Design and Fabrication of Wheelchair-to-bed System Using Fluid Power

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Abstract-*Wheelchair is a chair with wheels used to move a person/patient from one location to another due to their inability to move. This may be due to the user/patient being physically disabled, weakness due to their disease or old age. Hence after they arrive back to or when they are moving away from their beds, there is a transition from wheelchair to bed or bed to wheelchair. This transition is tedious and is proved to be harmful to both the patient and the helper by many studies and surveys. A provision can be provided to convert the wheelchair into a bed using hydraulics. Hence this paper deals in detail with the making of such a wheelchair that can be converted to a bed or to any reclining positions depending on the comfort of the user/patient using simple hydraulics and mechanical linkages.*

Keywords-- Bed, Hydraulics, Wheelchair, Wheelchair-to-bed

I. INTRODUCTION

Wheelchair is one of the basic necessities in a hospital. It serves the purpose of transporting a person/patient from one location to another. These patients generally have restricted movements due to their diseases or the weakness caused due to their diseases. Such patients have to make use of a wheelchair to move from one place to another. Patients may require moving due to reasons such as, need of fresh air, needing to visit bathrooms and/or to clean themselves. Wheelchair serves this purpose as it is cheap and most efficient device available.

The patient, who is incapable to move due to his/her diseases, needs to move himself from the wheelchair to bed or visa-versa. For this purpose they require external help. Also the translation, as proved by many studies, is detrimental to health of the helper as well as the patient. Hence to tackle this problem people have designed wheelchairs which could be converted into beds or visa-versa using mechanical linkages or electrical motor. These systems do not eliminate the need for an external help, as a ward boy or nurse is required to lower or raise the wheelchair into bed. The implementation of hydraulics improves efficiency as well as eliminates the need of external help.

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. Our project's main objective is to improve patient comfort and enhance the efficiency of entire system.

II. TYPES OF WHEELCHAIR

Prime objective of our design is to be robust, self sufficient and efficient. We studied various different designs implemented earlier throughout the history of wheelchair. Earliest recorded history of a wheelchair (or wheeled-chair) was seen in 3rd century BC. These chairs were made out of wood and were incomplete in many ways. Further development in technologies enabled the use of much better materials. Listed below are some of the basic designs of the wheelchair:

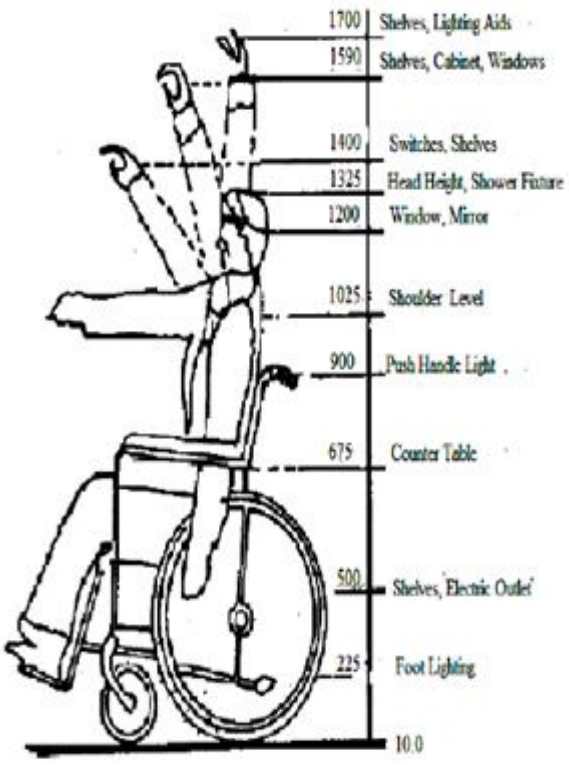


Fig. 1: Basic Wheelchair and its arm reach (A Review on Development of Wheelchair cum Stretcher)

A. Basic Wheelchair

This type of the chair is the one you see almost everywhere. These chairs serve the basic purpose of getting a patient from one location to another. These chairs are robust and require the rider to move it with their own hand force. Although the wheelchairs are used to travel over much short distances, using them over a period of times causes ligament and joint damages to our shoulders.

One such study was conducted to understand the effects of powering the wheelchair with their own hand. The study showed that 73% of the people who use these chairs suffer with chronic spinal problems later in their life.

The rider was asked to power a wheelchair on a treadmill at various speeds. Using pressure sensor, the pressure exerted on various parts of the arm was noted down and their long term effects were studied. It was found that powering the wheelchair with our own hands was detrimental to health in a long term basis. Also there is a need for the patient to shift himself/herself from the chair to bed or visa-versa every time. Hence to tackle one of these problems, a wheelchair power by electrical motor was introduced.

B. Electric Wheelchair

Electric Wheelchairs are those variants which are moved with an electrical motor and the navigational controls generally provided as a joystick on the armrest. These chairs are costlier than the basic wheelchairs due to improvement in technological implementations and also aesthetics.

Electrical wheelchairs also come with their own set of problems, however trivial though, they still create discomfort for the user. One such disadvantage is the regular need to charge it as they are operated on a battery. Also these chairs are costly and cannot be afforded by financially challenged people. Also like in the manually powered chairs, there is a need for the patient to move from the chair to bed or visa-versa. Therefore to solve these problems, further improvements in the wheelchair were done and a chair which could be converted into bed was invented.

C. Wheelchair-stretcher

As discussed earlier, the preliminary models of wheelchair were too raw and many improvements had to be made on them. After solving the problem of hand powering the wheelchair, in 2005, one such wheelchair was invented which could be converted into stretchers. These chairs eliminated the need to transfer the patient from the bed to chair every time he/she had to move.

These chairs used various ways to convert chairs into beds (which shall be discussed later). But one method not implemented was by the use of hydraulics.

Our project deals with this and hence by the use of precise hydraulics and intricate mechanics we can improve the performance of the system.

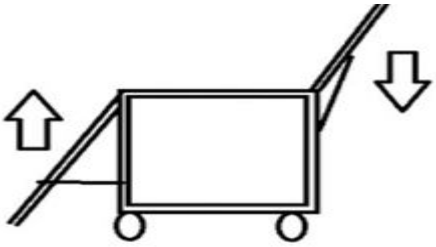


Fig. 2: Wheelchair to bed Mechanism (Wheelchair Cum Stretcher, an innovative product for small hospitals)

III. Mechanisms Used to convert Wheelchair to Bed

Three mechanisms have been implemented previously to make a wheelchair-bed. These mechanisms are discussed in deep below.

A. Mechanical Linkages

Very simple mechanisms were implemented to do three tasks. First mechanism was used to lift the chair up by some small distance and the second mechanism was used to lower the back rest and at the same time raise the foot rest.

a. Lifting Mechanism

A simple parallelogram mechanism was used to lift the chair up along with the patient. The input to this mechanism was given by a hand driven lever. The slider crank mechanism used is most efficient mechanisms that could be implemented for such application.

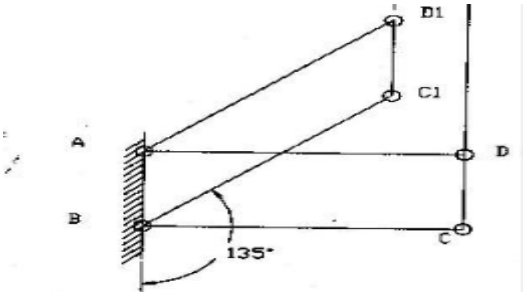


Fig. 3: Lifting Mechanism (Wheelchair Cum Stretcher, an innovative product for small hospitals)

b. Reclining Back or Foot raising mechanism

To convert the chair into a bed, the back rest must be reclined by 90o. An innovative slider crank mechanism was designed to perform this task. In this mechanism, the seat of the chair acts like a slider and the back rest acts like the connecting rod.

Similar mechanism is used to raise the foot rest. Both movements are done simultaneously. These mechanical linkages do not require any electric supply. Although this is an advantage, the necessary inputs to the linkages are manual. Hence there is a need for another person to help lower or raise the chair.

Due to this disadvantage and the need to introduce finish to the product, electrical system was developed.

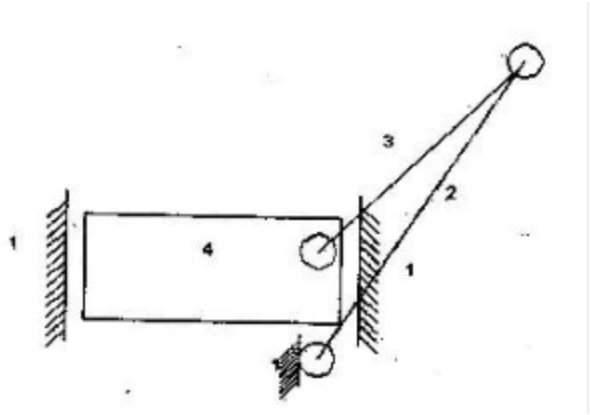


Fig. 4: Reclining and foot raising Mechanism (Wheelchair Cum Stretcher, an innovative product for small hospitals)

B. Servo Motors

Due to the limitations of purely mechanical system, electrical devices were introduced into the wheelchair to make the conversion.

Servo motors or step motors move in steps of certain angles. Therefore these motors were used to give input to the mechanical linkages. Servo motors work on electricity; hence they required an external source or a battery to operate. This adds additional weight to the already loaded wheelchair; in process making it heavy and difficult to power using hand force.

As the minimum angle provided on the servo motors can't be below 6o, complementary jerks are noticed in the system. These vibrations are unnecessary and cause discomfort to the patient.

Hence to eliminate the limitations of both Mechanical and electrical chairs, we have decided to implemented hydraulics to translate the chair into bed or visa-versa.

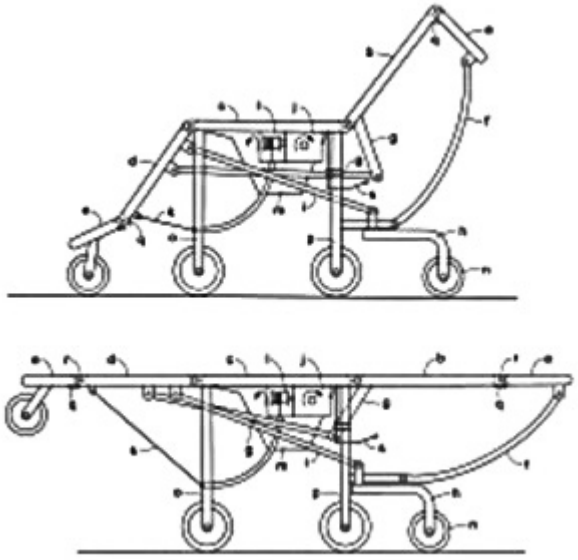


Fig. 5: Servo Motor Mechanism (Design and development of Conceptual Wheelchair cum Stretcher)

C. Hydraulics

There are two basic ways to implement hydraulics into the system. Firstly, we could use hydraulics as an input to the mechanical linkages. Alternatively, we could use only hydraulics to transform the chair.

Unlike in previous mechanisms, in hydraulics, the entire control is with the user itself. Also unlike them, this system can also be used to stop the reclining process in midway and hence multiple positions can be attained.

Also there is no need to provide entire system on the chair itself, the kit could be provided at a designated spot where it could be converted from chair to bed. The reverse conversion can be achieved by simply draining the pressurised fluids in the hoses into the accumulator provided on the chair.

Hence by using hydraulics, one can achieve multiple reclining positions, jerk free motion, patient is in entire control of his/her chair transformation and lightweight robust system.

IV. MATERIAL SELECTION

Selection of material was based on maximum loading condition and market research based on cost and ease of availability. Following materials were found most applicable for appropriate parts of the chair.

A. Frame

Frame is an important mechanical component of any structure. It determines the strength, stiffness, rigidity and the weight of the structure. Now the frame of a chair is very basic and easy, so is the frame of a bed. But the challenge is to merge these two frames into one frame.

Load on a wheelchair is distributed quite evenly; hence simple steel alloy, carbon fibre, airplane grade aluminium or titanium body can be used. We have decided to go with steel frame as it is cheaper than Carbon Fibre, and serves the strength requirements necessary for our chair/bed.

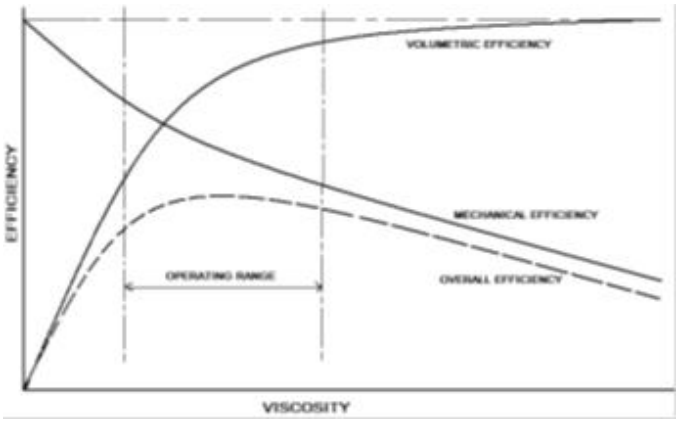
B. Cushioning

Our wheelchair must be comfortable as well as cheap to use. Hence, we have decided to go with simple cotton cushioning and cotton covers. The cushioning will be divided into four parts connected to each other by a tensioned cotton cloth so that while in sleeping position the patient won't feel the joints in these different parts. To further improve comfort levels, different variants of cotton can be used with costlier models of the chair.

C. Hydraulic Fluid

Hydraulic fluid is one of the most important components of any hydraulic system. It determines the efficiency and smoothness of the system. Certain hydraulic properties to consider while selecting a fluid are:

a) **Density**: The mass occupied per unit volume of the fluid.
b) **Viscosity:** This is the most important criteria. Viscosity is the measure of resistance of fluid flow. Highly viscous fluid may decrease efficiency; low viscosity may not attain required pressure.
c) **Lubrication:** The fluid must be self lubricating and must not need external agents to improve its lubrication properties.
d) **Environmental effects:** The fluid must not be toxic and should not release dangerous fumes at high temperature/pressure.
e) **Flame point:** fluid bust not be flammable and hence must have a high flame point.
f) **Cost**: The fluid must not be costly and must satisfy all the necessary properties.



Graph 1: Efficiency v/s Viscosity (Hydraulic Fluid Properties and its influence on system performance)

The above graph shows the relationship between the viscosity of fluid and efficiency of the system.

Fluid can only be selected after every calculation and considerations are done.

D. Hoses

Hose is a long cylindrical tube designed to carry pressurised fluid or power from one place to another. They are generally made of polyethylene, PVC or synthetic/natural rubber reinforced with metal wires to strengthen it.

Common consideration parameters are wall thickness, diameter and length. Hoses selected must also be such that they do not cause any leakages which affect the environment. Too lengthy hose can cause pressure drop across its length. The pressure drop is given by:

$$\Delta p_f = \lambda \frac{l}{d} \frac{\rho \cdot v^2}{2}$$

Where; λ is friction factor
d is diameter
p is pressure at the start of the hose
v is volume flow per second

E. Actuators

Hydraulic actuators are used to convert the pressure carried by the fluid into mechanical output. Actuators are selected based upon the load to be lifted and the pressure of liquid supplied.

Considering the maximum weight a patient, the dead weight of our chair and also adding miscellaneous weight;

gives us the total load to be lifted. This mass is denoted by 'F'. Now if the pressurised fluid enters the cylinder and applies the pressure 'P' on the piston, the loading capacity can be given by:

$F=P*(A_c-A_r)$

A_c is the cross sectional area of the cylinder
A_r is the cross sectional area of rod

F. Kit

Hydraulic contains a motor, pump/compressor and a reservoir. These components won't be loaded on the chair as they would make it heavier. Hence a separate kit would be provided along with 4-5 chairs to operate them simultaneously.

Motor and pump selection must be made such that it provides constant supply of pressurised fluid with efficiency. Enough amount of fluid must be in the reservoir at all times to ensure efficient working. A filter would be added at the entry and exit of the reservoir, pump and motor to ensure no dirt is trapped in the system.

V. ADVANTAGES AND LIMITATIONS

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 visa-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.

2. Limitations

- Increases weight of the chair
- Increases the cost of the chair
- Possibility of fluid leakage

VI. CONCLUSION

In this paper we discuss the need for the wheelchair-bed system in current world. We also studied the different mechanisms that can be implemented. This paper also sheds light upon the material selection and the importance of selecting proper materials. Although these chairs may prove to be costlier than standard chairs available in market, they improve patient's safety and comfort levels. This paper also gives us the overview of the chairs available in the current market.

Table 1: Conclusion Table

Variants of Chair available	Drawbacks	How is our project overcoming them
Basic Wheel Chair	• Self powered • Hurts shoulders • Inefficient • Need to transfer from wheelchair to bed or visa-versa • Non comfortable cushioning	• Less effect on shoulder by using better bearings • Converts wheelchair into bed • Higher quality cushions
Electric Wheelchair	• Works on electricity, needs continuous supply • Bulky • Costly • Need of external help to transfer from bed to wheelchair or visa-versa	• Less bulky, intricate parts • Medium cost • No need of external help
Wheelchair cum stretcher	• Raw mechanism • Works on external pressure/force applied by human • Needs a person other than patient to operate it • Low on space	• Hydraulics adds smoothness to movement • Patient can help himself • Enough space to be able to move

ACKNOWLEDGMENT

It is our privilege to acknowledge with deep sense of gratitude to our Project guide, Prof. S.V. Karankoti for their valuable suggestions and guidance throughout our course of study and timely help given to us in the completion of Project.

We're highly obliged to Dr. V.V. Shinde, Head of Department, Dr. M. S. Gaikwad, Principal, Sinhagad Institute of Technology, and entire staff of Mechanical Engineering department for their kind cooperation and help. We also take this opportunity to thank our colleagues who backed our interest by giving suggestions and all possible help.

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