

Design and Fabrication of Pneumatically Powered Wheel Chair-Stretcher Device

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ABSTRACT: Mobility aids are useful for disabled patients for transportation and a replacement for walking especially in indoor and outdoor environment. Wheelchairs and stretchers are the most commonly used medical equipment for the transportation of patients. Transferring the patients from wheelchair to stretcher or to the medical bed is always an issue for the patients and for the attendants/ nurses as well. This may even result in musculoskeletal disorders to those who are not trained to do so especially, when it comes to the caretakers. So there is a need for a wheelchair cum stretcher to facilitate the disabled patient's mobility and to provide novel medical equipment for use in the Indian hospitals.

Understanding the various issues regarding the mobility equipment and introducing a better design will be an asset for the medical field and a helping hand for disabled individuals. This paper presents the design and fabrication of pneumatically powered stretcher-chair convertible device with movable support segments in an attempt to help such patients and caregivers. 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.

KEYWORDS: Mobility Aid, Wheel chair, Stretcher, Design and Analysis.

I. INTRODUCTION

A mobility aid is a device designed to assist walking or otherwise improve the mobility of people with mobility impairment. Engineering sciences have come up with numerous aids for the patients. Out of these, mechanical aids for physically impaired, especially for immobile patients are a major class. Assistive technology for the mobility of impaired includes the wheelchair, lift aids and other devices, all of which have been around for centuries.

There are various walking aids which can help with impaired ability to walk and wheelchairs or mobility scooters for more severe disability or longer journeys which would otherwise be undertaken on foot. For people who are blind or visually impaired the white cane and guide dog have a long history of use. Other aids can help with mobility or transfer within a building or where there are changes of level.

Traditionally the phrase "mobility aid" has applied mainly to low technology mechanical devices. The term also appears in government documents, for example dealing with tax concessions of various kinds. It refers to those devices whose use enables a freedom of movement similar to that of unassisted walking or standing up from a chair. Technical advances can be expected to increase the scope of these devices considerably, for example by use of sensors and audio or tactile feedback.

In this age of nuclear families, the smaller number of available caregivers for paralyzed patients is a major problem. The shifting of such patients to a wheelchair is a delicate process and in most of the instances, two or more caregivers are required. Paralysis patients are highly dependent on their caregivers. Today, number of available caregivers per patient is showing a decreasing trend. The transfer of these immobile patients from bed to a wheel chair is a delicate process and in most of the instances, two or more caregivers are required. However, it is estimated that 1 in 3 nurses or caregivers will develop back injuries. Most injuries occur because the patient is relatively heavy to lift and access to

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

them is difficult when attempting to place the patient onto another seat. This poses a need for improving the available support devices to ease the effort of available caregivers. Besides this, the inconvenience to the patient during the transfer procedure also needs to be addressed. The transfer procedure gets harder with increase in the patient weight and with the degree of immobility.

This paper addresses the above issue by presenting a new type of mobility aid, which is Stretcher to wheel chair convertible device. The wheel chair can be converted to a stretcher whenever necessary with patient onboard. The transformation is very smooth and can be made possible just with a press of a button. This is made possible using a pneumatic system, which is first of its kind. Hydraulic based systems are already available in the market. However, due to its higher cost, complexity and maintenance requirements makes its usability sacrificed. The reason why the pneumatic system was not used in this system was its jerking behavior since air used in pneumatic system is compressible when compared to liquids

This drawback is overcome using a shock absorber system, which make the working smoother. So by making this system pneumatic, all the disadvantages of hydraulic based system is nullified and can make the system more user-friendly.

II. LITERATURE REVIEW

2.1 Patents Referred

A convertible bed and wheelchair unit was patented by Shaffer (1988). It comprised of a wheeled structure which was readily convertible between a full-sized single bed and a wheelchair. However this conversion proved to be difficult when a patient occupied the device.

Weiss (1997) invented wheelchair and bed with movable body supporting portions. This was a wheel chair/bed for paralyzed invalids comprise a support on which the invalid rests, the support comprising a plurality of support segments which define a support surface. The support segments can be moved simultaneously and act as a pressure relieving mechanism.

2.2 Selection of Wheelchair

According to Axelson et al. (1994), selection of an appropriate wheelchair will lead a comfortable living to the user. Performance, safety and dimensions are the three categories which have to be considered while selecting a manual or powered wheelchair. An excellent approach to the wheelchair selection is to set priorities based on user's mobility and seating needs. It is highly recommended that a novice can consult with their habilitation specialists in order to select the appropriate wheelchair.

2.3 Caster Wheel Shimmy

Kauzlarich (2000) says self-excited vibration is one of the most interesting topics in the field of vibrations and is the science prevailing caster wheel shimmy. Self-excited vibration is characterized by vibration that is produced by the motion of the system like wheelchair speed. It can be observed that in most of the cheapest wheelchairs, the design of the casters makes use of a sliding frictional damper in the spindle support to improve the shimmy characteristics. Understanding the theory of damping for the casters show how shimmy prevention works in ultra-light and powered wheelchairs.

2.4 Smart Power Assisted Wheelchair

Simpson (2002) says almost 10% of all individual who are legally blind also have a mobility impairment and majority of these individuals are dependent on others mobility. A Smart Power Assistance Module (SPAM) for manual wheelchair is being developed to provide independent mobility for this population. The power assist wheelchair that provides for obstacle detection and avoidance for those with visual impairments. The control of the wheelchair will be carried out by the microprocessor and also allow the SPAM to provide a smoother and nuanced control.

2.5 Wheelchair Configuration

Cooper (1998), rehabilitation is a humanistic profession. Measurement of the user and wheelchair are critical to achieving maximum functional mobility. He says Biomechanics and ergonomics provide the information necessary to understand many aspects of wheelchair use. These factors affect seating comfort and posture, propulsion, efficiency

and pain. Proper seating is an important aspect of wheelchair selection, and wheelchair cushions provide pressure relief and some postural support. Electric powered mobility may be the best choice for driving long distance and may be beneficial for people with upper and lower extremity impairments.

2.6 Patients Transfer System

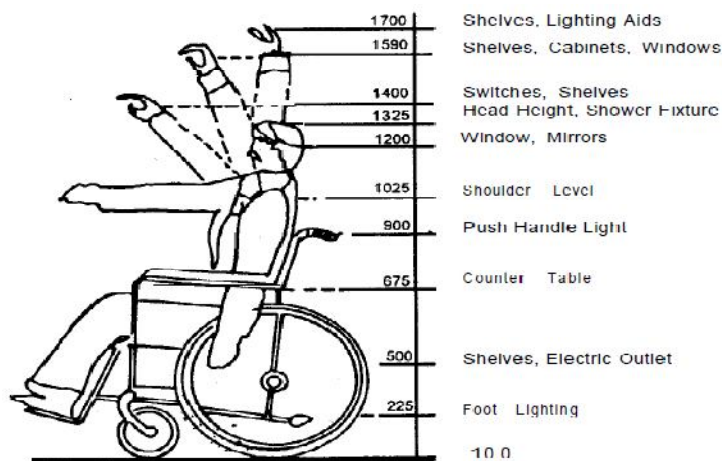
Jolly (2010) says proper preparation should be taken before transferring the patient from wheelchair to bed or vice versa. Use of sliding boards will be helpful for paraplegic patients. The best sliding board is made of hard wood, smooth, tapered on ends. Support of two assistance, support straps, belts etc will facilitate easy transfer. The patient should not be slide into chair, lift from the wheelchair and transfer is the optional and safety method for patient transfer.

2.7 Mechanical Principles for Wheelchair Design

Winter (2010) says following the mechanical principles will be helpful for a better design. Understanding the center of gravity location is important in wheelchair design. Weight should be the other important factor for wheelchair design. Reducing weight will result the comfortable use for the user and also lowers material cost. The best strategy is to maximize the strength and minimize the weight of the frame tubing. Calculating the moment of inertia and weight results the best strength and can be used to make the strongest frame at the least weight.

2.8 Anthropometric Consideration

Chakrabarti (1999) says primary consideration should be given for comfort, so that people can sit for long time without feeling any physical discomfort. Considering the suitable materials for seat surface, frame and can make a comfortable seating for the design. Without considering the ergonomics and application can make a diverse effect to the user. Seat cushions are so important in the design of wheelchair. A wheelchair or stretcher design without cushion is not recommended for the hospital purposes. A stretcher or wheelchair design without cushion may create spinal cord injuries to the patients.



Typical Dimensions for Essential uses within easy reach

Fig.2.1: Anthropometric data of wheelchair user related uses within easy reach
(Source: www.socialjustice.nic.in)

This figure shows the ergonomic details of a person sitting in a wheelchair and based on wheelchair ergonomics and posture analysis, the optimum angle between upper body and thigh region while sitting is 100-110° angle at the knee joint (between thighs and lower legs) is 105- 110°.

III.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.

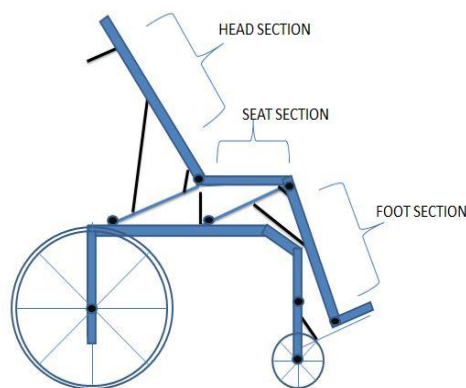


Fig.3.1: Preliminary sketch of the device in wheelchair position

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. Though hydraulic actuators are the best in terms of load handling and stability, the relatively high cost and the bulkiness of the units hindered their choice for our purpose. Electric motors have good load carrying capacity, speed control characteristics, precision etc. But their implementation necessitates the use of gears, belts or pulleys making the over unit becomes bulky and heavy.

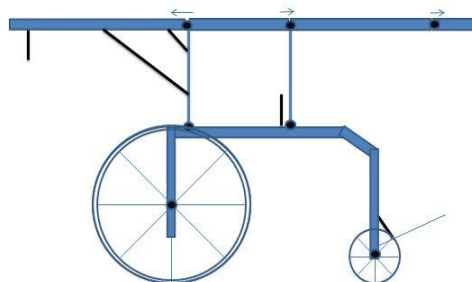


Fig.3.2: Preliminary sketch of the device in stretcher position

So pneumatic power where selected. The compressed air supply could be some distance away from the device. Pneumatic actuators provide high force and speed at low unit cost in a small footprint. The next phase of design was the choice of pneumatic cylinder specifications and the actuating mechanism as well as the link manipulation. After considering various space and convenience factors, inverted-slider crank mechanism was selected for pneumatic cylinders 1 & 2. Further the 2D design view was drawn using AutoCAD 2010 and 3D design view was drawn using 3ds max 2014, detailed examination of link dimensions, cylinder-link configurations, stress and strain analysis was done using ANSYS software version 14.5. Once the design of links is safe and fixed, similar trial and error procedure was repeated for various cylinder pressure, piston force and link configurations, incorporating the load/

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

the patient weight on the device. Since the design and fabrication of a prototype was intended, a maximum patient weight of 100 kg was set. The patient's body weight supported by each section of the device was estimated as per the percentage body weight distribution suggested in the book, Human Body Dynamics: Classical Mechanics and Human Movement by Aydin Tozeren. Also, based on wheelchair ergonomics and posture analysis, the optimum angle between upper body and thigh region while sitting is 100-110° angle at the knee joint (between thighs and lower legs) is 105- 110°.

3.1 Final Design and Solid Modeling

The 2D view of the device was designed using AutoCAD 2010 software. The dimensions were specific and appropriate and following views were obtained.

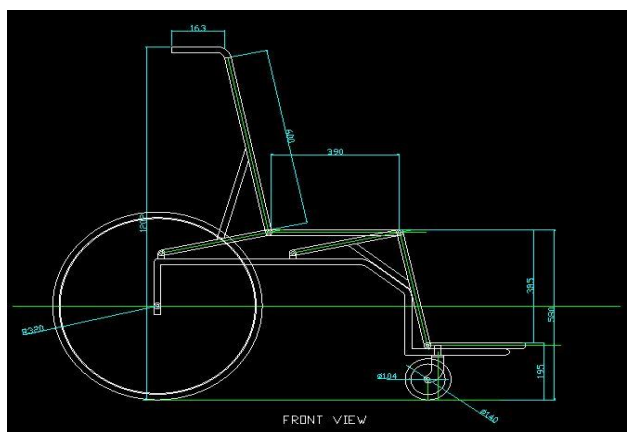


Fig.3.3: Front view of the device

This figure 3.3 shows the side view of the device in 2D. The head section is 600mm, seat section is 390mm and foot section is 395mm. The distance from head section to the ground is 1202mm and the distance from the foot section to the ground is 195mm. The front wheel is of diameter 140mm and the rear wheel is of diameter 320mm. The 3D view of the device was designed using 3ds max 2014. In the 3D section, the pneumatic cylinders are shown. The following views were obtained:



Fig.3.4: 3D view of the device in wheelchair position

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

The figure 3.4 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.



Fig.3.5: 3D view of the device in stretcher position

The figure 3.5 shows the 3D view of the device in stretcher position in which the two piston cylinders attached to the base frame are shown. The two piston cylinders are in outward stroke, while the device is in stretcher position

3.2 Bill of Materials

TABLE 3.1 Bill of Materials

Sl.No	Item	Qty	Specification	Material
1	Round pipe	12m	3/4inch	MS
2	Square pipe	18m	3/4inch	MS
3	Flat sheet	14Sqft	16gauge	GI
4	Nut and bolt	12	8mm	MS
5	Front wheel	2	200mm dia, 360 ⁰ rotation	SS
6	Rear wheel	2	800mm dia	SS
7	Battery	1	12V DC ,80Ah	
8	Hinged arms	4		
9	Hinged pins	4		
10	Balancing Springs	2		
11	Lead Screw with Nut	1		
12	Lead Screw Handle	1		
13	Steel rod	3	1m	MS

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

14	Air reservoir	1	20Litres	MS
15	Rear hatch lift support	1		
16	Hydraulic Shock Absorber	1	8 inch stroke length	60si2MnA spring steel
17	Air flow control valve	2	6 mm dia	
18	Male valve	4	6mm and 8mm dia	
19	Female valve	4	6mm and 8mm dia	
20	Split valve	2	6 mm dia	
21	Air compressor	1	12V DC,300psi	
22	Pneumatic Pipe	1	3m	Polyurethane

The table 3.1 shows the bill of materials that was used for the fabrication of the device. We mainly faced a high cost on fabricating the body frame as it consists of purchasing mild steel round and square rods, galvanized iron flat sheets. Although the labor charge for welding is high, we made efforts to reduce additional cost charges in welding as we ourselves did the welding work. Most of the components were purchased from shops and body building workshops.

TABLE 3.2 Specification of Pneumatic Cylinders

Pneumatic Cylinder	Make	Bore	Stroke	Pressure Range	No. s
1	Camozzi	32mm	300 mm	1-10 bar	2

The power for the stretcher-chair conversion is pneumatic, as mentioned in the by pneumatic cylinders. Double acting cylinders of two different specifications have been used depending on the load and orientation they are subjected to. The two cylinders are labeled as cylinder-1 and cylinder-2. Both the cylinders are fixed parallel to each other and simultaneously power the stretcher chair conversion of the head section.

TABLE 3.3 Specification of Solinoid Valve

SI No	Manufacturer	Electrical Specifications
1	Akari	12 V DC, 4.8 VA

The solenoid valves control the timing of cylinder activation by regulating the flow of compressed air into the cylinders. The solenoid valves used are 5/2, i.e. 5 ports and 2 switching positions. Pneumatic tubes convey the compressed air from a storage tank to the pneumatic cylinders which actuate all the movements in the fabricated device.

3.3 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 software version14.5. A total load of 2000N was uniformly applied on 4 nodes A, B, C and D respectively.

Following are the analysis result of the mesh independent study carried out

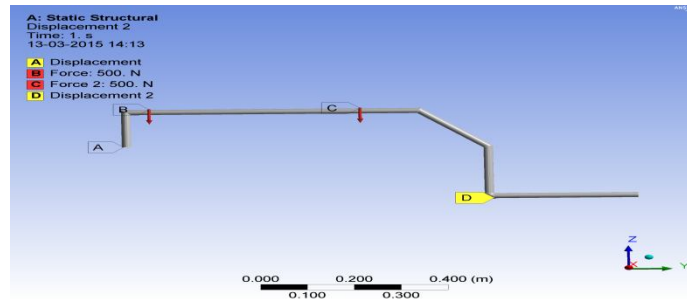


Fig.3.6: Displacement Analysis result

The force applied on nodes B and C were 500N each and the nodes A and D has rotary displacement respectively. The base frame has 4 hinged pins. The whole load is acted on the hinged pins of base frame so that each hinged pin will carry a load of 500N respectively.

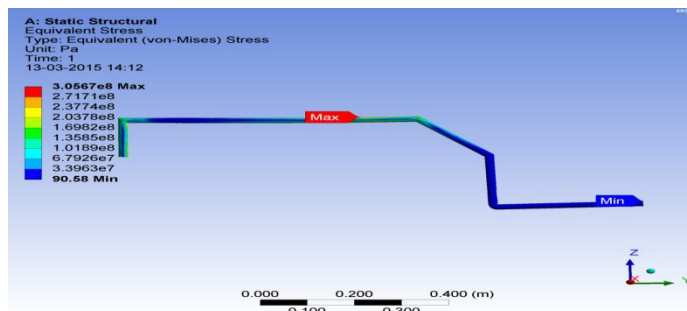


Fig.3.7: Equivalent Von- Mises Stress Analysis result

According to Von-Mises theory, Equivalent Stress analysis was done and the result obtained was that the maximum equivalent stress is experienced at the third hinged pin. Other than this, Maximum shear stress and strain energy analysis is also carried out, in order to make sure that the design is safe and the result obtained was satisfactory.

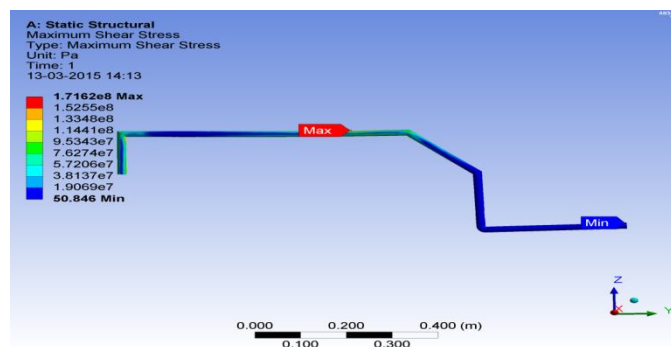


Fig 3.8 Maximum Shear Stress Analysis Result

As the Maximum Shear Stress is analyzed on four hinged pins of the base frame, the result obtained was that the maximum shear stress is experienced at the hinged point C with a value of 1.7162e8Pa and minimum shear stress at D with a value of 50.846Pa and both values are within the safe limit as shown in Figure 3.8.

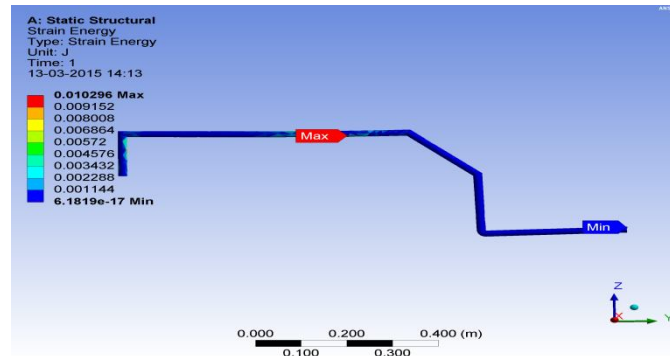


Fig 3.9 Strain Energy analysis Report

In the case of Strain Energy Analysis, it was found that maximum strain energy was experienced at point C with a value of 0.010296 Joules whereas minimum strain energy was experienced beyond point D with a value of 6.1819e-17 Joules as shown in Figure 3.9. Both the values obtained are within the safe limit.

From the above results, on the basis of Distortion Energy Theory and Von-Mises criteria, it was proved that the design is safe. As per the analysis result, the device could carry a load of 100kg.

IV. FABRICATION

The entire fabrication of the device has been done around a basic framework. The framework has been made by welding together mild steel pipes of square and rectangular cross sections, using Metal Arc Welding and Arc Welding Electrodes (3.15mm x 350, 100-140 AMPS, DC(+/-)/AC OCV 50(min)). The relative low cost, availability and properties like decent tensile, compressive strengths and weld-ability favored the choice of mild steel over other metals. The frame has three main sections, namely the head, seat and foot sections. The framework along with the support surfaces bears the patients weight. The seat section forms the basis as far as the assembling is concerned.

The head section and foot section are hinged to the seat section. The movable support segments are anchored in the seat and head sections. The movable segments are then given a cushion each. Also the head section is given a pillow type cushion. Arm rests are attached on either sides of seat section such that they can be swung sideways with the seat edge as the pivot. The leg of the fabricated prototype is integral to the seat section. The angular orientations of the legs are so as to provide the best balance. Each leg terminates into a flange on which a wheel is attached.

Rear wheels of 800mm diameter and front wheels of 200mm diameter have been used here. The wheels provide the mobility to the device both in the stretcher and chair position. Each wheel has the ability to facilitate steering and front wheels could facilitate 360 degree rotation of the device.

The total cost of the system is exactly 13, 614 INR. Which is comparatively less when compared to other similar products in the industry which make use of hydraulic drives instead of pneumatic drives.

V. TESTING

While testing the device, it encountered a problem of jerking while conversion from wheelchair to stretcher and vice versa. Also the process of conversion was not smooth working. In order to avoid the shock and jerking during the stretcher-chair conversion of the device, a hydraulic shock absorber was implemented in the device. With the help of this shock absorber, all the jerking and shock problem were solved. The shock damper uses SAE 60 lubricant oil for its functioning.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

Also a rear hatch lift support of a car has been implemented on the device for the smooth conversion processing of the device. It has enabled smooth working of the device especially when converting from stretcher to wheelchair. The figure 5.1 and 5.2 shows the image of the finally fabricated wheelchair-stretcher convertible device. The device in the figure is in wheelchair position where the two piston cylinders are in inward stroke and compression of pressurized air takes place inside the both piston cylinders. The air reservoir is visible in this image which is in blue color. The head section, seat section and foot section are equipped with cushions and armrests are attached to head section.



Fig.5.1: Image of the device in wheelchair position

The figure 5.1 shows the image of the finally fabricated wheelchair-stretcher convertible device in front view where the device is in wheelchair position. The highlights in this image are the head section, seat section and foot section which are equipped with cushions, footrests, armrests, rear wheel and front wheel.



Fig.5.2: Image of the device in stretcher position

The figure 5.2 shows the image of the finally fabricated wheelchair-stretcher convertible device in side view where the device is in stretcher position. The three sections viz. head section, seat section and foot sections forms a continuous mattress surface. The two piston cylinders are in outward stroke and expansion of pressurized air takes place inside the both piston cylinders.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

VI.CONCLUSION

A prototype of the pneumatically powered stretcher-chair device for a patient weight of 100kg was designed and fabricated. The chair to bed conversion feature of this device makes patient transfer easier. The use of simple shifting aids such as patient shifters can further optimize the patient transfer by avoiding heavy lifting situations and possible back injury to the caregivers. This device combines the concept of patient mobility, patient transfer as well as patient comfort. This enables the user to have two fold utility and satisfaction. Thus the spending of time for the patient to shift from a normal wheelchair to a separate stretcher or from a separate stretcher to wheelchair vice versa is reduced. The pneumatic components used herein have simple operation principles. Therefore, fault detections are simple. Also pneumatic system proves to be non-hazardous.

Software and techniques used in design of the device must be altered in accordance to the needs. For this study, several software packages were used independently to create and obtain an optimal wheelchair-stretcher convertible device design. The specific packages used include AutoCAD 2010, 3ds Max 2014 and ANSYS 14.5. Various stress and strain analysis was done and as per the result of analysis, the design was safe and implemented the fabrication of the device. The main objective of this product that is to eliminate the step of shifting patient from bed or stretcher to wheelchair and vice versa especially in the case of paralyzed patients was successfully attained. It reduces the effort of the caregivers and makes sure that the patient is not hurt during the process of conversion. It is possible to save 50% space by the wheelchair-stretcher device. The product will thus likely be an efficient mobility aid in hospitals.

REFERENCES

- [1] Shaffer W. G., "Convertible bed and wheelchair", *US Patent Number: 4,717,169*, 1988.
- [2] Weiss N., "Wheelchair and bed with movable body supporting portions", *US 3 Patent Number:5,659, 910*, 1997.
- [3] Axelson P., "A guide to wheelchairselection", paralyzed veterans of America, Library of Congress Cataloguing-in-publication data, Washington 1994.
- [4] Kauzlarich J.J., "Wheelchair caster shimmyII: Damping", *Journal of Rehabilitation Research and Development* Volume. 3, May/June 2000,, pp 305-313.
- [5] Cooper R, Corfman T, Fitzgerald S, Boninger M, Spaeth D, Ammer W, Arva J., "Performance Assessment of a Pushrim Activated Power Assisted Wheelchair", *IEEE Trans Control Sys Tech*, Volume 10, ISSN:1063-6536, Jan 2002.
- [6] Cooper R., "Wheelchair selection and configuration", ISBN 1-888799-18-8, March 1998.
- [7] Jolly D., "Wheelchair transfer", The Ohio state university college, Columbus, Ohio, retrieved on 24th Sept. 2010.
- [8] Winter A., "Mechanical principle of wheelchair design", Graduate Student, Department of Mechanical Engineering, Massachusetts Institute of Technology, US, retrieved on 24th Sept. 2010.
- [9] Chakrabarti D., "Indian Anthropometric Dimensions for Ergonomic Design Practice", National Institute of Design, Ahmedabad, 1999

BIOGRAPHY



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International Journal of Innovative Research in Science, Engineering and Technology

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