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A Review on Automotive Comfort Seat

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ABSTRACT
Seats are one of the most important components of automotives. In recent years, customer expectations for automotive comfort are increasing, and the development of seats that cause little fatigue, even for long distance driving, has been required. Automotive manufacturers recognize comfort as one of the major selling point, as it is thought to play an important role for buyers as well. This literature review incorporates previous studies related to automotive seating comfort and discomfort. It summarizes key literature related to seating design and criteria and reviews comfort issues in automotive seating. The aim of this paper is to describe the measurement methods that are used to improve the physiological comfort of automotive driver's seat. The paper has 3 sections. First, we explain the nature of sitting comfort and discomfort. Secondly, we describe the subjective and objective measurement methods that are used to evaluate the automotive seat. Thirdly, we propose a methodology for the development of comfortable driver's seats.

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Introduction

Today's globalized market competitions among the various automobile industries drives the automotive creators to design their commodities specific to consumers' choices and satisfaction. The comfort ability and safety of a seat is very vital to a car's design and fabrication. Drivers' comfort is equally important as the functional and aesthetic aspects of automobiles since it is given more preference by the customers for a comfortable drive [1]. As the seated posture of a human being exposes him to a variety of musculoskeletal complications, sitting comfort is of top priority that requires ergonomic interventions in the early designing stages.

Automotive seats need to accommodate a wide range of driver sizes over relatively long periods of time and provide isolation from vehicle vibration and shock. To fulfill these requirements, there have been remarkable advances in automotive seat design during the past decade incorporating seatback recliners, lumbar support, motorized multi-axes adjustments, and foam cushions. However, these added features have resulted in increased cost and have been used in only a limited number of seating environments. Even with the progress that has been made, however, many drivers continue to experience significant discomfort in automotive seating, and the factors that contribute to long-term discomfort or improved comfort are still not clearly understood. Thus, in spite of abundant research studies in automotive seating, many questions still remain about what really contributes to seating comfort. As stated by Corlett (1989): Though Hertzberg (1958) defined comfort as the absence of discomfort, there is no universally accepted operational definition of discomfort. Furthermore, there is no agreed upon, reliable method for quantifying the sensation of comfort or discomfort.

The driver comfort depends on different features and the environment during driving. Seat comfort is a subjective issue because it is the customer who makes the final determination and customer evaluations are based on their opinions having experienced the seat [2]. Various earlier researches suggest that the normal office chair design can be used to design the automotive seat. But, there are several important considerations which are taken into account while designing the automotive seat. In particular, the control locations and sight line requirements serve to constrain postures to a greater extent than in most other seated environments.

In order to provide future development and for additional research, a literature review of journals, technical reports and thesis was conducted to describe sitting comfort and discomfort, by objective and subjective measurement of automotive seats, such as cars, buses, trucks, agriculture tractors, trains, air planes and proposes a methodology for comfortable seats.

Seating Comfort and Discomfort in Automotive

The Cambridge Advanced Learner's Dictionary defines comfort as a pleasant feeling of being relaxed and free from pain. Hertzberg [3] describes comfort as absence of discomfort. Comfort is a generic and subjective feeling that is difficult to measure, interpret, and related to human physiological homeostasis and psychological well-being [4]. Generally, comfort issues not under debate by researchers are [5]: (1) comfort is a rise of a subjectively-defined personal character; (2) comfort is exaggerated by physical, physiological, psychological characters; and (3) comfort is a response to the environment.

The term "seat comfort" is typically used to define the short-term effect of a seat on a human body. 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 [6]. Many of researchers have adopted this definition as this is more straightforward to quantify discomfort than to measure comfort.

The concepts of comfort and discomfort in sitting are under debate. There is no broadly established definition, while it is beyond difference of opinion on comfort and discomfort manner [7]. Seating discomfort has been examined from a number of different perspectives. The problem with evaluating comfort in

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regards to pressure or any other factor is that, comfort is subjective and not easy to quantify. 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 [8].

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 [9]. The study by Adler et al. [10], shows that the driver posture is not static and changes over time. One main reason for discomfort is posture.

Discomfort feelings, as described by Helander and Zhang [11], is affected by biomechanical factors and fatigue. The sources of such discomfort are listed in Table 1.

Zhang [12] presented a model that illustrates the interaction of comfort and discomfort as shown in Fig. 1

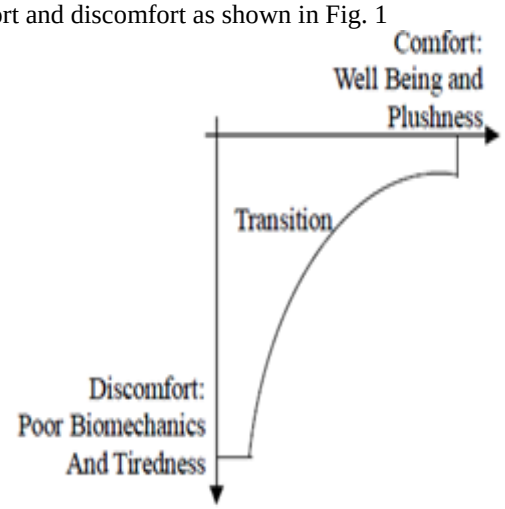

Figure 1. Hypothetical Model of Discomfort & comfort [12]

Transition from discomfort to comfort and vice versa are possible in the intersection of the axes. Hence, if discomfort is increased, such as with a longer time within task and fatigue, comfort will decrease. Its means that good biomechanics may not increase the level of comfort, it is likely that poor biomechanics turns comfort into discomfort

Objective and Subjective Review of an Automotive Seat

An objective assessment is one that needs no professional judgment to score correctly (although interpretation of the scores requires professional judgment). Subjective evaluations, on the other hand, yield many possible answers of varying quality and require professional judgment to score [14]. The comfort encountered by human objects in automotive seat can be categorized as a subjective evaluation, because it is possible to find an imbalance with different humans in a same state. Though, the aspects on which the conception of people on comfort or discomfort level are based on physical variables that specify the seat, for example, ergonomics, vibration, pressure, and temperature. The comfort offered by a seat is relatively easy to determine by many measures [15, 16], the most functional of which is to survey potential users of the seat as they differentiate the "feel" of a seat for a short period of time against each other seats in the same class. This habit is often acquired for dissimilar vehicles, varying from passenger vehicles to commercial vehicles such as trucks, busses, and off road vehicles. Since the subjective assessments are costly and time-consuming, a great deal of research has been conducted in recent years to find objective assessments for estimating seat comfort realization. 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 [17]. 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 [18].

A literature of various studies that related to the objective and subjective evaluation in relation to vehicle seat obtained from electronic data base such as SAE Technical Paper and Science Direct.

Objective Evaluation Review of Automotive Seat comfort

There are greater number of objective evaluations used for evaluating comfort and discomfort. From the literature explore, the objective assessment 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 studies related to objective evaluation for seat comfort and discomfort.

There are nineteen studies were related to ergonomics and posture assessment. The automotive industry strongly encourages research in the field of objective comfort assessment, especially dedicated to the seat and the related postures [19]. Driver posture is one of the important issues to be considered in the vehicle design process [20] regarding not only the car and the user [21, 22] but also the experimental constraints. 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).

There are ten studies were found in pressure assessment, which is the most used method that used by researchers to measure seat comfort objectively. Several researchers have measured the pressure at the human-seat interface using pressure mat (Tekscan), pressure monitor system, force sensor, seat deformation measuring device and pressure imaging system.

There are ten studies were 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 [22]. 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 [41]. The instruments that used are vertical vibration simulator, angulator rate sensor, accelerometer and whole body vibration measurement (Maestro).

There are seven studies were involved in 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 assessments 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. Six studies were 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.

Table 1. Causes of Seating Discomfort [11]

Human Experience	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		Vehicle cost

Table 2. Studies Related to Objective Evaluation for Seat Comfort and Discomfort

Objective evaluation	References
Ergonomics and Postural analysis	De Looze et al. [7]; Shen et al. [8]; Floyd et al. [9]; Adler et al. [10]; Helander et al. [11]; Gyi et al. [19]; Guenaelle et al. [20]; Porter et al. [21]; Zhang et al. [22]; Falou et al. [23]; Hanson et al. [24]; Kolich et al. [25]; Kyung et al. [26]; Kyung et al. [27]; Kyung et al. [28]; Marler et al. [29]; Park et al. [30]; Tamrin et al. [31]; Wu et al. [32] ;
Pressure distribution	Hertzberg et al. [3]; Shen and Parsons et al. [4]; Gyi et al. [19]; Porter et al. [20]; Mehta and Tewari [33]; Dhingra et al. [34]; Hinz et al. [35]; Inagaki et al. [36]; Parakkat et al. [37]; Zenk et al. [38];
Vibration evaluation	Ebe et al. [22]; Tamrin et al. [31]; Mehta and Tewari [33]; Hinz et al. [35]; Gruber[39]; Nawayseh[40]; Van Niekerka et al. [41]; Bouazara et al. [42]; Jang et al. [43]; Rakheja et al. [44];
Temperature and humidity	Nilsson [48]; Cengiz and Babalik et al. [51]; Nishimatsu et al. [52]; Solaz et al. [53]; Tsutsumi et al. [54]; Zhang et al. [55];
EMG	Inagaki et al. [36]; Parakkat et al. [37];
Spinal Loading	Eklund and Corlett [56];
Adrenalin	Uenishi et al. [57];
Oxygen saturation	Parakkat et al. [37];
EEG	Zhang et al. [55];

Table 3. Studies Related to Subjective Evaluation for Seat Comfort and Discomfort

Subjective evaluation	References
Local discomfort rating	Shen and Parsons [4]; Helander et al. [11]; Viano et al. [13]; Porter et al. [21]; Falou et al. [23]; Kyung et al. [28]; Park et al. [30]; Mehta and Tewari [33]; Zenk et al. [38]; Solaz et al [53]; Kolich and Taboun [58]; Mergl et al. [59]; Na et al [60]; Park et al. [61]; Smith et al. [62];
Local comfort rating	Adler et al. [10]; Kyung et al. [28]; Inagaki et al. [36]; Parakkat et al. [37]; Choi et al. [46]; Tsutsumi et al. [54]; Zhang et al. [55];
Body mapping	Kyung et al. [28]; Mehta and Tewari [33]; Zenk et al. [38]; Solaz et al. [53]; Mergl et al. [59];
Seat mapping	Inagaki et al. [36]; Park et al. [59];

Subjective Evaluation Review of Automotive Seat comfort

There are greater number of subjective evaluations used for evaluating comfort and discomfort.

From the literature explore, Kolich [58] reported 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 [33]. A properly designed questionnaire is paramount because it affords researchers an instrument from which to establish theories [23]. Table 3 shows the studies related to subjective evaluation for seat comfort and discomfort.

There are fifteen studies related with local discomfort rating. Local discomfort rating is used to measure the discomfort of subjects while sitting. According to Kolich [58], 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 [4] used the category partitioning scale (CP50) for rating seated pressure intensity and perceived discomfort.

Whereas there are seven studies related to local comfort rating. The subjective assessment also involved the use of body mapping technique. In this the subject will be rating the body areas experiencing discomfort and to rate this discomfort on a scale. Five studies were involved in the use of body mapping method. In addition, there were two studies involved in seat mapping. Like body mapping method, in seat mapping, the seat is divided in different sectors and subject is asked to rate on a scale.

Proposed Approach for Comfortable Automotive Seat Research

Automotive seat comfort research sounds good if it follows the stuff outlined in Fig. 2.

Automobile seat comfort research would be much more powerful (i.e. it would have a much larger impact) if it fits into the bigger picture. To be functional it must support/satisfy the needs of seat design teams.

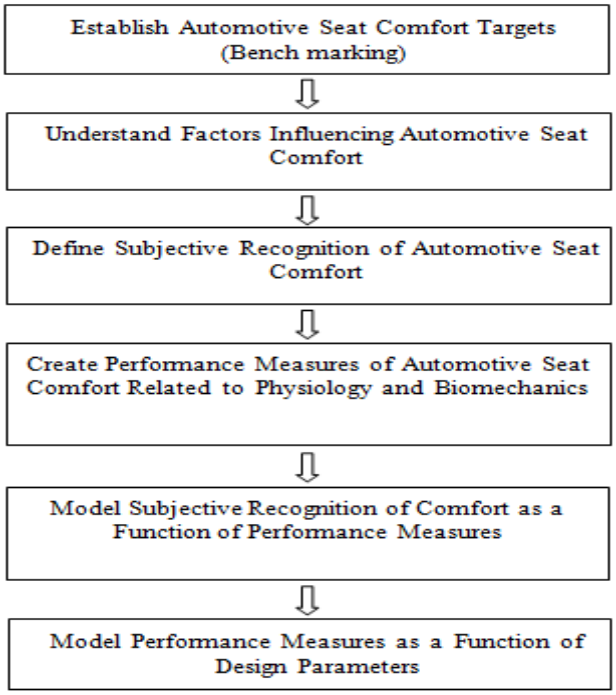

Figure 2. Research Required for the Science of Automotive Seat Comfort

Conclusions

In this paper, a methodology framework for the development of comfortable automotive 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 approach, the author would like to develop a framework thereby establishing/gaining recognition for the discipline of automotive seat.

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