

Design and Fabrication of Ergonomic Wheelchair

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ABSTRACT: Every year in India the number of disabled individuals is increasing imperceptibly. Wheelchair is one of the effective mobility devices to transport specially challenged people. Most of the wheel chairs require assistance. To help the disabled individual, first one should understand the various issues regarding the mobility equipment and introduce a better design, so that will be an asset for the medical field. Wheelchairs are classified into manual and electrical powered wheelchairs manual powered wheelchairs are driven manually and electrical wheelchairs are driven by electrical motors. In this project we proposed an ergonomic design of manual operated wheel chair of which the backrest and foot rest can be reclined to their comfort position/level and ultimately converted to bed/ stretcher completely by reducing the assistance. We referred number of designs before arriving on the final design. We have used lead screw mechanism to convert chair into bed. Lead screw is a mechanism in which it translates turning motion into linear motion. When mechanism is operated footrest goes till the level of seat of wheelchair and simultaneously the back support reclines to its maximum position and it can be converted to wheelchair vice versa.

KEYWORDS: Ergonomic design, Lead screw mechanism

I. INTRODUCTION

Wheelchairs have been around for hundreds of years; however early wheelchairs were only being used for disabled individual's assistance to from one place to other. As society evolved and disabled people became much more active, the role of the wheelchair began to change as well. Wheelchairs are now considered not only a means of conveyance but also as a way to allow users to express their personality. In 1665, Stephan Farfler invented one of the very first self-operable vehicles. In 1993, a disabled man Herbert Everest, who had broken his back in a mining accident, with his friend Harry Jennings. Harry created the first lightweight, steel, collapsible wheelchair in 1933. They both realized that their creation has huge business potential [1]. They became the mass manufacturers of wheelchair under their company named Everest and Jennings. Their signature "x-brace" design is still being used. The basic structure of the wheelchair contains various parts. In simple words it is a set of wheels attached to a chair or seat. There are few important things a wheelchair must contain [2]. A seat must be comfortable, so that the person does not get fatigued sitting on it for a long duration. It must contain a backrest that provides a good lumbar support. It must have an arm rest at an optimum height and an also a foot rest. Since the invention of the very first wheelchair there have been many modifications in its structural design and its various other features.

II. RELATED WORK

Journal papers explored here are related directly or indirectly to the proposed area of work that is design and development of a Wheelchair cum Stretcher.

Wheelchairs are designed to help the people with disabilities and patients. Stretchers are used to move patients from one place to another. Wheelchair and stretchers are very essential mobility aids in hospitals and clinics to help patients. Stretchers require assistance of someone to move patients from one place to another place. Whereas in wheelchair patient can either operate wheelchair manually or can use someone's assistance. These wheelchairs have cushion on backrest, hand rest and seat to make patient comfortable. The correct choice of the casters also assists to overcome the emergency situations.

According to Mr. Axelson, Mr. Jean Minkel and Mr. Denise Chesney, choosing a suitable wheelchair leads to the more comfort of the user. Performance, safety and dimensions are main three categories to be considered while choosing a power wheelchair. On basis of user's mobility and seating needs priorities are made for selection of the wheelchair. They also highly recommend that a beginner has to consult rehabilitation specialists in order to select the appropriate wheelchair [3].

Here author has given a view about the multi-functional self-caring wheelchair-bed, the combined view of wheelchair and bed is clearly discussed. Along with that free conversion of user sitting position to sleeping position and function of turning sides is quoted. This gives us the knowledge to know how patients and elderly persons can move freely using this and also brought about standing prototypes of wheelchair to satisfy patients demand to certain extent to carry out the purpose of rehabilitation.

From the literature survey it was found that more importance was not given to ergonomics.

III. METHODOLOGY

One of the specific procedures or techniques used to identify, select, process and analyse information about the topic is called methodology. This section permits the reader to evaluate a study's overall validity and reliability very critically. Typically, it contains notions such as theoretical model and quantitative or qualitative techniques. In this project the aim is to make the wheelchair design more ergonomic. For that various research and journal papers were studied to learn what research and development is taking place in the field of assistive device wheelchair. Then different concepts are listed to consider for the design. Then each design is compared against the current design in the market. Then further development is done on one concept and tested for different parameters. Finally, a report is prepared on this project.

IV. CONCEPT GENERATION

Concept generation is a creative phase of the project process, where several ideas or concepts are generated. It is the divergent phase where many prospects are considered without too much judgment[4]. By adopting the concept generation process, the following were the concepts generated for ergonomic wheelchair. Concept 1 - Ratchet and Pawl Mechanism, Concept 2 - Worm and Worm Wheel Mechanism Concept 3 - Pneumatic Mechanism, Concept 4 - Hydraulic mechanism, Concept 5 - Lead Screw Mechanism

4.1 Ratchet and Pawl Mechanism

A ratchet is a mechanical device that allows continuous linear or rotatory motion in only one direction while preventing motion in the opposite direction. Here the ratchet is fixed at the connection between backrest and the seat, while the pawl is attached to the backrest. The backrest can be brought down to horizontal position by lifting the pawl and releasing it once it reaches the bed level.

4.2 Worm and Worm Wheel Mechanism

This mechanism is a gear arrangement in which a worm (in the form of chain) meshes with the worm wheel/gear. The two gears are attached to the backrest and foot rest which are commonly attached to the third gear which is driven by an electric motor. As the motor turns, the gear worm connecting the gears in back and footrest moves resulting in backrest and footrest coming to horizontal position.

4.3 Pneumatic and Hydraulic Mechanism

Pneumatic and Hydraulic Systems are applications of fluid power. Pneumatics uses compressible gas such as air or suitable gas, while hydraulics uses liquid media such as oil.

4.4 Lead screw mechanism

A lead screw is a screw which acts as linkage in machine to translate turning motion to linear motion. Here the lead screw is connected to back rest and foot rest through mechanical linkage of rods. As the lead screw rotates it pulls the backrest down and lifts the foot rest simultaneously.

This step yielded five different concepts; the selection of best concept based on selective criteria is discussed in the next chapter (concept selection).

V. CONCEPT SELECTION

Once various concepts are generated and studied for design consideration, each concept is compared against the current design in the market based on various parameters. Here two steps concept screening and scoring are done. One concept is selected based on the result of screening and scoring and further development is done on that concept[5][6].

5.1 Concept screening

Concept screening refers to the evaluation process that new product/conceptual ideas undergo in order to determine if they will be pertinent to consumers' needs[7]. Screening for different concepts is shown in the figure 5.1.

Sl. No.	Design alternative	Ratchet and Pawl(reference)	Worm and Worm wheel	Pneumatic	Hydraulic	Lead screw
	Criteria					
1	Mobility	0	0	+	+	0
2	Ease of use	0	0	-	-	0
3	Comfort	0	-	+	+	+
4	Cost	0	-	-	-	0
5	Service and maintenance	0	0	+	+	+
6	Dependability	0	0	+	+	+
	Number of 0's	6	4	0	0	3
	Number of "+"	0	0	4	4	3
	Number of "-"	0	2	2	2	0
	Total	6	-2	2	2	3
	Rank	IV	V	III	II	I
	Continue ?	No	No	No	No	Yes

Fig.5.1 concept screening

5.2 Concept scoring

Concept Scoring is a more vigilant study of these relatively few concepts in order to choose the single concept most likely to lead to product success. Concept Screening is a quick, approximate evaluation aimed at producing a few feasible alternatives. Scorings done for different concepts are shown in figure 5.2.

Sl. No.	Criteria	weightage	Ratchet and Pawl (reference)		Worm and Worm wheel		Pneumatic		Hydraulic		Lead screw	
			Ranking	Weighted score	Ranking	Weighted score	Ranking	Weighted score	Ranking	Weighted score	Ranking	Weighted score
1	Mobility	0.19	3	0.57	3	0.57	3	0.57	3	0.57	3	0.57
2	Ease of use	0.26	4	1.04	2	0.52	4	1.04	4	1.04	4	1.04
3	Comfort	0.16	3	0.48	3	0.48	3	0.48	3	0.48	3	0.48
4	Cost	0.17	2	0.34	3	0.51	2	0.34	2	0.34	3	0.51
5	Service and maintenance	0.12	2	0.24	2	0.24	3	0.36	3	0.36	2	0.24
6	dependability	0.1	2	0.2	3	0.3	2	0.2	4	0.4	4	0.4
	Total		2.87		2.62		2.99		3.19		3.24	
	Rank		IV		V		III		II		I	
	Continue?		No		No		No		No		Develop	

Fig. 5.2 concept scoring

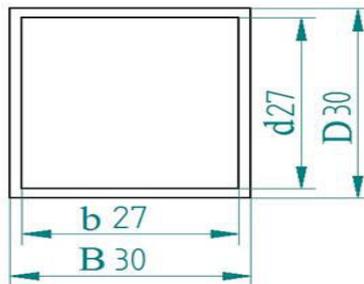
Since LEAD SCREW concept has rank no. 1 from the image 6.2, it is selected for further development.



VI. DESIGN AND DRAFTING

This phase involves the creation of drawings and models to address requirements of the project. Here various formulas are used to perform different calculations.

6.1 Design of Frame



B=30mm, b=27mm, D=30mm, d=27mm, t=1.5mm

Moment of Inertia:

$$I = \frac{BD^3}{12} - \frac{bd^3}{12} \dots\dots\dots (1)$$

$$I = \frac{30 \times 30^3}{12} - \frac{27 \times 27^3}{12}$$

Moment of Inertia = I = 23213.25 mm⁴

Max. Bending moment:

Force = 140 * 9.81 = 1373.4 N.

$$M = \text{force} \times \frac{\text{length}}{4} \dots\dots\dots (1)$$

Max. Bending moment = M = 1373.4 x $\frac{460}{4}$ = 157941 N – mm

We know that from bending equation,

$$\frac{M}{I} = \frac{\sigma b}{y} \dots\dots\dots (3)$$

where,

M = Bending moment

I = Moment of Inertia about axis of bending

y = Distance of the layer at which the bending stress is considered

$$y = \frac{30}{2} = 15$$

$$\sigma b = \frac{My}{I}$$

$$\sigma b = \frac{157941 \times 15}{23213.25}$$

$\sigma b = 102.05 \text{ N/mm}^2$ or MPa

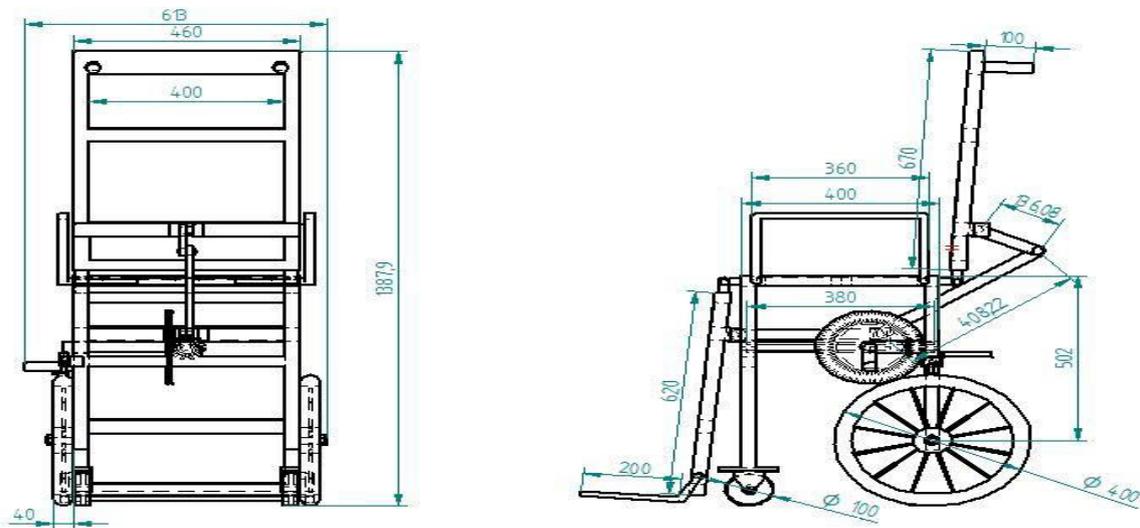
Factor of safety

Maximum strength for mild steel is 210 MPa.

$$\text{Factor of safety} = \frac{\text{Maximum strength}}{\text{Allowable Stress}} = \frac{210}{102.05} = 2.05$$

The factor of safety in this design is 2.05 which is greater than factor of safety for wheelchairs i.e. 2 which means the design is safe and it can withstand load up to 140 Kg.

Based on the calculation and their results 2d drawing is constructed and shown in figure. 6.1



All dimensions are in mm

Fig. 6.1 2D diagram of wheelchair

6.2 Stress and Strain Analysis

Stress and strain analysis is an engineering discipline that uses many methods to determine the stresses and strains in materials and structures subjected to forces. In mechanics, stress is a physical quantity that expresses the internal forces that neighbouring particles of a continuous material exert on each other, while strain is the measure of the deformation of the material. The analysis is done using the software ANSYS Workbench.

The maximum stress obtained is 7.87 MPa and the minimum stress obtained is 2.97×10^{-5} MPa. It is shown in figure 6.2.

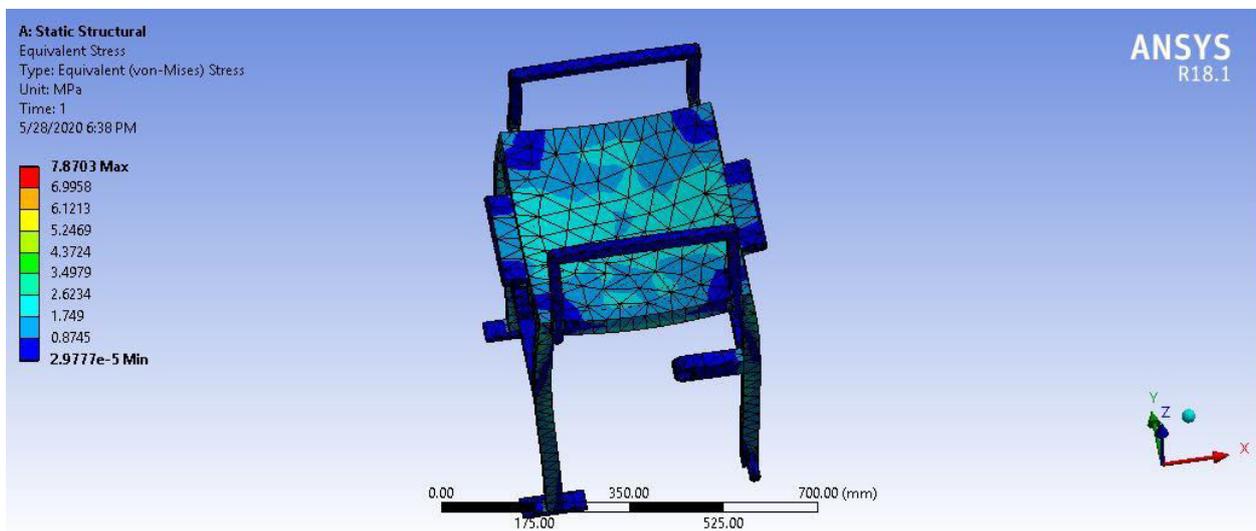


Figure 6.2 stress analysis

6.3 Assembled view

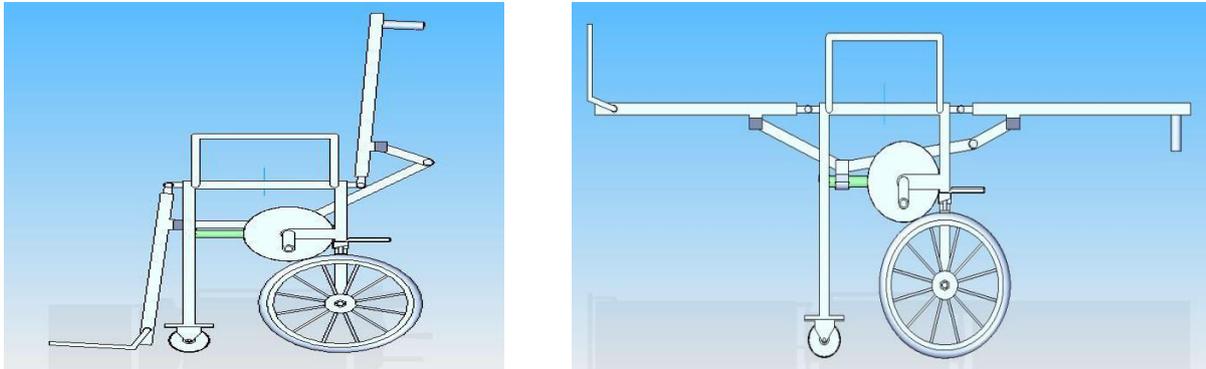


Figure 6.3 prototype model

VII. ADVANTAGES AND LIMITATIONS

Advantages

The advantages of lead screw mechanism are,

- The seat can be adjusted to the required angle.
- The operation of the wheelchair is easy.
- Increases the comfort level of patient.
- Can be used as stretcher to move patients which also helps to prevent injury to patients when shifting them from wheel chair to stretcher.
- Reduces the dependency on the care taker significantly.

Limitations

The limitations of lead screw mechanism are,

- They have a high degree of friction on the threads of lead screw, which can wear the threads out quickly.
- The weight of the wheelchair is slightly more.

VIII. CONCLUSION

The aim of this project was to design a wheelchair that can provide comfort as well as additional ergonomic features to the conventional wheelchair. The design was aimed at reducing the dependency. With this design the user can use this wheelchair in two positions, sitting as well as sleeping position comfortably. This design is ergonomic and not too complex. In mass production it will be cost effective.

IX. FUTURE SCOPE

Future scope of this project is, Alternate material with similar engineering properties can be considered for light weight. Electric motor can be included for moving the backrest and footrest instead of applying manual force. Alternate mechanism can be designed for more efficiency. Sensor can be included in order to adjust the position more accurately. GPS can be used locate the wheelchair.

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