Trends in Automotive Ergonomics

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Abstract: Around 70% of all vehicles produced in India are small automobiles, which dominate the industry. Therefore, car manufacturers place a high priority on comfort to increase customer satisfaction. Vibration, pressure, and ergonomics are the three main interior design focuses that help accomplish this. Automotive ergonomics is the study of how to create more user-friendly automobile designs. To do this, human variables like anthropometry must be considered starting with the packaging of the vehicle. Design professionals can effectively produce a more comfortable and effective driving environment by utilizing both static and dynamic anthropometry data. In general, applying the fundamentals of automotive ergonomics is essential for developing better, more comfortable vehicles that meet consumer demands in the fiercely competitive Indian auto market. A vehicle's sitting arrangement, where occupants spend most of their time, is an essential component. The danger of driver fatigue can be eliminated by improving the driver's seating arrangement. With a focus on improving occupant comfort, this paper aimed to provide an overview of the most recent developments in vehicle packaging and interior design. The numerous design factors that affect automotive ergonomics are covered, as well as the methods and ideas that have been developed to make car interiors more comfortable.

Index Terms: Automotive Ergonomics, Vehicle Packaging, Occupant Comfort, Seat Design.

I. INTRODUCTION

Ergonomics is the study of interaction between people and machines and the factors affect the interaction. It is the process of designing or arranging workplaces, products and systems so that they fit the people who use them. Ergonomics aims to create safe, comfortable, and productive workspaces by bringing human abilities and limitations into the design of a workspace, including the individual's body size, strength, skill, speed, sensory abilities, and even attitudes. Automotive ergonomics considers the methods of designing a vehicle for better use of human. Vehicle packaging decides the methods by which a vehicle should be designed according to the ergonomics. [1] Vehicle packaging decides the methods for integrating vehicle parts with people considering the space. It provides all the necessary information for the following stages of design of the vehicle. It is the method to safeguard and protect space for human user and necessary components. Vehicle packaging is a primary determinant of comfort of an occupant. Vehicle packaging defines roominess i.e., headroom, legroom, shoulder room and hip room. Seats are one of the important components inside a vehicle where the occupant spends most of the time. The function of automotive seating is to support, protect and to provide comfortable seating posture to its occupants. Seat means a structure, which may or may not be integral with the vehicle, structure complete with trim, intended to seat one adult person. The term covers both an individual seat and part of a bench seat intended to seat one person. One effect of bad posture is Repetitive Driving Injury (RDI). These injuries include foot cramps, low back pain, stiff neck, and sore shoulders from poor posture, stress, tension, and staying in one posture or position for an extended period. RDI is musculoskeletal disorder which causes discomfort and lower back pain.[1]

The sources of discomfort are.

- Transmission of vehicle vibration to the occupant
- Body pressure distribution
- Control of posture either statically or dynamically through differing load paths
- Clothing and seat covering material
- Perceptions and interior ergonomic characteristics

Transmission of vehicle vibration to the occupant is the prime reason for discomfort in an automobile. Human trunk has a natural frequency of 6Hz, and hence vibrations happening in that frequency will cause resonance creating discomfort. Load bearing capacity of human body is different at different locations. The ligaments near to the common load points are more capable of bearing the load than those are far away. Hence uneven pressure distribution causes discomfort. If the load paths are differed by changing the normal posture, the body will select fewer stable paths, which causes discomfort. Seat material and clothing are the components which dampens micro vibrations transmitted to the body. The perception of the comfort level assessed by each individual is influenced by certain external factors like, brand value and level of luxury.[1]

II. DRIVING TASK REQUIREMENTS

II.I Visual Requirements

The position of the head determines the posture of the body, and it is influenced by the visual task requirements. If the major visual are is 30 degrees below the straight ahead line of sight, it will be accessible only by tilting the head in a forward position. This action causes load on the neck muscles and alters the center of gravity of the body. The eye is sensitive for a range of 95 degrees to the left and right. The most optimum position for placing the controls is within 15 degrees of the either side of the straight-ahead line. Thus, the static loading of neck muscles can be avoided if the visual tasks are kept within the cone of 30 degrees above and below and 15 degrees to the left and right of the straight-ahead line of sight.[1]

II.II Postural Requirements

The position of the hands, arm and feet determines the posture and postural load. The comfort of a vehicle seat depends on its dimensions and its positioning in relation to foot pedals and controls. While driving, the drivers cannot maintain an erect trunk because of the requirement that both the driving hand and forearm should be in a level lower than the steering wheel for relaxed position whereas in level with the wheel for better control over the driving action. This continuous exchange of arm position prevents the driver from maintaining an erect posture. Resting the forearm on the door requires sideways and forward positioning of the trunk.[1]

II.III Temporal Requirements

The time spend by a driver in a vehicle depends on the nature of the usage. A vehicle which is used for personal use will require on average 3 hours whereas a vehicle for cab purpose requires an average 8 hours daily. The second condition requires higher level of flexibility to be built in the vehicle, since the body remains in the same position for a longer time.[1]

II.IV Design Requirements of Driver Position

Driver's position is dependent on the vision and reach demanded by the driving task. Clear view and comfortable sitting posture should be considered. The dimensioning depends mostly on eye, hand, and foot positioning. For different persons, adjustments to be provided to find their own comfort position. Driver's position should reduce postural stress and should help in reducing muscle effort. Safety should be taken into account while considering the design of seats without compromising the comfort.

III. ANTHROPOMETRY

Anthropometry is the scientific study of the measurements and proportions of the human body. Anthropometric measurements are used to assess the size, shape, and composition of the human body. For the purposes of ergonomic design, anthropometrics offers information about the average human build. The human body is commonly represented ergonomically as an open chain of rigid segments. A classic representation of the body for design purposes divided the body into 13 planar segments which includes a single segment from hip to head.

Types of Anthropometric Data includes Structural (Static), consists of measurements of the dimensions of body in static positions, Functional (Dynamic), includes measurements to describe the motion of the body part with respect to a fixed reference point, Newtonian, consists of measurements that are used in analyzing the mechanical loads acting on a human body.

Principles of Applied Anthropometry

Anthropometric measurements are a function of age, gender, nationality, user type and several other factors. It Ranges from 5th percentile of female to 95th percentile of male.

The different design parameters that constitute the ergonomics of a regular passenger vehicle are,

Seat Height which can be raised to ensure the driver has maximum vision of the road. Adequate clearance from the roof must be ensured.

Lower Limb Position in which knees should be bent to comfortably operate the accelerator, clutch, and brake and also the knees should have clearance from the steering wheel.

Seat Pan which has support for thighs along the length of the cushion. Pressure behind the knees must be avoided.

Back Rest which provides continued support along the length of the back, shoulders' position must be naturally slightly behind the hips.

Lumbar Support should ensure that there should be no pressure points or gaps between the spine and the car seat.

Steering Wheel should be designed in such a way that all controls should be in easy reach to prevent unnecessary reaching, elbows and shoulders should be in a relaxed position. Clearance for thighs and knees must be adequate. The display panel must be in full view and clarity must be maintained,

Headrest must provide a neutral position for the neck with the headrest directly behind the head.

Mirrors are positioned such that the rear and side view mirrors must be adjustable enough to ensure adequate vision of surrounding areas.[1]

IV. SEAT DESIGN

The seat model is established from three bodies, i.e., seat cushion, seat back and head restraint. These bodies have been connected to each other by three joints: one for the connection between seat cushion and its surroundings, one for the connection between seat cushion and seat back, and one for the connection between seat back and head restraint. These joints allow adjustment in the seat back angle and head restraint angle, but, in addition, represent the stiffness of the connections between seat cushion-seat back and seat back-head restraint.[3]

All the requirements in seat design is incorporated to ensure the comfort of driver and passengers. Special consideration should be considered for persons who do not conform to the average percentile norms. The posture should minimize the strain due to external loads and the equilibrium between ligaments and sections of muscle. The seat is reclined to rear to displace the center of gravity behind the body so that the arm and leg movements will be free. This is done by providing comfort angles. In the seated position, the loads imposed by the body on the legs shifts to the rear through the pelvis bones, which gives a relaxation sensation.

Lateral location of the pelvis must also be provided. A wide support area should be provided to avoid high pressure areas. Appropriate foam systems should be used in which static seat compression should be 40% of total spring travel. Foot controls are divided between the brakes, needing considerable force, for which free leg movement is required, and the precise control of throttle, where use of ankle articulation is better suited. A wheel tilted to the vertical could have a rim force greater than that with a vertical wheel but the rate of turning is halved and the effort is reduced considerably.

The cushion length, measured along the thigh line, should not exceed 440 mm from the depressed seatback, or 305 mm from the H-point. An adjustable-length cushion could be used to provide more under-thigh support for larger people, but only a small range of adjustability is needed. For sitters with long legs, the cushion may feel too short if the thigh angle relative to the horizontal is substantially greater than the cushion angle, so that only the buttocks are in contact with the seat. These sitters will be accommodated better by an adjustable cushion angle than by a greater cushion length.

Seat cushions should be a minimum of 432 mm wide, with 500 mm minimum clearance at the hips. The front of the cushion should be a minimum of 500 mm wide to allow for comfortable leg splay.

The seatback should be a minimum of 360 mm wide at a point 220 mm above the H-point along the sitter back line, and a minimum of 456 mm wide at a point 318 mm above the H-point. There should be no lateral clearance restrictions (i.e., no side bolsters) extending more than 288 mm above the H-point. The seatback should extend 410 to 550 mm above the H-point, measured along the sitter back line.[1]

V. COMFORT MEASUREMENT

Subjective Comfort Assessment

In this method, the comfort is assessed subjectively. Short term comfort is measured using this method. The method is executed by conducting surveys on potent users of seat and analyzing the data statistically. This method compares the short time feel of the seat against the other seats in the same class of vehicle. The drawback of this type of assessment is that it is time consuming and costly.[5]

Objective Comfort Assessment

Automotive industry encourages objective type comfort assessment. This method is dedicated to seat and related postures of the occupant. In this method, a biomechanical model of human is used. The commonly used model is H-Point Manikin. In certain conditions, simulation can be used for the analysis of comfort assessment.[5]

H-Point Manikin

A machine with back and seat pan representations of deflected seat contours of adult males. A graduated sliding probe is hinged from the H-Point to measure the headroom in the compartment. A quadrant is fastened to the probe to measure the back angle. An adjustable thigh bar, attached to the seat pan, establishes the thigh centerline and serves as a baseline for the hip angle quadrant. Lower leg segments, also adjustable in length, are connected to the seat pan assembly at the knee joining T-bar, which is a lateral extension of the adjustable thigh bar. Quadrants are incorporated in the lower leg segments to measure knee angles. Shoe and foot assemblies are calibrated to measure the angular relation to the lower leg segment.[5]

Seat Contour and Geometry Measurement

Initially a coordinate system is established in relation to the vehicle system with the help of a portable coordinate measurement machine known as Faro Arm. The seatback angle was set to 25° 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.[5]

Pressure Mapping

The seat-interface pressure technology included thin, flexible sensor arrays called mats. An electrical resistance inversely proportional to the pressure applied relative to the cell's surface characterizes each sensing cell. Occupant is asked to sit in the seat. Occupant was allowed to adjust the track position and the seatback angle. The preferred setting was called ‘‘occupant selected seat position’’ or ‘‘comfort position’’. The pressure map is then analyzed to identify the support provided by the seat.[5]

Subjective Evaluation

In this method, a survey was designed to assess showroom comfort. While it is evident that short term evaluation does not capture all aspects of seat comfort, subjective data is useful to compare occupant preferences and criteria associated with anthropometric accommodation. Parameters are rated on a numeric scale ranging from 0 to 8. Spider graph is prepared from the score, and it can be used for further analysis.[5]

VI. CONCLUSION

For secure and effective driving, it is essential to maintain the right posture. In addition to being crucial for effective driving, maintaining good posture while driving also serves to prevent disorders related to driving. The driver's comfort, protection, and health must all be taken into consideration at once. Designers must take both static and dynamic anthropometry data into account when creating a secure and comfortable seat. Moreover, since fatigue can impair attention, perception, decision-making, vigilance, and response time, it must be taken into consideration when designing car seats. Based on user subjectivity, seat geometry, occupant anthropometry, and utilization frequency, seat comfort is assessed. Along with qualitative analysis, quantitative measurements and feature-by-feature comparison can help us understand how internal packaging affects vehicle ergonomics and how to improve current designs to make users more comfortable.

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