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Ergonomic Aspects of Tractor Operator Seat Design

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ABSTRACT

The design aspects of tractor-operator seat are described from an ergonomic viewpoint. The design parameters of the seat have been determined using anthropometric data of Indian users. The existing dimensions of the tractor seat widely varies which indicates the need of anthropometric dimensions. The tractor seat should be designed to accommodate the size and shape of at least 90% of tractor operator's population, based on anthropometric data.

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INTRODUCTION

In India a wide choice of competitive tractor models, in the range of 18 to 75 pto HP is now available to the farmers. But the design changes in these tractors are not adequate enough due to economic reasons. However, the existing Indian tractors have yet to fall in line with world trends regarding operator workplace - a fact which primarily arises from the use of relatively older models which are under manufacture (Anonymous, 1990). Most of the Indian tractors are manufactured to suit the anthropometric measurements applicable to the countries where the tractor is designed. Opposite to highly sophisticated designs in Europe, North America and Japan (in saturated market), the two biggest nations of the world, China and India, could become important with their tractor productions using `medium technology' and units of low power level achieving annual growth in domestic sales (Renius, 1994).

The ergonomic design of tractor operator seat and workplaces is an effective method for improving operator comfort (Lehmann, 1958 and Pheasant, 1986). The seat design characteristics comprise of static and dynamic characteristics. The static characteristic of the tractor seat refers to the relation of comfort to seat construction type, and its geometric parameters and the physiological features. Therefore, there is need to design the tractor seat considering anthropometric data of tractor operators in India.

THEORETICAL CONSIDERATIONS

There are three primary aspects of maintaining a seated posture. First, the orthopedic considerations, which relate to a

possible damage to the operators health caused by poor design. Second, muscular aspects and third, the behavioral and biomechanical aspests of the operator who may be viewed as a `comfort seeker' or as a `discomfort' (Oborne, 1982).

Orthopedic Aspect of Seating

The primarily support structure of the body in seated posture is the spine. It consists of 33 vertebrae joined together by multiple ligaments and intervertebral discs. The vertebrae are divided into four categories. These are the topmost seven cervical, then twelve thoraic and five lumber vertebrae followed by five fused sacral and four fused coacygeal vertebrae. From the point of view of the seat design, the orientation of the lumber and sacral vertebral are important, since it is these vertebrae and thier respectively discs and muscles which take most of the spinal load of a seated operator (Oborne, 1982).

Keegan and Radke's (1964) data suggested that sitting posture which produces the nearest approximation to the `normal' lumber shape is one in which the trunk-thigh angle about 115º and the lumber position of the spine is supported. As the back moves from an upright to a hunched position the pelvis makes a corresponding backward notation, because it is attached to the sacral area. Grandjean (1973, 1988) suggests, that seats should be designed so that in both the forward and backward sitting postures they provide support to the upper edge of the pelvis in an assist this trend to rotate. In order to accommodate tractor oeprators ranging from 5th to 95th percentile, it is easier to adjust seat than adjusting controls, however there must be few compromises between hand and foot controls. The height of the seat can not be changed greatly as for a small person, a higher seat would result in worsened foot pedal relationship. The horizontal adjustment of the seat is required to accommodate tractor operator between 5th and 95th percentile stature. It is easy to provide horizontal adjustment in seat with little design efforts.

Muscular Aspects of Seating

The muscles and tendons keep vertebrae in position. Any alteration to a `natural' spinal shape will produce corresponding stresses in muscle activity which can be demonstrated and measured. A study was carried out by Floyd and Ward (1969) in which they recorded the activity of four groups of muscles (in the neck, on the collarbone, on the back just below the shoulder blades, and in the lumber region), when sitter adopted various positions. Their results concluded that `sitting-up-straight' without any backrest produce a fair degree of activity in the limber-region-presumably because this posture attempts to straighten the lumber curve. However the activity ceased as soon as a backrest was provided.

Biomechanical Aspect of Seating

Muscular fatigue and spinal deformation reduce comfort and increase the stress of the operator which in turn could reduce performance. Sitting behaviour, therefore, can be characterized by regular movements or fidgeting which help to relieve pressure maldistributions on parts of the spine. The hip portion of the body in sitting posture acts like an inverted pyramid. In physiological terms, compression fatigue is the reduction in blood circulation through the capillaries, which affects the local nerve endings and results in sensations of ache, numbness and pain.

On the one hand operator needs to vary his posture to relieve pressure maldistribution while on the other hand he needs to maintain and actively seeks stability. An efficient and comfortable tractor seat, therefore, needs to be able to accommodate these homestatic requirements and allow the operator stability and flexibility.

TRACTOR SEAT DESIGN

It is generally recognized that to minimize discomfort, fatigue and the possibility of damage to the back whilst seated, the spinal column should maintain its normal curvature as found in the standing position (Keegan and Radke, 1964). The main body support is provided by the seat pan, taking between 65 and 75% of the body weight (Branton, 1969), which is transferred via the ischial tuberosities and to a lesser extent the surrounding tissues. The linear dimensions of tractor seat must fit those of the most likely user population. This by now is axiomatic. Therefore, seat characteristics such as seatpan length, width and tilt, backrest height, angle and slope need to be designed considering anthropometric data of most likely user population of tractor operators. A number of principles are followed for a seat design.

(i) The type and dimensions of the seat are related to the reason for sitting.

(ii) The dimensions of the seat should fit the appropriate anthropometric dimensions of the sitter.

(iii) The seat should be designed to provide support and stability for the operator.

(iv) The seat should be designed to allow the operator to vary his posture, but the fabric needs to resist slipping when there is fidgeting.

(v) Backrests, particularly prominent in the lumber region, will reduce the stress on this part of the spinal column.

(vi) the seat pan needs sufficient padding and firmness to help to distribute the body weight pressures from the ischial tuberosities.

The dimensions of seat, location of controls and access/exit provisions are the parameters where anthropometric data can provide help in matching the workplace according to the user's capabilities. Anthropometric data like buttock-popliteal length, popliteal height and hip breadth (sitting) are very useful for the seat design. Anthropometrically, seat height should be from 40.0 to 45.0 cms which is based on Indian population. The weight range of corresponding percentile is 45.0, 73.0 kg. Therefore, European data related to seat design and workplace may not be suitable for Indian operators.

Seat Height

The seat height is adjusted correctly when the thinghs of the operator are horizontal, the lower legs are vertical and the feet are flat on the floor.

Seat height from foot rest level is based on typical link-joint biomechanical model (Oborne, 1982) and expressed as follows :

Front edge

$$H_p = \text{Cos}\ (\theta_k + \theta_{sp} - \pi/2) \quad \text{— (1)}$$

Rear edge

$$H_p = \text{Cos}\ (\theta_k + \theta_{sp} - \pi/2) - L_p \cdot \text{Sin}\ (\theta_{sp}) \quad \text{— (2)}$$

H_p = Popliteal height, cm

L_p = Buttock popliteal length, cm

θ_k = Knee angle for foot resting on foot rest, degree

θ_{sp} = Thigh angle with horizontal, degree

Seat Depth

In order to assure driver comfort and convenient posture change, the seat width should be wider than the buttock width. The limiting case should be the upper range of the operator.

Seat Depth

For tractor seat it is recommended that the seat depth accommodate even shorter people, since the only consequence of a taller member sitting in such a seat will be that his knee will protrude slightly at the front.

Seat depth < (Buttock-popliteal length of 5th percentile operator).

Seatpan Angle

In a tractor seat, operators requirements are to be positioned for easy access to his work in front of him.

Backrest Height and Width

In order that the sacrum and fleshy parts of the buttocks which protrude behind the operator can be accommodated, while at the same time allowing the lumber region to fit firmly into the backrest. Oborne (1982) suggested that a space of at least 12.5 to 20 cm is required to accommodate the buttock.

A high back rest prevents mobility of the arms and shoulders in rear viewing and hydraulic control lever operation. Therefore a small backrest which supports the lumber region only is suitable for a tractor seat. The proposed dimensions of the backrest relate quite simply, to distance from the upper lumber region to the upper side of the buttock (height) and to the shoulder width (width).

Backrest Angle

Like an angled seat pan, the angle of the backrest serves two purposes. First, it prevents the occupant from slipping forwards and second, it causes him to lean against the backrest with the lower (lumber) part of his back supported. The backrest angle larger than 105° provided in a easy chair is not suitable for tractor seat as it creates inconvenience in rear viewing and in operating hydraulic control levers.

CONCLUSIONS

Sitting is often considered to a natural posture, relieving the operator of the need to maintain an upright position. A tractor seat which requires the operator to adopt certain postures can create at the least muscular fatigue due to the static loads placed on the spinal and other muscles. In most of the Indian tractors, manufacturers are using suspended seat now a days but it should be designed to accommodate the size and shape of at least 90% the tractor operator's population, based on anthropometric data.

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