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Dynamic Performance Evaluation of a Seat using Dynamic Properties of the Seat and the Designed Dummy

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ABSTRACT

Vehicle seats are one of the important components affecting dynamic comfort cognized by a passenger. To investigate dynamic performance evaluation of a seat, we analyzed dynamic characteristic by modeling seat cushion as distributed springs and behavior of the dummy designed for classifying distribution pattern of the seat. The dynamic characteristics were analyzed by measuring the distributed stiffness from vibrations transferred through seats. The dummy have mechanical characteristics affected by the distributed stiffness of the seat and represent motion of a seated human body. Subjective evaluations for stiff, heavy, elasticity, balance observed by a person on a vibrating seats were used to estimate overall and specific dynamic performance of the seats. The effects of support properties on the subjective evaluation was analyzed using statistical analysis.

Keywords: Seat, dynamic stiffness, comfort, dummy
I-INCE Classification of Subjects Number(s) : 49.1, 49.3.2

1. INTRODUCTION

The seat, which is directly coming into contact with passenger in the vehicle, is one of the most important component on the dynamic comfort. Fundamentally, dynamic comfort is stemmed from vibration magnitude affecting the passenger. Therefore, to estimate the dynamic performance of the seat, calculating dynamic property, transmissibility from suspension of the vehicle to cushion seated by passenger, is basically needed. The seat effective amplitude transmissibility (S.E.A.T.) value use vibration magnitude recognized by passenger and is the popular method for evaluating dynamic comfort of the seat(1,2). S.E.A.T. value can estimate dynamic comfort of the seat. But it is difficult to analyze by comparing the dynamic comfort with dynamic properties of the seat because S.E.A.T. value focus on the response of passenger and is one value considered sensitivity of the human at frequency range. In static comfort area, static characteristics of the polyurethane foam cushion, static stiffness, the gradient of a force-deflection curve and pressure distribution is studied(3). To estimate and improve dynamic performance of the seat, it is necessary to delicately analyze dynamic properties of the seat. In this study, the seat is modeled as distributes complex stiffness which represent spring and damping properties. A dummy model which represent behavior of buttock and thigh of the passenger was suggested. In the dummy model, a concept of coupling stiffness was applied. The distributed dynamic stiffness, coupling stiffness and loss factor of the seat were measured, which help to deeply understand the dynamic characteristics of the seat. Subjective evaluation was conducted for overall dynamic comfort and specific dynamic feeling. Then the objective properties of the seat and subjective of the passenger were compared using statistical analysis for dynamic comfort improvement of the seat.

2. Mathematical model and experiments

2.1 Distributed mass-spring model of the seat

A seat is composed of a frame, elastic support, polyurethane foam, and cover. It is supposed that

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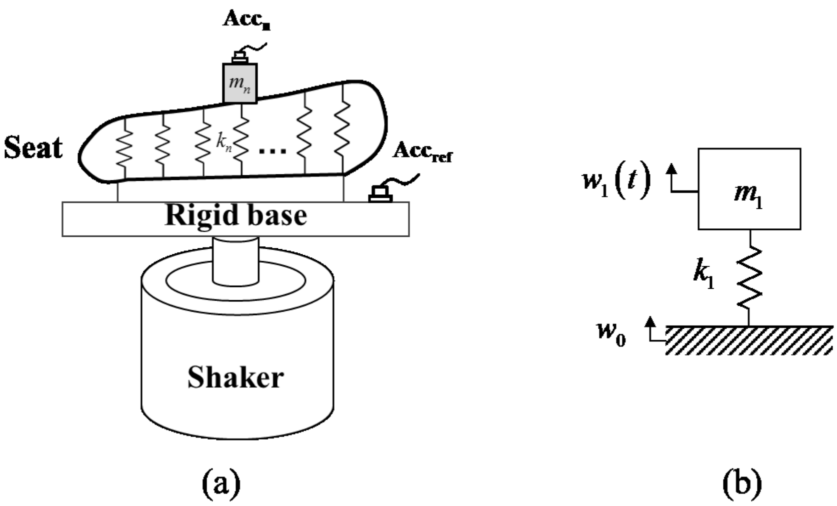

Figure 1 – (a) Distributed stiffness model of a seat supposed on a shaker and (b) mass-spring system.

the seat is arrayed by springs. When passenger sits on the seat, the seat is modeled as mass-springs system at each positions. We measured the complex stiffness using a dummy, which is a simple mass, and the coupling stiffness using coupling dummies, which is buttock shape masses. The governing equation of the mass-spring model is $m\ddot{w}(t)$ $-\hat{k}_1\left(w_1(t)-w_0(t)\right)$ and a harmonic solution is assumed as $w_0=\hat{w}_0 e^{i\omega t}$. Then transfer function is obtained as

$$\Lambda e^{i\phi}=\frac{\hat{w}_1}{\hat{w}_0}=\frac{k_1\left(1+i\eta_1\right)}{\left(k_1\left(1+i\eta_1\right)-m_1\omega^2\right)}, \quad (1)$$

where Λ is the amplitude and ϕ is the phase of the transfer function, k_1 is the stiffness and η is the loss factor of the seat, m is the weight of the dummy, ω is the angular velocity, w_0 is the displacement of the road condition and w_1 is the displacement of the dummy.

When the transfer function is measured experimentally, Eq. (1) is a function of the complex stiffness, $k(1+i\eta)$, and can be solved numerically[4].

2.2 Dynamic coupling model for the dummy

When two masses are nearly located on distributed stiffness, one mass affect the other mass. Then the frequency response characteristics become different. The effect was modeled by coupling stiffness which is attached between two masses. This phenomenon was observed between buttock and thigh of the passenger sitting on the seat because the stiffnesses at front and back of the seat are different, and the pressures at buttock and thigh of the passenger are different.

2.3 Experimental set-up

The seat is supposed on a Bruel & Kjaer V650 shaker, having a maximum displacement of ±12.7 mm. The seat is excited by random vibration induced by a shaker at r.m.s. acceleration levels of $3\,\mathrm{m/s}$ to consider the road condition. The weight of the distributed dummy is 1 kg, the weights of the coupling dummies for measuring coupling stiffness are 2.62 and 1.72 kg, respectively. Fig. 1 (a) shows the attached accelerometer to measure input vibration of the road condition. The accelerometer to measure out vibration was attached on the dummy.

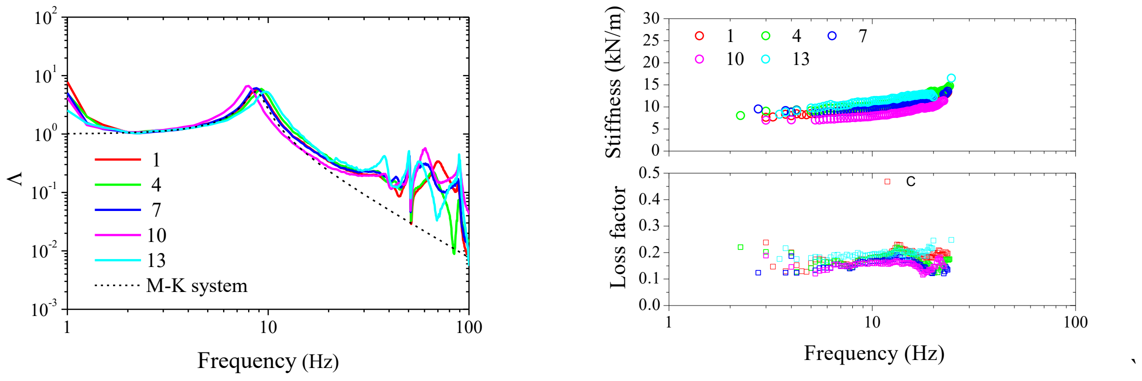

Figure 2 – (a) Measured and predicted transfer functions of the distributed dummy, (b) obtained dynamic stiffness and loss factor on the each locations

3. Results and discussion

3.1 Distributed stiffness and loss factor on the locations

Fig. 2 (a) shows the results of transfer functions when the distributed dummy is used on the each location to measure the distributed complex stiffness. The measured responses were compared with the predicted values, and there was an excellent agreement in the low frequency range, which is target frequency range for the dynamic comfort. So we confirm that it is possible to model the seat to mass-spring system on the low frequency range. Random vibration input was r.m.s. acceleration levels of $3\ \mathrm{m}/s$ and the transfer function is shifted by the location. Fig. 2 (b) shows the resulting stiffness and loss factor of the seat calculated numerically. The contour map of the distributed stiffness is presented by applying spline curve.

3.2 Subjective evaluations of dynamic feeling

To evaluate subjective dynamic feeling of seat, we used two methods. One was the paired comparison method for total dynamic comfort. The other was semantic differential method for specific dynamic feeling, such as stiff, heavy, elasticity and balance recognized by a person on a vibrating seats.

4. CONCLUSIONS

Laboratory methods to determine support properties of passenger seat and coupling stiffness affecting behavior of passenger were proposed to objectively analyze the seat characteristic. Effects of various parameters such as location, supporting area, pressure, and vibration on the stiffness and the loss factor is investigated. It is suggested the method to present contour map of the distributed stiffness and loss. This information is essential for understanding the seat comfort under dynamic conditions. Through the relation between objective properties of a seat and subjective rating of passengers are analyzed using statistical analysis, we will evaluate dynamic performance of some seat using its properties in advance.

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