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Comfort Analysis of Passenger Car Vehicle Seat

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Abstract* – Seats are one of the most important components of vehicles and customer's expectations for comfort in automobile seats rise continuously. Automotive seat design has been always challenge for engineers as design parameters for automotive seats are complex. Three design objectives, comfort, safety, and health need to be satisfied simultaneously. There are two main categories of comfort: Static and Dynamic. Static comfort is related to the form and support provided by the seat itself, the posture and orientation of the occupant, and location of the occupant relative to certain critical points in vehicle interior. Dynamic comfort is related to the level of vibrations experienced by the occupant sitting in a car seat. For comfort, various ergonomic and human factors considerations are discussed ranging from seat dimensions and adjustments to cushioning and occupant perceptions of comfort. Comfort measurement is difficult because of such factors as user subjectivity, seat geometry, occupant anthropometry and amount of time spent sitting. This paper describes various methods of comfort analysis of passenger car vehicle seat. The study was done in static condition. There are different vehicle manufacturers and comfort analysis was done on same vehicle seats. The analysis was done based on different criteria like fit parameters related to anthropometric measurements, feel parameters and support parameters defined with respect to seated posture. Particularly attention is given to appropriate lumbar support where five seats were quantified and compared to the survey information.

Index Terms— **Dynamic comfort, Occupant anthropometry, Seat, Seat geometry, Static comfort.**

I. INTRODUCTION

The choice of a passenger automobile depends on factors, such as the vehicle type, brand, trend, security, its performance, interior space, interior design, additional equipment offered, etc. The seat comfort is a very important issue for the users. Long time driving usually results in manifestation of low back pain or other musculoskeletal disorders, caused by the discomfort of the seats. Accordingly, the expectations of customers regarding the seat comfort are continuously increasing. The manufacturers of seats for passenger automobiles have to respond to market requirements fast and appropriately and offer seats with higher quality and comfort.

The manufacturers of automobile seats usually make prototypes for testing the comfort in order to achieve the desired results. Testing with prototypes is costly and time consuming process. Application of contemporary software products for virtual modelling of vehicle structure, as well as software products for simulation of processes and system behavior, reduces the time for testing of the new vehicle. Contemporary testing of new vehicles starts with virtual testing of virtual models, using virtual humans. The errors and inconveniences are reduced in the early phase. As a consequence, time and price for testing of new or improved vehicles are reduced. The final tests are applied on real models - prototypes.

The basic components of the automobile's user comfort were determined: angles for placement of the human body and the necessary space for the foot controls, as well as the ranges of adjustments of the driver's seat and the steering wheel. Then we determined what influence of the parameters like variation of the spatial mechanical properties of the polyurethane foam, such as thickness and density, as well as the shape of the contact surface between user and seat, have upon the seating comfort of the automobile.

II. BACKGROUND

There are many factors that affect automobile seat comfort. Vehicle package is a primary determinant of seat comfort. Vehicle package defines roominess i.e. headroom, legroom, shoulder room, and hip room. Similarly, the same seat when sold with different brand, may receive different comfort ratings. Brand is related to purchase price of vehicle. Both brand and purchase price of vehicle are considered social factors [5].

Individual factors, like age and body size, are thought to affect subjective perceptions of comfort. Posture may be the most important individual factor. Stiffness, geometry, contour, breathability, and styling are considered seat factors. Stiffness refers to the resiliency of the seat system. Geometry defines seat shape in terms of width, length, and height, whereas contour deals with the profile of the seated surface e.g. location and prominence of lumbar apex. The seat's geometry and contour must accommodate the anthropometric variability of the target population. Styling must be included as a seat factor because aesthetic quality may affect perceptions of comfort [5].

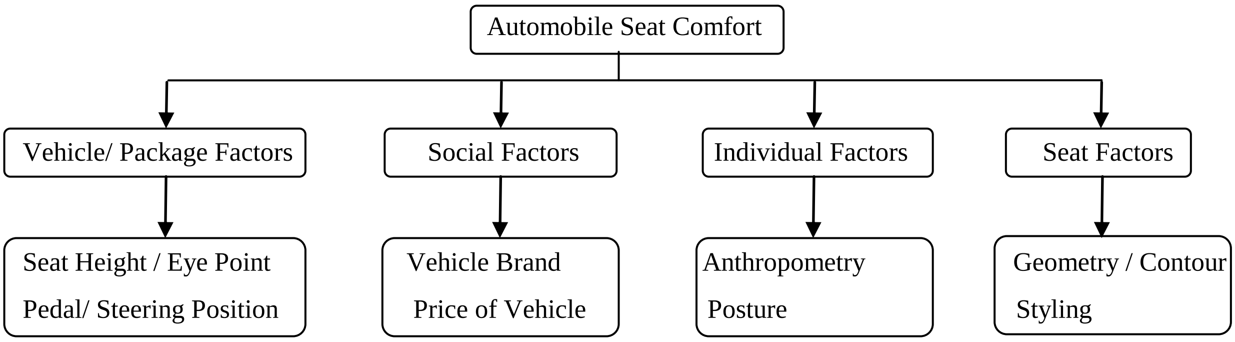


Fig 1. Factors affecting automobile seat comfort [5]

Main Functions of Automotive Seat are as follows
i) Support the occupant: The seat must be able to keep the occupant in a stable position for a long period of time.
ii) Position the occupant: The position of the occupant is extremely important for safe & comfortable vehicle operation.
iii) Provide comfort for the occupant: The motor vehicle is a structure engineered to allow the driver & all passengers in the vehicle to ride comfort.
iv) Protect the occupant: There are several ergonomic considerations those will impact the safety of the occupant.

The seat design parameters that have been demonstrated are likely to be associated with seat comfort and recommends levels for these parameters. The design parameters are divided into three categories.
i) Fit parameter: These are determined by the anthropometry of the occupant population and include such measures as the length of the seat cushion.
ii) Feel parameters: These are related to the physical contact between the sitter and the seat and include the pressure distribution and upholstery properties.
iii) Support parameters: These affect the posture of the occupant and include seat contours and adjustments.

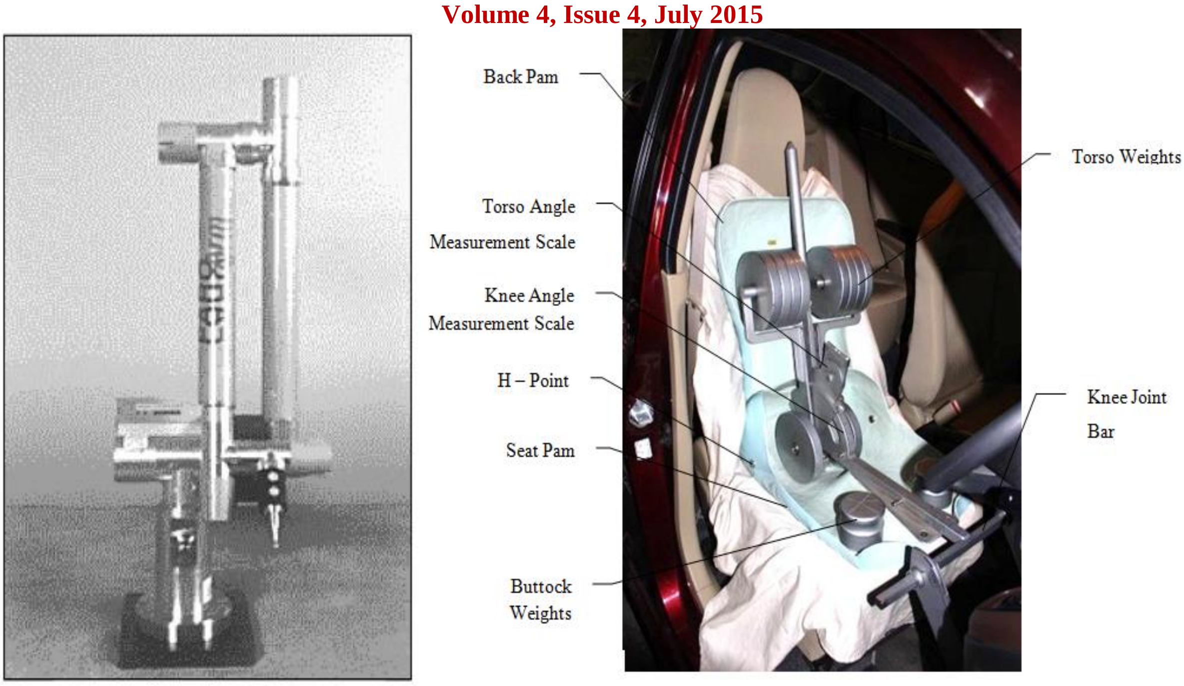
III. EXPERIMENTS

A. H-point measurement (Quantitative study):-

Seats are selected in vehicles which are produced by different manufacturers from the compact car segment. The five seats are distinguished by using letters A to E. For comparing the contour and geometry characteristics, the five seats were in similar set-up as follows:

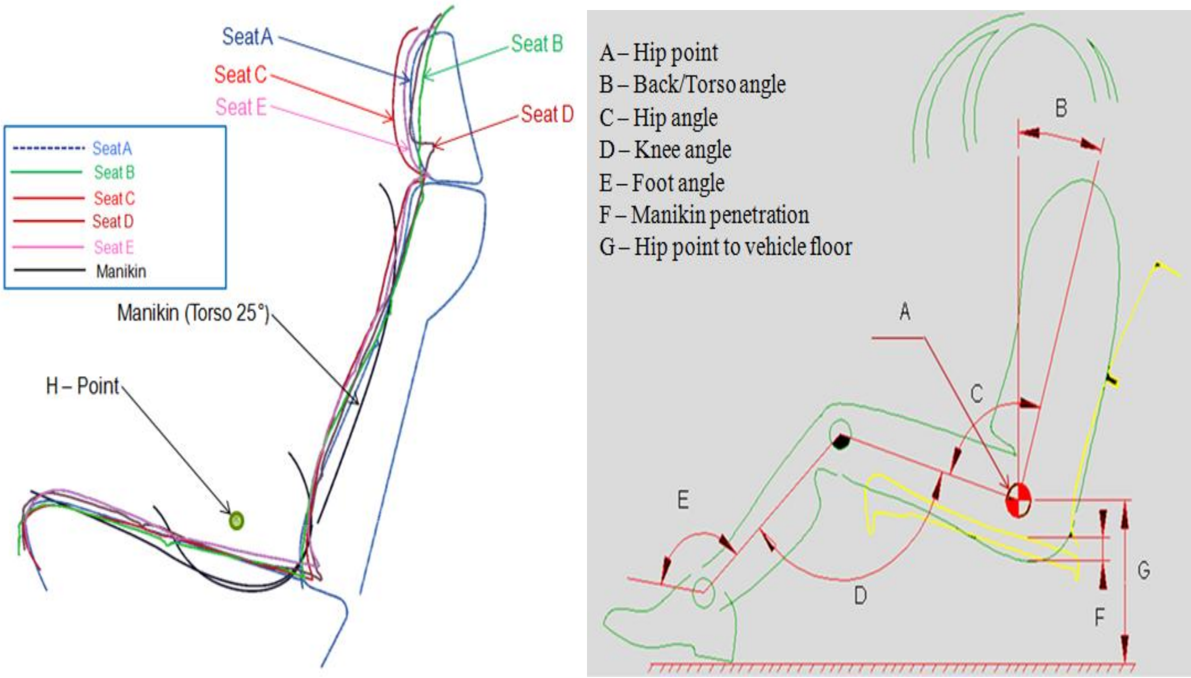
- A coordinate system establish in relation to the vehicle system with help of portable coordinate measurement machine (CMM), known as a FaroArm by taking a common reference.
- The seatback angle was set to 25^0 from vertical & track position was set to full rear.
- Manikin was placed in the seat without weights.
- It was adjusted until positioned properly & then weights added
- In this position, H-Point as well as the H-Point to heel point relationships and the manikin's critical angles were measured for each seat.
- Unload the Manikin from the seat.

After H-point measurement, seat centre profile was scan with help of CMM probe by taking enough points to create a line. Points were taken to the center of the probe. For this reason, the scan lines, in a post processing operation, were offset by the radius of the probe. For the study, cushion/back width and cushion/back length was also measured [9]. The location of the apex of the lumbar contour was measured as the most prominent point on the seatback contour tangent and parallel to the design position torso line. Once identified, a line was drawn through the apex that was perpendicular to the torso line. The height of the apex was 150 mm above H-Point measured along the torso line.



(a) (b)

Fig 2. (a) FaroArm CMM [9] (b) H – Point measurement set-up



(a) (b)

Fig 3. (a) Seat center profile scan comparison (b) Seat parameters

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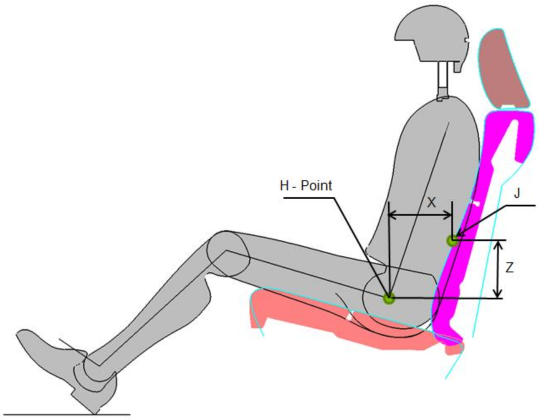

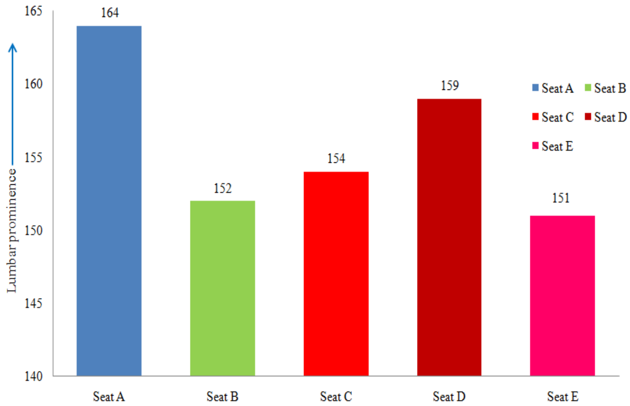

(a) (b)

Fig 4. (a) Lumbar position – J (b) Lumbar prominence

Table 1. Dimension comparison of lumbar position

Parameters	Seat A	Seat B	Seat C	Seat D	Seat E
Lumbar Position - J	X=164 Z=89	X=152 Z=95	X=154 Z=94	X=159 Z=91	X=151 Z=95

Form above dimension comparison table it is observed that seat A has less lumbar support than other seats.

B. Pressure mapping (Qualitative study):-

The seat-interface pressure technology included thin, flexible sensor arrays. The sensors featured a grid-work of 48 columns and 44 rows based on 10mm centers. At each of the 2112 intersection points on the grid, a sensing cell is created. An electrical resistance inversely proportional to the pressure applied relative to the cell's surface characterizes each sensing cell. By scanning the grid and measuring the electrical resistance at each grid point, the pressure distribution on the sensor's surface can be determined. The scanning electronics are packaged in a handle assembly that clips onto the sensor's interface tab and provides the electrical connection to each sensing cell. The sensor arrays also known as mats. The seat cushion and seatback were fitted with the calibrated mats. These mats were securely attached to the seat using strips of masking tape. Care was exercised to ensure that the mats were placed in a consistent location from occupant-to-occupant and seat-to-seat. Provisions included, lining up the center of the mat with the mid-point of the head restraint rods and tucking the mats into the biteline, which is defined as the region where the cushion and seatback converge. Occupants were not permitted to sit in the seat until they removed their wallets and belts. This was done to avoid false seat-interface pressure readings. Each occupant was allowed to adjust the track position and the seatback angle. In this study, there were no other seat features to adjust. The preferred setting was called ‘‘occupant selected seat position’’ or ‘‘comfort position’’ [8].

(a) (b)

Fig 5. (a) Pressure mapping set-up (b) Pressure mapping process

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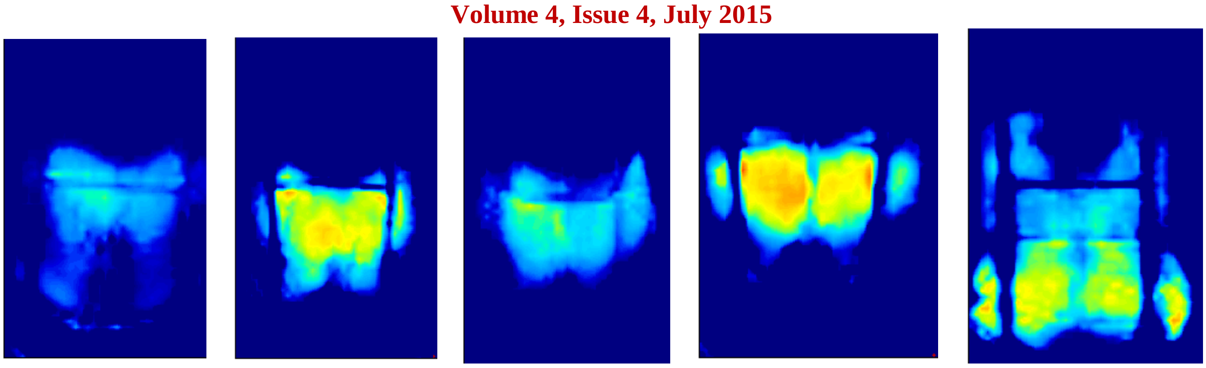
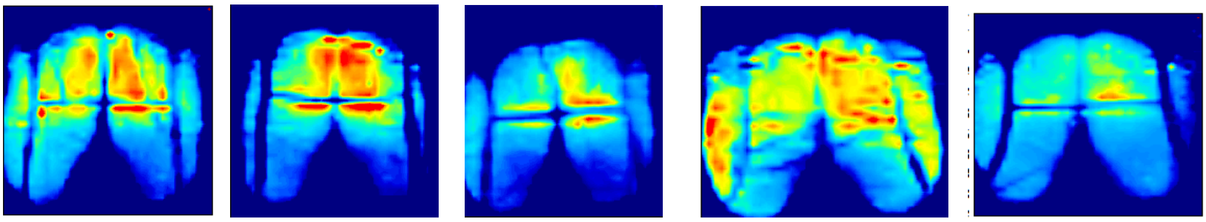


(a) (b) (c) (d) (e)



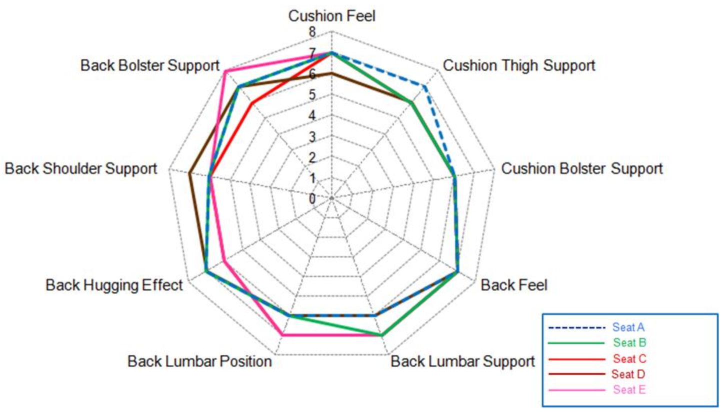
(f) (g) (h) (i) (j)

Fig 6. (a - e) Seat back (f - j) Seat cushion, pressure mapping results of seat A-E

Form above pressure mapping results it is observed that seat A has less lumbar support than other seats.

C. Jury evaluation (Qualitative study):-

The survey was designed to assess showroom comfort. While it is acknowledged that short-term evaluations do not capture all aspects of automobile seat comfort, the survey was appropriate in the context of this study's purpose. In other words, it was felt that the short-term, subjective data collected as part of the experimental protocol, because they were focused on specific aspects of seat contour/geometry, could be used to compare occupant preferences and criteria associated with anthropometric accommodation [9]. Seats from the same market segment were selected because they were thought to have comparable H-Point to heel point relationships. Coupled with the fact that the same 10 participants were used for all five seats, occupant preferred seat position was expected to be similar between seats. There was no standard procedure outlined for when occupants were to complete the survey. The reason should be obvious—it is difficult for occupants to rate the seat if they are sitting in it. Most of the items could be rated from 0 to 10. To obtain a single score from the survey, the absolute deviation of each item from just right was summed. This score was used for preparation of spider graph and further analysis.



(a) **(b)**

Fig 7. (a) Jury evaluation process (b) Spider graph

Form spider graph it is observed that seat A has less lumbar support than other seats.

IV. CONCLUSION

The study was done in static condition. The analysis was done based on different criteria like fit parameters related to anthropometric measurements, feel parameters and support parameters defined with respect to seated posture. Particularly attention is given to appropriate lumbar support where five seats were quantified and compared to the survey information. Based on above analysis it is observed that seat A has less lumbar support than other seats.

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