An Overview of Disarray in Optimization of Half Car Model Vehicle Dynamic System Subjected to Speed Bump with Time Delay and Nonlinear Parameters

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Abstract

This paper presents an optimum concept to design passenger-friendly vehicle suspension system with the help of Taguchi Approach. A full car suspension is considered as an illustrative example of vehicle model to demonstrate the concept and process of optimization. The optimum system parameters are predicted using Taguchi analysis and verified by the confirmation analysis carried out using MSC ADAMS. The concept proposed in this paper is applicable to generic cases, where more complex vehicle model and pavement surface condition apply. In this paper overview of various works are done. This paper tries to give an idea about the previous researches & their finding about study of nonlinearity of active suspension system parameters by considering half car model. Sometimes help of quarter car model and full car model is taken for more detail understanding of system behaviour.

Keywords – *ANOVA, Deterministic, Full Car Model, MATLAB/Simulink, Optimization, Orthogonal Arrays, Taguchi Method, State Space Model, Transfer Function.*

1. Introduction

The vibration of vehicle and seat leads to driver fatigue, and decreases driver safety and operation stability of vehicle. Hence development of improved suspension system to achieve high ride quality is one of the important ride challenges in automotive industry. Therefore the goal of vehicle suspension systems is to decrease the acceleration of car body as well as the passenger seat. In reality, some of the vehicle parameters are with uncertainties, so that it is an important issue to deal with vehicle suspension subjected to uncertain parameters in engineering application. The vehicle suspension system is responsible for driving comfort and safety as the suspension carries the vehicle-body and transmits all forces between body and road .It is well known that the ride characteristics of passenger vehicles can be characterized by considering the so-called “half-car” model. Physical models for the investigation of vertical dynamics of suspension systems are most commonly built on the half-car model. In this project, suspension parameters is been optimized. The concept proposed in this work is applicable to generic cases, where more complex vehicle model and pavement surface condition apply.

The commercial vehicles use passive suspension system to control the dynamics of a vehicle’s vertical motion as well as pitch and roll. Passive suspension system indicates that the suspension elements cannot supply energy to the suspension system. The passive suspension system controls the motion of the body and wheel by limiting their relative velocities to a rate that gives the desired ride characteristics. This is achieved by using some type of damping element placed between the body and the wheels of the vehicle, such as shock absorber.

In this paper literature on a passive suspension is discussed. Due to different road profile in India, the focus towards the suspension system is very essential. The vibration of vehicle leads to discomfort of passenger. Hence developing improved suspension system to achieve high comfort is one of the important challenges in automotive industries. Therefore goal of vehicle suspension system is to decrease the acceleration of car body as well as passenger seats. The vehicle suspension system is responsible for driving comfort and safety as the suspension carries the vehicle body and transmit all forces between body and road. The ride characteristics of passenger vehicle are well characterized by considering half car model. In this work suspension parameter is been optimized. By considering all above facts, this paper tries to cover literature which deals with a passive suspension system with half car model by considering suspension nonlinearities and time delay parameter. Some times in this paper reference of quarter car model and full car model for above situation is considered to elaborate the concept in simple manner.

2. Mathematical Modeling and Optimization of Vehicle Passive Suspension System Using Full Car Model

R. Kalidas et al. carried a work on Mathematical Modelling and Optimization of Vehicle Passive Suspension System Using Full Car Model. This paper presents an optimum concept to design passenger-friendly vehicle suspension system with the help of Taguchi approach. A full car suspension is considered as an illustrative example of vehicle model to demonstrate the concept and process of optimization. A full Car model is shown in Fig 1.

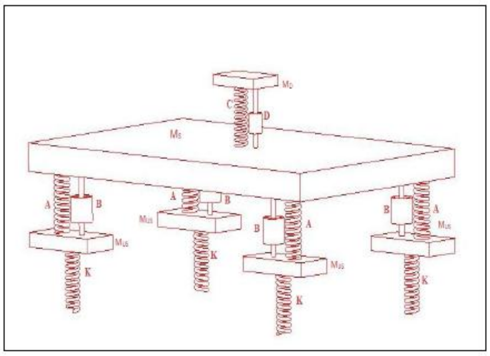

Fig. 1 Full Car Model

The experimentation have been conducted by varying the stiffness of four shock absorbers (A), damping co-efficient of four shock absorbers (B), stiffness of seat (C) and damping co-efficient of seat (D). The values of suspension parameters have been obtained by using the Taguchi design of experimental method. The implication of input parameters on seat displacement (DS) and settling time (ST) has been investigated by using analysis of variation. The optimum system parameters are predicted using Taguchi analysis and verified by the confirmation analysis carried out by using MSC ADAMS. In addition mathematical model using regression model is done for both seat displacement (DS) and settling time (ST). The result shows that stiffness of shock absorber and stiffness of seat spring are there most significant parameters which affect the seat displacement. The concept proposed in this paper is applicable to generic cases, where more complex vehicle model and pavement surface condition apply.

3. Modelling of Quarter Car Model Passive Suspension Using MATLAB and Input Signal Step Type.

Andronic Florin et al. published a paper on modeling of Quarter Car Model Passive Suspension Using MATLAB and Input Signal Step Type. The purpose of a vehicle suspension system is to improve ride comfort and road handling. In current article is simulated and analyzed the handling and ride performance of a vehicle with passive suspension system, quarter car model with two degree of freedom. The system shown in Fig.2 is an quarter car system were m_1- is the sprung mass, m2 - is the unsprung mass, k_1- is the stiffness coefficient of the suspension, k_2- is the vertical stiffness of the tire, b_1- is the damping coefficient of the suspension, b_2- is the damping coefficient of the tire, x_1- the vertical displacement of sprung mass, x_2- is the vertical displacement of unsprung mass, w - is the road excitation.

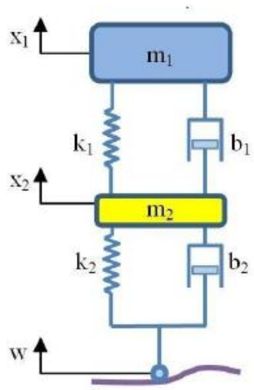

Fig.2 Passive Suspension System

Since, the equations of the system cannot be solved mathematically; they developed a scheme in Matlab/Simulink that allows analyzing the behaviour of the suspension. The scheme that was created in Matlab/Simulink, were compared with the State space model and the Transfer function.

4. Experimental Verification of Passive Quarter Car Vehicle Dynamic System Subjected to Harmonic Road Excitation with Nonlinear Parameters

Prof. S. P. Chavan et al. published a paper on Experimental Verification of Passive Quarter Car Vehicle Dynamic System Subjected to Harmonic Road Excitation with Nonlinear Parameters. For proper designing of suspension system, nonlinearities in suspension parameters must be considered. In this paper, nonlinearities of spring and damper are considered while preparing quarter car model. For this a simplified model and experimental set up for the same is developed as shown in Fig. 3 and 4.

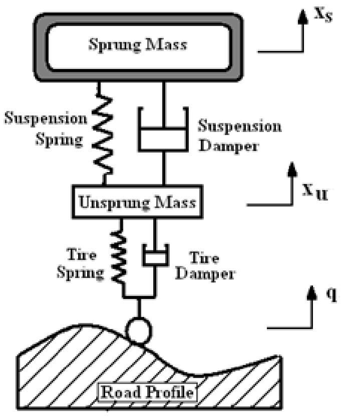

Fig. 3 TDOF Passive Quarter Car Model.

The deterministic impulses due to road profile are given by harmonic shaker which gives input motion to shock absorber. The sprung mass acceleration response obtained by FFT analyzer at sprung mass of quarter car model is compared with the results obtained by linear and nonlinear MATLAB/Simulink models.

Fig. 4 Experimental Setup

The simulation result shows considerable difference in linear and non-linear passive sprung mass. It is found that the chaotic response exists in nonlinear suspension. As the results of theoretical (combined nonlinear spring and damper) and experimental analysis of quarter car passive are quite similar because experimental model contains inherent nonlinear properties of suspension parameters, so it is necessary to consider the nonlinearities in suspension system for analysis of dynamic vehicle system.

5. Vibration Analysis of Quarter Car Vehicle Dynamic System Subjected to Harmonic Excitation by Road Surface

S.H. Sawant et al. published a paper on Vibration Analysis of Quarter Car Vehicle Dynamic System Subjected to Harmonic Excitation by Road Surface. A front suspension of Hyundai Elantra 1992 model is assigned as quarter car model as shown in Fig.5 and is considered for the performance study.

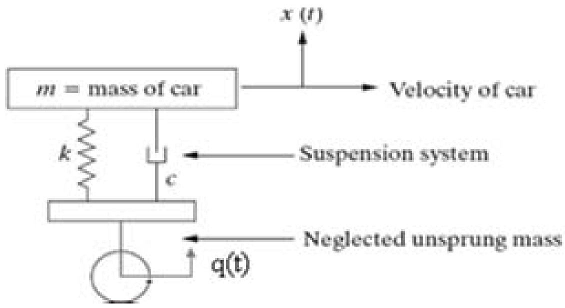

Fig. 5 Quarter Car Model for Hyundai Elantra 1992 Front Suspension

Modeling the dynamic performance of an automobile car system represents a complex task and forms an important step in its design procedure. In this paper the stationary response of quarter car vehicle model moving with a constant velocity over a rough road is considered for the performance study. For this a simplified model and experimental set up is developed. The deterministic impulses due to road profile are given by an eccentric cam which gives input motion to front suspension acting as a follower of the cam. The displacements obtained by FFT analyzer at upper mount of shock absorber were compared with the analytical and MATLAB results.

6. Suspension System Optimization to Reduce Whole Body Vibration Exposure on an Articulated Dump Truck

J.C. Kirstein submitted a thesis on Suspension System Optimization to Reduce Whole Body Vibration Exposure on an Articulated Dump Truck. In this document the reduced order simulation and optimization of the passive suspension system of a locally produced forty ton articulated dump truck is discussed. The linearization of the suspension parameters were validated using two and three dimensional MATLAB models. A 24 degree of freedom, three dimensional ADAMS/VIEW model with linear parameters was developed and compared with measured data as well as simulation results from a more complex 5o degree of freedom non-linear ADAMS/CAR model. The

ADAMS/VIEW model correlated in some aspects better with the experimental data than an existing higher order ADAMS/CAR model and was used in the suspension system optimization study. The road profile over which the vehicle was to prove its comfort was generated, from a spatial PSD (Power Spectral Density), to be representative of a typical haul road. The weighted RMS (Root Mean Square) and VDV (Vibration Dose Value) values are used in the objective function for the optimization study. The optimization was performed by four different algorithms and an improvement of 30 % in ride comfort for the worst axis was achieved on the haul road. Some of the tire models in order of complexity are shown in Fig. 6.

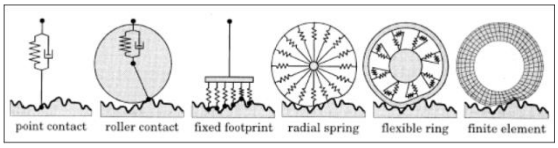

Fig. 6 Tire models suitable for Ride simulation

The improvement was realized by softening the struts and tires and hardening the cab mounts. The results were verified by simulating the optimized truck on different road surface and comparing the relative improvements with the original truck's performance.

7. Application of Taguchi Method in Indian Industry

Shyam Kumar Karna et al. presented a paper on Application of Taguchi Method in Indian Industry. The objective of the present study is to optimize the process by applying the Taguchi method with orthogonal array robust design. Taguchi parameter Design is a powerful and efficient method for optimizing the process, quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. The Taguchi method is one of the conventional approaches for this purpose. Analysis of variance (ANOVA) is used to study the effect of process parameters on the machining process. The approach is based on Taguchi method, the signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) are employed to study the performance characteristics.

8. Application of Taguchi Method for optimizing Passenger-Friendly Vehicle Suspension System

P. Senthil Kumar et al. presented a paper on Application of Taguchi Method for Optimizing Passenger-Friendly Vehicle Suspension System. This paper presents an optimum concept to design passenger-friendly vehicle suspension system with the help of Taguchi approach. A quarter car suspension test rig is used as an illustrative example of vehicle model to demonstrate the concept and process of optimization. The experimentation have been conducted by varying the stiffness of shock absorber (A), damping co-efficient of shock absorber (B), stiffness of seat (C) and damping co-efficient of seat (D). The values of suspension parameters have been obtained by using the Taguchi design of experimental method. The implication of input parameters on seat is placement (DS) and settling time (ST) has been investigated by using analysis of variation. The optimum system parameters are predicted using Taguchi analysis and verified by the confirmation analysis carried out using MSC ADAMS. The results shows that stiffness of shock absorber and stiffness of seat spring are there most significant parameters which affect the seat displacement, while damping coefficient of. The concept proposed in this paper is applicable to generic cases, where more complex vehicle model and pavement surface condition apply.

9. Optimization of Process Parameters Using Taguchi Approach with Minimum Quantity Lubrication for Turning

Dr. S. S. Chaudhari et al. carried a work on Optimization of Process Parameters Using Taguchi Approach with Minimum Quantity Lubrication for Turning. The performance of the manufactured products is often evaluated by several quality characteristics and responses and experimental techniques. In the present investigation a single characteristic response optimization model based on Taguchi Technique is developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool. Taguchi's L9 orthogonal array is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. This paper also aims to determine parametric relationship and its effect on surface finish.

10. Conclusion

By the literature review it is seen that by using optimum concept, the value of suspension parameter can be obtained. In earlier recherchés linear parameters of suspensions were considered but in practice the suspension parameters behaves nonlinear characteristic. So it is important to consider the nonlinearities of suspension system while designing the suspension system. This behaviour of suspensions system is studied with half car model for better understanding of nonlinearities of suspension parameters because it can elaborate more detail than that of the study quarter car model.

11. References

1. R. Kalidas, P. Senthil Kumar, and S. Vinoth Sarun, "Mathematical Modeling and Optimization of Vehicle Passive Suspension System Using Full Car Model", International Journal of Innovative Research and Development, ISSN: 2278 – 0211, vol 2 Issue 2, February 2013.

2. Andronic Florin, Manolache-Rusuioan-Cozmin, Pătuleanuliliana, "Passive Suspension Modeling Using MATLAB, Quarter Car Model, Input Signal Step Type", TEHNOMUS - New Technologies and Products in Machine Manufacturing Technologies, 2013.

3. Prof. S. P. Chavan, Prof. S. H. Sawant, Dr. J. A. Tamboli, "Experimental Verification of Passive Quarter Car Vehicle Dynamic System Subjected to Harmonic Road Excitation with Nonlinear Parameters", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), ISSN: 2278-1684, PP: 39-45, February, 2013.

4. S.H. Sawant, Mrunalinee V. Belwalkar, Manorama A. Kamble, Pushpa B. Khot and Dipali D. Patil, "Vibrational Analysis of Quarter Car Vehicle Dynamic System Subjected to Harmonic Excitation by Road Surface", Undergraduate Academic Research Journal (UARJ), ISSN : 2278 – 1129, Volume-1, Issue-1, 2012.

5. J.C. Kirstein, "Suspension System Optimization to Reduce Whole Body Vibration Exposure on an Articulated Dump Truck", Department of Mechanical Engineering Stellenbosch University, Private Bag, XI 7602 Matiel and, South Africa. Thesis-MscEng (Mech), September 2005.

6. Shyam Kumar Karna, Dr. Ran Vijay Singh, Dr. RajeshwarSahai, "Application of Taguchi Method in Indian Industry", International Journal of Emerging Technology and Advanced Engineering. ISSN 2250-2459, volume2, Issue 11, November 2012.

7. P. Senthil Kumar ,R. Kalidas , K. Sivakumar ,E. Hariharan , B. Gautham , R. Ethiraj, "Application of Taguchi Method for Optimizing Passenger-Friendly Vehicle Suspension System", International Journal of Latest Trends in Engineering and Technology (IJLTET), vol. 2.Issue 1.January 2013.

8. Dr. S. S. Chaudhari, S.S. Khedkar, N. B. Borkar, "Optimization of Process Parameters Using Taguchi Approach with Minimum Quantity Lubrication for Turning", International Journal of Engineering Research and Applications (IJERA), ISSN: 2248-9622, vol. 1, Issue 4, pp.1268-1273.