AUTOMATED NURSING BED

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelor of Mechanical Engineering

by

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June 2020

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ABSTRACT

A large number of people in Pakistan are bedridden because of certain diseases like Paralysis, Ulcer and orthopedic disorders etc. and many are bedridden because of certain injuries via accidents, vehicle accidents etc. About 5% of the population of Pakistan are paralyzed (partial and complete) and hence are restricted to move their bodies[1]. Most of these bedridden patients need assistances continuously via relatives, friends, caretakers, nurses or doctors. According to a survey[2], the number of hospitals in Pakistan were 1167, number of beds in those hospitals were 118869, and if we calculate so, the number of persons per bed are estimated to be as 1613. According to another survey[3] from 2018, for the care of patients in Pakistan, there are a total of 108,474 nurses registered in Pakistan which is very less considering the number of patients in Pakistan.

If we somehow reduce the dependency of bedridden patients on the caretakers or reduce the efforts of caretakers in managing the health of such bedridden patients, it would not only benefit the patients but will also stabilize the infrastructure of health in Pakistan. To solve such problems Nursing Beds are made. Hospital Nursing Beds are usually manufactured for disabled, Ulcer and paralyzed patients for the physical movements of their body parts. In addition to basic movements like lifting the head up and down and tilting the body right and left, it provides sanitary features as well. It would also be convertible to wheelchair. It does not only have medical significance but also reduces the effort of caretakers. Almost all these types of beds are imported in Pakistan from China, America, Japan, Sweden and Germany which makes it much expensive and a burden on our suffering economy. Manufacturing these hospital beds within Pakistan will not only reduce its cost but also strengthen our economy and have a promising future in the Commercial Market.

ACKNOWLEDGMENTS

We appreciatively acknowledge the valuable support and guidance of our supervisor and guide, Dr. Rehan Zahid throughout our project. He motivated and encouraged us for completing every level of the project timely with perfection.

We appreciate Hamza Asif Nizami for his guidance towards helping us frame the mechanisms in achieving the actuations as per the requirements of the deliverables of our project.

We also acknowledge Dr. Najam ul Qadir for his supervision all along in the material selection as per the requirements of the bed.

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Date: June 15, 2020

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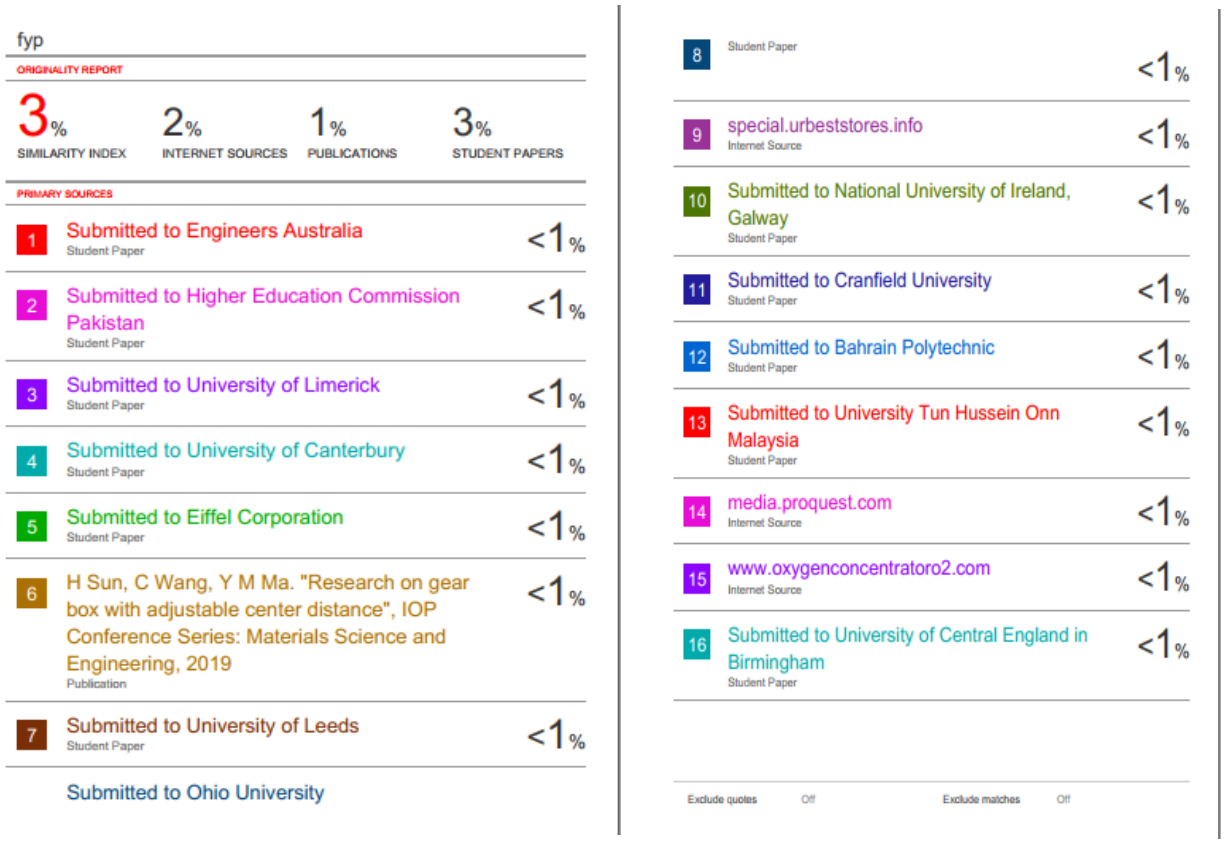

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NOMENCLATURE

m_B	Mass of Human Body
m_H	Mass of Backrest
m_L	Mass of Leg rest
m_M	Mass of Middle Part
m_S	Mass of Sanitation Pot
T_{BR}	Torque on Backrest
m_P	Mass of Opening Plate
T_{LR}	Torque on Leg rest
F_{BR}	Force on Backrest
F_{LR}	Force on Leg rest
F_P	Force on Opening Plate
F_S	Force on Sanitation Pot
W_P	Weight of Opening Plate
W_S	Weight of Sanitation Pot
W_W	Weight of Wheel
W_{leg}	Weight of Leg
R_W	Radius of Wheel

T_W	Torque on Wheel
L_{leg}	Length of Leg
P	Power
E	Modulus of Elasticity
k	Effective Length Factor
F	Force
s	Distance
ω	Angular Velocity
v	Linear Velocity
N	Number of Revolutions

CHAPTER 1: INTRODUCTION

Motivation of Work:

Pakistan was not able to meet its MDGs i.e. Millennium Development Goals on the healthiness and "ranks as 149 in the total of 188 countries in the worldwide evaluation of countries' progress towards the United Nations health-related SGDS (Sustainable Development Goals)."[4]

The population of Pakistan is estimated as 200 million by 2019. According to a survey or a research conducted in 2015[2], the population of Pakistan was 191.71 million and for this population, there were 1167 hospitals, 5695 dispensaries, 5464 sub health centers, 733 child health centers and maternities, 675 health centers for rural areas, 339 Tuberculosis centers, a total of 118869 beds and if we calculate so, the number of persons per bed are estimated to be as 1613. Also, the population growth of Pakistan was increased by 37% over the last 15 years while the number of hospitals increased by 33% which demonstrated that there was insufficiency in the infrastructure of health in Pakistan. According to another survey from 2018[3], for the care of patients in Pakistan, there are a total of 108,474 nurses registered in Pakistan. About 4.2% of population in Pakistan is older than 65 years of age and the percentage is expected to reach 15.8% by the year 2050. A substantial number of those old people are bedridden due to old age health problems. On the other hand, a large number of people in Pakistan are also bedridden because of certain diseases like Paralysis, Ulcer and orthopedic diseases etc. and many are bedridden because of certain injuries like accidents, vehicle accidents etc. About 5% of the population of Pakistan are paralyzed (partial and complete) and hence are restricted to move their bodies. Most of these bedridden patients need assistances continuously via relatives, friends, caretakers, nurses or doctors. As described above about the insufficiency in the number of hospitals, nurses and beds in Pakistan, if we somehow reduce the dependency of bedridden patients on the caretakers or reduce the efforts of caretakers in managing the health of such bedridden

patients, it would not only benefit the patients but will also stabilize the infrastructure of health in Pakistan.

Problem Statement:

By reviewing above researches and conducting some surveys on our own, it motivated us in planning a way to enhance the quality of healthcare conditions in Pakistan and to rank Pakistan up in the worldwide evaluation of countries' progress towards the United Nations health-related SDGs (Sustainable Development Goals). The Healthcare quality could be enhanced by applying the short-term ways, which in our case was to reduce the efforts of nurses or caretakers to manage or care the bedridden patients. The dependency of bedridden patients on the caretakers or nurses could only be reduced by fabricating a bed having multiple features while for it having automation methods to make it work. This thought assisted us to make advance us towards introducing the problem statement for our final year project which is described as follows:

"To design and fabricate Automated Nursing Bed, for the bed-ridden patients, containing multiple features."

Various deliverables were taken into consideration while introducing the problem statement, and the probabilities or possibilities of those deliverables were also assessed and after the assessment of several deliverables, following deliverables were finalized:

- Inclination/Declination Mechanisms
- Sanitary Mechanism
- Convertible to Wheelchair
- Control of Wheelchair

Objectives:

Nursing care beds are generally fabricated for disabled, Ulcer and paralyzed patients for the physical movements of their body parts. In addition to basic movements like lifting the head up and down and tilting the body right and left, it provides sanitary features as well. It would also be convertible to wheelchair. It does not only have medical significance but also reduces the effort of caretakers. The objectives of our project were to design and fabricate such bed having the features as described earlier while taking the costs in consideration. Almost all these types of beds are imported in Pakistan from China, America, Japan, Sweden and Germany which makes it much expensive and also a burden on our suffering economy. Manufacturing these hospital beds within Pakistan will not only reduce its cost but also strengthen our economy and have a promising future in the Commercial Market.

In the regard of the objectives described above, a need to study different attempts on making the designs of such beds was felt. Some of the researches, published articles and patents for the designs of such beds are described below in the Literature Review.

CHAPTER 2: LITERATURE REVIEW

While planning on the bed requirements and the features it needed, various studies and researches, of attempts to fabricate such beds, were studied. Following are some of the works that has been done yet on this product:

Research on Publications:

Various studies, researches and published works are available in the field of the healthcare development for the bedridden patients. As we know that bed is the most integral part for the healthcare of bedridden patients, so the focus of our study was mainly concentrated on the design and features of beds so that the bedridden patients were managed by the caretaker with less efforts. Different researches have been made while considering the designs of such beds using different approaches. For the facilitation of patients, such approaches of bed designs were classified into three major categories:

1st Approach for the facilitation of patients:

This approach was to develop a bed or a wheelchair which had to be robotic i.e. the bed or the wheel had to be controlled by the bedridden patients themselves.

Lin Tan et. al Figure 1 presented this approach by giving a bed design. This bed was designed particularly for the patients having paralysis. The bed was designed such as it could raise the back of the patients, lift the legs of the patient up as well as down, and to tilt the bed right and left. The bed could also be operated on a voice recognition control system.[5]

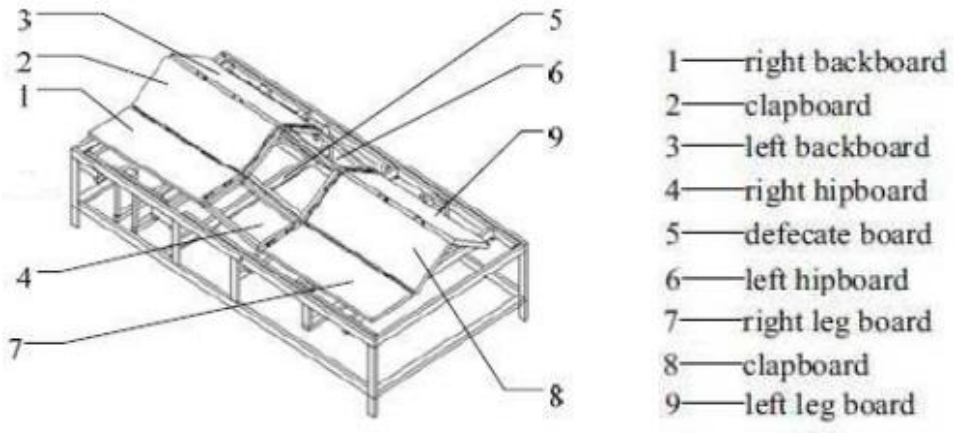

Figure 1 Bed Surface Structure[5]

Shih-Wei Peng, and Feng-Li Lian also presented a design Figure 2 based on the first approach. They gave a design of a test bed having mechatronic control system. The bed comprised of two bed. One was a main bed whose function was to change the position of the body. The other bed was the nursing bed which was designed for transporting the body. There was a belt system to attach both the beds together.[6]

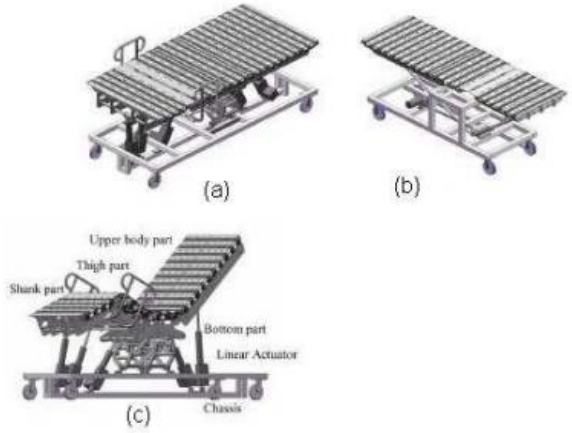

Figure 2 (a) Main Bed (b) Nursing Bed (c) Main Bed with its positions[6]

2nd Approach for the facilitation of patients:

The second approach was focused on the transportation of bedridden patients within the bed for positioning or to prevent the body from body sores.

Arin Basmajian et. al proposed the idea of Marionette bed. Marionette bed is a bed used for repositioning and rolling of the patients. A patient lying flat is demonstrated in Figure 3. The patient tilted via the mechanism of sheet is demonstrated in the Figure 3. The patient rolled the rotation of roller is demonstrated in the Figure 3. Horizontal transportation of the person is demonstrated in Figure 3.[7]

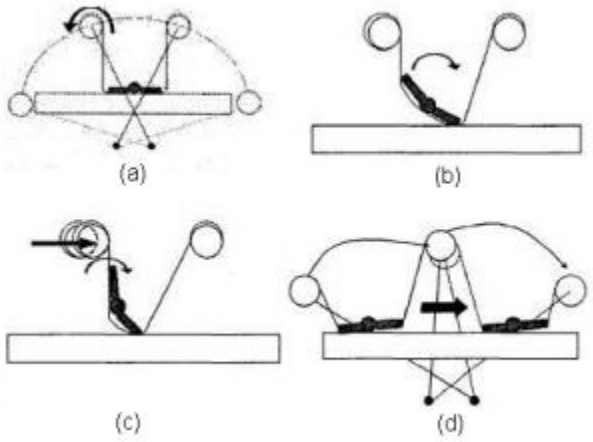

Figure 3 Marionette Bed[7]

3rd Approach for the facilitation of patients:

The main focus of this approach was the transportation of bedridden patients from the bed to the wheelchair and from the wheelchair to the bed too.

Hangbo Wang and Fumino Kasagami proposed designs for a moving system of bedridden patients for the transportation of the patients Figure 4 in the hospital. They believed that, by applying this design, the bedridden patients could easily be transferred from beds to stretchers and also from the stretchers to bed.[8]

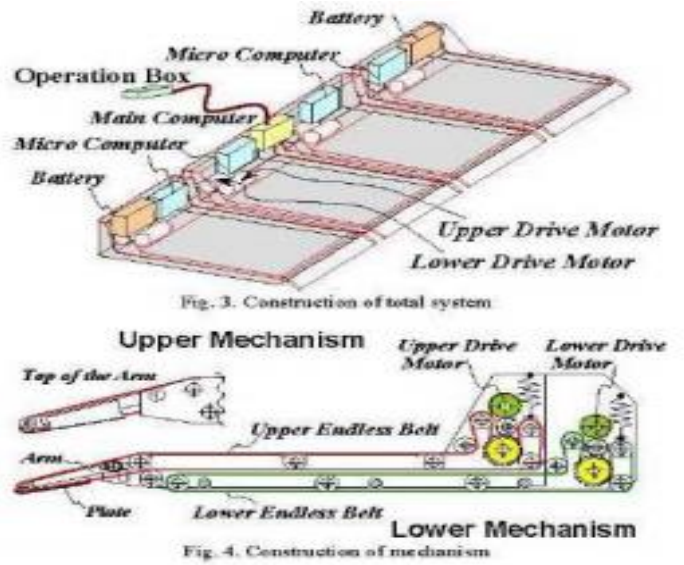

Figure 4 Mover system for transferring patients[8]

H. Asada and Joseph Spano utilized an actuation method distributed by surface waves Figure 5 for the transportation of patients. To design and develop such a feasible bed, several designs adjustments and various guidelines were discussed, based on the experiments and the prototypes.[9]

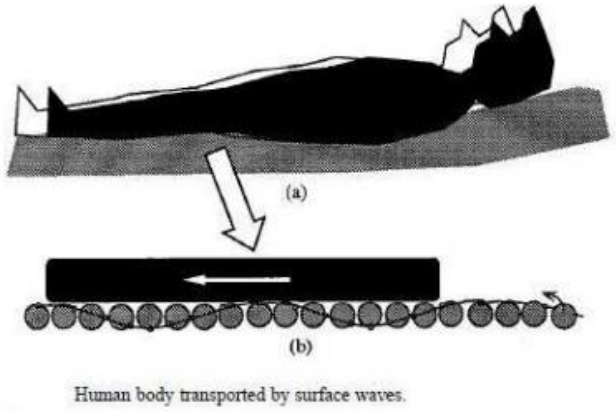

Figure 5 Surface wave distributed actuation method[9]

After reading the above researches and published articles, we could say that most of the beds were focused on the facilitation of the patients by developing an automated system to operate the beds or for the transportation of patients from bed to wheelchair and vice versa.

This increases the costs of the nursing beds and also the caretakers have to have a knowledge to use the control system of the beds.

Review of Patents:

Different patent works are also available in the field of the healthcare development for the bedridden patients. In this research our main focus was to develop a mechanism of sanitation i.e. to attach a toilet with the bed, so the focus of our study in this search was mainly concentrated on the design and features of toilet system (Pot System) so that the bedridden patients had to make less effort for using the toilet. Different researches have been made while considering the designs of such pots using different approaches. For the facilitation of patients, such approaches of pot designs were classified into the following categories:

1st Approach for Sanitation Facilities:

This approach was whirling around the idea of attaching a toilet pot to the bed when if required. Havens Thomas in a Patent No 5384920. Figure 6 gave the design of the bed. The bed consisted of a flat surface (2). The flat surface also had one end tapered (3). An opening for the toilet (4) is attached over the flat surface. The part of bed which is removable is fixed below the opening of toilet. At the corner (1), the toilet pot at end of the flat surface (5) is sustained via adjustable legs. There are also four support openings for the rail (6) on the flat surface (2). There is a back rail (7), scaled such that it fits into any of the pair of two contiguous rail support openings. Side folding rails (8) is formed by two tubes of the shape of 'L'. If the patient had to use to the toilet, the legs which are at the position of the corner (1) are extended, and then managed such as to move it to the bed's height and its position is then locked. By opening of handles (8), bedridden patients are placed over the toilet.[10]

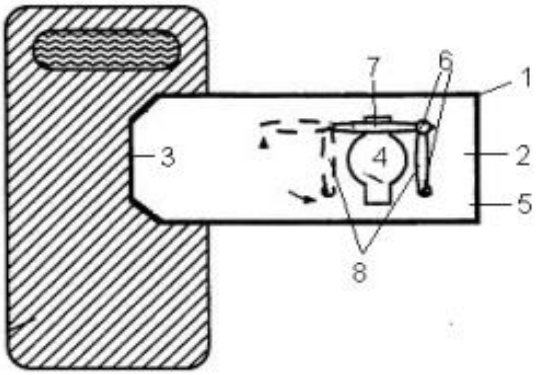

Figure 6 Toilet in bed for disabled patients[10]

2nd Approach for Sanitation facilities:

This approach was focused on making a hole in the bed's surface and on the mattress. The mattress is removed, and the pot is attached accordingly when required. Weronica Dry used this approach i.e. US Patent No 1589377 Figure 7. In this arrangement of bed, the bed has an opening which is covered with flaps (1). A pot (3) is placed in the cavity (2) which is below these flaps (1). Thi pot is attached with the bed using clamp (5) and the straps (4). This pot works as a commode for the patients when the flaps open.[11]

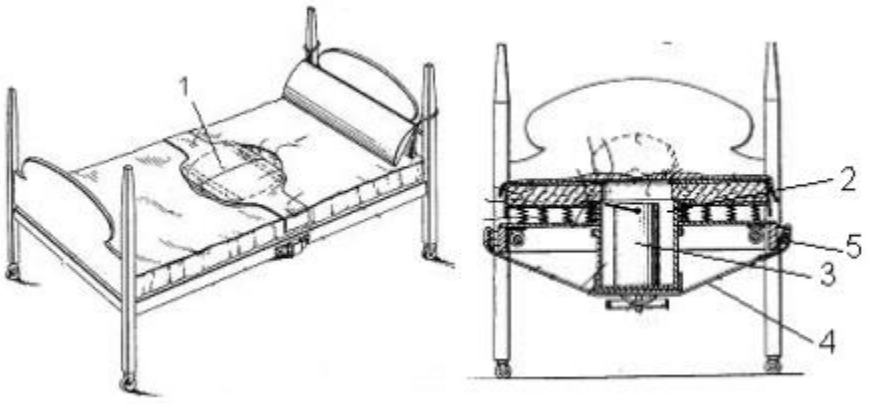

Figure 7 Hospital Caring Bed[11]

Violante Anthony had the Patent No. 4282613 in which he gave a design of the bed Figure 8. The bed had a pothole (1) in the bed's mattress (2). A piece of mattress (3) was also placed on it and was removed by moving the patient on a side. The pot (4) was attached below the hole and was removed after usage. The bed is given a chair posture by attaching the clips (5) with the hooks (6).[12]

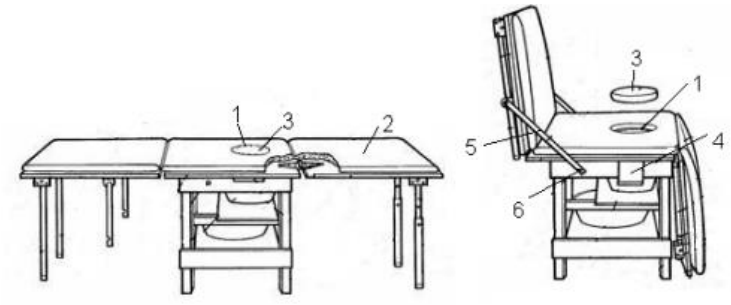

Figure 8 Bed cum chair[12]

3rd Approach for Sanitation Facilities:

This approach was focused on the transportation of the patient within the bed over the toilet. Di Matteo Paul in the patent no. 4023218 gave a design of the bed Figure 9 such that, the legs of the patient are first lifted via rotation of leg rest about the two pins (1, 2). While doing so, the seat (3) of the bed slides down and simultaneously the cover of commode (4) touches the buttock of the bedridden patient via rotating about the pin (5). The patient was placed on the toilet seat (7) by rotating the backrest of the bed about the pin (8) in the sitting position. The patient was fastened by belt (6) all along for his safety.[13]

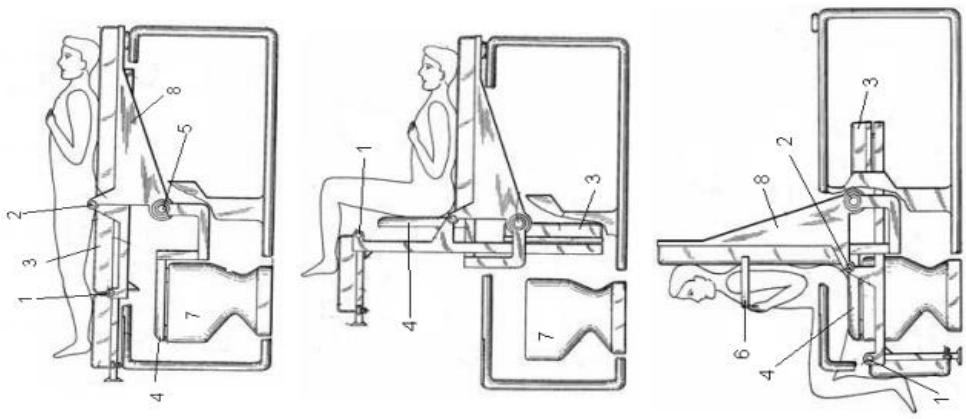

Figure 9 Arrangement of Bed[13]

4th Approach for Sanitation Facilities:

This approach was of the idea that a toilet is introduced in the bed by putting a pothole in upper surface of the bed as well as the mattress. The pothole is concealed via expandable cushions. When in use, the cushion contracts and then the commode which is placed underneath it is utilized for the purpose. Tokunaga Kenki et. al had the Patent No 5077845 Figure 10 proposed a design in which the bed system consisted of a toilet which is fixed (1). There are balloons (3) which cover the pot opening (2) over the toilet. In normal posture the balloons are inflated via the compressed air and they are deflated if to use the toilet, by removing the air from it and opening the pothole. The bed was also comprised of leg rest and back rest.[14]

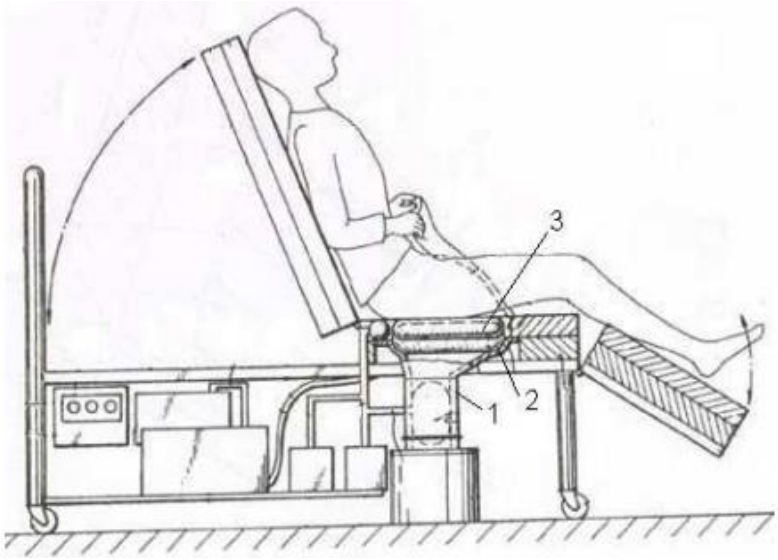

Figure 10 Convertible Bed having built-in commode[14]

5th Approach for Sanitation Facilities:

This approach proposed an idea in which there was a fixed toilet which was placed below a hole. The hole was made in the mattress as well as the upper surface of the bed. The toilet was available for usage when the hole opened. Rene Bucher had the Patent No 3965501 Figure 11 gave the following design arrangement. There is a toilet seat (3) which is ready for the usage and is placed beneath the mattress. The section of mattress (1) is shifted aside via a mechanism and is attached to the pins (2). There are cables available at the footrest which operates the mechanism to move the mattress.[15]

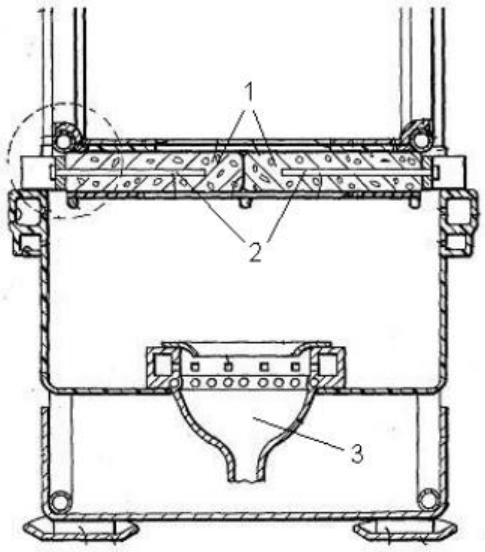

Figure 11 Bed for disabled persons[15]

6th Approach for Sanitation facilities:

This approach proposed an idea in which there was a movable toilet which was placed below a hole. The hole was made in the mattress as well as the upper surface of the bed. The toilet was available for usage when the hole opened. Fugett Mary had the Patent No 4631762 Figure 12. In the design of this hospital bed, the movement of the parts are carried out through geared mechanisms. The section of mattress (1), held by a part (2) are moved away via a gearing mechanism. There is another gearing mechanism (5) which lifts the toilet seat (4) upward. Both the gearing mechanisms are operated via powered motors.[16]

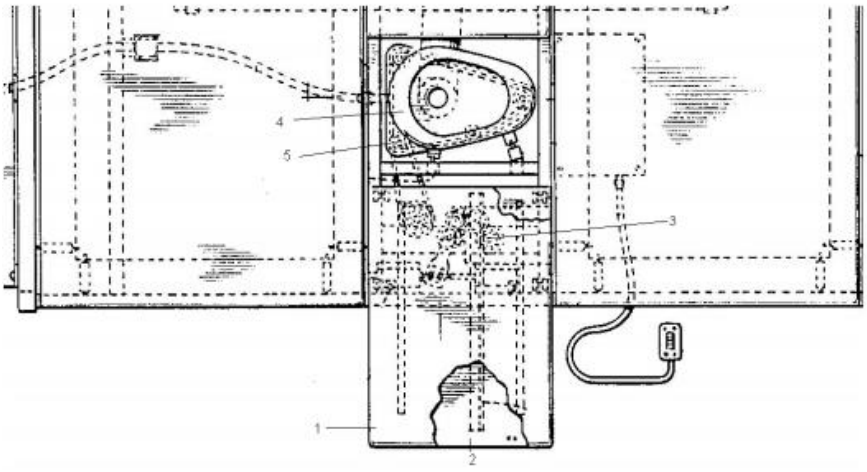

Figure 12 Bed having moveable toilet feature[16]

Yoshitaka Ishikawa also used such arrangement in US Patent No 3943583 Figure 13. The bed's inclination and declination movements work on the air bag mechanism. For a person to use commode, the air bag mechanism, as shown in the figure, lifts the backrest (1). The mattress (8) is then disconnected by sliding it over the guides (11) via the arrangement (9) using the blower (10) and air bags (7). The air bag (5) using its mechanism then pushes the linkages arrangement (3) via link (4) and hence commode (2) then gets to the place. When the person uses the toilet, the commode gets down via gravity as the air bag (5) deflates. The pothole (12) closes by the deflation of the air bag (7) and hence the mattress (8) gets to the normal posture via the vertical movement using the spring (6).[17]

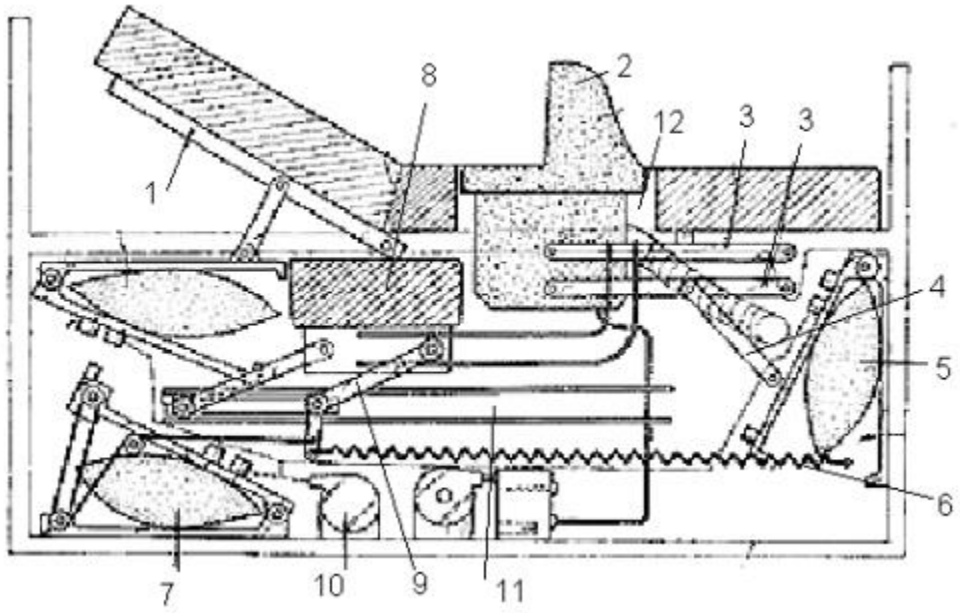

Figure 13 Bed for the bedridden people[17]

Sumiyo Kanai had the similar kind of arrangement i.e. US patent No 5513404 Figure 14. The bed consists of a vertical commode system (1). In this arrangement, the mattress (2) is attached on the toilet. The commode gets up to the position via an air compression as shown in the mechanism while the material is detached by the suction process.[18]

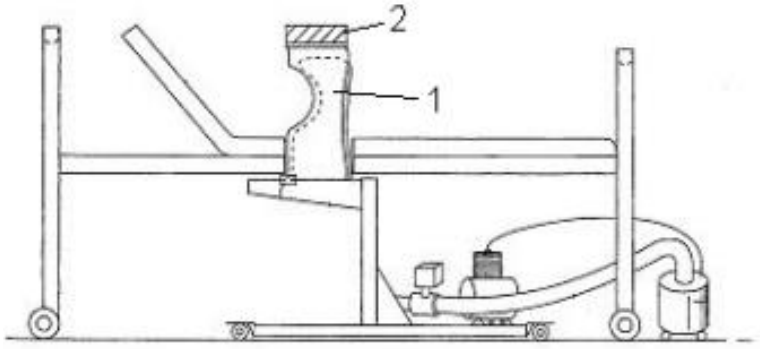

Figure 14 Vertical toilet combined with the bed for sick patients[18]

Kiyoshi Okamoto and Hironobu Nakayama also used this approach for their design i.e. US patent No 5926875 Figure 15. In this arrangement, they used a shutter (2), which rolls horizontally, to cover the toilet (1). The mechanism works in a manner that a component (3), which covers the commode, lifts on the hinges (4) up to the buttocks of the person.[19]

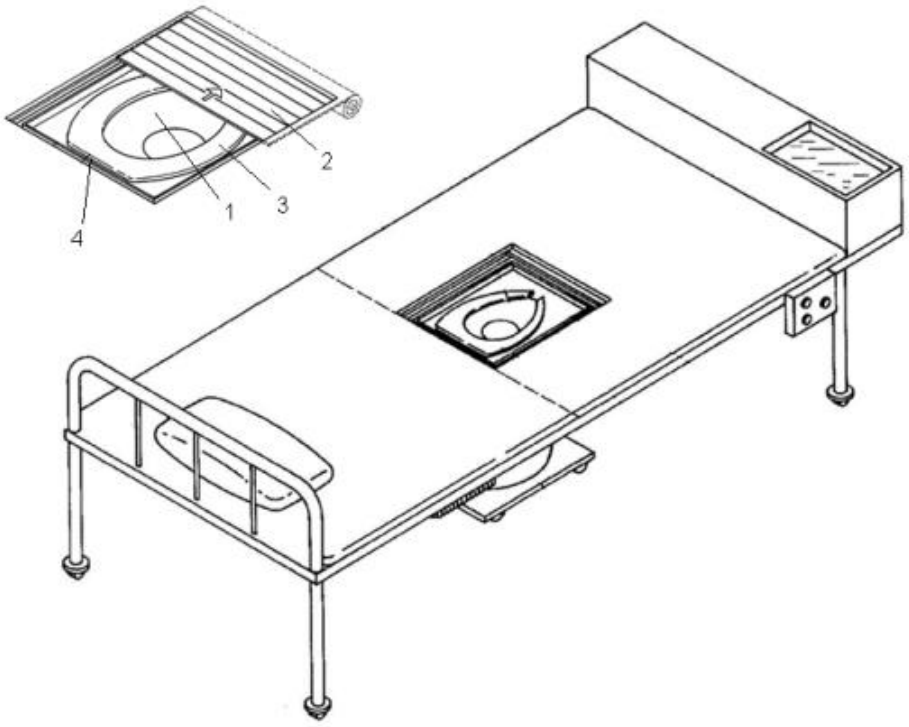

Figure 15 Flush toilet attached to the bed[19]

Patwardhan Bhaskar used this approach for his arrangement in European patent no. 2182907 Figure 16. In this arrangement of bed, the person gets to the sitting position via the operation of the hydraulic cylinder (1). The person gets to a particular height by the operation of strings (3). The strings are operated by a beam (2) which is pushed by the hydraulic cylinder (1). The pulleys (4) controls the movement of the strings (3). The mattress (7) has a pothole (6) in it. In the normal posture of bed, the commode (5) is locked by a lever beam (9) while fixed on the hinges (8). As the lever beam (9) moves, the

commode gets down to make way for the mattress piece (10). The mattress piece (10) is disconnected and henceforth the commode gets locked in position.[20]

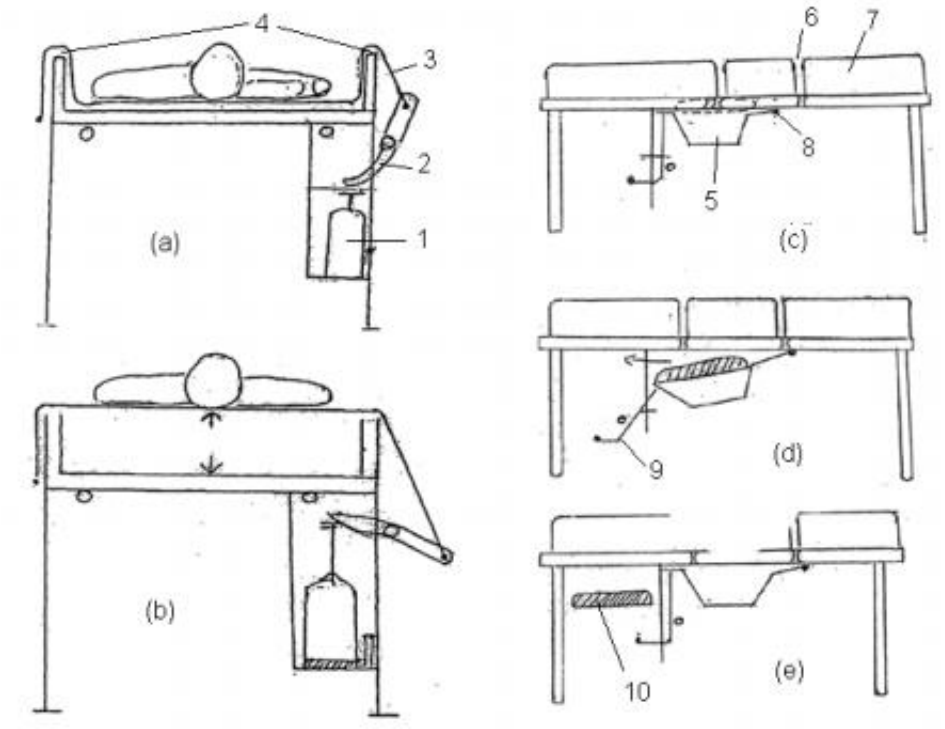

Figure 16 Bed convertible to chair with commode for person[20]

Research on Available Products:

After conducting a research on studies, designs, journals and patents of various beds, a search of manufacturers of such beds were also conducted in Pakistan. Currently, no such beds are manufactured in Pakistan that contains all of the deliverables of our Automated Nursing Bed. Therefore, we conducted a survey over the basic components required for our project and their availabilities in the market. Some of studies done over such components have been described down below.

Actuators available in the market:

Actuators are the machines that controls a system and acts on its surrounding by turning energy into motion. Actuators are divided into an ordinary control system and program-based system i.e. automated. Actuators are further subdivided into categories based on their output movement and the input power/ energy they use. Some of the types of these actuators that are available in the market has been described below.

Hydraulic Actuators:

The hydraulic actuators Figure 17[21] work on the phenomenon of incompressibility of liquids. The motion produced by hydraulic actuators can also be linear, oscillatory or rotating. In such actuators, movement or motion is produced via the power of fluid using a fluid-based motor. These actuators are very powerful as compared to the other ones because of its dependency over fluids.

Figure 17 Hydraulic Actuator

Pneumatic Actuators:

The pneumatic actuators Figure 18[22], works on the phenomenon of the power of compressed air and vacuum. The motion produced by pneumatic actuators can be linear or rotary as per the design requirements. Movement is produced by the motor that uses the compressed air or vacuum hence even small pressure can make large movements. At high amount of pressures, these actuators are good for engine mechanics because of its quick response.

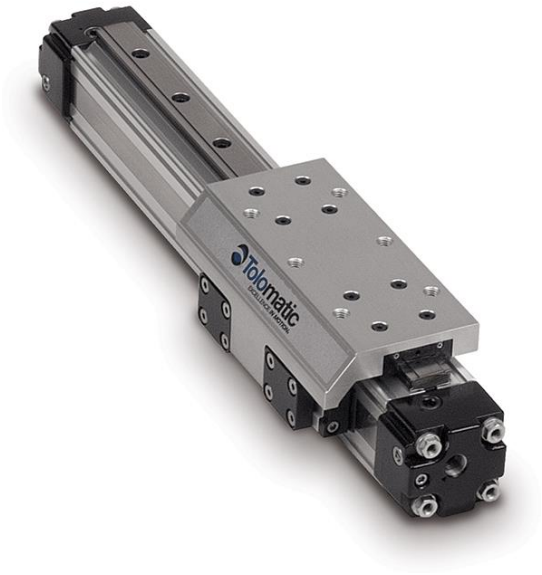

Figure 18 Tolomatic pneumatic actuator

Electrical Actuators:

The electrical actuators Figure 19 works on the phenomenon of an electric input. These types of actuators are abundant in the market. They take electrical energy in the form of Direct Current or Alternative Current as an input source and then convert it into mechanical movements.

Figure 19 Types of Electric Actuators by SMC[23]

Thermal Actuators:

Thermal Actuators Figure 20[24] are also known as magnetic actuators. These actuators are small, have light weight and are not expensive. Thermal actuators use Shape Memory alloys (SMMs) to generate a large amount of power density hence they are mostly used in commercial applications.

Figure 20 Thermal Actuators

Mechanical Actuators:

Mechanical Actuators Figure 21[25] are generally used for linear movement applications like translation, elevation etc. These types of actuators use mechanical components to produce linear motion as output by taking rotary motion of the component as input. They have high reliability and have ease in usability. Examples of such actuators are rack and pinion, screw type etc.

Figure 21 Mechanical Actuators

Research on Wheelchair Designs:

Certain studies, researches and work has been done on the designs and manufacturing of wheelchair in the area of medical care for injured and sick patients. Various patents of wheelchair designs have also been submitted by various designers all over the world. As one of the main deliverables of our project was to design and fabricate a wheelchair, so we did a research over such designs. A lot of approaches were given by designers for their arrangement of this system for the facilitation of bedridden patients. Some of the acknowledged approaches for the designs of such wheelchair have been listed below.

1st approach on wheelchair facilities:

Leonard R. Nitzberg had this approach in US patent no. 4566707A Figure 22[26]. Nitzberg used an arrangement such that it provides the patients a nominal sitting position. The chair consists of a back frame, a seat, leg frame and caster wheels. The back frame works on certain orientations as required by the patients. The leg frame spreads downwardly and have caster wheels at the base. These caster wheels are driven by another set of wheels attached at the back end of the base which is run by a power source. The power source can either be motor driven or hand driven.

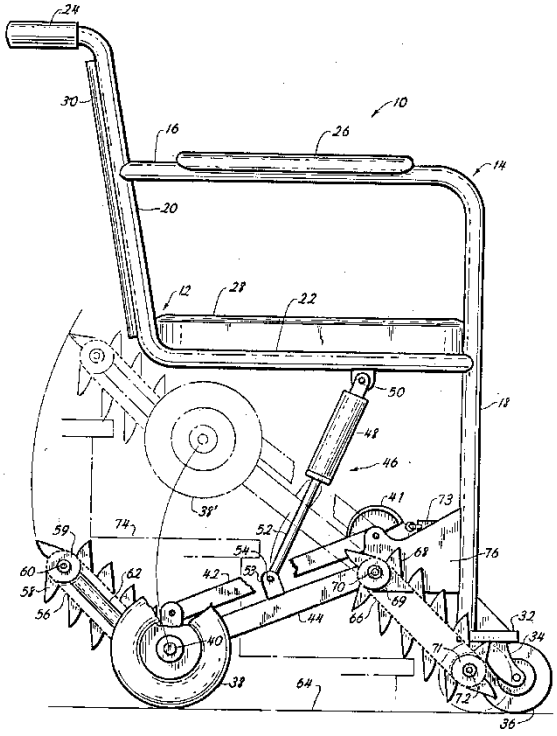

Figure 22 Wheelchair design

2nd approach on wheelchair facilities:

This approach was based on a wheelchair which is also convertible to bed. The bed has a pothole. When in use, the piece of mattress moves aside, and pot gets into the position for use. Hargest Thomas used this approach for his approach wheelchair cum bed design i.e. US patent no 5842237 and US patent no 6009570 Figure 23[27]. The bed consists of a leg rest and backrest for the occupant's comfort. The system also has a caring bed with a support section (1) for the support of the hips. There is commode piece below these support pieces. When in use, these pieces slides to the sides and commode seats gets to the position for the collection of excrete. The chair position consists of wheels which are driven by a certain power source.

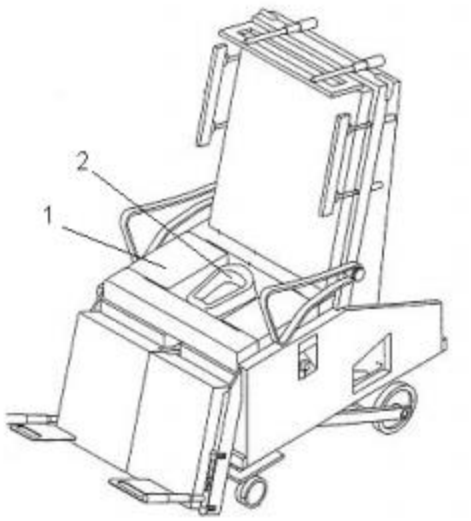

Figure 23 Bed convertible to wheelchair with a commode

CHAPTER 3: METHODOLOGY

After taking up the final year project to fabricate an automated nursing bed, following methodology was adopted.

Market Survey:

During our initial research, we did a thorough market survey. In our survey, we visited local hospitals and found about the existing technology available there. We also met with bed-ridden patients and knew about their sufferings regarding their movement constraints. We learned about the difficulties the management and caretakers were facing while attending such patients. During our survey, we also visited the market and did a research about price analysis of existing beds and components that might be needed to achieve actuation for our nursing bed. Our survey concluded following results:

- The design should be such that it minimizes the human interaction involved.
- The design should include sanitation and flushing mechanisms.
- The design should help position the patient for easy urination and defecation.
- The design should be easily operated.
- The design should be made with price range affordable to average working class.
- Motion of bed should be such that patient's rest should not be affected.
- The design should ensure silent operation of actuators used in automatic bed.

Product Deliverables:

Based on our survey, the important bed requirements were decided.

1. A back rest was included which would incline to straighten up the patient's back. The patient would be able to achieve a sitting position.
2. A leg rest was incorporated in the design to give a motion to the lower leg part and help patient completely sit if he wants to.
3. A cut was made in the middle part of the bed was made. This cut would be actuated to move up and down.

4. A commode would be mechanized to move up the opening and touching the patient's buttocks.
5. An additional mechanism would help in achieving flushing and sanitation.
6. The controls of mechanism should be user-friendly.
7. The price should be within the range of middle-class citizens.

Bill of Materials:

Wheelchair:

PKR 16000/-

- Stainless Steel (strong, high and low temperature resistant, ease of fabrication)
- Plastic seat with pot (PETE, good strength-weight ratio)
- Manual inclination/declination of backrest (Clutch controlled)
- Height ~1.4 ft (floor to seat), Width ~2ft (frame end to end), length ~2ft (middle part)

Figure 24 Wheelchair bought

Bed Frame:

PKR 16000/-

- Cold-rolled Steel (strong, hard i.e. resistance to deformation such as bending)
- Length ~6ft (edge to edge), Width ~3ft (edge to edge), Height ~2.5ft
- To be used to hold the patient and wheelchair

Figure 25 Bed Frame bought

Electric Linear Actuator:

- PKR 20,000/- (for Power Rating 30W:Backrest)
  - Stroke length 38cm
  - 24 V DC motor attached
- PKR 8,000/- (for Power Rating 5W: Leg rest)
  - Stroke Length 10cm
  - 12 V DC motor attached

Figure 26 Electric Linear Actuator

ET-CGM64 Gear Motor:

PKR ~1200/- (x2)[28]

- Custom rpm (0.5-15rpm)
- High torque motor (up to 25kg.cm)
- Planetary/worm gear assemble in Gear box
- Weight 160g, Size 64x38mm, Shaft diameter 6mm
- To be used for pot opening, wheelchair steering.

Figure 27 ET-CGM64 Gear Motor

Pilot Automotive Q-HY-1500L 12 V Electric Car Jack:

PKR 8700/- [29]

- Dimensions: 18.2 x 12.3 x 7.1 inches
- Weight ~5kg

Figure 28 Pilot Automotive Electric Car Jack

One-Touch Sliding lock:

PKR ~1000/- (x2)[30]

- Stainless Steel, Plastic knob
- Dimensions: 40 x 40 x 36mm

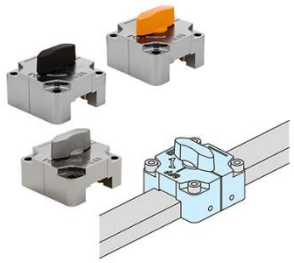

Figure 29 One touch sliding lock

Stainless Steel plates:

PKR ~600 per kg (10kg)

- Thickness 5mm
- Used for back rest and leg rest

Figure 30 Stainless Steel Plates

Stainless Steel rods:

PKR ~1000 per kg (10kg)

- Diameter 1-1.5 in
- Used for wheelchair support rods and side railings

Figure 31 Stainless Steel Rods

Adjustable Cooling Pipe Nozzle:

PKR ~300/-[31]

- Length 300mm
- Hose inner diameter 3mm
- Used for sanitation commode

Figure 32 Cooling pipe Nozzle

Reservoir Water tank:

PKR ~1000/-

- Length 50cm, Width 20cm
- Capacity 8 litre

Bolts, Screws and Nuts:

PKR 500-1000/-s total

- Multiple bolts, screws, nuts and small plates for different purposes

Hydraulic Damper:

PKR 600/- (x2)[32]

- To be used at back rest and leg rest for safety purposes

Figure 33 Hydraulic Damper by TIEVING

Magnet Lock:

PKR 70/-

- Magnet to hold the object at place
- To be used to hold pot opening

Figure 34 Magnet Lock

Workshop Expenditure:

Rent: PKR 3000/-

Welding, Cutting, Electric wiring and other labour charges: PKR 6000/-

Table 1 Bill of Materials

Sr. No	Component	Quantity	Cost (PKR)	Total
1.	Wheelchair	1	16000	16000
2.	Bed Frame	1	16000	16000
3.	Electric Linear Actuator (Backrest)	1	20000	20000
4.	Electric Linear Actuator (Leg-rest)	1	8000	8000
5.	Geared Motor	2	1200	2400
6.	Electric Car Jack	1	8700	8700
7.	One Touch Sliding Lock	2	1000	2000
8.	Stainless Steel Plates	10kg	600	6000
9.	Stainless Steel Rods	10kg	1000	10000
10.	Cooling pipe nozzle	1	300	300
11.	Reservoir Water Tank	1	1000	1000
12.	Bolts, Screws and Nuts	-	1000	1000

13.	Hydraulic Damper	2	600	1200
14.	Magnet Lock	4	70	280
15.	Miscellaneous	-	9000	9000
		Total Cost (PKR)		101,880/-

Material Selection

Annealed Stainless steel:

Table 2 Properties of Annealed Stainless Steel

Sr. No	Property	Values
1.	Elastic Modulus	2.07e+11 N/m^2
2.	Poisson's ratio	0.27 N/A
3.	Mass Density	7860 kg/m^3
4.	Tensile Strength	685000000 N/m^2
5.	Yield Strength	292000000 N/m^2
6.	Thermal Expansion Coefficient	1.7e-5 /K
7.	Thermal Conductivity	16.3W/m·K

Polyethylene Terephthalate Plastic (PET):

Table 3 Properties of PET

Sr. No	Property	Values
1.	Elastic Modulus	2960000000 N/m^2
2.	Poisson's ratio	0.37 N/A
3.	Mass Density	1420 kg/m^3
4.	Tensile Strength	57300000 N/m^2
5.	Yield Strength	92900000 N/m^2
6.	Thermal Conductivity	0.261 W/m.K

Cold Rolled steel:

Table 4 Properties of Cold Rolled Steel

Sr. No	Property	Values
1.	Elastic Modulus	2.05e+11 N/m^2
2.	Poisson's ratio	0.29 N/A
3.	Shear Modulus	8e+10 N/m^2
4.	Mass Density	7870 kg/m^3
5.	Tensile Strength	420000000 N/m^2

6.	Yield Strength	350000000 N/m^2
7.	Thermal Expansion Coefficient	1.17e-5 /K
8.	Thermal Conductivity	51.9W/m.K

Dimensional Synthesis:

From data gathered from our market surveys, literature reviews, deliverables of our product design, patients, concerned people and including factor of safety dimensions to accommodate a patient of 6 ft. and 330.69 lbs. were decided which are:

1. Total length of the bed frame excluding the head and foot board would be 7 ft. Total width would be 3ft. Height was decided to be 2.5ft.
2. Of the total 7 ft. length, 1 ft. at top of the bed was made exclusive for static support. The remaining 6 ft. would be utilized to achieve actuated motion.
3. Of the total 3 ft. width, 0.5 ft. at both sides would form part of static frame for support purposes. The remaining 2 ft. would be utilized to achieve actuated motion.
4. The thickness of the static frame was evaluated to be 1 in. while the remaining bed parts would be of 0.7 in.
5. 6 ft. length of bed allocated for actuated motion is further divided into three parts i.e. back rest, middle part, leg rest.
6. Back rest to help torso move up in a sitting position, would have a dimension of 2.5 ft. length and 2 ft. width.
7. Leg rest to support shank in sitting position would have a dimension of 1.5 ft. and 2 ft. width.
8. Middle part would be of 2 ft. length and 2 ft. width.
9. An opening in the middle part for commode would be cut having dimensions of 1.2 ft. length and 1 ft. width.

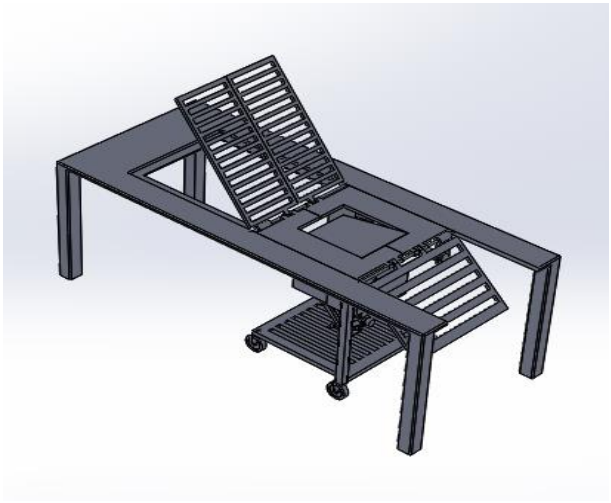

Figure 35 Assembly of Actuated Bed

Mechanism:

Backrest movement:

The inclination and declination mechanism of backrest would be controlled by motor-driven 24 V actuator. The required maximum and minimum angles of inclination were 0° to 90°. The base of the actuator world rest on a static frame connected to the middle part in such a way that both the lateral and rotational movement of the actuator base would be restricted. The piston tail would be connected to a rocker that, in turn, would be welded to a rod. The rocker would control the rotation of the rod. The rod would rest in two journal bearings connected to the middle part. The rod would be jointed with the frame of backrest through few arc welded supports. Therefore, when the piston moves outward, the rocker connected to the tail rotates the rod which, in return, moves the backrest. For specific displacement of the piston, the backrest rotates through calculated degrees of angles.

Leg rest movement:

The declination and inclination mechanisms of leg rest were also controlled by motor-driven 24 V actuator. The required minimum and maximum angles of rotation varied from -90°to 0°. The base of the actuator world rest on a static frame connected to the middle part in such a way that both the lateral and rotational movement of the actuator base would be restricted. The piston tail would be connected to a rocker that, in turn, would be welded to a rod. The rocker would control the rotation of the rod. The rod would rest in two journal bearings connected to the middle part. The rod would be jointed with the frame of backrest through few arc welded supports. Therefore, when the piston moves outward, the rocker connected to the tail rotates the rod which, in turn, moves the leg rest. For specific displacement of the piston, the leg rest rotates through calculated degrees of angles.

Pot Opening:

The inclination and declination angles of the pot opening part was managed using a motor driven four bar mechanism. The required degrees of angle varied from -105° to 0°. The simple four bar mechanism would open and close the pot. However, the motor rpm would be controlled via gear box configuration.

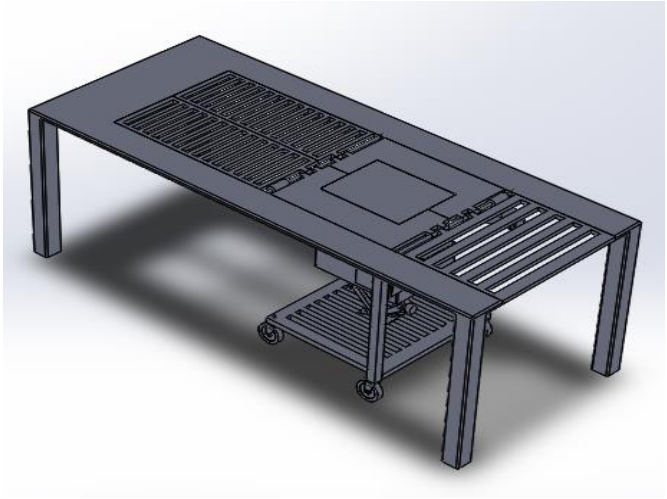

Figure 36 Assembly of Actuated Bed in Bed Orientation

Convertible to Wheelchair:

A one touch slider locker would be used to connect and disconnect the chair from the bed. The base of the switch containing the knob for locking and unlocking would be welded to the static bed frame. The beam that will move inside and outside of the locker base would be welded to the chair in such a way that when the wheel chair is brought to the space inside the bed, the beam slides into the locker and, hence, the position of the chair would be locked.

Sanitation pipe on the Commode:

The cleaning procedure would be assisted with the use of water nozzle. The purpose of the nozzle would be to help clean the area using water. The nozzle would be attached to a thin pipe at the back which, in turn, will be connected to a small water reservoir attached to the static frame at the rear side. The reservoir will be held in a steel frame welded to the bed.

Calculations:

Torque Calculation:

Based on weight distribution of human body,

$$m_B = 150\ kg$$

$$m_H = 71.25\ kg$$

$$m_L = 17.70\ kg$$

$$m_M = 61.05\ kg$$

$$Centre\ to\ centre\ length\ of\ rocker = 6\ in = 0.1524\ m$$

For 0-degree orientation:

$$T_{BR} = 9.8 \times 71.25 \times (32 - 20.25)$$

$$= 208.07\ N \cdot m$$

$$T_{LR} = 9.8 \times 17.7 \times 6.67$$

$$= 29.31\ N \cdot m$$

Force to be delivered by the actuator:

$$F_{BR} = \frac{208.07}{0.1524}$$

$$= 1365.288\ N$$

$$F_{LR} = \frac{29.31}{0.1524}$$

$$= 192.32\ N$$

For 45-degree orientation:

$$T_{BR} = 9.8 \times 71.25 \times 0.298 \times cos45$$

$$= 147.12\ N \cdot m$$

$$T_{LR} = 29.31 \times cos45$$

$$= 20.72\ N \cdot m$$

Force to be delivered by the actuator:

$$F_{BR} = \frac{147.12}{0.1524}$$

$$= 965.35\ N$$

$$F_{LR} = \frac{20.72}{0.1524}$$

$$= 135.96\ N$$

For 90-degree orientation:

$$T_{BR} = 9.8 \times 71.25 \times 0$$

$$= 0\ N \cdot m$$

$$T_{LR} = 9.8 \times 17.7 \times 0$$

$$= 0\ N \cdot m$$

Force to be delivered by the actuator:

$$F_{BR} = 0\ N$$

$$F_{LR} = 0\ N$$

Power Requirements:

Backrest Actuator:

Considering the maximum force required scenario i.e. 0^o inclination.

$$F_{BR} = 1365.288\ N$$

The backrest moves from horizontal angle of 0^o to maximum of 90^o. Undertaking patient's comfort, we take a value of 0.25 rpm of backrest motion, so the time required to undergo this motion is given by:

$$t = 60.00\ s$$

Now, calculating the distance travelled by backrest,

$$s = r \times \theta$$

$$= 0.762 \times \frac{\pi}{2}$$

$$= 1.196\ m$$

Power required,

$$P = \frac{F \times s}{t}$$

$$P = \frac{1365.288 \times 1.196}{60}$$

$$P = 27.21\ W$$

Leg Rest Actuator:

Considering the maximum force required scenario i.e. 0^o inclination;

$$F_{LR} = 192.32\ N$$

The leg rest moves from horizontal angle of 0^o to maximum of 90^o. Undertaking patient's comfort, we take a value of 0.25 rpm of leg rest motion, so the time required to undergo this motion is given by:

$$t = 60.00\ s$$

Now, calculating the distance travelled by leg rest,

$$s = r \times \theta$$

$$= 0.457 \times \frac{\pi}{2}$$

$$= 0.717\ m$$

Power required,

$$P = \frac{F \times s}{t}$$

$$P = \frac{192.32 \times 1.196}{60}$$

$$P = 3.83\ W$$

Pot Opening Motor:

The maximum mass on the opening plate is mass of the plate itself given as;

$$m_P = 2\,kg$$

Considering the maximum force that the opening plate has to bear;

$$F_P = W_P = 2 \times 9.8$$

$$= 19.6\,N$$

The plate moves from its closed angle of 0^o to maximum of 105^o. Undertaking mechanical aspects, we take a value of 0.538 rpm of motion, so the time required to undergo destined motion is given by:

$$t = 30.00\,s$$

Now, calculating the distance travelled by plate,

$$s = r \times \theta$$

$$= 0.365 \times 1.832$$

$$= 0.668\,m$$

Power required,

$$P = \frac{F \times s}{t}$$

$$P = \frac{19.6 \times 0.668}{30}$$

$$P = 0.436\,W$$

Screw Jack Motor:

Screw Jack moves the pot a vertical distance of 10 inches, so;

$$s = 0.254\, m$$

Total mass of pot and platform supporting the port are,

$$m_S = 2\, kg$$

Considering the maximum force that the screw jack has to apply to move pot is given as;

$$F_S = W_S = 2 \times 9.8$$

$$= 19.6\, N$$

The motion of pot in synchronized with the plate of pot opening, so the rpm is taken as 0.538 i.e. the time required for our desired motion is given by;

$$t = 30.00\, s$$

Power required,

$$P = \frac{F \times s}{t}$$

$$P = \frac{19.6 \times 0.254}{30}$$

$$P = 0.167\, W$$

Sanitation Pump:

The required power rating of pump needed for sanitation and flushing purpose is given as;

$$P = \rho \times g \times H \times Q$$

Taking value of Q as 10 $^{L}/_{min}$ based on practical applications,

$$P = 997 \times 9.8 \times 2.43 \times 1.66 \times 10^{-4}$$

$$P = 3.94\ W$$

Wheelchair Automation Motor:

$$Total\ Mass = Mass\ of\ Human\ Body + Mass\ of\ wheel\ chair$$

$$m_T = m_H + m_C$$

$$m_T = 120 + 60 = 180\ kg$$

$$W_T = 180 \times 9.8 = 1764\ N$$

Weight on single wheel is given as;

$$W_W = \frac{1764}{4} = 441\ N$$

Torque on wheel of radius of 1.5 inches;

$$T_W = W_W \times R_W$$

$$T_W = 441 \times 0.0381$$

$$T_W = 16.80\ N \cdot m$$

Considering patient's comfort, the speed of wheelchair is taken as 5 mph;

$$\omega = {}^{v}/_{R_W}$$

$$\omega = {}^{2.24}/_{0.0381} = 58.79\, rad \cdot s^{-1}$$

$$N = 561.4\, rpm$$

Power is given by;

$$P = \frac{2 \times \pi \times N \times T_W}{60}$$

$$P = \frac{2 \times \pi \times 561.4 \times 16.80}{60}$$

$$P = 987.6\, W$$

Stress Analysis:

Buckling Analysis of Static Frame's Leg:

Factor of Safety = 2

$$W_{leg} = \frac{2 \times 150}{6} = 50\, kg$$

$$L_{LEG} = 2.5\, ft = 0.76\, m$$

For Buckling of Circular rod:

$$P_{cr} = \frac{\pi^3 \times E \times r^4}{k^2 \times L^2}, \qquad E = 2.05 \times 10^{11}\, N/m^2$$

Where P_{cr} is the critical load at leg i.e.:

$$50 \times 9.8 = 490\ N$$

And k = 1,

$$r = 0.354 \times 10^{-3}\ m = 0.01\ in$$

Buckling Analysis of Wheelchair's Leg:

Factor of Safety = 2

$$W_{leg} = \frac{2 \times 150}{6} = 50\ kg$$

$$L_{LEG} = 26\ in = 0.66\ m$$

For Buckling of Circular rod:

$$P_{cr} = \frac{\pi^3 \times E \times r^4}{k^2 \times L^2}, \qquad E = 2.05 \times 10^{11}\ N/m^2$$

Where P_{cr} is the critical load at leg given as:

$$50 \times 9.8 = 490\ N$$

And k = 1,

$$r = 2.4 \times 10^{-3}\ m = 0.09\ in$$

Manufacturing Process:

- The research was done on the fundamental materials required for the frame and other components of the bed. The market research was done to find the most


Figure 37 Chair and the Bed structure bought

convenient choice for the manufacturing and fabrication of the project. We had two choices: to buy raw materials and run all the processes like cutting, machining and welding according to the required dimensions; to buy few already manufactured parts and apply necessary modifications to it. After careful consideration related to the cost and time efficiency of the choice, we decided to buy: a wheel chair and make the necessary modifications in it according to the design requirements; a bed frame to hold the mechanism and the patient's body.

- The wheelchair of the material stainless steel with the weight capacity of 160kg, space for sanitation and manual inclination and declination feature *(see* Bill of Materials:*)*. However, the necessary modifications that were needed in the chair were: the backrest frame (preferred stainless steel or aluminium) according to the dimensions (2 x 2 ft) was to be made; the footrest of the wheelchair was to be replaced with our leg rest frame (preferred stainless steel or aluminium) of dimensions (2ft x 2ft); the height of the chair was to be brough to 2ft by

replacement of support rods with relatively longer rods at the sides of the chair to create necessary space for the sanitation pot , actuators and other mechanisms.

- The backrest already had clutch mechanism for manual inclination and declination of the patient. Using the same connections, we planned to replace the mechanism with motor driven actuators. *(see* Bill of Materials:*)*.
- The wheelchair was taken to the workshop in Rawalpindi where the worker was provided with the design requirements. Under our supervision, the worker had the job of: producing the back and leg rest frame using the same material; replace support rods to increase height according to the requirement; to remove the clutch brake from the back but keeping few necessary connections there.
- The next step to the manufacturing was to fabricate the back and leg rest frames to the wheelchair using the rod as junction between the parts for independent rotation of the parts *(see* Mechanism:*)*. We didn't have to change anything at the fabrication backrest frame because the rod provided junction between the middle part and back rest the middle part contained bearings at the holders and the back-rest frame was welded to the rod.
- For Leg rest frame, same procedure as that of the middle part-backrest fabrication was to be used that used rod as a junction between two parts, enabling independent rotation of the backrest and leg rest *(see* Mechanism:*)*.
- For next step, the actuators *(see* Bill of Materials:*)* were to be fabricated at the provided locations i.e. 5 inches from the left and right edges of middle part & 4 inches from the alternate top and bottom edges as shown in Figure 39. Testing was to be done to ensure the smooth movement and working of the mechanism.

Figure 39 Isometric View of Wheel Chair

- Then, the motor driven screw-jack mechanism was to be attached to the pot at the frame at the bottom underneath the Wheelchair as shown in Figure 38. The rpm of the motor would be adjusted for screw-jack motion through Gear motor. The

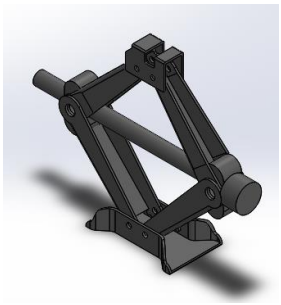

Figure 38 Isometric view of the screw jack mechanism

working of the mechanism was to be tested again.

- The pot opening would be controlled using motor-driven four bar mechanism *(see* Mechanism:*)*. The placement of the motor would be adjacent to the hinged edge of the pot opening. The motor base would be held in place using a holder connected to the middle part.
- Necessary steps would be taken like cutting and adjustment of the parts to ensure the tolerance in the project and smoothness of the body.
- The most important step of the manufacturing was to fabricate the wheelchair with the bed frame of cold-rolled steel *(see* Bill of Materials:*)*. The frame of the bed was

to be cut according to the required dimensions i.e. 2ft wide cut at 0.5 ft from the longer edges and 0.5ft from the top, up to the shorter edge of the bed.

- As it is visible form Figure 37, the bed has internal arms and spaces. So, after the cutting is done, a metallic strip or beams of width 1-2 inches would be welded at the internal side to bound and cover the internal contours of the bed.
- To connect and disconnect the chair with the bed, one touch sliding lock would be used *(see* Bill of Materials:*)*. The lock would be welded to the rear side of the static bed frame adjacent to the wheelchair space. The inside beam would be welded to the middle part of the chair. The location of the lock would be slightly adjacent to the backrest under the static frame 3-4 inches away from the middle rest. When the beam jointed to the middle frame of chair would rest inside the lock, the wheelchair would be locked at its position and would be connected to bed *(see* Mechanism:*)*.
- Now the small water pump would be connected to the pot for cleaner sanitation. The pump would be controlled by a thin pipe and a reservoir. A small water reservoir would be bolted to the rear part of the static frame. And the pipe would carry the water to the pot. The flow and stoppage of the water would be controlled via electric valve *(see* Mechanism:*)*.
- After the proper fabrication of all the components and testing of the mechanisms as per design requirements, the electric circuit would be made to operate all the motors used in the system which would be controlled by a wired remote for now. This process would be done with the help of the worker at the workshop who would make a control box with all the necessary connections inside it and would be controlled via wired remote.
- When the wheelchair is disconnected form the frame, the motor would be used to direct and move the wheelchair thus automated. The steering mechanism for the chair would be designed inspired by the one used in few remote-controlled toy cars[33] *(*Figure 40*)*. In which, the polarity of the motor i.e. clockwise or

anticlockwise rotation of the motor spindle, would define the right or left movement of the tires. The polarity would be controlled via button on the remote.

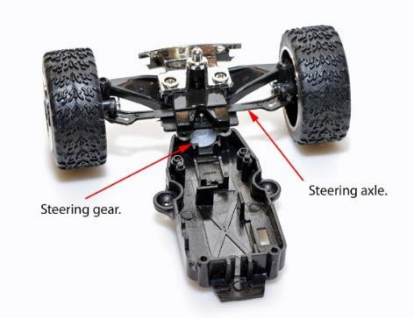

Figure 40 Google image of toy car steering mechanism

- To increase the safety of the patient, dampers would be installed on both back rest and leg rest in case of any aberrations in the actuator assembly. Moreover, the pot would be locked at position via magnet lock in the middle frame.
- The success of the project would highly depend on the continuous testing and optimization of the design as needed along the way keeping the cost as minimum as possible.

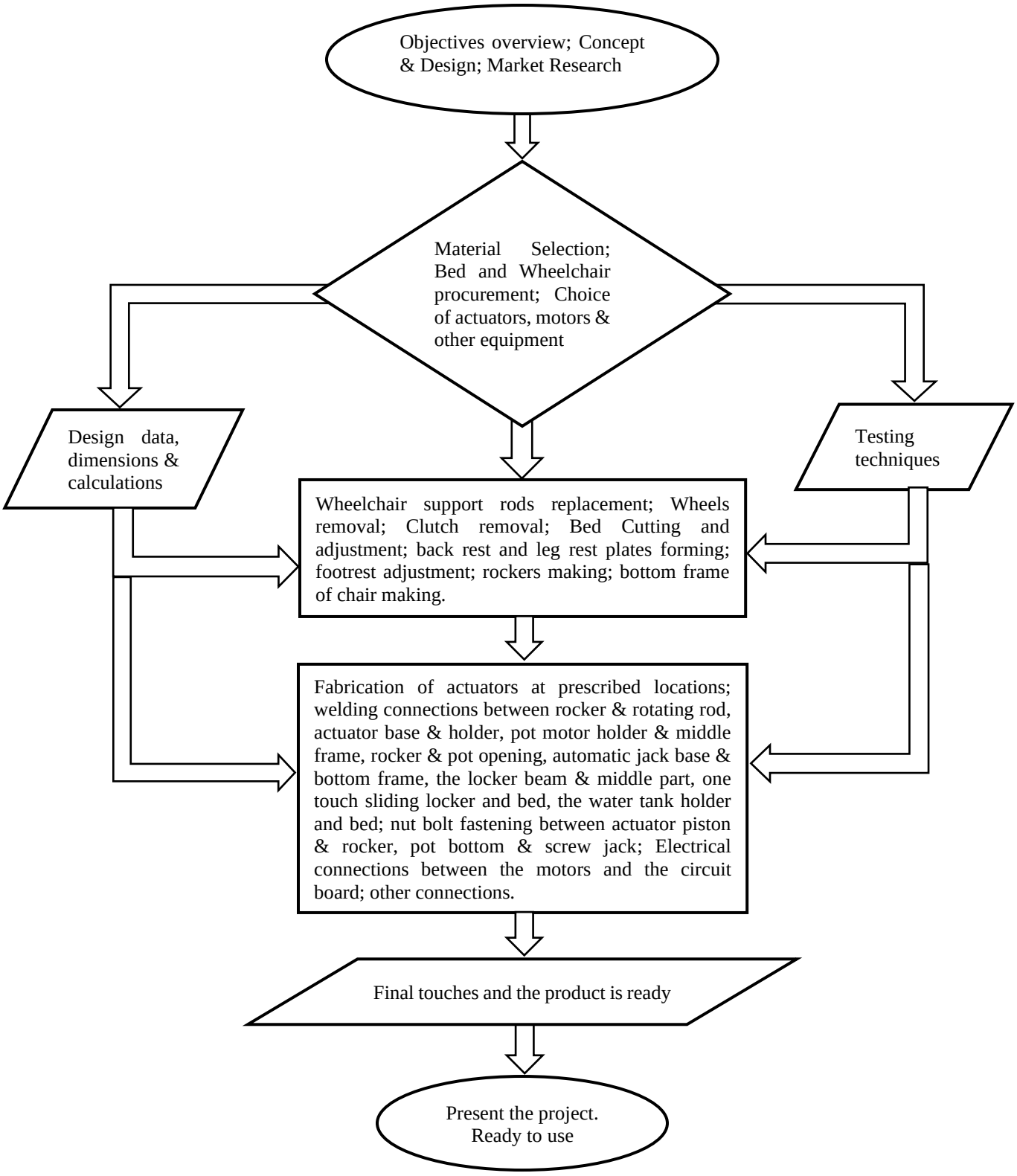

Figure 41 Flow chart of the Manufacturing Process

CHAPTER 4: RESULTS AND DISCUSSIONS

SolidWorks software was used to design the Nursing Bed. For final design, 3 sub-assemblies were designed, and those assemblies were assembled to achieve final design.

- Wheelchair
- Screw jack
- Caster wheel

SolidWorks software was used for two purposes:

I. Computer Aided Design Modelling
II. Finite Element Analysis

Computer Aided Design Modelling:

All parts of the subassemblies were carefully designed keeping in view the market availability of these parts so that we can buy parts with standard dimensions, this approach also reduced the cost of this product.

Wheelchair:

As this project was required to be convertible to wheelchair, so firstly wheelchair was designed and assembled with all the required mechanisms i.e. inclination of backrest, declination of leg-rest, opening of middle part for sanitation and pot mechanism using motorized screw jack. If we see already available models of nursing beds, it is observed that they don't provide us with all the features i.e. Smooth Inclination/declination of backrest, Smooth inclination/declination of leg-rest, opening of middle section for sanitation mechanism and automation of Wheel Chair. So, it was aimed to design this model by keeping in view all these requirements. CAD Model of this nursing bed was successfully completed nearest to the realistic conditions.

Figure 42 Wheelchair

Screw Jack:

After the opening of middle part, height of sanitation pot was required to be adjusted to avoid splash. In similar designs of already available nursing beds, different mechanisms were applied to increase height i.e. Linear actuator, screw jack, four bar mechanism etc.

We selected motorized screw jack because of its simplicity and cost efficiency.

Plastic pot was attached with the upper part of screw jack, so in this way its height was altered. Pot was attached in such a way to make it stable on screw jack, in such a way that it should not tilt or tip on any side.

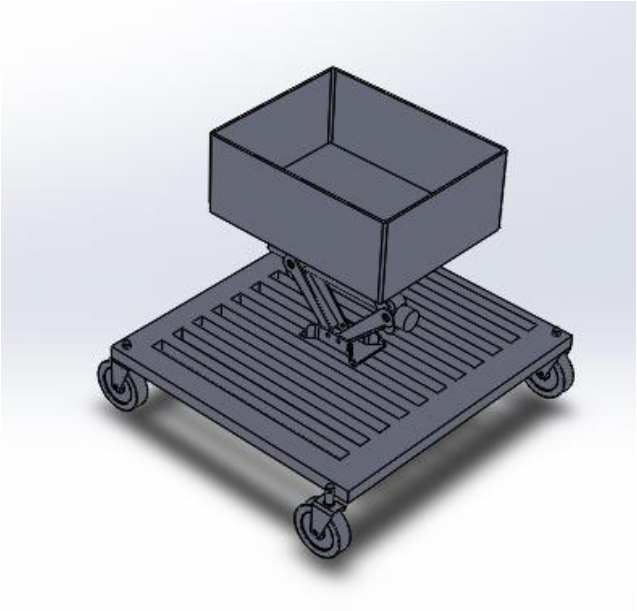

Figure 43 Screw Jack with Pot

Caster Wheels:

Caster wheels were attached with the legs of wheelchair for its movement. This wheel was also designed on solid works so that before manufacturing its all design specifications should be discussed in details and its viability with the wheelchair too. These wheels were designed and selected keeping in view all the loading conditions that these will bear and will help in the movement of wheelchair. All the load will be equally distributed to its 4 wheels and these wheels will help stabilizing this wheelchair model and avoid tipping about any point or axis.

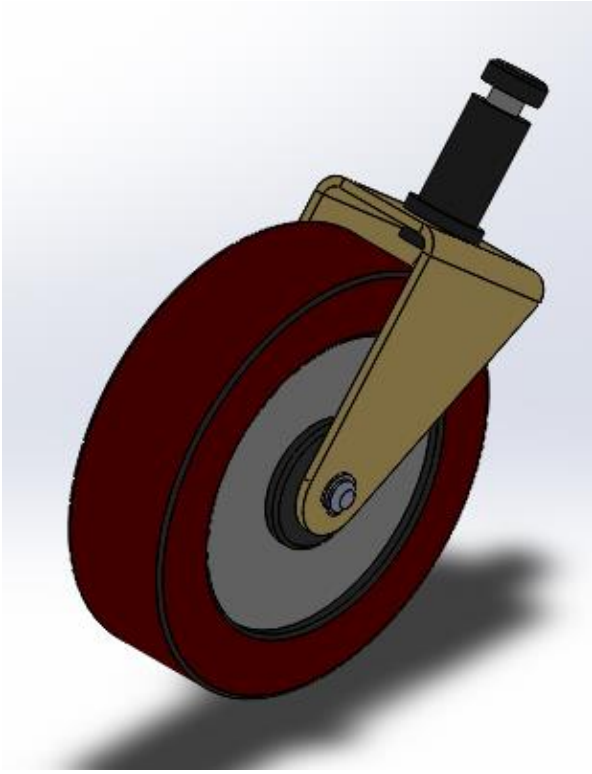

Figure 44 Caster Wheel

Finite Element Analysis:

After completing the final design and assembly of Nursing bed, it was required to run Finite element analysis to study this design for stresses and failures under different load conditions. As wheelchair assembly is quite critical, because after separating it from the static frame, all load will be on this assembly. So, it was required to carefully design this wheelchair after sufficient safety factor. As this nursing bed is to be used by paralyzed patients who can't stand or walk on their own so its design and analysis was required to be quite brief as we can't risk anyone's life. After modeling, Solid works was also used to run a static loading analysis on this. If a man is lying on the bed, he will be applying distributed load on the whole model and also for the inclination and declination of backrest and leg-

rest, electric linear actuator will also be applying forces with its piston. So, under these loading conditions its analysis was done.

To avoid failures and simplify the design, sharp corners were replaced with the fillets. After completing the modeling, material selection was made according to the requirements. Mostly cold rolled steel was used as it was completing all our requirements i.e. Yield strength, failure load etc. After that under constrained bodies were checked using one of the tools of SolidWorks. All the under constrained bodies were made fixed to make this model fully constrained. After applying constraints and connections to the model, fixtures were also applied to make this model fully stable. Distributed Load of 1200N was applied on upper side of the structure and 1000N load was applied on the piston of each electric linear actuator to bear the load. This analysis was carried out on different positions of backrest and leg-rest. From analysis it was observed that maximum stresses were on the joining rod of backrest and middle rest. So, this part needs to be made quite robust and strong as it was vulnerable to failure. It was also observed that other parts of this model were very safe, stresses on other parts were quite small as compared to the yield strength of material.

Three types of analysis were carried out on the model.

- Stress Analysis
- Strain Analysis
- Displacement Analysis

In this analysis, it is observed that the value of Von Mises stress on the maximum stress point is less than the yield stress so this will avoid failure. As we can observe that yield strength of this model is 350 MPa and all the stress values lie below this point. Maximum displacement values at the free end of back-rest are in millimeters, so these values are quite negligible so we can say that our design model is quite safe from all these types of failures.

Stress Analysis:

Stress analysis on this wheelchair model at different positions and different loading conditions is given below:

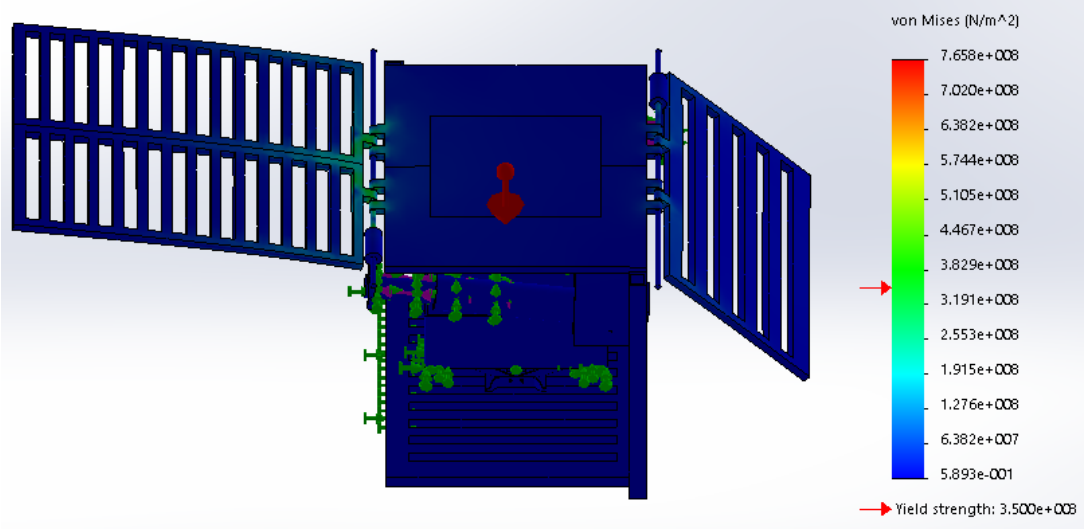

Figure 45 Von Mises Stress Analysis with 1200N on upper side and 1000N on pistons

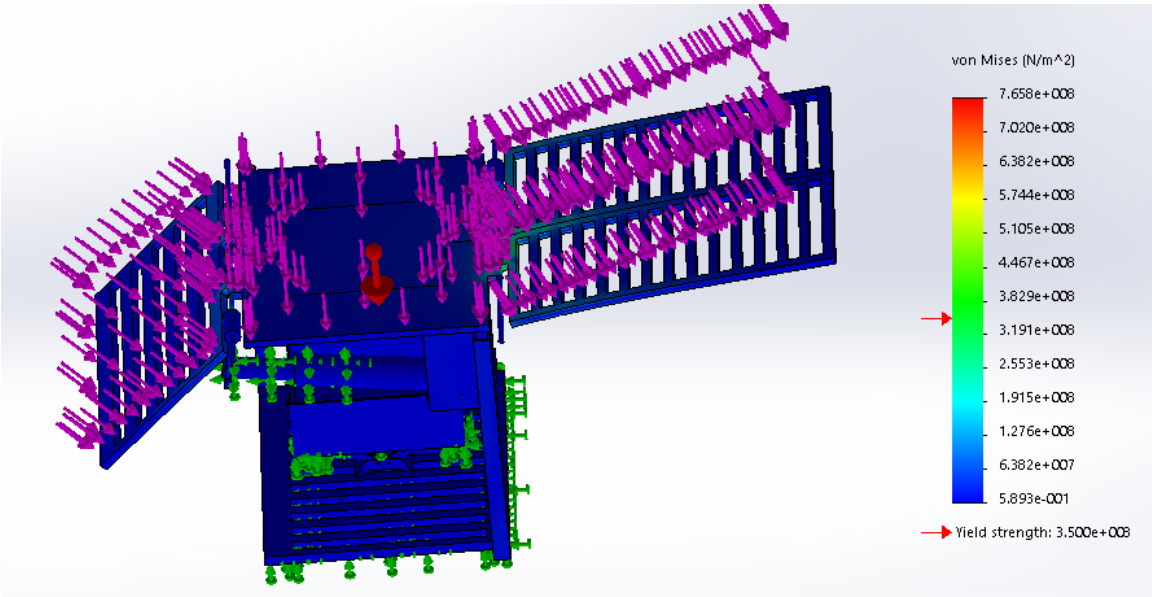

Figure 46 Von Mises stress Analysis on Wheelchair with distributed load of 1200N

Strain Analysis:

Strain analysis on different positions and under different loading conditions is given:

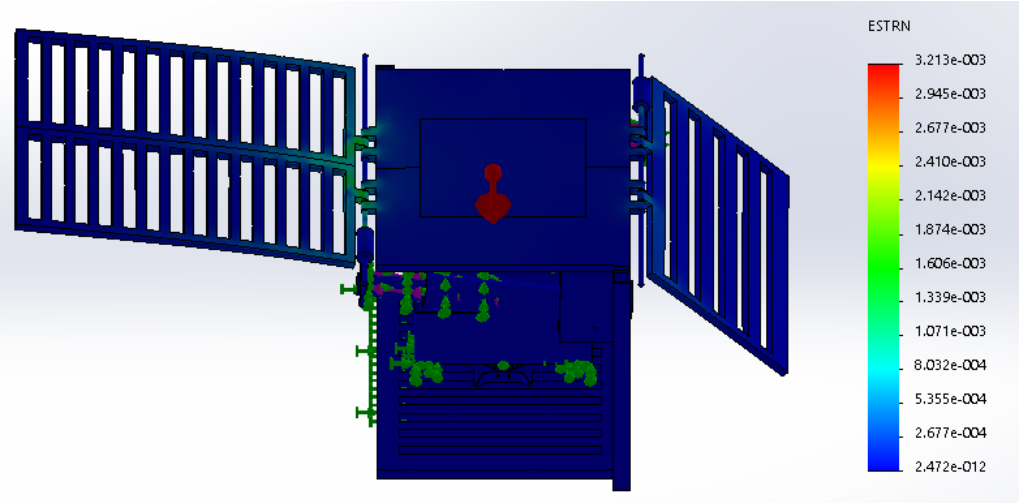

Figure 47 Strain Analysis with 1200N on upper side and 1000N on pistons

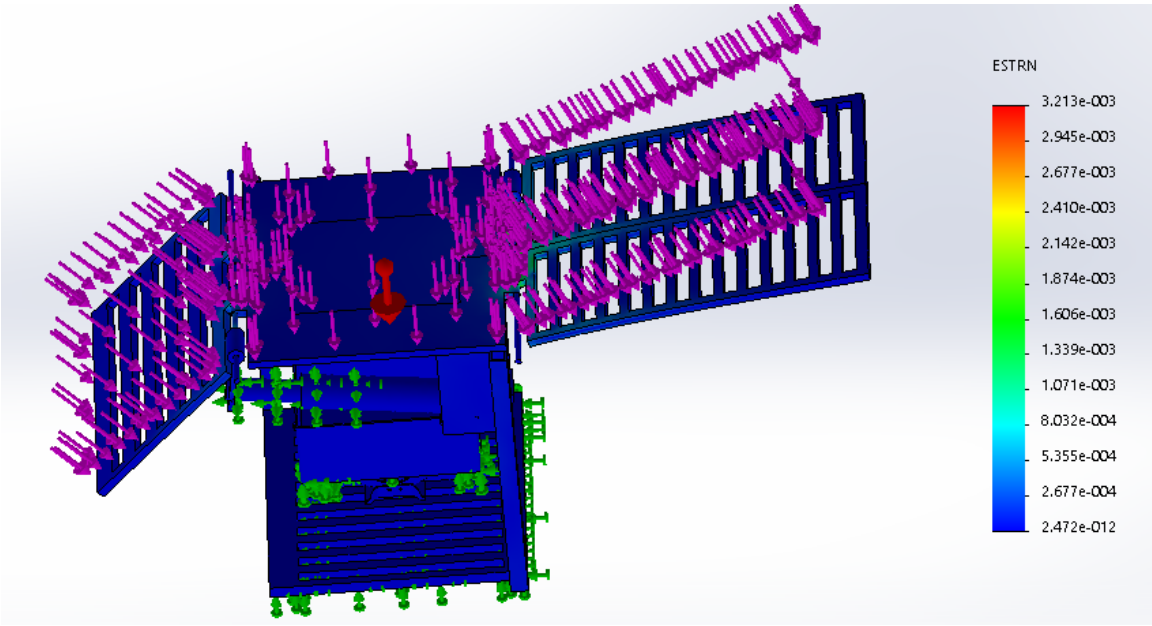

Figure 48 Strain Analysis on Wheelchair with distributed load of 1200N

Displacement Analysis:

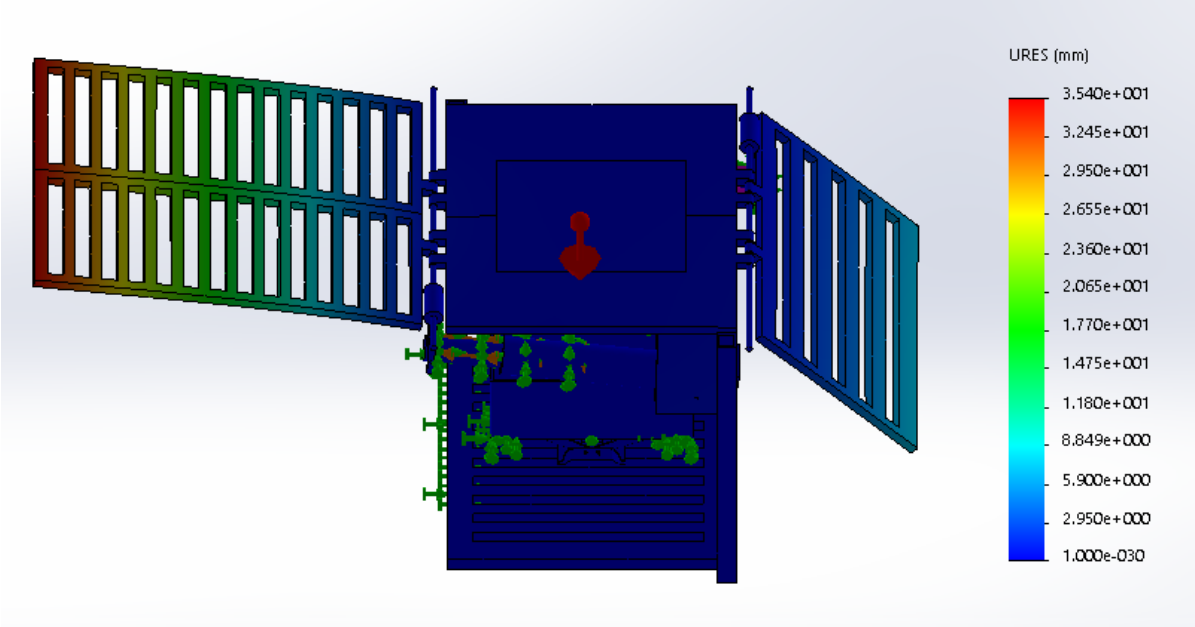

Figure 49 Displacement Analysis with 1200N on upper side and 1000N on pistons

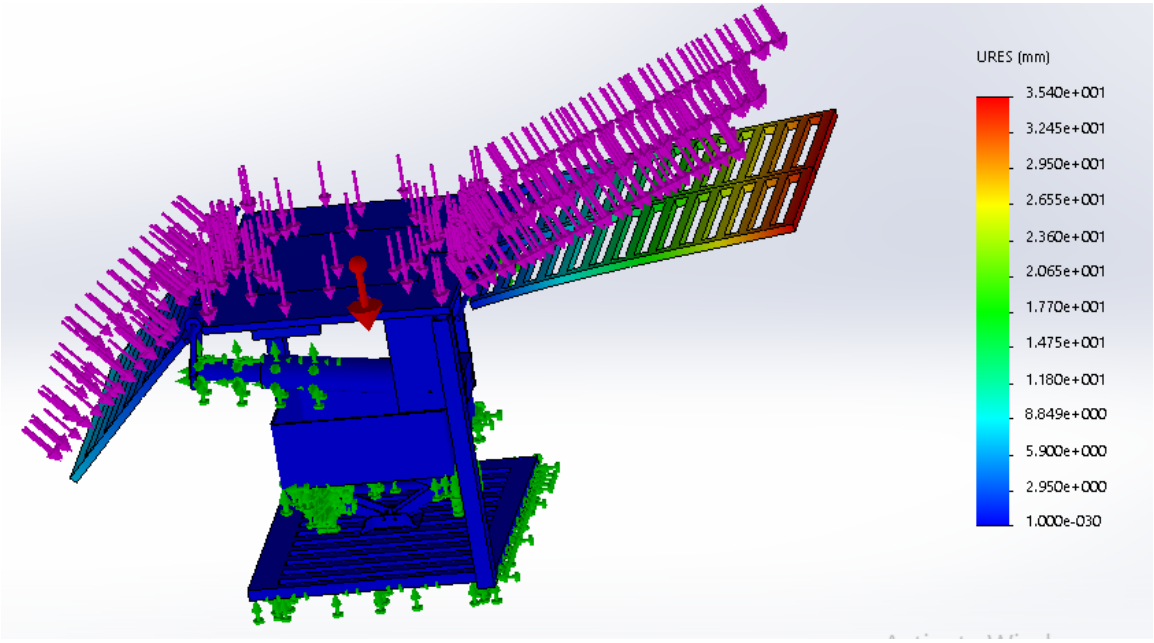

Figure 50 Displacement analysis on Wheelchair with distributed load of 1200N

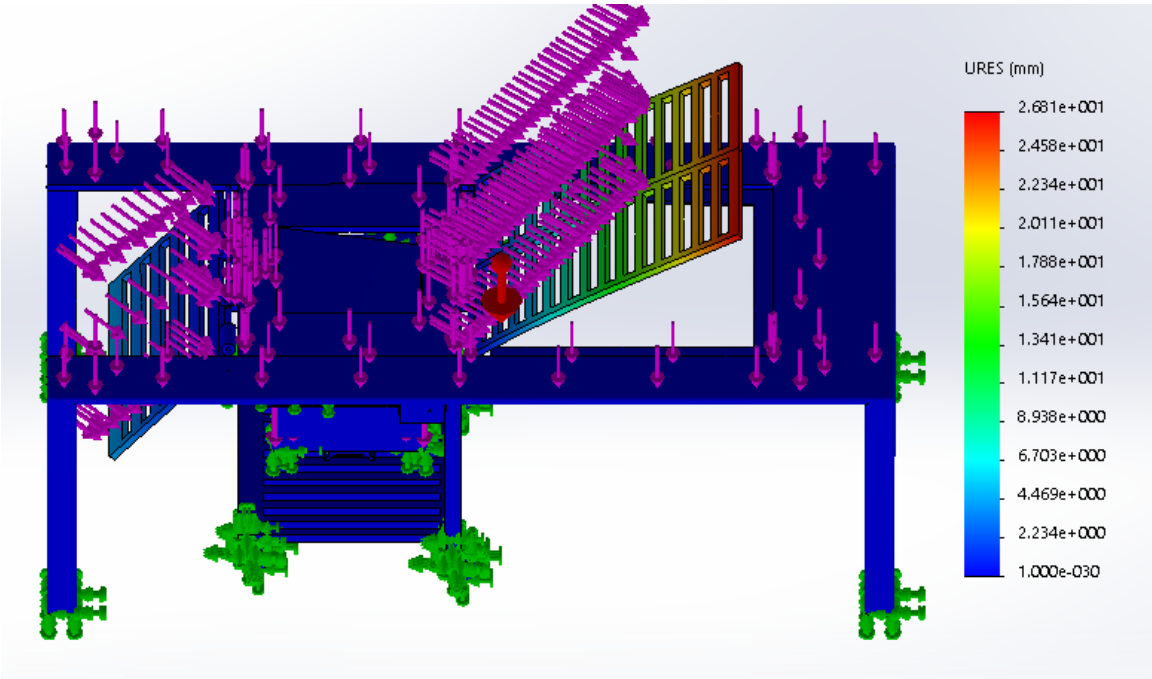

Figure 51 Displacement Analysis of bed under distributed load of 1000N

In this analysis, some observations were made to refine the design, joint positions between backrest & middle rest and middle rest & leg-rest needs to be designed and manufactured after considering all the loading conditions and stresses. As model of wheelchair is very critical, it bears all the load when it is separated from static frame, so all the stress, strain analysis was focused on its structure. As when wheelchair is converted into bed, load on wheelchair reduces as some load will be distributed on static frame now So when it is in the form of wheelchair, it will be under maximum loading condition.

Consumer Experience:

As we have all the mechanisms, designs, calculations and analysis of the project, the physical appearance for general understanding of the product outlook is also essential. We used Sketch Up pro for said purpose. The software helped us develop an outlook of the product about how it would appear physically to the consumers.

There are the set of pictures: one with the bed fully assembled; one with inclined backrest and declined leg rest within the frame; one with the chair separated from the main bed. Shown on next page:

Figure 52 Bed appearance as fully assembled in a room (Rendered)

Figure 53 Bed with inclined backrest and declined leg rest in a room (Rendered)

Figure 54 The chair detached from the bed in a room (Software developed)

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

Scope of the Project:

An automated nursing bed was developed under the scope of this project with following objectives:

- To cater for the growing percentage of bedridden patients suffering from the paralysis or other diseases that hinder the mobility of body limps.
- To assist the nursing staff and reduce the manual help required to look after such patients, since the hospitals of Third World Nations are severely understaffed.
- To minimize the external help required and help patient perform tasks like urination and defecation using automation systems.
- To minimize the effort required on the behalf of patient and nursing staff and also the agony and torment a patient undergoes when transferred from bed to a wheelchair to make him mobile.
- To provide such automated nursing bed at cost affordable to the majority of people in developing countries like Pakistan.

Facilities included in the bed:

With these objectives in mind, we modelled a bed that included facilities such as:

- A backrest with the ability to move from horizontal to vertical position, thus providing comfort and convenience to incapacitated patient to change his posture according to the need.
- Similarly, an actuated motion of leg rest is provided to help patient move his legs to a comfortable position and lessen the chances of developing ulcer sores.
- The middle part has been provided with a plate that can be opened manually with minimal force either by patient himself or by the person caring after him.

- An automated sanitation pot fills in the opening, thus helping patient to urinate or defecate without moving.
- The pot also has the capability of flushing the excretions and a water jet to help the patient wash himself.
- To help in the mobility of the patient from one place to another altogether, the bed is convertible to wheelchair.
- The wheelchair is detachable from the static frame of bed and is provided with automation system to further reduce the external help.

Kinematic Designs:

Thus, a bed convertible to wheelchair has been provided with all necessary features that are required to cater for incapacitated patients. All the mechanisms used to provide the above-mentioned facilities are developed using simple technologies that are widely available in the market at rates affordable to the majority of the population. These technologies are employed in a simple-to-understand and easy-to-use way. The kinematic design is as following:

- Backrest inclination has been achieved using a linear electric actuator. A rocker arm connected to the piston of actuator transfers the load from actuator to its other end clamped to a rod connected to the backrest. As the force pushes the rocker arm, the clamped end forces the backrest to move from a horizontal to vertical position in a controlled way and can be brought to a halt at any position suitable to patient's comfortable posture.
- A similar but less power rated linear actuator is attached to the legrest via a rocker arm. A similar motion to the backrest is achieved to suit the patient's posture.
- For opening of plate, a manual switch is used which helps the plate to detach from the static part on the use of minimal force that can be applied by patient or nursing staff. An electric motor, a set of gears and 4 bar linkage is used to move the plate

downwards. The gears help control the speed of opening as to avoid any shock or disturbance to the patient since he is directly in contact with the plate.

- To raise the pot to the required level, a motorized screw jack is used. The speed of raising platform is synchronized with the opening plate, to avoid any collapse between the two and also to fill the void as soon as possible.
- A pump is used to flush the excretion and can be switched by a button on the control panel. A water jet is used to wash the patient. For this purpose, a hose is housed within the pot and is operated with a button.
- A detaching mechanism is used to detach the wheelchair from static frame of nursing bed. This mechanism is a one touch slider locker and can be easily operated by patient.
- Electric motors are used for the movement of wheelchair. The rear wheels are connected to a single motor which drives the wheelchair. The front wheels are attached with a steering mechanism to help control the direction of wheelchair. This control is then transferred to patient using a remote control.

The design has been made with special attention to the patient's comfort and convenience. All the mechanisms are developed to achieve simplicity and cost effectiveness. External help required to take care of the patient has been minimized.

Total cost on the development of project incurred is Rs 101800 PKR/-. The cost was higher than expectation due to import of some actuators and higher taxation on imports. Labor cost also added to the expense. It can be minimized if the project is produced at mass level.

As a whole the project, once mass produced, will be available to the people at affordable rates and will help a lot of patients, not only in Pakistan but also other developing countries.

Future Recommendations:

Automated Nursing Bed was manufactured keeping in view various aspects of giving the patients with the best facilities, to reduce the efforts of the caretakers and to reduce the time required for the treatments of the patients. The objectives of our project were to design and

fabricate the bed having the features as described earlier, for the best care of the bedridden patients, while taking the costs in consideration.

While the bed was best for its ease, for the patients and the caretakers, and to its usability, there are still some suggestions and recommendations that can be implemented on this bed. Some of the recommendations are listed down below.

Left and Right tilting mechanism:

This mechanism has not yet been introduced into the design. However, the suggested mechanism is splitting the backrest and middle part into two components each. One component would be the rigid frame (that will be moved up and down by the rod as per our design) and the other component would be two separate slabs internally hinged to the frame such that the right slab rotates anticlockwise and the left slab rotates clockwise independently. Two arms would be welded to the slabs through the space of slots within the frame. The arms would be moved by a motor driven rod in the middle of the rear of back and middle part frame (using Geneva Mechanism). On one polarity, the rod will move the right slab, and on the other polarity, rod will move the left slab through locking and unlocking.

Improvements in Toilet System:

Our Automated Nursing Bed has a pot whose motion is controlled by the screw jack mechanism as described earlier. The pot is used for the collection of excretes/wastes of the patients. The toilet system also had a water jet mechanism for the washing of waste out of the patient. We also recommend some more facilitations in the toilet system for the patients i.e.

- If the head of the water in the pipes is low, the pressure of the water jet mechanism can be intensified.

- Seal traps can also be used to avoid waste and water leakage.
- To dry off the water out of the occupant, blower can also be attached in the toilet system.
- Toilet odor sprays can also be installed alongside the water jet pipes to eradicate bad odor.

Wireless Automation in the Bed:

Our automated nursing bed was designed with precise measurements and dimensions keeping in view the patient's comfort. Actuators were installed for the inclination and declination mechanisms of back rest and leg rest. Geared motor was used for the opening of the pothole in the bed. Screw jack mechanism was used for the up and down motion of the commode at pot opening. Wheelchair's front and backward motion as well as the direction movements were also controlled by the motors. All these machines were connected with a wired remote. Some suggestions that too can be applied on this automaton mechanism are as follows.

- Implementation of Electronics to design and manufacture a wireless control system for the operation of all the mechanisms of the Nursing Bed.
- A mobile application can also be generated to control the system without the remote.
- A voice recognition sensor can also be used to operate the mechanisms and the wheelchair using the occupant's voice only.

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