Truck Seating Comfort: Objectify and Subjectify Measurement Approach

CheeFai Tan, Ranjit Singh Sarban Singh, Siti Aisyah Anas

Abstract*— Technology has changed trucks significantly over the years. Truck companies are getting interested in comfortable equipment for their employees in order to create a healthy and stimulating working environment. Due to this reason, truck manufacturers recognize comfort as one of the major selling point, as it is thought to play an important role for the buyer as well. Seat is one of the most important components of truck and they are the place where professional driver spend most of their time. The aim of the paper is to describe the measurement methods that used to improve the physiological comfort of truck driver's seat. There will be three sections in the paper. First, the paper describes the nature of sitting comfort and discomfort. Secondly, it describes the subjective and objective measurement methods that are used to evaluate the truck seat. Thirdly, the paper proposes a methodology for the development of comfortable truck driver's seats.

Index Terms*— Truck Seat, Comfort, Objective measurement, Subjective Measurement.

I. INTRODUCTION

Comfort is an attribute that today's drivers demand more and more. The driver comfort is depends on different features and environment during the driving. Seat comfort is a very subjective issue because it is the customer who makes the final determination and customer evaluations are based on their opinions having experienced the seat [1]. One of the products often considered in truck industry is the driver's seat. The truck driver's seat has an important role to play in fulfilling driver comfort expectations. Seat is one of the important features of vehicle and there is the place where the truck driver spends most of their time. According to the 'European Union Legislation for Drivers and Promote' [2], the weekly driving time for truck drivers shall not exceed 56 hours. Assuming eight weeks of vacation and one week holiday, results in 2408 hours driving time per year. Commercial trucks are unique in that they are specifically designed to transport loads over long distances, in contrast to passenger vehicles that are designed for individual comfort. The truck driver's seat, which is in contact with the drivers, plays an important role to position the driver to perform the task of driving, meet the safety requirements, and be acceptable to the driver's comfort needs. The paper describes sitting comfort and discomfort, objective and subjective measurement of seat, and proposes a methodology for comfortable truck driver's seat.

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II. SITTING COMFORT AND DISCOMFORT

Comfort is defined as a pleasant feeling of being relaxed and free from pain by Cambridge Advanced Learner's Dictionary. Hertzberg [3] describes comfort when there is absence of discomfort. The term "seat comfort" is typically used to define the short-term effect of a seat on a human body [4]. Comfort is a generic and subjective feeling that is difficult to measure, interpret, and related to human physiological homeostasis and psychological well being [5]. Generally, the comfort issues that not under debate by researchers are [6]: (1) comfort is a construct of a subjectively-defined personal nature; (2) comfort is affected by factors of a various nature (physical, physiological, psychological); and (3) comfort is a reaction to the environment.

The concept of comfort and discomfort in sitting are under debate. There is no widely accepted definition, although it is beyond dispute that comfort and discomfort are feelings or emotions that are subjective in nature [6]. Seating discomfort has been examined from a number of different perspectives. The problem with evaluating comfort in regards to pressure or any other factor is that, comfort is very subjective and not easily quantified. Seating discomfort varies from subject to subject and depends on the task at hand. Comfort, however, is a vague concept and subjective in nature. It is generally defined as lack of discomfort [7]. For example, truck drivers require sitting for long periods of time approximately eight hours. The extended period of sitting includes higher risk of back problems, numbness and discomfort in the buttocks due to surface pressure under the thighs [8]. In the study by Adler et al. [9], the results showed that the driver posture is not static and changes over time. Posture changes and continuous motion are strategies of the driver to avoid mechanical load and ischemia of tissue, which has been identified as one main reason for discomfort. Discomfort feeling as described by Helander and Zhang [10], is affected by biomechanical factors and fatigue. The sources of such discomfort are listed in Table 1. Zhang [11] presented a model that illustrates the interaction of comfort and discomfort as shown in Fig. 1. Transition from discomfort to comfort and vice versa are possible in the intersection of the axes. Hence, if discomfort is increased, such as with increased time on task and fatigue, comfort will decrease. Its means that good biomechanics may not increase the level of comfort, it is likely that poor biomechanics may turn comfort into discomfort.

Table 1: Causes of Seating Discomfort [10]

Human experience mode	Biomechanical Physiology causes	Engineering causes	Seat/environment source
Pain	Circulation occlusion	Pressure	Cushion stiffness
Pain	Ischemia	Pressure	Cushion stiffness
Pain	Nerve occlusion	Pressure	Seat contour
Discomfort	-	Vibration	Vehicle ride
Perspiration	Heat	Material Breathability	Vinyl upholstery
Perception	Visual/auditory/tactile	Design/vibration	Vehicle cost

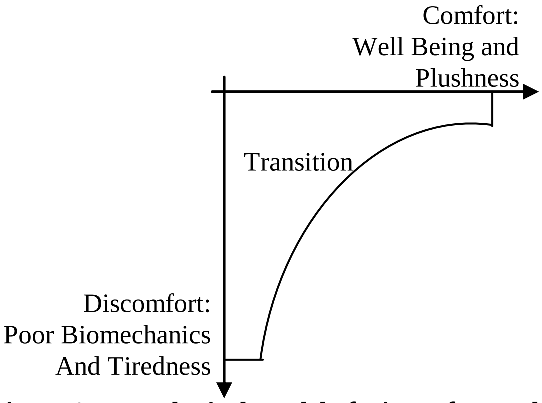

Figure 1: Hypothetical Model of Discomfort and comfort[11]

III. OBJECTIVE AND SUBJECTIVE MEASUREMENT OF SEAT COMFORT AND DISCOMFORT

The comfort experienced by humans in seat can be classified as a subjective assessment, because it is possible to find a variation with different people in a same situation. Nevertheless, the factors on which the opinions of people on comfort or discomfort level are based on physical variables that characterize the seat, for example, pressure, vibration, posture and temperature.

The comfort offered by a seat is relatively easy to determine by many measures [12, 13], the most effective of which is to survey potential users of the seat as they compare the “feel” of a seat for a short period of time against other seats in the same class. This practice is often adopted for different vehicles, ranging from passenger vehicles to commercial vehicles such as trucks, busses, and off road vehicles. The problem, however, with subjective evaluations is that they are costly and time-consuming. In response, a great deal of research has been performed in recent years to find objective measures for predicting seat comfort perception. Some of the proposed objective measures include vibration, interface pressure, and muscle activity. These objective measures are correlated with subjective data to determine the relative effects of each measure related to comfort [14]. Research has shown that some of the main factors that affect seating comfort are seat-interface pressure distribution, whole-body vibration and pressure change rate [15].

A literature search in computerized systems such as ScienceDirect and SAE Technical Paper database obtained various studies that related to the objective and subjective measurements in relation to vehicle seat.

i) Objective Measurements of Automotive Seat Comfort

There are vast majority of objective measures used for evaluating comfort and discomfort. From the literature search, the objective measurement methods for seat such as pressure distribution, posture, computer-aided design (CAD), computer-aided engineering (CAE), temperature, humidity, vibration, electromyography (EMG), and adrenaline. Table 2 shows overview of studies in relation to objective measurements for seat comfort and discomfort.

Nine studies were found in which pressure measurement is used to study the discomfort feeling among the drivers. Pressure measurement method is the most used method for the seat developer to measure the comfort and discomfort of seated persons. The instruments that used in pressure measurement such as pressure mat (Tekscan), pressure monitor system, force sensor, seat deformation measuring device and pressure imaging system.

Eight studies were related to posture measurements. The automotive industry strongly encourages research in the field of objective comfort assessment, especially dedicated to the seat and the related postures [16, 17]. Driver posture is one of the important issues to be considered in the vehicle design process [18] regarding not only the car and the user [19, 20] but also the experimental conditions. The instruments that used in the posture measurement are camera, optoelectronic system (ELITE), driving posture monitoring system, digital signal processing, ultrasonic device (Zebris), 3D motion analysis (Vicon), and motion measurement system (Qualisys).

Six studies are involved with the vibration measurement methods. A major portion of the vibrations experienced by the occupants of an automobile enters the body through the seat [21]. Whole-body vibrations, which are vertical vibrations, tend to affect the human body the most. These vibrations are transmitted to the buttocks and back of the occupant along the vertebral axis via the base and back of the seat [22]. The instruments that used are vertical vibration simulator, angulator rate sensor, accelerometer and whole body vibration measurement (Maestro).

Six studies have used computer-aided engineering (CAE) methods to measure the seated person comfort such as finite element method (FEM), virtual human, simulation software (Ramsis and Madymo), and artificial intelligence (Neural Network).

Other studies for objective measurements are related to human physiology.

The physiology of human such as brain, muscle, heart, skin and spinal can be used to measure the seated person comfort or discomfort level. The spinal load measurements have been performed in two studies. Five studies are carried out to measure the skin temperature and humidity level. Two studies using electromyography (EMG) to measure the muscle reaction in relation with the subject discomfort feeling. There is a study which used adrenalin content in the urine to measure the driver's stress level. Besides, the brain activity can be detected by electroencephalography (EEG) as well as oxygen saturation can be used to measure discomfort level of seated person too.

ii) Subjective Measurement of Automotive Seat Comfort

This is Kolich [4] described that the lack of proven analytical metrics, vehicle manufacturers have opted to rely on subjective evaluations as the main indicator of seat comfort. The vehicle manufacturers developed elaborative subjective evaluation protocols that involved highly structure questionnaires. The questionnaires direct occupants to assign feelings of discomfort to a specific region of seat. The questionnaires, which typically contain numeric scales (e.g. 1 = very uncomfortable to 10 = very comfortable), produce subjective ratings that are translated into performance requirements/specifications [24]. A properly designed questionnaire is paramount because it affords researchers an instrument from which to establish theories [23]. Table 3 shows the overview of studies in relation to subjective measurements for seat comfort and discomfort.

Local discomfort rating is used to measure the discomfort of subjects while sitting. According to Kolich [4], many researchers have adopted Hertzberg [3] definition because, in the current environment, it is more straightforward to quantify discomfort than to measure comfort. The local discomfort rating scale can be rate on a scale such as 1 to 10 or -10 to 10. Shen and Parsons [5] used the category partitioning scale (CP50) for rating seated pressure intensity and perceived discomfort. There are sixteen studies related with local discomfort rating. Whereas there are six studies related to local comfort rating.

The subjective measurement also involve the used of body mapping technique. In this the subject will be rating the body areas experiencing discomfort and to rate this discomfort on a scale. Seven studies are involved in the use of body mapping method. In addition, there are two studies involving seat mapping. Like body mapping method, seat is divided in different areas and subject is asked to rate on a scale.

Table 2: Overview of Studies Related to Objective Measurements for Seat Comfort and Discomfort

References	Objective measurements
Dhingra et al. [29]; Hinz et al. [31]; Inagaki et al. [32]; Kolich and Taboun [34]; Kyung et al. [35]; Mehta and Tewari [24]; Parakkat et al. [43]; Shen and Parsons [5]; Zenk et al. [53];	Pressure distribution
Adler et al. [9]; Hanson et al. [30]; Hinz et al. [31]; Kyung et al. [36]; Marler et al. [38]; Park et al. [42]; Tamrin et al. [48]; Wu et al. [51] ;	Postural analysis
Bouazara et al. [25]; Hinz et al. [31]; Jang et al. [33]; Mehta and Tewari [24]; Rakheja et al. [44]; Tamrin et al. [48];	Vibration eveluation
Cheng et al. [26]; Choi et al. [28]; Montmayeur et al. [39]; Nilsson [40]; Rasmussen et al. [45]; Verver et al. [50];	CAE
Cengiz and Babalik [27]; Nishimatsu et al. [41]; Solaz et al. [47]; Tsutsumi et al. [49]; Zhang et al. [52];	Temperature and humidity
Inagaki et al. [32]; Parakkat et al. [43];	EMG
Eklund and Corlett [57];	Spinal Loading
Uenishi et al. [54];	Adrenalin
Parakkat et al. [43];	Oxygen saturation
Zhang et al. [52];	EEG

Table 3: Overview of Studies Related to Subjective Measurements for Seat Comfort and Discomfort

References	Subjective measurements
Kolich and Taboun [35]; Kyung et al. [37]; Mehta and Tewari [24]; Mergl et al. [56]; Na et al [58]; Park et al. [55]; Shen and Parsons [5]; Smith et al. [46]; Solaz et al [47]; Zenk et al. [53];	Local discomfort rating
Adler et al. [9]; Kyung et al. [37]; Parakkat et al. [43]; Tsutsumi et al. [49]; Zhang et al. [52];	Local comfort rating
Kyung et al. [37]; Mergl et al. [56]; Solaz et al. [47]; Zenk et al. [53]; Mehta and Tewari [24];	Body mapping
Park et al. [56]; Inagaki et al. [32];	Seat mapping

IV. PROPOSED METHODOLOGY FOR COMFORTABLE TRUCK DRIVER'S SEAT

A methodology is proposed to improve the comfort of truck driver's seat as shown in Figure 2. As refer to Figure 2, subjective and objective measurement methods are used to study the truck driver's sitting discomfort while driving. The subjective methods will be questionnaire and observation technique. The objective methods will be integration of bio sensors and measurement equipment into the seat to obtain physiological and postural data from driver. After that, both subjective and objective data will be analyses to obtain the correlation data. A comfort improvement measures will be designed that based on comfort ranking. After that, the design will be optimized and prototypes are developed with optimized comfort characteristics. The developed smart seat prototypes will be tested and experimented to validate the design. Finally, a comfortable smart truck driver's seat will be developed.

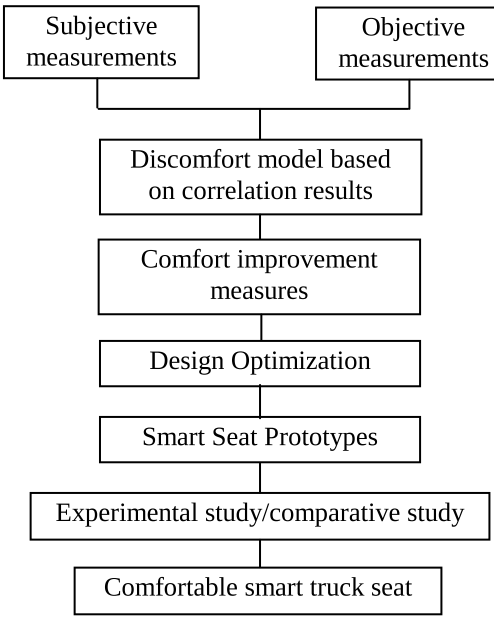

Figure 2: Proposed methodology framework for comfortable truck driver's seat

V.CONCLUSION

In this paper, a methodology framework for the development of comfortable truck driver's seat has been proposed. The literature review from various studies that related to seat comfort research shows that pressure distribution method is the most common methods for objective measurement. It is follow by postural analysis method. For subjective measurement, local discomfort rating and body mapping method is the most frequently used methods. It is recommended that objective measurement and subjective measurement should be combined for the seating research for better result. From the proposed methodology, the author would like to develop a smart aware environment in truck driver's seat that have the capability to reduce long haul truck driver's stress from time to time.

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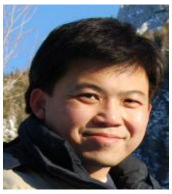

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