

A Review on Automotive Seat Comfort Design

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Abstract— Seats are one of the most important components of automotive. In recent years, customer approaches for automotive comfort are growing, and the advance of automotive seats that origin minute fatigue for extensive distance driving is essential. Automotive makers recognize comfort as one of the major trade point, as it plays a significant role for buyers as well. This literature review incorporates previous studies related to automotive seating comfort and discomfort. It reviews key writings related to seating design and criteria and reviews comfort issues in automotive seating. The objective of this paper is to designate the measurement methods that are used to improve the physiological comfort of an automotive driver's seating. In this paper, first, we describe the background of sitting comfort besides discomfort. Then, we turn to 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.

Keywords—Automotive Seat Design; Automotive Seat Comfort and Discomfort Assessment; Automotive Seat Research Review

I. INTRODUCTION

Today's globalized market competitions among the various automobile industries drives the automotive creators to design their commodities specific to consumers' choices and fulfilment. The comfort facility and security 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 worries, as comfort sitting is the main importance that needs 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 shock and vibration. To achieve these desires, there has been amazing developments in automotive seating design during the past decade incorporating lumbar support, recliners, 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 have been made though numerous drivers endure to practice significant discomfort in automotive sitting, then the characteristics that add to remaining 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, here is no universally known effective definition of discomfort. Furthermore, there is no approved dependable technique for measuring the feeling of discomfort or comfort. While driving the occupant comfort hang on different features and the environment. As the customer who makes the final determination and customer evaluations are based on their opinions having experienced the seat [2], the seat comfort will be a subjective concern. 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.

II. 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 lack of discomfort.

Comfort is a generic and subjective feeling that is tough to quantify, know related to human physiological homeostasis and psychological sound presence [4]. Usually, comfort concerns not below discussion 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 while seating. Seating discomfort has been detected by a number of dissimilar attitudes. The tough with assessing comfort in respect to pressure or any other feature is that, comfort is genuine subjective and not just enumerated. Seating discomfort differs from subject to subject and depends on the task at pointer. Still comfort is an imprecise idea and personal in environment. Normally the term comfort is well-defined as absence of discomfort [6]. Many of investigators have

implemented this definition as this is more straightforward to quantify discomfort than to measure comfort.

The concepts of comfort and discomfort in sitting are under discussion. There is no approximately well-known definition, while it is elsewhere change of view on comfort and discomfort manner [7]. Seating discomfort has been observed from a number of different outlooks. The difficulty with assessing comfort in respect to pressure or any other specific is that, comfort is fixed subjective and not just enumerated. Seating discomfort differs from subject to subject and depends on the assignment at hand. Still comfort is an imprecise cognizance and personal in environment. Normally the term comfort is well-defined as absence of discomfort [8].

For example, truck drivers require sitting for long periods of time roughly eight hours. The lengthy era of sitting comprises higher risk of back pain troubles, unfeelingness and discomfort in the buttocks due to surface pressure under thighs [9]. The work by Adler et al. [10], shows that the driver posture is not static and alterations over time. One key cause for discomfort is posture.

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

TABLE I. CAUSES OF SEATING DISCOMFORT [11]

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

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

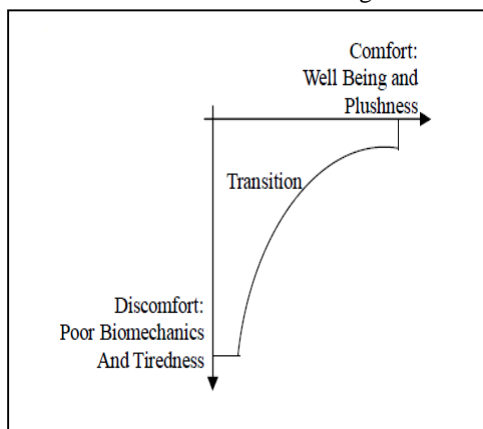


Fig. 1. Hypothetical Model of Discomfort and comfort [12]

Transition from discomfort to comfort and vice versa are possible in the intersection of the axes. Hence, if discomfort is augmented, with a lengthier time inside task and fatigue, comfort will diminish. It means that good biomechanics may not increase the equal of comfort, it is probable that unfortunate biomechanics chances comfort into discomfort.

III. OBJECTIVE AND SUBJECTIVE REVIEW OF AUTOMOTIVE SEAT

An objective assessment is one that needs no professional judgment to score correctly (although interpretation of the scores requires professional judgement). In addition to that, subjective assessments, yield numerous feasible responses of instable class and require professional judgment to notch [13]. The comfort met by human substances 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 stipulate the seat, like pressure, ergonomics, temperature and vibration. The comfort existing by a seat is relatively easy to determine by many methods [15, 16], the most useful 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 frequently attained for unlike vehicles, varying from passenger vehicles to commercial vehicles such as busses, trucks, and other off road vehicles. Meanwhile the subjective assessments are costly and timewasting, an excessive deal of research has been led in recent years to find objective assessments for estimating seat comfort realization. Some of the proposed objective measures comprise muscle movement, pressure and vibration. These objective events are connected 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 whole-body vibration, pressure change rate and seat interface pressure delivery [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.

A. Objective Evaluation Review of Automotive Seat Comfort

There are greater number of objective evaluations used for evaluating seat comfort and discomfort. After the literature review, the objective assessment methods for seat such as pressure distribution, posture, CAD (Computer Aided Design), CAE (Computer Aided Engineering), temperature, humidity, vibration, electromyography (EMG), and adrenaline. Table 2 shows studies related to objective evaluation for seat comfort and discomfort.

TABLE II. 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];
CAE	Wu et al. [32]; Cheng et al. [45]; Choi et al. [46]; Montmayeur et al. [47]; Nilsson [48]; Rasmussen et al. [49]; Verver et al. [50];
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];

There are nineteen studies were related to ergonomics and posture assessment. The automotive engineering powerfully inspires investigation in the arena of objective comfort valuation, particularly keen to the seat and the associated postures [19]. Occupant posture is one of the significant concerns to be measured in the automobile proposal procedure [20] concerning not only the vehicle and the occupant [21, 22] then also the investigational constraints. The gadgets that castoff in the posture quantity are camera, ELITE (Optoelectronic system), digital signal processing, driving posture intensive care system, Zebris (Ultrasonic device), Vicon (3D wave investigation) and Qualisys (Motion quantity system).

There are ten studies were found in pressure assessment, which is the utmost castoff technique that used by investigators to degree seat comfort by objective assessment. Numerous investigators have dignified the pressure intensity at the occupant seat boundary by pressure mat (Tekscan), seat deformation measuring device, force sensor, pressure monitor system and pressure imaging method.

There are ten studies were involved with the vibration measurement methods. A key slice of the vibrations qualified by the tenants of an automotive arrives the body over the seat [22]. Whole body sensations, which are erect vibrations, have most tendency to to have emotional impact on the occupant physique. These feelings are conveyed to the buttocks and spinal of the tenant along the vertebral axis via the base and back of the seat [41]. The gadgets that castoff are vertical vibration emulator, angular rate device, Maestro (whole body vibration measurement) and accelerometer.

There are seven studies were involved in CAE (Computer Aided Engineering) approaches to quantity the occupant comfort like FEM (Finite Element Method), virtual human, simulation software (Ramsis and Madymo), and Neural Network (Artificial Intelligence).

Additional revisions for objective assessments are associated to occupant physiology. The physiology of human such as muscle, spinal and skin can be castoff to quantity the occupant comfort or discomfort level. The backbone consignment quantities have been accomplished in two revisions. Six studies were conceded out to quantify the skin heat and humidity level. Two revisions using EMG (electromyography) to quantity the muscle response in relative with the subject discomfort sensation. Here is a revision which castoff adrenalin comfortable in the urine to quantity the driver's stress level. Also, the brain action can be noticed by EEG (electroencephalography) as well as oxygen capacity can be castoff to quantity discomfort level of occupant too.

B. Subjective Evaluation Review of Automotive Seat Comfort

There are greater number of objective evaluations castoff for assessing discomfort and comfort. On or after the collected works explore, Kolich [58] stated that the absence of established logical metrics, automotive makers have chosen to trust on subjective assessments as the key pointer of seat comfort. The automotive makers established elaborative subjective assessment procedures that elaborate extremely structured questionnaires. The surveys through tenants to allocate emotional state of discomfort to an exact area of seat. The questionnaires, which characteristically comprise numeric gauges (e.g. 1 = very uncomfortable to 10 = very comfortable), yield subjective scores that are interpreted into routine requests / conditions [33]. A suitably planned questionnaire is vital as it gives investigators a tool from which to found concepts [23]. Table 3 shows the studies related to subjective evaluation for seat comfort and discomfort.

TABLE III. 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]; Kyung et al. [28]; Falou et al. [23]; 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]; Smith et al. [62]; Park et al. [61];
Local comfort rating	Adler et al. [10]; Kyung et al. [28]; Inagaki et al. [36]; Parakkat et al. [37]; Choi et al. [46]; Zhang et al. [55]; Tsutsumi et al. [54];
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];

There are fifteen revisions associated with native discomfort assessment. Native discomfort assessment is castoff to quantity the discomfort of subjects while occupying. As per Kolich [58], numerous researchers have accepted Hertzberg [3] definition since, in the existing situation, it is more frank to enumerate discomfort than to quantity comfort. The native discomfort assessment scale can be proportion on a scale like 1 to 10 or -10 to 10. Shen and Parsons [4] castoff the kind dividing ruler (CP50) for assessment of seated pressure and apparent discomfort.

Although here are seven revisions associated to native comfort assessment. The subjective assessment also involved the use of body mapping technique. In this the subject will be grade the physique parts feeling discomfort and to degree this discomfort on a measure. 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.

IV. PROPOSED APPROACH FOR COMFORTABLE AUTOMOTIVE SEAT DESIGN RESEARCH

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

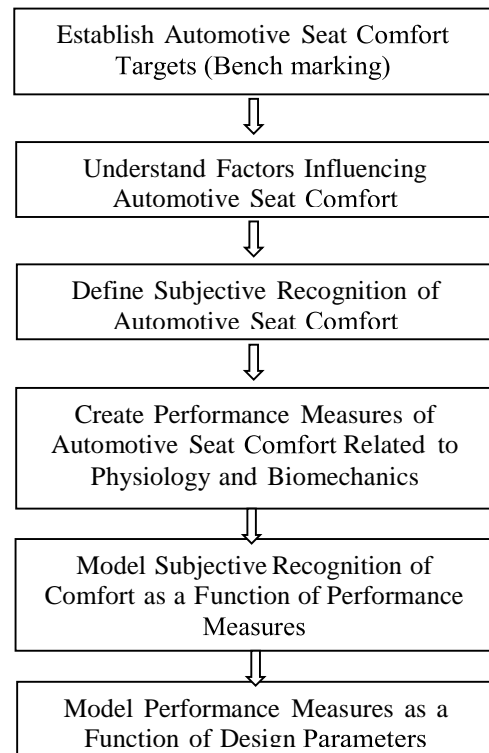


Fig. 2. Research Required for the Science of Automotive Seat Comfort

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.

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 assessment. It is followed by postural investigation technique. 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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