An Integrated Model of Static and Dynamic Measurement for Seat Discomfort

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Abstract. A driver interacts directly with the car seat at all times. There are ergonomic characteristics that have to be followed to produce comfortable seats. However, most of previous researches focused on either static or dynamic condition only. In addition, research on car seat development is critically lacking although Malaysia herself manufactures its own car. Hence, this paper integrates objective measurements and subjective evaluation to predict seat discomfort. The objective measurements consider both static and dynamic conditions. Steven’s psychophysics power law has been used in which after expansion; $\psi = a + b\phi_s^\alpha + c\phi_v^\beta$ where $\psi$ is discomfort sensation, $\phi_s^\alpha$ is static modality with exponent $\alpha$ and $\phi_v^\beta$ is dynamic modality with exponent $\beta$. The subjects in this study were local and the cars used were Malaysian made compact car. Static objective measurement was the seat pressure distribution measurement. The experiment was carried out on the driver’s seat in a real car with the engine turned off. Meanwhile, the dynamic objective measurement was carried out in a moving car on real roads. During pressure distribution and vibration transmissibility experiments, subjects were requested to evaluate their discomfort levels using vehicle seat discomfort survey questionnaire together with body map diagram. From subjective evaluations, seat pressure and vibration dose values exponent for static modality $\alpha = 1.51$ and exponent for dynamic modality $\beta = 1.24$ were produced. The curves produced from the Eq.s showed better R-sq values (99%) when both static and dynamic modalities were considered together as compared to Eq. with single modality only (static or dynamic only R-Sq = 95%). In conclusion, car seat discomfort prediction gives better result when seat development considered both static and dynamic modalities; and using ergonomic approach.

Keywords: Car Seat, Static Measurement, Dynamic Measurement, Seat Discomfort, Steven’s Law, Psychophysics

1. INTRODUCTION

According to ergonomic classification, a driver’s car seat is a workspace. It is exposed to both static and dynamic working conditions. Therefore, measurement and evaluation should consider both static and dynamic con-
discomfort. There are very limited numbers of past researches that combine static and dynamic conditions when studying seat discomfort. Of recent, the most referred literature is by Ebe and Griffin (2000a, 2000b). Applying Steven’s Psychophysics Power Law (Stevens, 1975), Ebe and Griffin found that whenever seat stiffness which was the static discomfort being studied was high, dynamic discomfort was high, and vice versa. However, the research found that if the static discomfort was low but the dynamic discomfort was high, perception on discomfort was also high.

Gescheider (1997) as quoted by Hacaambwa and Giacomin (2007) suggested that the transformation from mechanical (objective) sensation (pressure or acceleration) to perceived (subjective) human discomfort response falls into the general category of psychophysical relationships. In many researches (Ebe and Griffin, 2000a; Ebe and Griffin, 2000b; Hacaambwa and Giacomin, 2007; Stevens, 1975), Steven’s Power Law was applied to relate the objective measurement with human discomfort sensation. The Steven’s Power Law is expressed as:

\[ \Psi = k \varphi^n \]

where \( \Psi \) represents sensory modality in this case the magnitude of subjects discomfort, which is proportional to the stimulus intensity \( \varphi \) to a power \( n \). Steven (1975) suggested that the exponent \( n \) for pressure (on hand palm) is 1.1 and for vibration (of 60Hz on finger) is 0.95.

Eq. (1) can be expanded into the summation of two (or more) stimulus effects (Ajovalasit and Giacomin 2007, Amman et al., 2005, Giacomin and Fustes, 2005, Howarth and Griffin, 1990) and is expressed as:

\[ \Psi = a + b \varphi_s^\alpha + c \varphi_v^\beta \]

where \( a, b \) and \( c \) are constants, \( \varphi_s \) and \( \varphi_v \) represent seat pressure and vibration magnitude and exponent \( \alpha \) and \( \beta \) are exponents acquired from static the rate of increase in discomfort associated with the pressure and vibration magnitude.

This paper aims to produce an integrated model of that combines static and dynamic investigations on seat discomfort. The static condition being studied is the seat pressure distribution whilst the dynamic condition is the whole-body vibration.

### 2. METHODOLOGY

In order to integrate static and dynamic measurements of seat discomfort, separate measurement has to be carried out to obtain the exponent values of the Steven’s Power Law for both modalities. Basically, three experiments were carried out for the purpose of this study. Firstly, static measurement was done by measuring the seat pressure distribution of subjects in a stationary car. On the other hand, dynamic measurement was done by recording of vibration in a real moving car. Subjective evaluation on seat discomfort was carried out in both conditions. Thirdly, both modalities were examined continuously and subjective evaluation was again carried out in the third experiment. The first experiment was to determine exponent \( \alpha \) and the second one is to determine exponent \( \beta \). Therefore, the relationship between discomfort and both of the modalities, seat pressure and vibration can be determined from the third experiment.

The number of subjects for each experiment varies as it involves subjective evaluations. It is quite difficult to get significance and highly correlated relationship between the objective and subjective measurements especially since all the experiments were carried out in the field and not in a controlled lab environment. Nevertheless, the subjects are from the same pool of subjects who has agreed and had given their consent to participate in all three experiments.

#### 2.1 Seat Pressure Distribution Measurement

Real driver seat in a stationery vehicle from a Malaysian premium class sedan was used as the experiment set-up. Seat pressure distributions were recorded using a pressure mapping device (XSensor Technology Corporation) and continuously sampled at 5Hz for about an hour. The procedure and results has been discussed in detail previously in Deros et al. (2009a).

#### 2.2 Whole-Body Vibration Measurement

For each subject, the measurement of the vibration was recorded for 20 seconds. Prior to the test, subjects’ permission was given in the form of letter of consents after they were briefed on the procedures involved. The on road measurements were carried out between 9.30 am and 11.00 am so as to avoid busy traffic. Subjects were seated on the front passenger seat. The in-vehicle tests were carried out on smooth and paved road in Putrajaya, Malaysia. The car was driven at a constant speed at 80km/h. The same driver drove the car for each subject to minimize variability of driving condition for each test.

The measurement devices used were Bruel and Kjaer portable and multi-channel PULSE type 3560D with Bruel and Kjaer HAT type 4100 and Bruel and Kjaerisotron accelerometer model 751-100. The measurement software is also Bruel and KjaerPulse Labshop. The accelerometers were calibrated using the Bruel and Kjaer calibration exciter type 4294. The accelerometers were fixed on top of the front passenger-seat surface and on the floor below the seat.

#### 2.3 Subjective Evaluation

Eleven healthy male subjects participated in the experiment. Each of them gave written consent to attend