

Anthropometric Data for Combat Vehicle Seating Design Optimization of Indian Mechanized Forces

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ABSTRACT

Anthropometry is the science of measurement and the foundation of human factor engineering and ergonomic designing. Anthropometric measurements considered for designing should help in achieving comfort level, reduce Musculoskeletal Disorder and improve performance. The objective of study was to generation of anthropometric data for optimising the designing of combat vehicle and recommendation according to the anthropometry of Indian troops. It was conducted on 600 Indian soldiers and Thirty six (36) body measurements, crucial for designing an ergonomic combat vehicle workstation were studied. The data was analysed using SPSS (v18). Seat dimensions for the combat vehicle to be utilised by the mechanised forces are seat height should be 41cm, seat depth 41cm, seat width 44cm, backrest height 45cm and visual display position be 80cm.

Seat recommendations are based on infantry mechanised force anthropometry and gives the maximum coverage so as to improve comfort, mobility and optimize protection of the users.

Key words: Anthropometry, Combat vehicle, Designing, Mechanized forces and workstation.

INTRODUCTION

Military personnel are exposed to many physical strains as inherent part of their job and consequently there is risk for morbidity in terms of injuries and musculoskeletal disorders. The operating conditions for crew of combat vehicle are basically characterised by working position in confined space, exposure to whole body vibrations and strain on musculoskeletal disorders while driving. Driver seat design plays important role as it indirectly affects the performance of troops.

Combat vehicle is a self-propelling, weaponized military vehicle which is being used in military operations and it is also known as ground vehicle. It can be of two types; wheeled and tracked. Wheeled combat vehicle offers improved mobility and works in smooth terrain whereas tracked works on rough terrain. BMP-II is one of the example of tracked combat vehicle being utilised in combat roles.

BMP is derived from the Russian “Boyevaya Mashina Pekhoty” which literally means infantry combat vehicle. The BMP-2 is a tracked infantry armoured fighting vehicle designed and manufactured by the Russian defence industry. This vehicle was based on the Russian-made BMP-1. The BMP-2 was manufactured under license in India under the name of "Sarath", and also in some east countries, as the Czech Republic under the name of BVP-2. The BMP-2 infantry fighting vehicle is designed to enhance mobility, firepower and protection of mounted infantry men on the battlefield under NBC (Nuclear, Biological and Chemical) attack. The BMP-2 entered in the Russian armed forces services in 1980, and the vehicle was seen for the first time in public during a military parade on the Red Square in Moscow in November 1982. The BMP-2 was deployed by Russian army during the war in Afghanistan.

The BMP-2 combat vehicle can accommodate three crew members (commander, gunner and

driver) and seven personnel members. Its speed on land is 65km/hr while on water it is 7 km/hr. The function & design of the BMP-2 was improved from the original version for enhanced functionality moving of the commander's position from his hull placement to the new two-man turret, joining the gunner to allow better communication between gunner and commander. The passenger cabin was reworked and reduced to include space for only six infantry (from the original eight seated arrangement. Four firing ports were allotted to the left hull side with three along the right which allowed passengers to defend the vehicle with personal weapons as necessary.

Designing products, environments and systems should be according to the physical size and shape of user population which is basically referred as physical accommodation (Garneau and Parkinson 2016). Anthropometric studies has many applications in a variety of fields including ergonomics which has design and layout of the spaces, reach and operate controls like switches, buttons, knobs (Bullock 1974 , Nowak 1978, Sengupta and Das 2000; Das , Shikdar and Winters 2007; Fathallah et al. 2009; Lin et al. 2016), Clearances (adequate head room, elbow room ,leg room etc which separate the body from hazards such as surrounding equipment) {Dianat et al. 2013; Hsiao 2013; Ghaderi , Maleki and Dianat, 2014}, posture (relationship between body dimensions and those with workstation) {Wang et al 1999; Das, Shikdar and Winters 2007 }

Due to the space constrained issue in hull part of BMP –II there is a mismatch between the man-machine interfaces which leads to frequent postural awkwardness with enhanced muscular effort. Further, long duration sitting in constrained position may lead to number of problems for the individual such as musculoskeletal pain, back pain, fatigue, discomfort and other related problems with decrement in performance (Grandjean 1980, Andersen *et al* 2002).

An ill designed or Unergonomically designed workstation not only degrades individual performance and system productivity but it also leads to accidents and errors (Johnston *et al.* 2007). In order to consider seat ergonomics, there is a need to determine seat fit parameters for anthropometry and various studies have been carried with local vehicle seating dimensions A study was undertaken in Malaysia to determine the degree of compatibility of seat fit parameters by comparing the anthropometry of 216 participants to two local automobile seats (Daruis *et al.* 2011).

There are studies with reference to variations in seat height can cause uncomfortable pressure on the back of the thighs (Bush 1969) and seat width being too wide and too deep may prevent the user to take advantage of armrests and backrests contours which transfer the weight to the spine (Occhipite *et al.* 1985).

The studies on mismatch of the vehicle seating space with the anthropometric dimensions of mechanised forces can have crucial impact on the health and efficiency and increase the postural load on the body (Aaras *et al.* 1997, Straker and Mekhora 2000). Use of Anthropometric data in designing fundamentally helps in overcoming the issues pertaining to health and comfort of user (Barroso *et al.* 2005, Jung and Lee 2000). The main aim in seat designing is to alleviate or decrease factors that lead to discomfort rather than elicit feeling of well being (Reed *et al.* 1994). Similar studies have been carried out in Australian Motor vehicle Certification Road (AMVCB) which provides vehicles standards for the manufacture and installation of seats (National Code of Practice 2013).

In India, automotive industry standards are available as part of the code of practice for bus body design. Different seat classification exists such as individual seat, driver seat, bench seat

etc according to type of vehicle (Automotive Industry Standard 2014). In combat vehicle usually driver seat and bench seat is present to accommodate ten infantry personnel but this classification standards cannot be applied to infantry personnel.

Very little work has been done on anthropometry of Indian soldiers, especially pertaining to vehicle design. Detailed anthropometric studies should be carried out during automobile design to accommodate individuals with a range of stature for adequate field of view, pedal reach, hand controls and ensure a comfortably fit with the seats to avoid risk to safety in case of collision.

Anthropometry has three major principles which are being followed in designing various products:-

1.Design for extreme individual

- 2.Designing for an adjustable range
- 3.Designing for the average

Seated anthropometric measurements are crucial in designing armour vehicle workstations with reference to the anthropometry of human being. For example in designing the seat surface height of any armor vehicle, popliteal height of individual is taken into consideration. For other parameters related to seat, anthropometric variables taken into consideration are:-

- Seat height: Sitting Popliteal Height (vertical distance from the floor to the underside of the knee).
- Seat depth: Buttock to Popliteal (horizontal distance from the back of uncompressed buttock to the back of the knee).
- Seat width: Sitting Hip Breadth (maximum horizontal distance across the hips in the sitting position).
- Back rest height: Sitting shoulder height from seat surface (vertical distance from the sitting surface to acromion).
- Monitor/Visual display position: Sitting eye height (vertical distance from the sitting surface to eye).

IMPORTANCE OF ANTHROPOMETRICS:

Anthropometry is derived from the Greek word anthropos means man and metron means measure and it is the branch of science which deals in measurement and establishing the physical geometry, mass properties and strength capabilities of human body. It is also the foundation for human factor engineering and ergonomic design to provide necessary inputs in reaches, clearances and other constraints that the performer faces during his/her task. This field extensively works in product designing when user's ability and safety is concerned between human being and the interacting environment. Anthropometric measurements which are considered for designing aid in achieving optimal comfort level reduce Musculoskeletal Disorder (MSD's) and help optimize the performance of individuals

It plays a very important role in designing of furniture to underground mines to naval vessels (Lossa, 2010; Hughes, 2006; Schute, 2003). It plays a significant role in functional area of the workstation such as placement of instrumentation and controls, accessibility for maintenance, visibility through bridge windows and clearance for safe and efficient movement within the vehicle.

Poor anthropometric design can result in people bumping into overhead structures, not accessible to reach controls and not having visual contacts with critical instrumentation and leading to discomfort and degrading their performance.

Examples of inappropriate anthropometric design are

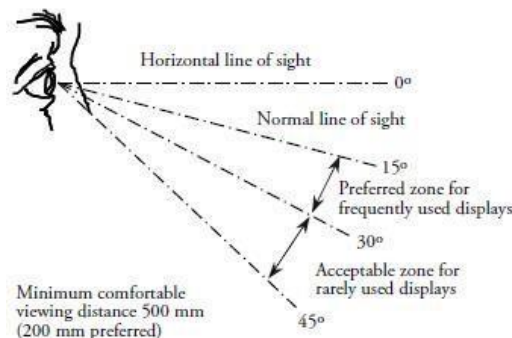
- Mismatch between the anthropometry and functional instrument such as valve handles in the engine room of Swedish design container ship of Korean crew personnel.
- Inability of US Navy personnel to access equipment for maintenance in a newly built auxiliary ship.
- Inadequate clearance between truck accelerator and brake pedals in utility trucks, resulting in unintended acceleration for drivers wearing large boot or shoe sizes (Freier, 2010).
- Difficulty of Korean soldiers in operating US Army standard weapons, in particular the M-1 rifle (e.g., grasping the stock, reaching the trigger and sighting) (Hart, 1967).

It can be availed that Anthropometrics helps in making distinctions differences in body variables of different populations, while body mechanics mainly focus on common practices of any human body.

Examples of good body mechanics include the following (Greenwich, ABS 2003):

- Maintaining a balanced, comfortable and aligned position.
- Facility of arm rest in straight chairs to sit in firm position and avoiding low seated chairs.
- Arrange displays for easy reading.
- Placing controls and actuators (e.g., valve handles) within easy reach (preferably above hip level and below shoulder level) and manipulation.
- Avoid twisting the back.
- Pushing is safer than pulling.
- Lift with the legs, not the back.
- Ensure proper eye height for comfortable viewing (Figure 1). The height of the viewer's eye when standing or seated will vary among and within populations depending on body variables taken under consideration

Fig. 1. Lines of Sight (Based on MoD Std 25-17)



Any mechanical design may result in excellent body mechanics or ergonomics for one population but may fail for another population, sometimes with serious degradation to performance, safety and comfort.

OBJECTIVE: -Generation of Anthropometric Database of Mechanized Force’s personnel for recommending appropriate seat dimensions inside the combat vehicle.

METHODOLOGY: - The current study was conducted on 600 Indian soldiers belonging to different army stations viz (Suratgarh, Bikaner and Bhatinda). Body measurements, crucial for designing an ergonomic combat vehicle workstation were taken into consideration. Body measurements were taken in sitting position of the subjects as per the standard operating procedure (Lohman *et al.* 1988). All measurements were taken in cm or otherwise as listed. GPM anthropometric rod and Martin sliding caliper was used to record the measurements.

RESULTS AND DISCUSSION

Workstation Parameter	Anthropometry Parameter	Anthropometry						
						Percentiles		
		Mean	S.D.	Min	Max	5	50	95
Seat Height	Popliteal height	44.5	2.4	33	54.9	41.2	44.5	47.5
Seat Depth	Buttock to Popliteal length	48	2.5	40	57.2	44	48	51.7
Seat Width	Hip breadth	34.8	2.6	29.5	48	31	34.7	39
Back rest height from seat surface	Sitting shoulder height from seat surface	61.9	2.6	55	87.5	58	61.8	66
Visual display screen position	Sitting eye height	79.7	3.0	61	87.8	74.7	79.7	84.4

Table 1: Anthropometric and workstation parameters of Mechanised forces

This is a first of its kind study using indigenous Indian force’s anthropometry for Combat Tank design and it is a novel study. BMP-II needs to be improvised according to the user population i.e. Indian mechanized forces who are specifically recruited/selected to operate these tanks.

This study aims at improving the BMP-II combat tank using Indian Mechanized Forces anthropometry as the BMP-II is based on the Russian anthropometry and it is a Russian made vehicle. Anthropometric data of Indian mechanized forces who are user of this combat vehicle BMP-II was taken in the present study to optimize

efficiency as the vehicle was designed according to Russian Anthropometry which is not fit for the user population.

Recommendations have been given based on Indian Anthropometry for combat tank. Literature reviews found no existing Indian anthropometry available specifically for combat tank/vehicle design. In the international arena, comparison between tracked combat vehicles (BMP-II being such kind of vehicle), literature is scant in this aspect and existing user population of such combat vehicles varies a lot.

When designing seat of combat vehicle for infantry troops where driver seat and crew members seat are different, major criteria should be the comfort while seated in the vehicle. Comfort basically depends on the thigh support, cushion parameters, seatback lateral support and adjustability of lumbar region (Kolich 2003, Reed *et al.* 1994).

Seat Height

The occupant's 5th percentile popliteal height is taken into account while designing a driver or bench seat of combat vehicle. According to Chaffin (1999), when seat height is very low, the knee bending angle becomes sharp. Since the weight of the trunk is transferred to the seat through the back of the thigh, a sharp knee bending angle during prolonged sitting causes discomfort to the individuals. When the seat height is so high that the feet do not touch the ground, pressure on the back of the thigh leads to low back pain during sustained seating as the person tends to go to the front of the seat of the chair, to allow support to the feet (Bush 1969, Kroemer 1971). Parcells *et al.* (1999) has defined the appropriate height and popliteal height seating should lie between 88% and 95% of popliteal height of the populace.

Seat Depth

ISO 9241-5: 1998 document states that the seat depth is important both to ensure that the legs can be placed without compressing the back of the knees and to be able to rely fully on the back. Due to the sensitivity of the skin at knee's back surface, the tendons have little protection and hence depth of the seat should be slightly shorter than the length between the back of the knee and thigh for optimal functioning of the legs. A deep seat does not permit appropriate use of back support which causes curvature of the spine (kyphosis) and may lead to discomfort. For designing seat depth, 5th percentile buttock popliteal length is considered.

Parcell *et al.* (1999) stated that seat depth of $\leq 80\%$ or $\geq 95\%$ of buttock popliteal length is considered as a mismatch. Greater seat depth hampers the use of backrest. If the person tries to use the backrest, feet would collide with the front edge of the seat and may remain hanging in the air. Moreover, getting up from the seat would be difficult.

The ideal seat depth for the population should be in the range of 41.3 cm (80% of buttock popliteal length of 95th percentile) to 41.8 cm (95% of buttock popliteal length of 5th percentile). The designer and developer may design the seat pan depth depending on the buttock popliteal length of the user and seat pan depth 41.0cm (95% of the 5th percentile and 80% of 95th percentile) can be suitable for the entire population under study.

Seat Width

The bench or driver seat of combat vehicle should be wider than the hip breadth of the user to allow space for movement and clothing. ISO 9241-5: 1998 A.2.3 states that besides the obvious need to ensure that a reasonable proportion of the users can easily get up and sit down. This is one of the most important way to ensure that the user lessens the burden by taking the postural position. Due to the flattening of the buttocks and the tendency to open his legs while sitting, width of the seat should be larger than the width of the hips of the person. According to Gouvali and Boudolos (2006), seat width should be at least 10% more (to accommodate hip breadth) and at the most 30% larger than hip breadth for free movement and easy change of posture. Seat width design is based on minimum width requirement for accommodating maximum user population. Hence, 95th percentile sitting hip breadth is taken into account to accommodate 95% of the infantry male population which is 44 cm.

Backrest Height

This is applicable only for the driver seat of combat vehicle where the back of the seat supports some of the weight of the occupant, reducing the weight on other parts of the body (Waller 1997). The ultimate test of fit is highly posture dependent. All backrests should provide adequate lumbar support and buttocks clearance. For tasks requiring upper body mobility, the backrest should provide adequate back support, but not interfere with the user's movement (typically these backs should not be higher than the bottom of the user's shoulder blades). Most appropriate backrest height should be 60-80% of the user's sitting shoulder height (Gouvali and Boudolos 2006).

In the present study it has been observed that backrest height as per the 60-80% of sitting shoulder height norm should be 34.8 cm to 46.4 cm for 5th percentile and 39.8 to 52.8 cm for 95th percentile population. The back rest height can be fixed to 45cm.

Visual Display Position

Display screen position or periscope that is too high or low will result in working with head, neck, shoulder, and even the back in awkward postures. When the visual display screen is too high, for example, head and neck have to be tilted back. Working in these awkward postures for prolonged periods fatigues the muscles that support the head. For display or screen height, general rule is that the top of the visual display unit should be no higher than eye level, while keeping the head and neck not bent and twisted (Mac Leod 1999). The visual display height for crew members of BMP –II should be 80 cm from the sitting plane..

CONCLUSION

Seat Height: Based on the present study, seat height needs to be designed such that the minimum popliteal height of 33 cm and the maximum popliteal height of 54.9 cm can comfortably be seated. i. e. seat height should be 41.0 cm.

Seat Depth:-The range for seat pan depth is recommended as 40 cm to 57.2 cm. A seat pan depth of 41.0 cm can be suitable for the entire population under study.

Seat Width:- In the existing situation the maximum seat width should be about 44.0 cm which is approximately 10% larger than the 95th percentile hip breadth and is compatible for the whole population under study.

Backrest Height:-The backrest height of the seat for 5th to 95th percentile male may be fixed at a height of 45.0 cm which can be compatible for both 95th percentile and 5th percentile male.

Visual Display Position:-For visual display unit position, Sitting Eye height is considered which ranged from 61.0 cm to 87.8 cm. To accommodate 90% population, the display position should be 80 cm from the sitting surface.

It can be concluded that this study is Based on infantry mechanized force anthropometry and the seat recommendation will have maximum coverage so as to improve comfort, mobility and optimize protection of the users of combat vehicle. One size does not fit all, whether for shoes or naval marine vehicles, combat vehicles. Anthropometric data may be used for follow-on designs. Anthropometric data should be reviewed at the beginning of a design to include changes to the population . Anthropometrics in design helps in an improved fit between the operator and the vehicle and thus enhanced crew performance.

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