an active suspension control for a quarter car model to improve the riding quality without compromising the handling characteristic by directly controlling the suspension forces to suit the road and driving conditions. In order to achieve the desired ride comfort, road handling and to solve the uncertainties, a sliding mode control technique is presented. A nonlinear surface is used to ensure fast convergence of vehicle's vertical velocity which changes the system's damping. Extensive simulations are performed and the results obtained shows that the proposed controller perform well in improving the ride comfort and road handling for the quarter car model using the hydraulically actuated suspension system. S.Pathmasharma et.al [12] have studied about improving the suspension system which increases the market share when a vehicle is provided with maximum comfort. This improvement is done by the analysis of the existing of the suspension system. The data of the Passenger vehicle suspension system of the existing vehicle are collected and a model is created using UG. Automatic dynamics of Mechanical System (ADAMS) has become an important feature of roadside hardware design and analysis in recent year. The analysis of existing model is carried out using ADAMS which is used to determine the forces acting on components of suspension system. With the view of minimizing the forces acting on the components of the suspension system all of the critical components of the suspension system such as mounting points, track width and mass were modified and incorporated into the new model along with the capacity to make the most important components force act with time by carefully modeling the geometric details such as mounting points. It is believed that these modifications significantly improve the performance of simulating impacts with off road side.V.V. Jagirdar et.al [13] has developed Wishbone structure for double wishbone front-independent Suspension for a military truck application is presented. At present, the vehicle is equipped with rigid axle with leaf springs. There are two aspects that dictate the design of wishbone structure, viz. the path of relative motion between the constituents of the suspension system and the forces transmitted between them. Also, enhancement of mobility was made possible by maintaining the live axle in the system. A double wishbone, double coil spring with twin damper configuration was employed for this application. MBD Analysis was carried out using MSC ADAMS. A double wishbone independent suspension has been designed for the front axle and has been successfully integrated with the vehicle. Niranjan Singh [14] has studied about the fatigue stress analysis of springs used in automobiles. To isolate the structure and the occupants from shocks and vibrations generated by the road surface the automobile suspension systems is used. The suspension systems basically consist of all the elements that provide the connection between the tyres and the vehicle body. A spring stores mechanical energy and act as an elastic body that can be twisted, pulled, or stretched by some force. It returns to their original shape when the force is released. Kalaivani Rajagopa et.al [15] has developed Multi Objective Optimization (MOO) of Vehicle Active Suspension System (VASS) with a hybrid Differential Evolution (DE) based Biogeography-Based Optimization (BBO) (DEBBO) for the parameter tuning of Proportional Integral Derivative (PID) controller. Initially a conventional PID controller, secondly a BBO, an rising nature enthused global optimization procedure based on the study of the ecological distribution of biological organisms and a hybridized DEBBO algorithm which inherits the behaviors of BBO and DE have been used to find the tuning parameters of the PID controller to improve the performance of VASS by considering a MOO function as the performance index. Simulations of passive system, active system having PID controller with and without optimizations have been performed by considering dual and triple bump kind of road disturbances in MATLAB/ Simulink environment. The simulation results show the effectiveness of DEBBO based PID in achieving the goal. Abdolvahab Agharkakli et.al [16] has investigated whether the active suspension system is synthesized based on the Linear Quadratic Regulator (LQR) control technique or a quarter car model. By using road profile comparison between passive and active suspensions system are performed. The mathematical model for the passive and active suspensions systems for quarter car model and an active suspension control for a quarter car model subject to excitation from a road profile using LQR controller. The performance of this controller is been determined by performing computer simulations using the MATLAB and SIMULINK toolbox. A.Purushotham [17] has developed a two-dimensional mathematical model of a McPherson suspension. There are two main suspension systems namely: double wishbone suspension system and McPherson suspension. The MacPherson strut setup is still being used on high performance cars such as the Porsche 911, several Mercedes-Benz models and lower BMW models due to its light weight, design simplicity and low manufacturing cost. The McPherson suspension model considers not only the vertical motion of the chassis(sprung mass) but also rotation and translation for unsprung mass(wheel assembly). Furthermore, this

model includes wheel mass and its moment of inertia about the longitudinal axis. Yousfi Khemissi [18] have studied about the proposition of sliding mode position controller of the magnetic suspension ball system which is a mechatronic system already acknowledged and accepted by the field experts. The main function of the sliding mode control (SMC) Controller is to maintain the balance between the magnetic force and the ball's weight. The proposed controller guarantee the asymptotic regulation of the states of the system to their desired values. Complete mathematical models of the electrical, mechanical and magnetic suspension system are also developed.

III. REVIEW ON SPRINGS

U. S. Ramakanth et.al [19] have studied about multi leaf springs having nine leaves where generally a leaf springs which are one of the oldest suspension components are used, especially in commercial vehicles. The automobile industries have shown interests in replacement of steel springs with composite leaf springs due to high strength to weight ratio. In this a Finite element approach for analysis of a multi leaf springs using Ansys software is carried out. The model is generated using solid works and imported in Ansys. Fatigue analysis of leaf springs is carried out for steel leaf springs, and Static analysis for steel leaf springs, composite leaf springs and hybrid leaf springs**.**

Pankaj Saini et.al [20] has developed design and analysis of composite leaf spring where the comparison of the stresses and weight saving of composite leaf spring with that of steel leaf spring is done. Now a days the Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The composite leaf spring is used to reducing weight while increasing or maintaining strength of products which is getting to be highly important research issue in this modern world. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring.

Ghodake A. P. et.al [21] have studied about the new materials which can be used for leaf spring and then selected glass fiber reinforced plastic (GFRP) and the polyester resin (NETPOL 1011) which is used against conventional steel. This study is been done because the Automobile Industry has shown keen interest for replacement of steel leaf spring with that of glass fiber composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance and tailor-able properties. The numerical analysis is carried via finite element analysis using ANSYS software. Stresses, deflection and strain energy results for both steel and composite leaf spring material were obtained. Result shows that, the composite spring has maximum strain energy than steel leaf spring and weight of composite spring was nearly reduced up to 85% compared with steel material.

Baviskar A. C. et.al [22] have investigated for improving the performance of leaf spring. The study states that the suspension system in a vehicle which significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort, stability etc. Leaf springs are commonly used in the vehicle suspension system and are subjected to millions of varying stress cycles leading to fatigue failure. In this investigation a lot of review on some papers on the design and analysis leaf spring performance and fatigue life prediction of leaf spring is seen. There is also the analysis of failure in leaf spring. Also the analysis of leaf spring with ansys is done. Abdul Karim Selman Abdul Karim et.al [23] have investigated about a rational technique to design leaf spring for light truck . The Light truck is used for the world economic growth since it was used in transportation for various kinds of commodities. Leaf spring is the most admire alternative utilized in the suspension system of this specific truck due to their low production cost, reliability and maintainability. Simulation resembles to constrained condition when mounting on the vehicles were undertaken to examine the stresses distribution for each leaf.

IV. REVIEW ON VIBRATIONS

Saikat Dutta et.al[24] has developed a phenomenological model of MR damper in which Magnetorheological (MR) fluids can produce good controllable damping force under application of magnetic field. MR damper can be used as effective element in semi active vibration control. Out of various semi-active control strategies, the on-off sky-hook control strategy is used in this work. A single degree of freedom system with MR damper under sinusoidal excitation is first studied to check the performance of the proposed on-off controller with MR damper. By changing the input voltage according to the control scheme the parameters of MR damper in the model are varied. Performances of this controller for two types of road profiles, namely, sinusoidal road profile, random road profile are studied. The control strategy is found to be effective for a quarter car model. To examine optimal damper force vehicle required to isolate

the vibration several performance indices have been chosen which are functions of vehicle performance measures such as sprung mass acceleration, vehicle handling and working space. Saeed Asiri et.al [25] have studied about new class of periodic mounts for isolating the vibration transmission from vehicle engine to the car body and seats is presented. Periodic mounts exhibit unique dynamic characteristics that make them act as mechanical filters for wave propagation. As a result, waves can propagate along the periodic amounts only within specific frequency bands called the "PassBands" and wave propagation is completely blocked within other frequency bands called the "Stop Bands".

Deulgaonkar V.R et.al [26] has studied the correlation between pressure and vibration levels of different sources with acoustical and structure transfer path and at the same time the effectiveness of the firewall, silencers and engine mounts are checked and compared. The various automotives produce a lot of noise & vibrations for which a reduction technique is studied through energy flow path. Various international and Indian standards for vehicles consider two types of noise measurement i.e. pass by noise and stationary noise. In this study the appropriateness of SN test for in use vehicle is discussed. Two vehicles of same class but of different makes were compared and evaluated for interior noise and vibration levels. Yogendra S. Rajput et.al [27] has investigated about the vibration characteristics of the frame including the natural frequencies and mode shapes. The off-road racing vehicle for the SAEINDIA's BAJA competition has raised the value of dynamic analysis under severe uneven loading. The dynamic analysis is carried out by the finite element method simulation there by predicting failure modes of the vehicle frame under vibration analysis. B. Soleimani et.al [28] have developed the dynamic response of the wheel on irregular rail track which is been analyzed with analytical approach using the method of Multiple Scales (MMS). The Hertzian contact theory is used to obtain the relationship between normal contact force and the displacement of the mass center of the wheel. Analytical approach is expanded for performance of train's wheel travelling on the rail. The Wheel/rail contact simulation is one of the most complicated problems in the modeling of railway vehicles. The wheel/rail interaction plays a unique role in rail vehicle dynamics. A. Bala Raju et.al [29] have developed the equations of motion and studied the vibrations of the suspension system under different disturbing conditions. The suspension system of an automobile helps to support the car body, engine and passengers, and at the same time absorbs shocks received from the ground while vehicle moves on rough roads. Haiping Du et.al [30] have studied about the active control of seat suspension to reduce vertical vibration transmitted from uneven road profile to driver body and to provide ride comfort, in particular, commercial vehicles, to reduce driver fatigue while long hours driving. The control problem will be firstly studied by proposing an integrated seat suspension model which includes vehicle chassis suspension, seat suspension, and driver body model. A static output feedback controller is then designed for the seat suspension with using measurement available signals. Driver mass variation and actuator saturation are also considered in the controller design process. The conditions for designing such a controller are derived in terms of linear matrix inequalities (LMIs). Finally, numerical simulations are used to validate the effectiveness of the proposed control strategy. Zulkifli Mohd Nopiah et.al [31] has investigated the effects of vibration to noise in passenger car cabin generally the vibration is caused by two main sources: engine transmission and interaction between tyre and road surface. The noise which produced by the car system can cause hearing impairment, hypertension, annoyance and sometimes can decrease the driving focus which may cause an accident. Vehicle acoustical comfort index (VACI) was used to evaluate the noise annoyance level and vibration dose value (VDV) was used to evaluate the vibration level. By using the changes trend of noise and vibration level depending to engine speeds, optimization model was proposed to optimize the vibration level in the passenger car cabin.

V. CONCLUSIONS

The following observations are drawn from the investigation of the previous researchers mentioned in the introduction.

Ride comfort and handling characteristics of semi active suspension system is better as compared to conventional passive suspension system and less expensive than the active suspension system. There are two criteria of good vehicle suspension performance: the first one is typically their ability to provide good road handling and the other is grantee the passenger comfort. The main disturbance affecting these two criteria is terrain irregularities. Active suspension control system reduces these undesirable effects by isolating car body motion from vibrations at the wheels. Suspension control is highly a difficult control problem due to the complicated relationship between its components and parameters. The research was carried out in suspension control system cover a broad range of design issues and

challenges. Conventionally, the vibration energy of vehicle suspension is dissipated as heat by shock absorber, which wastes a considerable number of resources. The composite spring has maximum strain energy than steel leaf spring and weight of composite spring was nearly reduced up to 85% compared with steel material. The design and analysis of leaf spring performance and fatigue life prediction of leaf spring is reviewed also the analysis of leaf spring with ANSYS is done. The rational technique to design leaf spring for light truck is investigated. Simulation resembles to constrained condition when mounting on the vehicles were undertaken to examine the stresses distribution for each leaf. By using the changes trend of noise and vibration level depending to engine speeds, optimization model was proposed to optimize the vibration level in the passenger car cabin. The vibration characteristics of the frame including the natural frequencies and mode shapes are studied where the dynamic analysis is carried out by the finite element method simulation thereby predicting failure modes of the vehicle frame under vibration analysis.

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