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Design and Ergonomic Evaluation of Multipurpose Student's Bed

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Abstract:A bed is a piece of furniture used as a place to sleep or relax. Students generally need a wide range of accessories to meet their daily requirements like beds for sleeping, tables for studying, shelves for keeping things etc. which demands a lot of space. So, here a multipurpose bed is designed targeting especially on college students living in hostels. Different customer needs have been identified, existing models have been studied and bed has been ergonomically designed. Concept of ergonomics and its applications in product design along with anthropometric data has been reviewed. The additional features of the bed are attached reading table, shelf for storing books, hanger for hanging clothes, and place for keeping foot wear. Bed and all other components are designed and mechanisms have been developed using CAD software (CATIA V5R17) and simulated. The model has been also evaluated using digital human modeling.

Keywords*: Multipurpose student bed, CAD, Digital human modeling, Anthropometry.*

1 Introduction

Beds, tables, chairs and shelves are the basic requirements of students. All these things occupy most of the space of their rooms leaving no further space for their free movement. This motivated to the design a multipurpose bed which satisfies most of the needs and more comfortable, economical than the traditional ones. Products generally achieve overall success in terms of generating sufficient sales revenue, user compatibility and user satisfaction only if ergonomic design considerations are engineered into it [1-2]. The purpose of ergonomicdesign is to improve the performance of systems by improving human machine interaction. This can be done by 'designing-in' a better interface or by 'designing-out' factors in the work environment, in the task or in the organization of work that degrade human–machine performance [3]. Investigations for studying human-machine/product compatibility from a traditional physical ergonomic perspective, necessarily involved building real physical mockups and subsequently trials with real human beings which is time consuming and quite expensive [4]. Computer aided digital human modeling and simulation technology has emerged as the state of art expertise for human centric ergonomic evaluations and is highly useful because of many associated benefits [5]. Digital human model (DHM) is the computer generated 2D or 3D structure of a human used to represent the complex physical and cognitive aspects of human beings. It can also be considered as a digital representation of the human inserted into a virtual environment to facilitate prediction of safety and performance [6-8]. DHM has many applications in design such as vehicle design [9], vehicle interior design [10],

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physically-based grasp posture generation [11], automatic head and facial feature extraction based on geometry variations [12] and human body shape modeling [13] etc.

In design of bed, ergonomics is considered in width of the bed, its length& height from the ground, reading table dimensions. Anthropometric data which deals with human body measurements are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture and clothing to ensure that physical mismatches between the dimensions of equipment, products and the corresponding user dimensions are avoided [14]. The anthropometric variables used in the design of bed are Stature (full body length in erected stretched posture), Maximum body breadth when relaxed, Upper lumbar (height from seat to first lumbar vertebra), Elbow rest (height from seat to lower most point of elbow) and Foot length (distance parallel to the long axis of the foot, from the back of the heel to the tip of the toe).

Researchers are working on various kinds of beds so as to improvise and rationalize the design of beds. They came with many innovative multifunctional beds but cost, comfort and space are still the key challenges. Wang Sheng et al. [15] developed a multifunctional student bed including bed board, bed frame, wardrobe, drawer with oblique surface, computer desk, writing board, keyboard supporting frame etc. Similar work has also been done by Yang Xi law et al. [16]. Qiujun Chen [17] developed a bed with writing board, comprising a bed body and a guard bar provided with an eversible writing board, on which a locking pin is fixed. Yezhi Biao et al. [18] designed a simple bed table which comprises carrying rails and a table. WU Xu Lin et al. [19] designed a combined student bed for military schools which can be combined into a bed and a study table, and belongs to the field of tools used in student dormitories. Xue Shiwei[20] designed a simple student's bed with more concentration on appearance and structure.

The proposed design consists of additional features like adjustable reading table, shelf, hanger, inclined head board etc. The proposed design is virtually developed and ergonomic evaluation was done in CAD environment.

2 Concept Exploration

This phase consists of:

- *Identification of target users:*College students (Primary target users) and school students (Secondary target users) living in hostels.
- *Identification of need:* A small user survey on students of NIT Rourkela has been done which led to some useful need statements. Statements include comfort in studying, ease of shifting, space for keeping books and hanging clothes and occupying reasonable space etc.
- *Concept development:*Based on the need statements, some rough concepts have been generated and the concept satisfying all the needs has been selected and modelled.
- *Study of Anthropometric data:*Before starting the design, anthropometric variables are taken into consideration as shown in Table 1. This data is collected from [14].

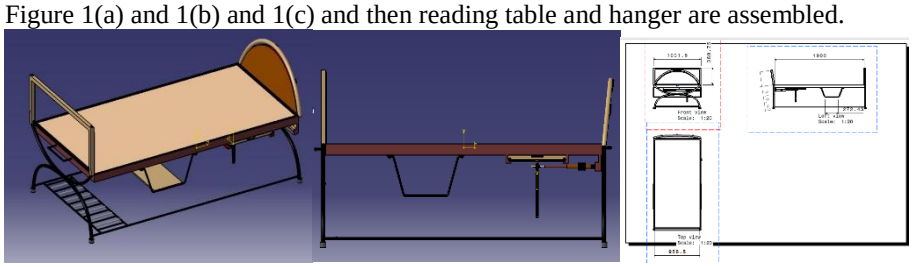
Table1 Anthropometric data used in the design of bed

Sl. No.	Anthropometric variable	Percentile of data used	Value of percentile data(cm.)	Purpose
1	Stature	95th (male)	175.1	Length of the bed
2	Maximum body breadth when relaxed	95th (male)	61.9	Width of the bed
3	Upper lumbar	50th (male)	30	Height of head board
4	Elbow rest	95th (male)	27	Maximum height the table can be reached above the bed
5	Foot length	95th (male)	27.4	Height of hanger from the bed

Stature and maximum body breadth of 95th percentile male is considered to accommodate maximum population on the bed. For determining comfortable height of the head board, upper lumbar height of 50th percentile male is considered so that 5th percentile and 95th percentile persons may also accommodate comfortably. If the 5th percentile person's lumbar height is considered, 95th percentile may face problem and if 95th percentile person's lumbar height is considered 5th percentile may face problem. So, average of both (50th) is considered. Similarly other anthropometric variables are taken into consideration in order to accommodate maximum population comfortably.
Considering all these variables, CAD model of bed has been made.

2.1 Assembly of model

First, the whole bed consisting of book shelf and provision for foot wear as shown in Figure 1(a) and 1(b) and 1(c) and then reading table and hanger are assembled.



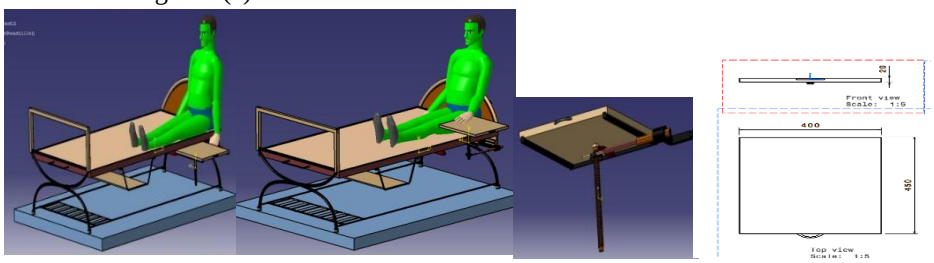
(a) (b) (c)

Figure.1 shows (a)Isometric view of bed (b)Side view of bed (c)2D Model of bed

2.1.1 Assembly of Reading Table

A provision is given beneath the bed to adjust the height of the reading table. Its mechanism can be explained as follows:

- Worm gear mechanism is used here. The knob beneath the reading table is connected to the worm rod which can be rotated. The rotational motion of worm rod along its longitudinal axis can be transferred to the gear in conjugation.
- The rotation of gear causes vertical motion of a screw that runs through its axis.
- A provision is given at the top of the screw where the protruded part of table gets inserted and the table slides. With the help of prismatic and revolute joint given here, table can rotate and slide in the horizontal plane.
- Ball bearings are also added between the screw and rotating bar (at the top of the screw) so that when one part is stationary, other rotates and also to reduce frictional force.
- As the table is drawn out from the bed, the whole worm gear mechanism also comes out with it. Thereafter, on rotating the knob, table is lifted up.The table assembly is shown in Figure 2(c).

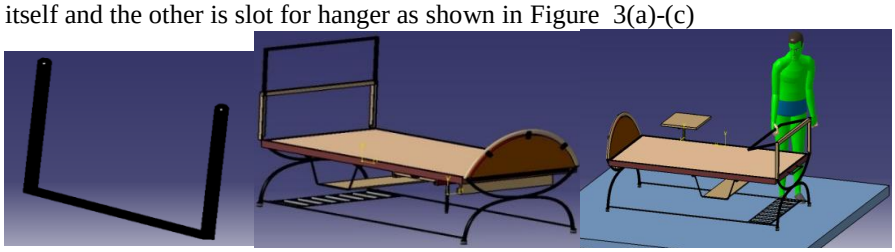


(a) (b) (c) (d)

Figure.2(a)& (b)Person using reading table (c)&(d) Assembled table& its dimensions

2.1.2 Assembly of Hanger

Two holes are made in the hanger and these holes are inserted into the slot present in the bed through which revolute joint is created. Whenever necessary, the hanger can be drawn out from the bed and two provisions can be obtained for hanging, one is hanger itself and the other is slot for hanger as shown in Figure 3(a)-(c)



(a) (b) (c)

Figure 3 representation of (a)Hanger, (b)Bed with hanger and (c) Usageofhanger

2.2Merits

- It consists of reading table which is adjustable. Height of the table can be adjusted due to worm gear mechanism and it can be rotated in horizontal plane due to revolute joint.
- It has a provision for storage of books and laptops.
- It has a provision for keeping footwear.
- The back rest of bed has been given an angle of 8^0(app.) so that it is comfortable.
- It has provision for hanging clothes.
- Holding rods are provided for easy shifting of the bed.
- The space under the bed can be utilized for keeping bags and suitcases.
- The floor beneath the bed can be cleaned easily.

2.3 Comparison with some existing beds

S.No.	Reference No.	Limitations of existing designs	Limitations overcame by proposed design
1	[21]	Though this design has features like inclined head board, under storage and back shelves, this can't be used for reading or studying by students.	Proposed design consists of attached reading table which is adjustable. Also consists of hanger for hanging clothes.
2	[22]	Consists of fixed reading table and has no shelf or storage space.	Consists of adjustable reading table and storage space.
3	[23]	These beds (murphy beds) are specially used by students living in dorm rooms. They can be folded for saving space but doesn't have head boards, foot boards or bed rails. Folding a big bed every day can be a tiresome job and these are generally costly.	Already occupies less space and has many additional features.
4	[24]	Though completely and easily foldable, it can't accommodate reading table, shelf and other features.	It consists of reading table, shelf, and hanger.

3 Ergonomic Evaluation Using Digital Human Modeling:

After preparing the model of bed, ergonomic evaluation is done using digital human modelling. For this purpose, manikins are prepared according to Indian population

dimensions.A 95th percentile male manikin is taken and made him to sleep on the bed as shown in Figure4

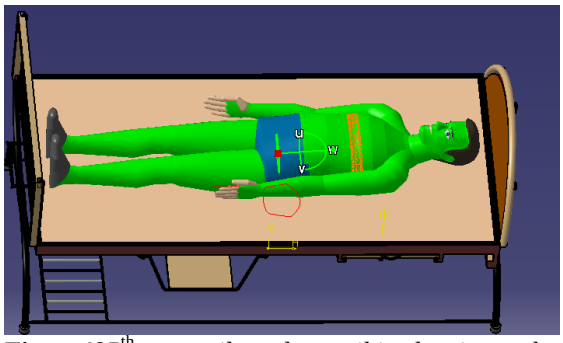


Figure495th percentile male manikin sleeping on bed

Here, it is clear that the bed can accommodate the whole length of the person.
There may be cases in hostels where due to the lack of availability of beds, two persons are provided with only single bed. So, bed is designed for two 95th percentile persons taking their body widths into consideration. So, two 95th percentile male manikins are considered for ergonomic evaluation as shown in Figure5

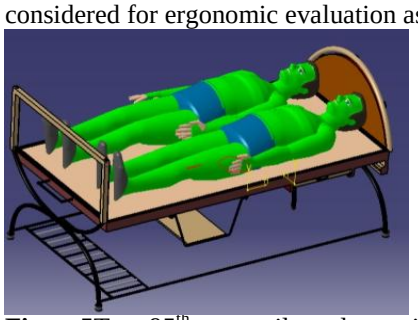


Figure5 Two 95th percentile male manikins sleeping.

Here, it is clear that two persons can also fit in the bed and the angles of manikins are shown in Table2.

Table2 Joint angle data of manikin in sleeping posture

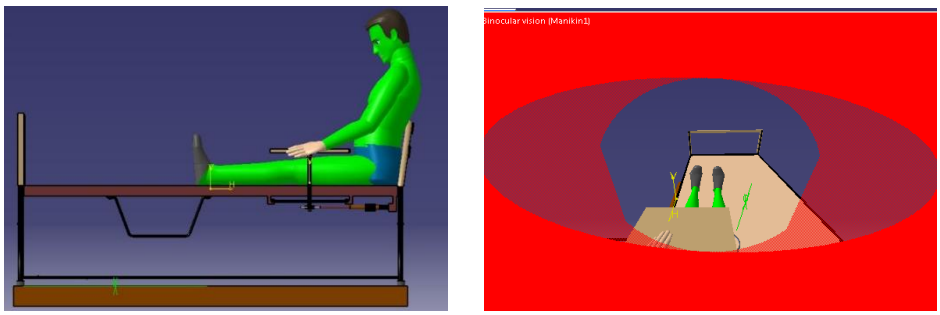
Segment	Degree of Freedom(DOF)	Right side comfort angles (in deg.)	Left side comfort angles (in deg.)
Arm	1 (flexion/ extension)	0(flexion)	0(Flexion)
	2 (abduction/ adduction)	0(abduction)	0 (abduction)
	3 (medial/ lateral rotation)	0(lateral rotation)	0(lateral rotation)
Clavicular	1 (flexion/extension)	0(extension)	0(extension)

	2(elevation/depression)	0(elevation)	0(elevation)
	1(flexion/extension)	0(flexion)	0(flexion)
Forearm	2(pronation/supination)	160(pronation)	160(pronation)
Head	1(flexion/ extension)	0(flexion)	
	2 (lateral left/ right)	0(lateral left)	
	1(flexion/ extension)	0(Flexion)	0(Flexion)
Leg	3(medial/lateral rotation)	0(medial rotation)	0(medial rotation)
Lumbar	1 (flexion/ extension)	-8.297(extension)	
Thigh	1 (flexion/ extension)	7.03(flexion)	7.03(flexion)
	2 (medial/ lateral rotation)	0(abduction)	0(abduction)
Thoracic	1(flexion/ extension)	-4.269(extension)	
	1(flexion/extension)	-20.39(extension)	-11.52(extension)
Hand	2(radial/ulnar deviation)	20(radial deviation)	20(radial deviation)

Next, 95th percentile manikin is again taken and some comfort ranges are given to segments for evaluating his reading posture as shown in Table3. Green color is given to the manikin in the given comfort range and red color is given to range outside the comfort and manikin is made to sit in reading posture as shown in Figure6.

Table3 Comfort ranges of manikin in reading posture

Segment	**Degree of Freedom(DOF)**	**Comfort range (in deg.)**
	1 (flexion/ extension)	-15 to 35 [25]
Arm	2 (abduction/ adduction)	0 to 30 [25]
	3 (medial/ lateral rotation)	-27.758 to 45 [25]
Clavicular	1 (flexion/ extension)	-3 to 5 [25]
Forearm	1 (flexion/ extension)	15 to 100 [25]
Lumbar	1 (flexion/ extension)	-10 to 25 [26]
Thoracic	1 (flexion/ extension)	-10 to 25 [26]
Head	1 (flexion/ extension)	-5 to 20 [26]
	2 (lateral left/ right)	-20 to 20 [26]



(a) (b)

Figure 6 (a)95th percentile in reading posture and (b) eye reach in reading posture

Here, total manikin color is green which indicates that he is comfortable and it is clear that the maximum height reached by table is above the thigh height and it is also in comforatable height when a mattress of about 3cm. is used and table is in the eye reach and the angles in reading posture are shown in Table4.The angles are within the range of the standards and hence it is comfortable

Table4 Joint angle data in reading posture of 95th percentile male manikin

Segment	**DOF**	**Right Side comfort angles (in deg.)**	**Left Side comfort angles (in deg.)**
Arm	1(flexion/extension)	0(flexion)	22.708(flexion)
	2 (abduction/adduction)	7.323(abduction)	7.323 (abduction)
	3 (medial/ lateral rotation)	9(medial rotation)	9(medial rotation)
Clavicular	1(flexion/ extension)	0(extension)	0(extension)
	2(elevation/depression)	0(elevation)	0(elevation)
Forearm	1 (flexion/ extension)	28.25(flexion)	47.194(flexion)
	2 (pronation/supination)	160(pronation)	160(pronation)
Head	1 (flexion/ extension)	17.792(flexion)	
	2 (lateral left/ right)	0(lateral left)	
Lumbar	1 (flexion/ extension)	4.83(flexion)	
Thoracic	1 (flexion/ extension)	1.089(flexion)	
Hand	1 (flexion/ extension)	-20.39(extension)	-11.523(extension)
	2 (lateral left/ right)	20(radial deviation)	20(radial deviation)

4 Conclusion

This work presents design of multi-purpose student's bed which ensures less space usage. The proposed model is compared with some existing ones and it is different from them in

terms of features, space usage and user's comfort. The model is developed in virtual CAD environment and ergonomic evaluation is also done using digital human modeling. In the future, the work can be extended for structural analysis so as to make it a robust one.

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