

DESIGN AND VALIDATION OF DRIVER SEAT SUSPENSION USING SEMI-ACTIVE DAMPER

Submitted in partial fulfillment of the requirements for the award of
BACHELOR OF ENGINEERING IN AUTOMOBILE

BY

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DEPARTMENT OF AUTOMOBILE ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **MURALI KRISHNAN.K (39860701)** and **PRANAVAN.B (39860016)** who have done the Project work as a team, who carried out the project entitled "**DESIGN AND VALIDATION OF DRIVER SEAT SUSPENSION USING SEMI-ACTIVE DAMPER**" Under my / our supervision from August 2022 to April 2023.

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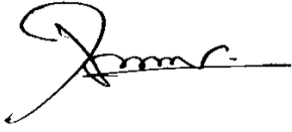
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DECLARATION

We **MURALI KRISHNAN.K AND PRANAVAN.B** hereby declare that the Project Report entitled “**DESIGN AND VALIDATION OF DRIVER SEAT SUSPENSION USING SEMI-ACTIVE DAMPER**” done by me under the guidance of **Dr. JINO.L, M.Tech., Ph.D** at Sathyabama institute of science and technology, Chennai is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering / Technology degree in AUTOMOBILE Engineering

DATE: 26.04.2023

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Abstract

This paper mainly focused on necessary in developing seat vibration control system to find an idea to increase safety and comfort for vehicle driver seat. Both on-road and off-road are focused in extending various levels of vibrations and mainly low frequencies. Taking under consideration of driver health and damage effects to body this investigation has under gone in various level of vibration. In automobile seats, active, passive, and semi-active suspension systems are used to reduce the detrimental and destructive effects of transmitted vibration to the human body. The operator's body movement and acceleration must be decreased to increase riding comfort. To reduce the vibration and to protect the passenger's low frequency vibration control performance in commercial vehicle seating system. For seating and ride comfort, control policies with semi-active and active devices such as magnetorheological (MR) dampers, magnetorheological isolators, magnetorheological mounts, electrorheological dampers, actuators, and pneumatics are combined with automotive seating systems (ASS). According to the findings of this review study, adopting cost-effective intelligent vibration control policies with adopted solutions would increase ride comfort and will be made available in every ASS in the near future.

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Chapter 1

Introduction:

Nowadays, considering the advancement of different technologies, motor vehicle manufacturers have concentrated on the research to find new techniques to promote the safety and comfort of the ground vehicle operators [1]. Plenty of investigations have been carried out and researchers have proposed several criteria for estimating discomfort and the fitness of various vehicles' seats such as those of trucks, cars and agricultural vehicles in operating condition [2]. One of the challenging tasks for engineers in automotive industries is the design of the suspension system. It is crucial to design reliable, safe and convenient seats to eliminate road excitation, since transmitted vibrations to the driver's body may cause some damaging effects on their health and efficiency [3]. Truck drivers and operators of any earth-moving machine during their operation will experience a wide range of vibrations, most often originating from road surface unevenness [4]. The vibration felt in a typical earth-moving machine vehicle usually happens at frequencies from 0 to 20 Hz [5]. The results for operators are the lack of concentration, tiredness and reduction of the effectiveness of the work being conducted [6]. There is a direct link between vibration discomfort frequencies for heavy-duty vehicles and eigenfrequencies of the operator's body. Based on the conducted studies by Paddan [7], the vibration at low excitation frequencies (0.5–4 Hz) are the principal hazard causes for lumbago or a backache, which harmfully affect the mental and physical well-being of operators and travellers and decrease their working performance [8]. Most passive suspensions in normal seats are not able to isolate these low-frequency vibrations [9]. To satisfy these conditions, there has been extraordinary progress in automotive seat design during the past decade. Targets have been developed to maximize seat quality and performance and decrease driver's stress during long operating hours. An essential part of the improvement is the driver's seat, so research of seat suspension systems has become the focus of attention in all automotive and truck companies, directions, horizontal and vertical [24]. The horizontal sensation function is used for both lateral and longitudinal accelerations. In ISO-2631, the human filter is presented as a transfer function with various sensitivities for different frequencies. In a because the driver's body is connected to the vehicle by the seats and all of the vibration is transmitted to the driver's body through the seats [9,12,13]. The human body is sensitive to vibrations and the feeling of the vibration is different depending on the frequency and the direction of the vibrations [9]. By using a frequency weight, the

feeling can be translated from the vibration in space to how it is felt inside the driver's brain where discomfort is recognised. The frequency weight is offered in ISO-2631 [23] and divides the sensitivity into two directions, horizontal and vertical [24]. The horizontal sensation function is used for both lateral and longitudinal accelerations. In ISO-2631, the human filter is presented as a transfer function with various sensitivities for different frequencies. The Whole Body Vibration in terms of the body frame x-y-z is described in Figure 2, where the three translational vibrations are along the x, y, and z axes; the three rotational vibrations, which are also described as roll, pitch, and yaw motions, are around the three axes.

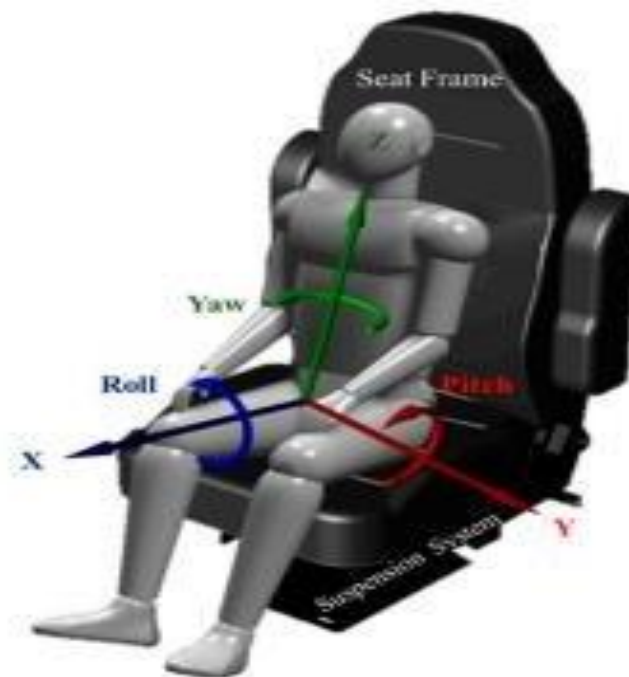


Figure 1. Whole body vibration of the seated human body

This implies that when designing a multiple-DOF seat suspension, the yaw vibration control, which would have the weakest impact on ride comfort comparing with the vibration in other DOFs, could be neglected in order to decrease the complexity of the seat suspension configuration; the translational vibration along the z-axis could be decoupled from other DOFs in order to clarify the vibration control [53]. The simple vehicle seat form contains an isolation

system and a seat frame, as given in Figure 2.

1.1 Passive Vibration Control Systems:

Most seat suspensions utilise a passive mechanism to reduce the effect of the vehicle vibration which are created by uneven road surface on the human body. The passive suspension as a conventional suspension system contains a sprung mass with a damping shock absorber to regulate unwanted vibrations [54]. The basics of passive vibration control are shown in Figure 3 to present the fundamental concepts. A passive control system can absorb structural vibrations and remove energy from the dynamic system without an external energy source. The method is to connect the structure to elements and materials with damping characteristics that overcome vibrations. A passive system is regularly implemented with springs and dampers with time-invariant stiffness and damping coefficients [55].

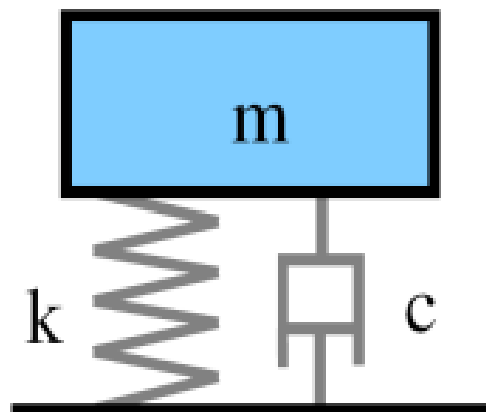


Figure 2. Single-degree-of-freedom system [56]

given A conventional suspension system was chosen by Maciejewski et al. [6]. The proposed system includes a shear guidance mechanism, an air-spring, a hydraulic shock-absorber and buffers. The geometry of the seating system is shown in Figure 4. The damped vibration effect is given by the spring force coupled with the shock-absorber force. Amplification of vibration in the 0–2 Hz frequency range was mentioned [57]. At the greater frequencies, the desired performance of the seat suspension was and vibrations transmitted by the seat were decreased significantly [58], the modified seat suspension outstandingly promotes the vibro-isolating characteristics of the seat in the 0–4 Hz frequency range. For bigger frequencies, vibro-isolating features of both seats (conventional and modified) are nearly the same [60].

1.2 Semi Active Vibration Control Systems:

The vibration transmissibility of passive vibration isolation systems is low in some frequencies, especially in the low-frequency range. The main objective of implementation of the semi-active seat suspension systems is to find a way to reduce vibration transmissibility in the low-frequencies, in addition to the high performance at high frequencies. Semi-active suspension measures the stiffness and damping characteristics of the isolation system and makes it possible to control the vibration in a broad vibration frequency range [61,62]. Furthermore, if the stiffness matrix of the system is positive definite, then the semi-active control systems are unconditionally stable. Besides this, semi-active systems are more efficient because of their lower power consumption in comparison with other active control systems. Adjustable damping and stiffness features in semi-active suspensions have resulted in this system having been applied in broad industrial fields such as vibration control of high-precision machinery [63], automotive suspensions [64], helicopters [65], engine mounts [66] and earthquake-response suppression [67]. Vibration isolation by semi-active control can be enhanced by employing controllable stiffness and damping systems. Semi-active devices manipulate the stiffness of the structure very quickly to turn uncontrollable stiffness systems into governable systems, and this feature makes it possible to decrease the vibration transmissibility. With the advancement of magnetorheological (MR) or electrorheological (ER) dampers, semi-active control of seat suspension has been developed to enable variable damping force and has less power consumption than active control systems [14,68].

Based on the implemented experimental tests by Sun et al., they considered transmissibility as a parameter, which is the ratio of affected response acceleration to excitation acceleration. The transmissibility ratio shows whether the suspension system is efficient or not. They offered a comparison between passive and semi-active seat system acceleration and explained that the acceleration amplitude in the semi-active case is considerably decreased in comparison with passive ones. According to the obtained results in the semi-active state, the seat acceleration had the minimum value, which verified that the semi-active rotary MR damper-based seat suspension was much more efficient in decreasing the vibrations. The experimental results, as given in Figure 9, proved that the semi-active system by utilizing MR damper can efficiently decrease the transmissibility and presents the best performance over a wide frequency range.

As a risky occupation, the drivers of heavy commercial vehicles are prone to prolonged exposure to low-frequency whole-body vibrations generated from road excitation, which could influence drivers' comfort or even adversely affect their health. According to [2], the long-term operation of heavy commercial vehicles with low-frequency vibration can cause diseases of the muscles, bones, digestive system, and even the visual system.

An active seating system vibration control (Figure 16) using an electromagnetic linear actuator and a related controller was designed by Gan et al. (2015) [63]. The system uses a combination of active and passive suspensions, where the passive suspension is primarily responsible for static load bearing, while two electromagnetic active suspensions (XTA-3806) that can produce a peak force of 1116 N are placed at both ends of the seat to generate the force needed to reduce vibration. In the next step, an adaptive controller (Figure 17) based on the traditional filtered-X least mean square (FXLMS) algorithm combined with an on-line fast-block LMS identification method was developed. For this project, the conventional FXLMS method was used to deal with the time-varying and nonlinear nature of the system, and the narrowband feed-forward FXLMS algorithm was employed to reduce the narrowband vibration caused by mechanical equipment. Finally, an online identification using a Fast-block least-mean-square (FBLMS) controller was used to mitigate low-frequency periodic vibrations, and multiple two-weighted adaptive filters were used in the system to reduce multiple

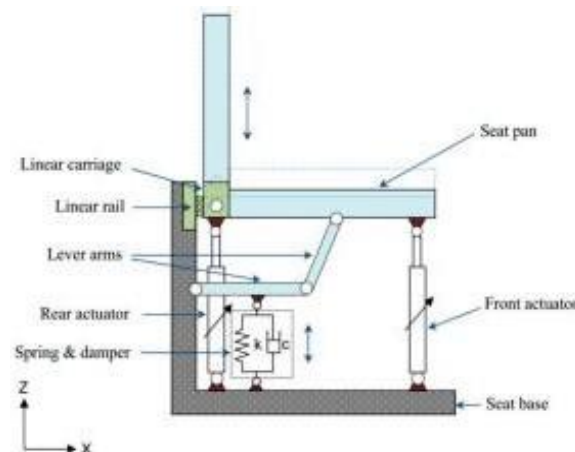


Figure 3. The model of the active seating system [63]

Chapter 2

Literature survey

Analytical literature search yielded six sequences as shown in Fig. 2. Sequence (1) tries to look for words from cluster-1 and shaped as class A. Sequence (2) tries to look for words from cluster-2 and from cluster-3. The words belonging to cluster-1 are combined with “AND” alongside words from cluster-2 or cluster-3, with no additional limits, for creating class B and class C, severally. Sequence (5) combines class B and C, and rejects duplicates forming class D. Sequence (5) was carried out, and also the inclusions were applied to the title and abstract. The snowball process has resulted in 38 extra swing from which the full text is read. Inclusion criteria are outlined to ensure capturing all relevant literature. The articles that dealt with following words from clusters,

1. Semi-active devices
2. Control policies
3. Mathematical (numerical) modelling of different types of MR dampers
4. Mathematical modelling of seat with semi-active damper
5. Generation of Road profiles
6. System and Damper controller
7. Degrees of Freedom of Seating Systems, Performance criteria, application and comparison of different control policies.

Chapter 3

Aim and scope

This review will focus on the necessity for developing seat vibration control systems as a part of manufacturers' investigation into finding innovative methods to increase the comfort and safety of the vehicles' drivers. Operators of either on-road or off-road vehicles are regularly subjected to an extended variety of various vibration levels, especially at low frequencies. Considering that exposure to such vibration in long term has some damaging effects on driver's health, many comprehensive investigations have been carried out and researchers have proposed several measures for estimating discomfort and the suitability of various vehicles' seats such as those of trucks, cars and agricultural vehicles in operating condition. Active, passive and semi-active suspension systems are employed in vehicle seats to alleviate the harmful and damaging effects due to the transmitted vibration to the human body. In order to improve riding comfort, the operator's body displacement and acceleration must be reduced. According to the research, active suspension control systems are the best choice to reduce the transmitted vibration to the drivers' body and provide the best ride comfort in comparison with passive and semi-active systems.

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Chapter 4

Methodology

In the study of active seat suspension of vehicles, in addition to using a prototype to verify the control algorithm, conducting simulations with professional software is also a common method to verify the feasibility of the controller design. Du et al. (2013) [65] proposed a model combining automotive chassis suspension, active seat suspension, and the driver's body to analyse and achieve integrated vibration control. A static output feedback controller considering driver weight changes and actuator saturation was designed for an active seating system. The simulation results showed that this integrated control strategy for an active seat Simulink is a MATLAB-based graphical programming environment for modelling, simulating and analysing multidomain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation and model-based design pension system could improve comfort and robustness.

1. Identification of problem
2. Literature survey
3. Mathematical modeling of passive seat suspension
4. Modeling of MR seat suspension
5. Performance analysis of MR damper
6. Comparison of passive and semi active suspension

CHAPTER 5

Performance analysis:

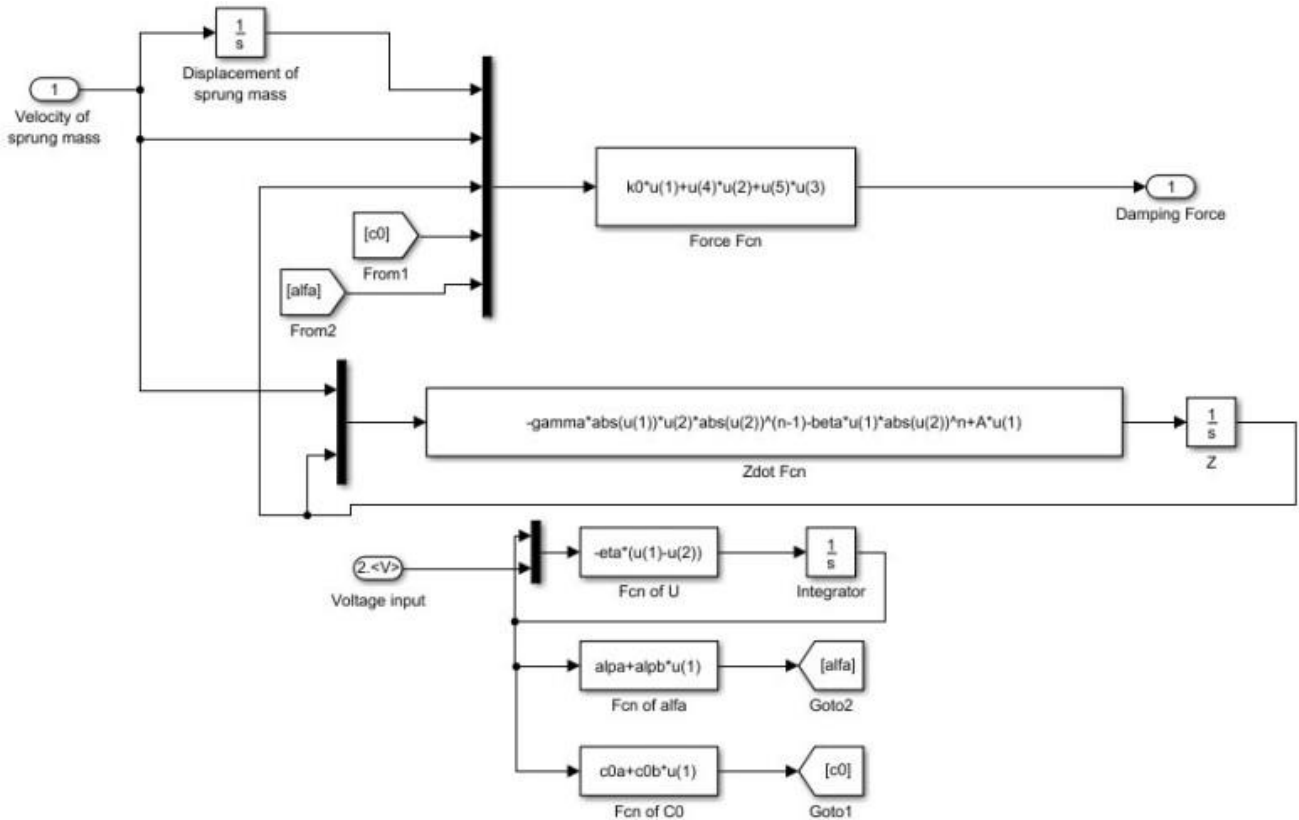


Fig 5. Simulink Model of Bouc-Wen

Simulation model of sprung mass and un-sprung mass have been made under quarter car model mask. The input forms are sine excitation and random excitation. The sprung mass is experiencing the force excitation generated from the road and that force is generating a specific damping force via a voltage command. The error of force transmitted to sprung mass and damping force produced is reduced by the controller. Thus, gives the desired suspension affect.

Chapter 6

CONCLUSION:

This presentation gave a survey of current developments in various seating systems for trucks, buses, and earth-moving vehicles, with a focus on cutting-edge vibration control systems. Vibration has a direct impact on drivers' health and performance. Designing a safe and comfortable seating arrangement has become one of the primary goals of high-tech car manufacturing firms. It has several negative impacts on the human body as a result, current research has concentrated on innovative approaches such as active and semi-active control systems that can directly regulate vibration. These mechanisms are more complicated, costly, and difficult to maintain than typical spring and damper systems. Because of the interdisciplinary nature of the environment in which cars or trucks operate, the research and design of control systems in vehicle seating systems have yet to overcome many hurdles, such as the low frequency of transmitted vibrations to the operator's body. As a result, our research team will seek for unique ideas to create a pleasant and ergonomic seating arrangement for commercial vehicles. The advantages of adopting the semi-active suspension system are as follows: it accommodates different human masses, has changeable damping characteristics, uses less energy, has the worst road profile, and can be utilized as a passive suspension system if the damper fails. Based on a review of the literature, the following actions may be utilized to lower vibration levels in automobile seating systems; optimal controller policies can be used to build semi-active seat suspension.

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