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ScienceDirect
International Journal of Industrial Ergonomics 38 (2008) 546–554
International Journal of INDUSTRIAL ERGONOMICS
www.elsevier.com/locate/ergon

Review of anthropometric considerations for tractor seat design

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Received 11 July 2007; accepted 28 August 2007
Available online 26 November 2007

Abstract

Tractor driving imposes a lot of physical and mental stress upon the operator. If the operator's seat is not comfortable, his work performance may be poor and there is also a possibility of accidents. The optimal design of tractor seat may be achieved by integrating anthropometric data with other technical features of the design. This paper reviews the existing information on the tractor seat design that considers anthropometry and biomechanical factors and gives an approach for seat design based on anthropometric data. The anthropometric dimensions, i.e. popliteal height sitting (5th percentile), hip breadth sitting (95th percentile), buttock popliteal length (5th percentile), interscye breadth (5th and 95th percentile) and sitting acromion height (5th percentile) of agricultural workers need to be taken into consideration for design of seat height, seat pan width, seat pan length, seat backrest width and seat backrest height, respectively, of a tractor. The seat dimensions recommended for tractor operator's comfort based on anthropometric data of 5434 Indian male agricultural workers were as follows: seat height of 380 mm, seat pan width of 420–450 mm, seat backrest width of 380–400 mm (bottom) and 270–290 mm (top), seat pan length of 370 ± 10 mm, seat pan tilt of 5–7° backward and seat backrest height of 350 mm.

Relevance to industry

The approach presented in this paper for tractor seat design based on anthropometric considerations will help the tractor seat designers to develop and introduce seats suiting to the requirements of the user population. This will not only enhance the comfort of the tractor operators but may also help to reduce the occupational health problems of tractor operators.

Keywords: Tractor; Seat; Anthropometric data; Seat design

1. Introduction

The nature of tasks on a tractor necessitates a number of actions to be performed by the operator, which puts varying physiological demands on the body. Examples of these tasks are steering of tractor, looking backward to observe and control the machine/implement, and operating clutch, brake, and hydraulic control levers. The task and workplace determine the postures and create a pattern of loading on the structures of the body of the individual. The seat is one component affecting these loads. Tractor seat design can be used as a means to modify loads on the body structures to reduce operator's discomfort (Mehta and Tewari, 2000).

The agricultural tractor driving requires the operators to maintain a stable posture despite dynamic conditions. These requirements may involve a large number of turning movements from looking ahead to behind and vice versa resulting into a poor posture (Donati et al., 1984). The seating comfort is strongly related to postural support characteristics of the seat. It is desirable to design seats that can provide a comfortable and controlled seating posture (Grandjean, 1988).

Dupuis (1959) investigated the strain on the tractor operators during operation of different controls. It was observed that human energy consumption could be reduced by 13–29% by making improvement in tractor controls and seat. It was concluded that the efficiency and comfort of the operator were improved with a properly designed tractor workplace.

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0169-8141/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2007.08.019

Whyte and Stayner (1984, 1985) conducted subjective trials on various aspects of tractor seat design, which contributed to the postural support of the driver. Ten subjects tested five combinations of backrest and seat pan, such that each subject used each backrest and each seat pan once, the seat pans and backrests were changed after every 15 min run. They obtained optimum values of tractor seat pan width, seat length, backrest width, backrest height and backrest inclination and are reported in Table 1. Tewari and Prasad (2000) concluded that the seat pan with radius of curvature 750 mm, backrest with radius of curvature 300 mm and backrest inclination of 10° were the most suitable values for Indian tractor operators.

Shao and Zhou (1990) described the design principles of tractor driver-seat static comfort from ergonomics viewpoint. They considered geometric parameters of seat construction from anthropometric data of Chinese population. The included geometric parameters were lumbar support, backrest slope angle, seat width, seat length, seat height, seat pan angle, etc. They concluded that the seat position should be vertically and longitudinally adjustable. Seat should allow the operator to change his position from time to time in order to relieve pressures and rotate muscle groups under tension. The position of lumbar support should be vertically adjustable.

The International Standard (ISO 4253, 1993) and Indian Standard (IS 12343, 1998) lay down range of dimensions for the operator's seat and location of specific control relative to the seat index point (SIP) within the seating accommodation on agricultural tractor with a track width greater than 1150 mm (Fig. 1) and are given in Table 1. The SIP as per ISO 5353 (1984) is the interaction on the central vertical plane passing through the seat centre-line of the theoretical pivot axis between a human torso and thighs. At present, the Bureau of Indian Standard (IS 12343, 1998) has incorporated most of the requirements of the ISO 4253 (1993) standard except seat height. The ISO standard is primarily based on the data of Western/European workers.

Mehta (2006) evaluated five designs of tractor seats provided on most popular brands of 35–45 hp Indian tractors. The measured dimensions like seat length, seat width, seat backrest width and seat backrest height ranged 335–366, 417–470, 373–415 and 260–300 mm, respectively, on the tractor seats. The results indicated that there was a wide variation in seat dimensions on different models of tractors seats provided by different manufacturers. However, the different models of the tractors are being used by the same anthropometric population of Indian tractor drivers. It was concluded that there was a need to consider anthropometric data of user population in the tractor seat design to improve comfort and safety of tractor drivers.

The recommendations on tractor seating dimensions given by various researchers (Donati et al., 1984; Shao and Zhou, 1990; Whyte and Stayner, 1984, 1985) are reported in Table 1 and these are compared with IS 12343 (1998) and ISO 4253 (1993) standards. Table 1 shows that there is a variation in recommendations for seating dimensions by various investigators. This may be due to variation in anthropometric dimensions of the user population. However, the recommendations meet the ISO 4253 (1993) standard except for seat length and seat backrest inclination. This is due to large range of dimensions in the ISO 4253 (1993) and IS 12343 (1998) standards.

Seat design provides the interface between a mechanical system, the tractor, and the delicate and sensitive biological system, the human operator. Modern tractor seat design is an interdisciplinary task relying upon the latest advances in seating dynamics, ergonomics and human factors, and structural mechanics. The design parameters for tractor seat must simultaneously meet three design objectives, namely, comfort, health and safety of the operator. The comfort refers to the ergonomic and human factor considerations such as seat dimensions and their adjustments, cushioning materials, and operator perception of comfort. The health refers to the long-term spinal support, seat ergonomics and terrain-induced vibration attenuation.

Table 1
Comparison of recommendations on tractor seating by various researchers with ISO standard

Dimensions	ISO 4253 (1993)	IS 12343 (1998)	Shao and Zhou (1990)	Whyte and Stayner (1984, 1985)	Donati et al. (1984)
Seat pan width[a] (mm)	>450	⩾450	⩾400	450–480, 465 (optimum)	⩾450
Seat length[b] (mm) (in front of SIP)	210–310	210–310	240–290	300–330	250–310
Seat pan tilt[c] (°)	3–12	3–12	3–7	–	4.5–10
Seat backrest width (mm)	–	–	–	350–425	–
Seat backrest height (mm) (above SIP)	>260	>260	–	300–330	333
Seat backrest inclination (°)	95–105	95–105	105–115	102–103	>111
Seat height[d] (mm)	–	<540	380–400	–	–

[a]The horizontal distance between the outside edges of the seat surface measured in a plane perpendicular to the median plane of the seat or the width measured along a horizontal transverse line passing through the seat index point (SIP).

[b]The horizontal distance parallel to the longitudinal plane of the tractor measured from the front edge of the seat cushion (offset 150 mm on either side of the longitudinal centreline) to the 140 mm to the rear of the vertical transverse plane containing seat index point (SIP).

[c]It refers to the angle of the seat pan to the horizontal.

[d]It is measured from footrest to front of seat surface with 55 kg weight on the tractor seat.