Effectiveness of Balance Seat on Vibration Comfort

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Abstract. People who spend a significant amount of time on driving are concerned about seating comfort. Seat cushion is considered as one of the important factors affecting the comfort of your seat. In automotive seat cushions, flexible polyurethane foam has been widely used for vibration isolation and cushioning purpose. More recently, car seat designers are paying more attention to improving car seat cushion for ride comfort of drivers and passengers. This study introduces the new type of balance seat where cushion is designed with a 2-layered honeycomb structure made of a high elastic polymer, Vetagel. The purpose of this study is to analyze seating comfort of car seat with honeycomb structured balance seat and compare with car seat without balance seat. For experiment, the honeycomb structured balance seat was placed on the car seat. Vibration experiments have been performed on the Buzz Squeak and Rattle (BSR) simulator with random vibration to verify the effectiveness of the balance seat for vibration comfort. Tri-axial accelerometers were used to record vibration at the foot and hip. All vibration parameters measured in the vertical direction (z-axis). The whole-body vibration exposure parameters such as weighted root-mean-square (RMS), transmissibility (SEAT value) calculated as per ISO 2631-1 standard. Ten healthy participants attended that experiment and grouped according to body weight. In result, the measured vibration satisfied the ISO 2631-1 standard in case of without a balance seat but was in close margin. When the balance seat was used, the vibration met the ISO 2631-1 standard and was in safe limit from vibration discomfort. The SEAT value had a reduction of vibration when using the balance seat as compared with the absence of it in all of groups.

Keywords: Balance seat · Vibration comfort · Human vibration

1 Introduction

With the advancement of automotive industry and increasing habit of driving, sensibility design of driving seat have got much attention to automotive manufacturers. Ride comfort is most influential factor in order to obtain passenger satisfaction. Ensuring ride comfortability is a major challenge for automotive manufacturers nowadays. In the era of sensitivity design, lack of ride comfort and passenger satisfaction may hamper

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continuous advancement of vehicle industry. In order to achieve drivers comfort, various sensibility and human factors such as, vibration, noise, air condition, body-seat contact surface temperature, humidity etc. need to be considered. There are several studies in order to identify factors effecting ride quality of vehicles [1–3]. Whole-body vibration (WBV) is one of most considered factors for automotive seat design. Transmission of vibration from vehicle to body is main factor in ride discomfort. Vibration originates from engine, rotating parts of vehicle, uneven surface of road etc. Transmission of Whole-body vibration happens through the seat surfaces, backrests, and through the floor to an individual sitting in the vehicle [4]. Comfort has been defined as a status where passenger is not discomforted and many studies have been accomplished to define a standard for a non-discomfort status [5]. During designing the vehicle seat, the minimization of vibration transmission should be considered to reduce ride discomfort. The dynamic properties of a seat (e.g., damping and stiffness) are influenced by the physical properties of foam or other material (e.g., density, thickness, firmness) that might be engineered to achieve the desired seating comfort including vibration isolation [6].

WBV is measured on seat surface that interacts with driver's body (BS 6841, 1987; ISO 2631-1, 1997). The standards describes that vibration discomfort can be predicted from the acceleration of the interfacing surface of the body and a seat. There have been several experimental test methods developed for evaluating seat vibrational comfort [7, 8]. In order to minimize whole-body vibration during driving, a various studies has been proposed. Road maintenance can lower WBV exposure [9] and variety of engineering controls including seat suspension systems [10] and seat cushion systems [11] have been developed to attempt to reduce vibration exposures.

The optimum design of a seat should consider some factors, such as the shape, the width, and the height of the seat pan and the backrest, and the seat cushioning, that have influence on the static discomfort of the seat occupants and their vibration discomfort [12]. Several studies were performed in order to investigate vibration attenuation effect on different types of seat cushion with various kinds of shape, material, size etc.

The objective of our study is to investigate vibration characteristics and effectiveness of honeycomb structured balance seat on vibration reduction of a novel type of seat cushion made by a special material, Vetagel. Here we will analyze vibration effects on car seat with and without Vetagel honeycomb seat cushion.

2 Methodology

2.1 Seat Cushion Materials

The seat cushion used in this experiment is structured with double-layered honeycombs made of Vetagel. Vetagel is antibacterial high elasticity special polymer widely used in cosmetic industry. The air-pumping effect by respective air-cell-cell in hexagonal piller keeps seat contact area fresh and dry (Fig. 1).

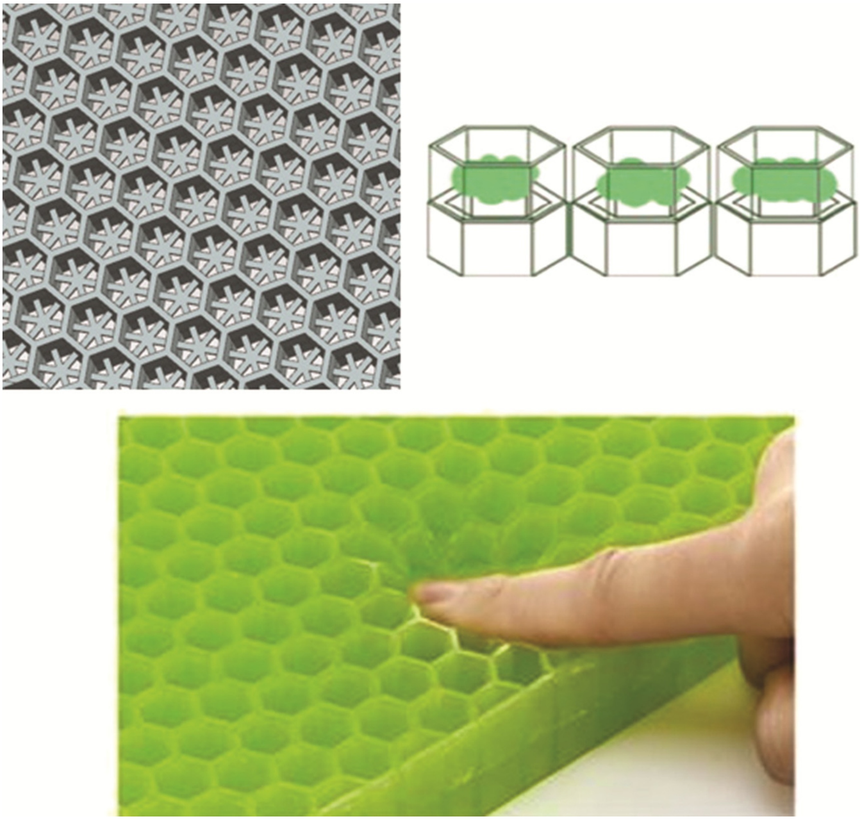

Fig. 1. Structure of double-layered honeycombs made of Vetagel polymer, and commercial Bullsone Balance seat using honeycomb-structured cushion.

2.2 Vibration Measurement Tools

Vibration was measured in seat contact surface between human body and seat. VATS™ (Vibration Analysis ToolSet), Biometrics DataLOG (MWX8; 8 channels), Data Acquisition Unit, Series 2A Accelerometers have been used in order to measure vibration experienced by car passenger (Fig. 2). To analyze the vibration and SEAT index, we used a vibration exciter (multi-axis noiseless BSR exciter) and a measuring and analytical instrument VATS (SV106). The specifications of multi-axis noiseless BSR are as described here. Noiseless as less tan 30 dBA, max payload of 350 kgf, frequency with DC 200 Hz, −40 °C to 50 ° C operating temperature. The specifications of VATS are as frequency of up to 20 kHz/channel (160 kHz total per DataLOG) ranging F.S. (each axis) of 10 G MAX (98 m/s^2).

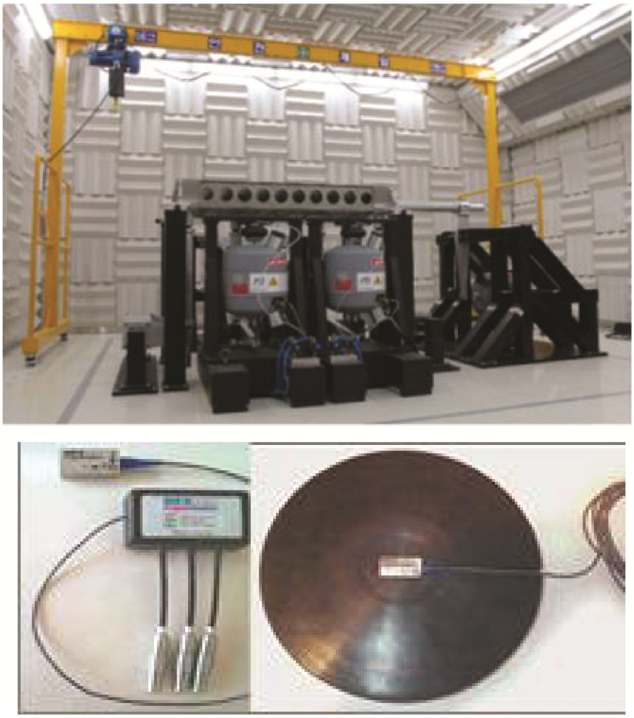

Fig. 2. Multi-axis noiseless BSR exciter simulator (*top*), Vibration Analysis ToolSet, VATS™ (bottom).

2.3 Experiment Participants

The subjects were ten healthy adults with a mean age of 29.6 years.

2.4 Experimental Procedure

The car seat was installed on the vibrator as a simulator. A vibration meter was installed on the seat of the car under the normal seat condition and the participant was seated on it. Then, the excitation was performed for 5 min in the oscillator. At the same time, data were collected on a vibration meter (Fig. 3).

Normal Seat With Balance Seat condition is that a balance seat is installed on a car seat and a vibration meter is installed on it. The experimental procedure was carried out as described above.

In order to obtain the SEAT index, this experiment excited a 5 Hz to 100 Hz vibration on the platform with a constant white noise. The vibration of the seat was measured by the participant using a vibration meter (VATS). The vibration and SEAT index were analyzed with the data obtained from the above experiment. Weight is set as independent variables and vibration as dependent variables.

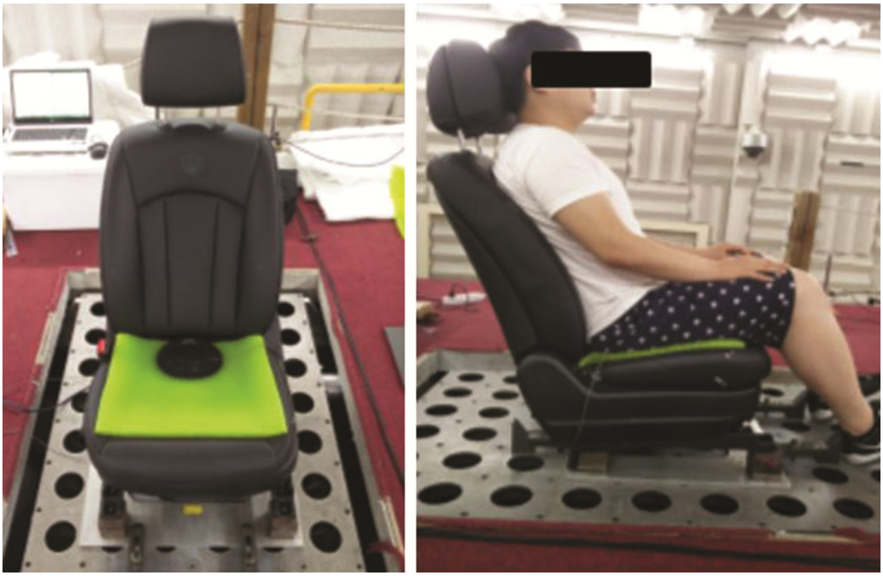

Fig. 3. Experimental setup for measuring vibration experienced by person sitting over balance seat.

2.5 Analysis Methods

The acceleration measured at the hip position when the artificially generated vibration signal has the base of the car seat on which the balance seat is not placed is called the normal seat. The acceleration measured at the position of the butt that occurred after having the acceleration of the same magnitude as that of the previous determination for the car seat with the balance seat is called the Normal Seat with Balance Seat. The two measured accelerations were compared by weight.

The SEAT index (seat effective amplitude transmissibility), which is widely used as an objective indicator of seat performance, was used here [12].

Among them, the direct method of calculating the SEAT index was used by calculating the ratio of the vibration measured on the seat track of the vibrator platform to the vibration measured on the seat.

$$\mathrm{SEAT}(\%) = \left[\frac{\int G_{ss} W_i^2(f)dt}{G_{ff} W_i^2(f)dt}\right] \times 100 \tag{1}$$

$$G_{SS} = |H(f)|^2 G_{ff} \tag{2}$$

Where G_{ff} is the power spectral density (PSD) of the excitation force specified by the exciter, and G_{SS} is the power density function of the acceleration measured at the hips above the seat when the participant is seated. Means a frequency axis weighting function corresponding to a coordinate axis defined by ISO 2631-1 and a corresponding axis, and a weighting function of a vertical vibration is applied in this study.

As can be seen from the above equation, the SEAT index implies the transmission rate of vibration riding considering human body response characteristics. That is, if the SEAT index is greater than 100%, it means that dynamic riding comfort is better on the platform corresponding to the denominator in Eq. 3, which means that the seat is negative in improving the dynamic ride quality. On the other hand, when the SEAT index is less than 100%, the seat absorbs the vibration of the platform well, which means that the dynamic ride comfort is improved. The smaller the index value is, the more the effect of dynamic ride is.

3 Results and Discussion

3.1 Vibration Result by Weight

In the experiment of measurement of vibration experienced by subject sitting on the Normal Seat and Balance Seat, it is found that the measured vibration was lowered when the balance seat was used rather the normal seat. When the balance seat cushion was not laid over normal seat, it felt vibration approaching close to limit according to ISO 2631-1. However, using the balance seat, there was a vibration attenuation effect (~45 kg, ~100 kg) which reduces vibration, satisfying ISO 2631-1 with proper margin. It means that the effect of attenuating vibration is greater on seat with balanced seat cushion than the normal seat. So, it can be confirmed that honeycomb structured balance seat makes a damping effect of a vibration to the human body. As the weight increases, the measured vibration on the seat

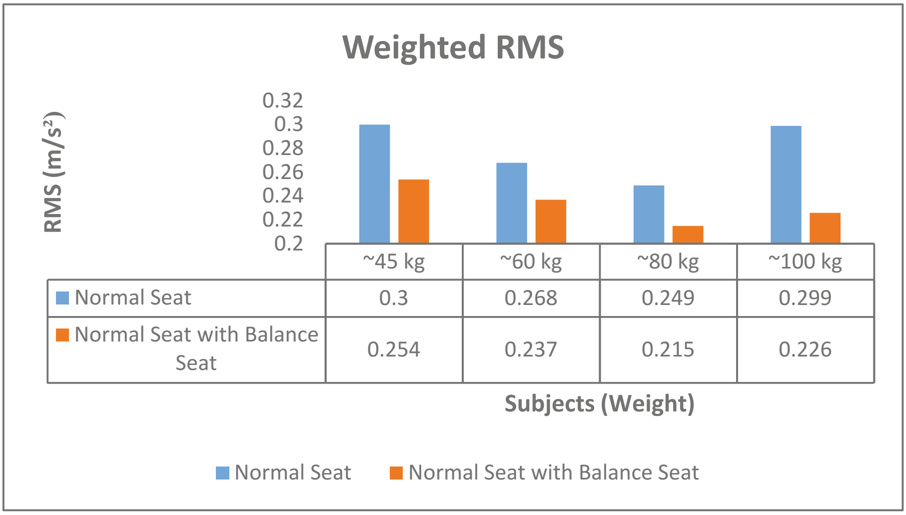

Fig. 4. Comparison of result of vibration experienced siting over normal seat and balance seat with variation of weight.

with the balance seat cushion tends to be lowered. This indicates that the effect of vibration damping tends to increase as the weight increases (Fig. 4).

It can be seen that the allowable vibration time of ISO 2631-1 is increased for the maximum vibration value. For example, in the case of 45 kg, if a balance seat is used, even if exposed to vibration for up to 21 min, it may not feel discomfort, though there are individual variations. Similarly, it is well observed that the ability to bear vibration exposure is increased for all weights when a balance seat is used. In other words, it signifies that there is an effect of attenuating the vibration, which is felt uncomfortable even if the vibration occurs from the outside during sitting on the seat.

3.2 SEAT Index Results by Weight

As mentioned earlier, the SEAT index is an objective indicator of the performance of the seat. As shown on SEAT index in Fig. 5, SEAT value of both normal and balanced seats are less than 100%. This indicates that both the normal seat and the balance seat are worn and the ride comfort is good. However, it can be seen that the SEAT index is lower in the case of a car seat having a balance seat than a normal seat. The difference is 12%–17% difference, which can be more comfortable ride. In the experimental analysis of SEAT index in weight variations, it is found that the vibration damping efficiency is higher in the case of 45 kg and the case of 100 kg.

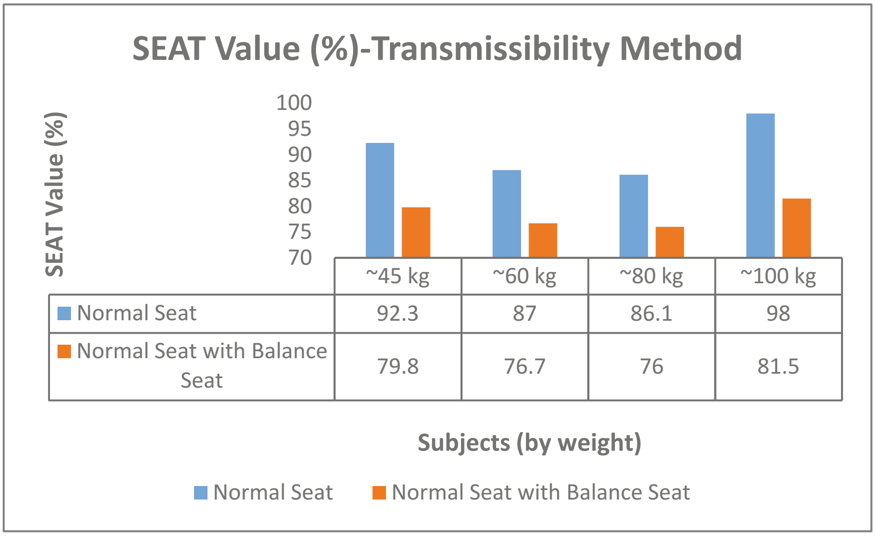

Fig. 5. Comparison of result of SEAT value (%) experienced siting over normal seat and balance seat with variation of weight.

4 Conclusion

A comparative analysis of human vibration and ride quality of normal seat and honeycomb-structured balance seat is presented here. In result, it is found that balance seat cushion has significant vibration attenuation effect which increases ride quality of drivers and passengers. In future, further experimental is be carried out with various seating position, seat height in order to find out optimum sitting comfort. Horizontal vibration parameters also will be measured and analyzed in future in order to get complete ride comfort study.

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