Seat Transmissibility and Human Comfort – A Review

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Abstract - *Vehicle ride comfort is the study of the relationship between the vibrations transmitted through the human body and the body's response to those vibrations. Ride comfort is influenced by various parameters, such as whole body vibration, road irregularities, tires, suspension system, cab mounts, seat design, sitting posture, noise, etc. These vibrations cause fatigue and stress, resulting in discomfort. Human multibody biodynamic models can easily assess seat design in the early seat design stage. With the help of multibody models, it is easy to study how a human body responds to different types of input.*

***Key Words*: Ride comfort, Seat transmissibility, Multi-body dynamic (MBD), Human Biodynamic Model, Lumped-Parameter Models.**

1. INTRODUCTION

Globally automobile industries are growing fast and comfort is the main approach of customers. One of most important part for comfort is car seat because it is in direct contact with human body and transfers vibrations coming from base to human body. One of method to measure vibrations is to check transmissibility from base to human body through seat.

Where transmissibility is ratio of excitation of body to the excitation of base.

$$\text{Transmissibility} = \frac{\text{Excitation of body}}{\text{Excitation of base}}$$

Where excitation may be in terms of displacement, velocity or acceleration.

Overall, these vibrations cause fatigue and stress, resulting in discomfort. Currently, in automobile industries, seat design is mainly based on previous experimental results and experience. As customers demand for luxury and safety increases, there should be a better way to evaluate seat design. A valid human biodynamic model is very useful for studying the human body's response to whole body vibration. Whole body vibration is one of the important factors in the study of vehicle ride comfort. The environmental vibrations are transferred to the human body through floor and seat. Seated posture is the most commonly used position in automobiles. Therefore, studying the human body response in a seated position has attracted a lot of attention. Because the human body is in direct contact with the seat, its design plays a very important role in vibration transmission. With the help of this seat model, transmissibility of vibration to a human body is evaluated in the frequency range.

2. RELEVANCE

The ride comfort depends on the exposure duration, amplitude, and frequency of vibration to a human body. The human body is a dynamic system whose mechanical properties vary from moment to moment and from one organ to the other. Out of all these factors, seat design is important as it is in direct contact with human body. Most vibrations are transferred to the body through the seat contact area. So, it is useful to study the relationship between seat design and the vibrations transferred to the human body.

In respect to vehicle comfort, car seat is one of most important part. Since it is direct in contact with human body and transfers vibrations to human body coming from vehicle base. But development of new car seats is very costly and time consuming since it is depend on experimental procedures on prototypes. Hence computer simulation models can save cost and time for development of new car seats. For a multibody dynamics (MBD), many researches have been done. For this purpose, we can use multibody dynamic software MSC ADAMS.

There are many factors that affect to discomfort in a driving vehicle, such as pressure at seat interface, sitting posture, vibration, noise, visual effects, humidity etc. Among them whole-body vibration causes many problems in human health, comfort and performance. So many researchers studied the cause-effect relationship between whole-body vibrations. The human feelings like discomfort and the level of injury can be estimated with this relationship and measured 12-axis whole-body vibration. This discomfort estimation can be used in experimental method in vibrating environment such as vehicle. But this experimental method is time-consuming and needs much effort. So the simulation of the mechanical human models would be better to estimate dynamic characteristics of human body in simple dynamic simulation. In many papers various biodynamic models have been developed to depict human motion from single DOF to multi-DOF models. These models can be divided as lumped parameter and distributed model.

Transmissibility is non-dimensional ratio of the response amplitude of a system to the excitation amplitude expressed as a function of the vibration frequency. These characteristics are changeable from moment to moment and from individual to another because the human body is a complex active dynamic system.

In recent years people become more concerned about the vibration seeking more comfortable environment. As traveling increases, the driver is more exposed to vibration mostly originating from the interaction between the road and vehicle. Vibration will make them feel discomfort and fatigue sometimes along with injury. It is important to know how the vibration is transmitted through the human body before we try to manage it. Over the years the dynamic responses of the seated subjects exposed to vibration were investigated by many researchers. The responses have been widely assessed in terms of the driving-point impedance, apparent mass, and transmissibility. The first two are related to the forces and motion at the driving position such as the position of the hip or floor while the third one is related to the transmission of motion through the human body.

3. REVIEW OF PRIVIOUS WORK

To increase the seat comfort, many researches have done on car seat. Prasad Kumbhar, Peijun Xu, James Yang et al. [1] proposed three seat model- hard seat, seat with cushion, seat with cushion and base suspension. They explained for the hard seat (case 1), because there was nothing to isolate the human body from vibrations, all vibrations were transferred to the body. For seat with cushion (case 2), the natural frequency was reduced, and the magnitude decreased due to stiffness and damping of the seat cushion and backrest cushion. For seat with cushion and base suspension (Case 3), is the best setup for vibration isolation. By choosing proper spring stiffness and damping values of seat suspension and cushion, the natural frequency can be reduced to smaller than 4 Hz in the vertical direction. Also, the transfer function magnitude can be much lower than those of Case 1 and Case 2. Most vibrations from the floor were isolated due to stiffness of the seat suspension and cushion. The study also showed that the backrest, cushion, and seat suspension can improve the human body's horizontal ride comfort.

After numerical analysis for transmissibility between car seat and human body they concluded that by optimizing cushion material and base suspension stiffness and damping coefficients, can increase in seat comfort.

Tae-Hyeong Kim, Young-Tae Kim, Yong-San Yoon et al [2] developed a biomechanical model of human body in sitting posture for evaluating the head vibration transmissibility and apparent mass on vertical vibrations. A vehicle seat works as a vibration isolator between the human body and the vehicle. It is beneficial to study how seat design parameters affect the isolation. In this paper, we attempt to study the human body's response to different types of seats. Also they selected one multibody biodynamic model. Backrest support is considered in this model as there is a large difference in human body response with and without backrest support. Three types of seats were used for this analysis. The first seat has neither cushion nor seat suspension. The second seat has cushion but no seat suspension. The third seat has both seats cushion and seat suspension. With the help of these seat models, transmissibility of vibration to a human body is evaluated in the frequency range. For this they tested various eight models and selected best suited model after putting experimental data

S.K. Patra, S. Rakheja, H. Nelisse, P. Boileau, J. Boutin et al. [3] performed experiments to measure biodynamic responses of human body with different mass groups with and without back support with hands in lap or on steering wheel and concluded that body mass influences significantly irrespective of back support and hand position.

Cho-Chung Liang, Chi-Feng Chiang et al. [4] studied lumped-parameter models of seated human subjects exposed to vertical vibration and also analyzed and validated in terms of seat to head (STH) transmissibility, driving point mechanical (DPM) impedance, and apparent (AP) mass by the synthesis of various experimental data. A study on the biodynamic models of seated human subjects exposed to vertical vibration is carried out. The lumped-parameter models from literature have also been analyzed and validated in terms of STH transmissibility, DPM impedance, and AP mass by the synthesis of various experimental data.

L. Wei, J. Griffin et al [5] proposed method for predicting seat transmissibility from mathematical models of the seat and the human body using an indenter and sand bag. Also they proposed another linear model having one-DOF. In this model, the buttocks and legs are in rigid contact with the seat, and the mass of seat is neglected. Griffin proposed a similar model with different model parameters and modified the one-DOF model and made a linear two-DOF model in which the human body is represented by the head and the body.

Younggun Cho, Yong-San Yoon et al [6] developed a 9 DOF biomechanical model of human on a seat with back support and validated it with experimental data.

Prasad Kumbhar, Peijun Xu, James Yang et al [7], [10] used optimization based method to optimize seat dynamic parameters of seat cushions and suspensions to minimize occupant's body fatigue i.e. power absorbed human body.

C.R. Mehta, V.K. Tewari, selected seat cushion materials of different thicknesses had different densities and compositions. The cushioning material in a tractor seat plays a dominant role in supporting operator posture, isolating vibration and improving ride quality. Vibration attenuation in a tractor seat is achieved by selecting proper suspension and damping mechanism. This paper describes damping characterization of tractor seat cushion materials to improve operator's comfort. Nine commercially available seat cushion materials of different densities, thickness and compositions were selected for the study. They studied that the equivalent viscous damping coefficient of cushion materials decreased with the increase in frequency and peak-to peak amplitude of vibration.

W. Wanga, S. Rakhejaa, P.-E. Boileau [9] has obtained effects of sitting postures on apparent mass response of seated occupants exposed to whole body vertical vibration were investigated through measurements performed on 13 male and 14 female subjects. Postural differences arising from variations in hands position, seated heights, and inclinations of the seat pan and the backrest, were considered for the analysis. Owing to the complex dependence of the apparent mass response on the body mass, the statistical analyses are performed with body mass as a covariant in an attempt to eliminate the contributions due to body mass. From the results, it is concluded that an increase in seat height yields higher peak magnitude response attributed to larger portion of the body mass supported by the seat.

4. CONCLUSION

From above literature review it is observed that seat transmissibility has great impact on seat comfort so that it is useful to study the relationship between seat design and the vibrations transferred to the human body. By considering all above facts, this study tries to cover literature which deals with study of various dynamic parameters of seat cushions and suspensions along with optimizing methods of seat transmissibility.

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