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Design and Fabrication of Wheelchair cum Stretcher with Multi Fold

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ABSTRACT

In this paper lead screw mechanism is used to convert a wheelchair into stretcher and vice versa. When lead screw mechanism is operated, the foot rest which is downward goes till the level of seat of wheelchair and simultaneously the back support goes down to the same level making, it stretcher and vice versa, when it is converted into wheelchair from stretcher. Below the seat, a defecation system has been provided which is detachable and is operated by sliding mechanism. It is designed and fabricated in such a way that it can be used in hospitals as well as for personal use at home.

Keywords: Fabrication, hospital, stretcher, wheelchair

1. INTRODUCTION

Disabilities have affected thousands of families in the world. As of today 650 million people are suffering from disability. Their disabilities can be empowered and enable them to live a normal and independent life with the help of wheelchair. New and modified wheelchairs can satisfy the need of disable people rather than the old and conventional ones. To help the disabled various design changes have been done. One is by introducing a detachable defecation system to it. It provides ease to the patients and the staffs.

Engineers are continuously applying their ideas to make these products more and more sophisticated so as to facilitate the doctors, patients and staffs more. Wheelchair is one of the easiest modes which serves the purpose of transportation for patient and is considered as basic necessities in hospital. Studies showed that 40% of the helpers who helped physically challenged person for the translation from bed to chair and vice versa are suffering from the back and joint pains. To tackle this problem many people have designed wheelchairs with various applications which could be converted into a bed or visa-versa using mechanical linkages or with the help of an electrical motor. A slipping mechanism or pulling mechanism is used for lowering the back portion. Then the implementation of hydraulics and pneumatics improved the efficiency as well as eliminated the need of external help but it had a drawback as it created noise and it was bulky. To overcome the problem, the new proposed work came which uses an electrically driven conversion system for the disabled patients. This is even helpful when the patient want to take a nap/sleep by converting the wheelchair to an easy chair where the person can stop the chair at a particular position where they would feel comfortable. The driving and conversion mechanism is both based on the electric motors.

2. HISTORICAL BACKGROUND

Sunny et al. [1] discussed about wheelchair cum stretcher which comprises of hydraulic jack, screw rod, wheel, free wheel, waste lid and braking lever. Two lead screw setup with hinge joint is used form a stretcher or back to wheelchair. A port with lid is provided at the middle part to eliminate the human waste. Hydraulic jack is used to vary the height of stretcher or wheelchair. Brake lever is used to provide to stop wheelchair movement. Suryawanshi et al. [2] discussed about the conceptual design of inbuilt person transfer mechanism in a Wheelchair. The various concepts are generated for selection of Wheel chair. Different methods like FD, DARE analysis and Pugh concept selection method for converting the needs of the customers into a conceptual product are discussed in detail.

This wheelchair developed can easily help the people disabled in legs to transfer themselves to bed without any assistance. Alexander et al. [3] described that the use of gear motor mechanism for conversion of wheelchair into stretcher and vice versa. The patient can move themselves by their own hands with the help of some mechanism that is used to move the wheelchair which are wheelchair which are having their own advantages and disadvantages. It is thought to combine the concept of wheelchair and stretcher and design a system which serves the both purposes and hence in order to meet the patient requirement this paper aims at designing an electric wheelchair that can be converted

into a bed/stretcher with variable adjustable positions with the help of electric motor. John et al. [4] discussed about the various combination of mechanism use to reduce the space i.e. caster wheel and porta wheel mechanism. The work "Multipurpose Medical Bed" is introduced to solve problems related to the conventional medical care equipment and would be cheap and affordable and could be efficiently used in hospitals to save space, time and to provide better care to the required. Ahmed et al. [5] worked on the use of pneumatic system for the conversion to stretcher from wheelchair and vice-versa. This helps the caregiver avoid heavy lifting situations that put their back at risk of injury. The caregiver can merely shift the patient from a bed on to the device while the device is in the form of a stretcher. Then the device can be converted into a wheelchair automatically with a press of a button. This can be done in the reverse direction as well, when the patients in sitting in the wheel chair can be converted to a stretcher smoothly for the purpose of diagnosis etc. Sivadas et al. [6] worked on wheelchair cum bed with side panel movement for bed has been designed using to lead screw to convey the required motion to the links. Two motors supply power to the lead screw via pulley attached on the lead screw. It has been found that worm gear was used to increase the required torque and the electric system can be used to reduce the health due to leakage in pneumatic system. Borkar et al. [7] present the explanation of recliner mechanism used for the conversion. The spring is used for setting the desired position. Mobility aids are used for transportation of patients. Wheelchairs and stretchers are the most commonly used mobility aids for the movement of patients. It proposed a design of wheelchair convertible stretcher which is a boon to the medical field. It is so made that it could be maintained and operated easily either by the patient or by the attendant according to the comfort of the patient. Kulkarni et al. [8] studied of different mechanism that is mechanical linkage, parallelogram mechanism, reclining mechanism and hydraulic mechanism has been done for the conversion. Using simple hydraulic components, the wheelchair can be converted into bed at designated spots where the trainer kit is placed. Using hydraulics also gives an added advantage of being able to get the wheelchair into multiple other positions according patients comfort. The main objective of this work is to improve patient comfort and enhance the efficiency of entire system.

3. MATERIALS AND METHODOLOGY

3.1 Working principle

The model works on lead screw mechanism. A lead screw or power screw or translation screw is a screw used as a linkage in a machine to translate turning motion into linear motion. Because of the large area of sliding contact between their male and female members, screw threads have larger frictional energy losses compared to other linkages. They are not typically used to carry high power, but more for intermittent use in low power actuator and positioner mechanisms. Lead screws are available in three types based on their type of thread, such as square thread, buttress thread, acme thread. This is mostly described for a square of buttress thread. The force of the load is directed downward. The normal force is perpendicular to hypotenuse of the triangle. The frictional force is directed the opposite direction of the direction of the motion.

The main components involved in this project consist of DC gear motor, lead screw, battery, caster wheel, bicycle wheel, two way switch, and a waste lid. In this project one lead screw setup with hinged joint and connected to links is used to form the stretcher and bend to wheel chair are provided. At the present position this model is a wheelchair type. Below chair a lead screw which is connected to lids, the links are connected to the bottom side plate and top slide plate when the lead screw is rotated anti-clockwise; the movement of the link brought the bottom side plate upward and top side plate downwards to convert the wheelchair into stretcher. From stretcher when the lead screw is rotated clockwise, the links movement brings the top side plate upward and bottom side plate downward to convert stretcher into wheelchair. At the middle part a removal port with lid is provided to eliminate the human waste.

Table 3.1: Human body weight distribution

Part of human body	Weight (%)	Weight of human body parts (kg)
Trunk	48.3	38.64
Head and neck	7.1	5.68
Thigh	10.5	8.4
Shank	4.5	3.6
Foot	1.5	1.2
Upper arm	3.3	2.64

Forearm	1.9	1.52
Hand	0.6	0.48

Table 3.2: Material used

Parts	**Dimension(mm)**
Mild steel hollow cylindrical bar diameter	27.85
Mild steel triangular bar cross section	0.5(25X25)

Table 3.3: Parts dimension

Parts	**Dimension(mm)**
Rear wheel diameter	600
Back width	725
Front width	458.75
Height of stretcher from ground	725
Distance between front and rear wheels	462.5
Dia. Of rear wheel shaft	12mm
Dia. Of front castor wheel	100mm
Bolt diameter	10mm

3.2 Material properties

Table 3.4: Mild steel properties

Density	7200 kg/m^3
Thermal expansion	10.1 to 16.6X10^{-6} $mm/^0C$
Young's modulus	68.9-207 GPa
Poisson's ratio	0.23 to 0.3
Melting point	1230 to 1530 ^0C
Ultimate tensile strength	450 to 500 MPa

4.LOAD CALCULATIONS

4.1 Front caster

- Weight of the body = 14.24 kg = 139.552N
- Weight of wiper motor = 2 X 2.25 = 4.5kg = 44.1N
- Human body weight = 80kg = 784N
- $F_{vertical}$ = (139.552 + 784)N
- Load on each caster = 923.552N / 2 = 461.776 N
- Inclination angle = 10^0
- $F_{inclined} + F_{vertical}$ x Cosθ = 923.552 X Cos10 = 909.52 N
- Force on each caster = 909.52/2 = 454.760 N

4.2 Rear wheel

- Weight of body = 14.24kg = 139.552 N
- Human weight = 784 N
- F_{rear} = (139.552+784) = 923.552N/2 = 461.776 N
- $F_{rear}(\theta=10)$ = 923.552Cos10 = 909.521/2 = 454.76 N

4.3 Back rest

- Human back weight = 31.693kg = 310.91N
- Incline = 30^0
- Back rest weight = 6kg = 58.8N
- Force = 310.91 + 58.8 = 369.71N
- Force (actual) = 369.71Sinθ = 184.855

4.4 Leg rest

- Inclination = 55^0
- Weight of human leg = 4kg = 39.2N
- Force = 39.2 + 39.2 = 79.4N
- Force (actual) = 78.4 x $Sin55^0$ = 64.22N

5. DESIGN OF LEAD SCREW

5.1 Specifications of lead screw

Pitch of lead screw, P = 10mm
Speed of lead screw, N = 50rpm
Thickness, T = 4mm
Outer Diameter, d_2 = 18mm
Inner Diameter, d_1 = 14mm

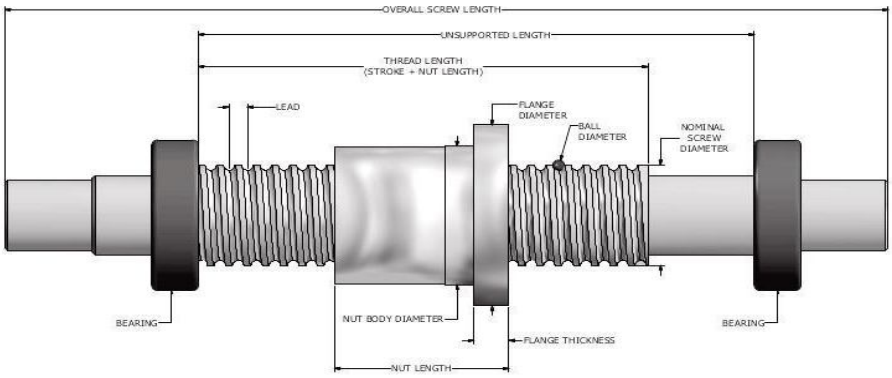

Figure 1 Lead screw specification

5.2 Calculations

Linear velocity of the lead screw = N x P = 50 x 10 = 500mm/min = 8.33mm/sec

$$\text{Angular velocity of lead screw} = \frac{2\pi N}{60} = \frac{2\pi 50}{60} = 5.236 \text{ rad/sec}$$

Pitch diameter (D_p) = (d_2 + d_1)/2 = (18 + 14)/2 = 16mm

$$\text{Helix angle } (\alpha) = \tan(\alpha) = \frac{1}{\pi \, x \, Dp} = \frac{1}{\pi \, x \, 16} = 11.25^0$$

Friction angle (ϕ) = μ = tan ϕ

0.23 = tan ϕ

ϕ = 12.95_0

$$\text{Torque required to raise the load } (T) = W \, x \, \frac{\frac{Dp}{2}}{\frac{16}{2}} \, x \tan(\phi + \alpha)$$

= 784.8 x $\frac{\frac{16}{2}}{2}$ x tan (12.95 + 11.23)

= 268.42 Nmm

Power of lead screw $= T \times \frac{2\pi N}{60}$

$= 0.268 \times \frac{2\pi 50}{60} = 1.4$ W

Direct compressive stress $\sigma_c = W/A_c$

$A_c = \frac{\pi d1 \, x \, d1}{4} = \pi \times 14^2/4$

$= 153.938$ mm^2

$\sigma_c = (80 \times 9.81)/ 153.938 = 5.098$ N/ mm^2

Torsional moment $= M_{ts} = W \times \frac{d2}{2} \times \tan(\phi + \alpha) = 80 \times 9.81 \times 9 \times \tan(11.25 + 12.95)$

$= 3174.32$ Nmm

Torsional shear stress(τ) = = (16 x 3.174)/(π x 14$_3$)

= 5.89 x 10^{-3} N/mm$_2$

Principle shear stress (τ_{max}) = = = 2.549N/mm$_2$

Principle normal stress(σ_{max}) = =

= 5.098 N/mm$_2$

Transverse shear stress in screw (τ_s) = W\(π. d_1. t. i) = (80 x 9.81)/(π x 14 x 4 x 43)

= 0.103 N/mm^2

Efficiency of screw = tan α/ tan (ϕ + α) = tan (11.25)/ tan(12.95 + 11.25) = .44 = 44%

As η < 50%

So, it is self locking.

5.3 Design and analysis

The basic design of the device has evolved from the concept of a convertible wheelchair. Thus the initial sketches for the project design included only the skeletal structure of a wheelchair.

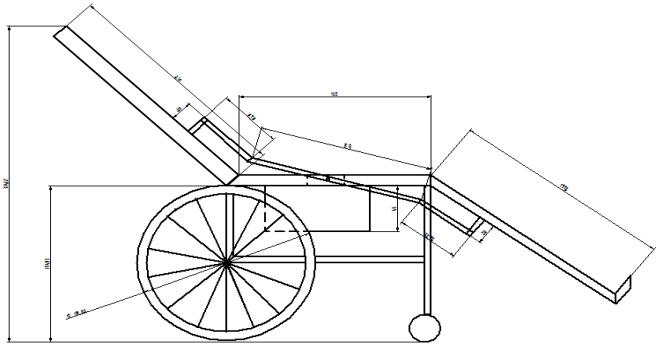

Figure 2 Preliminary sketch of the device in wheelchair position

Then the convertible feature was included to the design at a conceptual level and tremendous amount of brainstorming was done. Since the fundamental aim of is to provide comfort to the patient as well as his/her caregiver, powered conversion of the device between chair and stretcher was given focus. In the second phase, the power source was to be selected. Electric motors have good load carrying capacity, speed control characteristics, precision etc.

5.3.1 Solid modeling

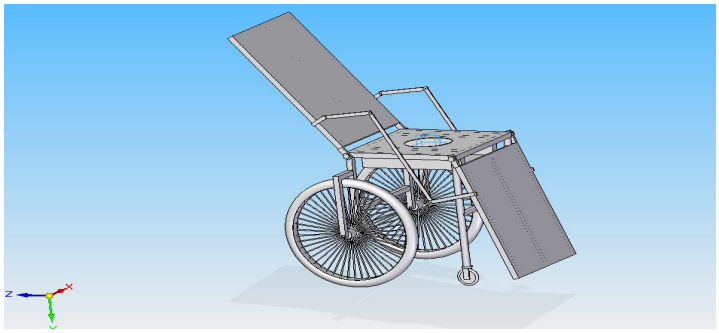

Figure 3 3D view of the device in wheelchair position

The figure 3 shows the 3D view of the device in wheelchair position. The front view of head section, seat section, foot section, foot rest, front wheels and rear wheels are shown in the figure.

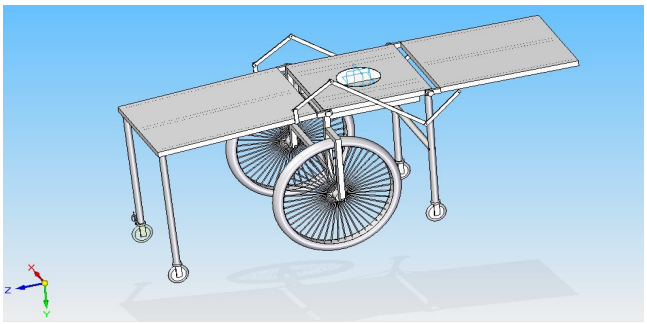

Figure 4 3D view of the device in stretcher position

The figure 4 shows the 3D view of the device in stretcher position in which links is used to connect backrest and leg rest so that by operating the link wheelchair can be converted in stretcher position.

5.3.2 Stress analysis

Since the most critical and failure prone part of the system is base frame, it is subjected to Finite Element Analysis (FEA) using ANSYS 14.5. A total load of 800N was uniformly applied on seat of the frame.

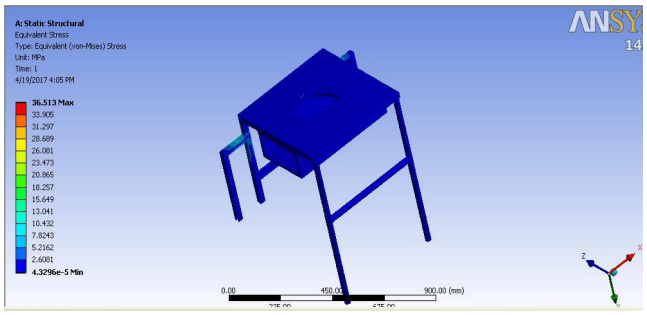

Figure 5 Equivalent Von-Mises Stress Analysis result

6. SELECTION OF MATERIALS

6.1 Factors determining the choice of materials

The various factors which determine the choice of material are discussed below.

6.1.1 Properties

The material selected must possess the necessary properties for the proposed application. The various requirements to be satisfied can be weight, surface finish, rigidity, ability to withstand environmental attack from chemicals, service life, reliability etc. The following three types of principle properties of materials decisively affect their selection

- Physical
- Mechanical
- From manufacturing point of view

The various physical properties concerned are melting point, thermal Conductivity, specific heat, coefficient of thermal expansion, specific gravity, electrical conductivity, magnetic purposes etc. The various Mechanical properties Concerned are strength in tensile,

Compressive shear, bending, torsion and buckling load, fatigue resistance, impact resistance, elastic limit, endurance limit, and modulus of elasticity, hardness, wear resistance and sliding properties. The various properties concerned from the manufacturing point of view are,

- Cast ability
- Weld ability

- Surface properties
- Shrinkage
- Deep drawing etc.

6.1.2 Manufacturing case

Sometimes the demand for lowest possible manufacturing cost or surface qualities obtainable by the application of suitable coating substances may demand the use of special materials.

6.1.3 Quality required

This generally affects the manufacturing process and ultimately the material. For example, it would never be desirable to go casting of a less number of components which can be fabricated much more economically by welding or hand forging the steel.

6.1.4 Availability of material

Some materials may be scarce or in short supply, it then becomes obligatory for the designer to use some other material which though may not be a perfect substitute for the material designed. The delivery of materials and the delivery date of product should also be kept in mind.

6.1.5 Space consideration

Sometimes high strength materials have to be selected because the forces involved are high and space limitations are there.

6.1.6 Cost

As in any other problem, in selection of material the cost of material plays an important part and should not be ignored. Sometimes factors like scrap utilization, appearance, and non-maintenance of the designed part are involved in the selection of proper materials.

7. COST ESTIMATION

7.1 Material cost = 8250/-

7.2 Labour cost

Drilling, welding, power hacksaw, painting cost = 4000/-

7.3 Overhead charges

The overhead charges are arrived by “Manufacturing cost”.

Manufacturing cost = Material cost + Labor cost

= 12250/-

Overhead Charges = 20% of the manufacturing cost

= 2450/-

7.4 Total cost

Total cost = Material cost + Labor cost + Overhead charges

Total cost for this project = 14700/-

8. TESTING

While testing the device, it encountered a problem of height of wheelchair which is not feasible for an average height person. In order to solve the problem the height of wheelchair is reduced from both sides in a proportion to be fit for average height person.

Figure 6 Device in wheelchair position

The figure 6 shows the image of finally fabricated wheelchair cum stretcher with defecation system convertible device. The device figure8.1 is in wheelchair position where lead screw is in initial position. The head section, seat section and foot section are equipped with cushions. In this image the wheelchair cum stretcher with defecation system is in front view where the device is in wheelchair position. The highlights in this image are the head section, seat section, foot section which are equipped with cushions, rear wheels, caster wheels, motor, the connecting mechanism links, the lead screw mechanism and defecation lid.

9. ADVANTAGES, LIMITATIONS AND APPLICATIONS

9.1 Advantages

- Increase in comfort level of the patient.
- Prevents further damage to patients and the helper while transferring him/her from chair to bed or vise-versa.
- Patients with serious injuries need not be moved to aggravate their injuries even more.
- No special training required to operate them.
- Is more efficient than other chairs.
- Less costly than electrical version of the same chair.

9.3 Limitations

- Increases weight of the chair.
- Increases the cost of the chair.

9.3 Applications

- It is used in hospitals.
- It can also be used in houses.

10.Conclusion

In this report it is discussed that the need for the wheelchair beds system in current world and the different mechanisms that can be implemented. It is concluded that now a-days in hospitals fully atomized beds, wheelchairs and stretchers are used for the patient handling purpose. But they are very costly and are not affordable to all the hospitals. The stresses developed during the handling of patient in both, i.e., patient and staffs are same for all the hospital. A new design of wheelchair cum stretcher for patient handling has been done. Cost of such type of wheelchair cum stretcher will be affordable for all type of hospitals and it will be beneficial for patient handling. The product will thus likely be an efficient mobility aid in hospitals.

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