CHAPTER 14
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SIT TO STAND WHEELCHAIR – SECOND GENERATION

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INTRODUCTION

The goal of this project is to design and build a wheelchair that allows an individual to transition from a conventional seated position to a supported standing position. The finished product must be safe, reliable, and last for an extended period of time. This wheelchair has many benefits for the client. Providing an individual in a wheelchair with the ability to stand on his/her own provides various health benefits and added independence, comfort, and convenience. The current sit to stand wheelchairs in the market are extremely expensive and very heavy. The proposed solution is to design a sit to stand wheelchair for our client to use that will be lightweight, reliable, and inexpensive. A four bar linkage is employed to generate the wheelchair's motion and two gas spring cylinders are used to provide the necessary force to lift the chair into the standing position, requiring little effort by the user. The wheelchair quickly and easily changes positions. Design considerations included functionality, weight, reliability, and most

Fig. 14.1. Pictures of the final sit-to-stand unit in a standing position.

importantly safety of the wheelchair. While safety and function are absolute necessities with this project, the client requested other requirements for the proposed device. Physical restraints such as arm, leg, and chest supports had to be built into the device to facilitate safe operation. Overall floor size requirements of 26 x 27 inches were established in order to assimilate with the client's main transportation vehicle. Side supports, in addition to adjustable offset footrests, were also incorporated into the final design as illustrated in Figure 14.1.

SUMMARY OF IMPACT

Spina Bifida (SB) is a birth defect caused by improper development of the spinal cord occurring when the spine of the fetus fails to close during the first months of pregnancy. The degree to which one's life is affected by this condition varies. The client, Ms. Jill Caruso, is paralyzed from the waist down and requires the use of a wheelchair for mobility and transportation reasons. Jill requested a wheelchair that is able to go from a conventional seated position to a supported standing posture. She wanted this type of chair for a variety of reasons. For someone in a seated position all day, occasionally standing has dramatic health benefits. It improves circulation, helps prevent sores, takes the pressure off of one's skin, and improves overall comfort. She also wanted to be able to see over the walls at her son's hockey game. Also, the chair assists her in reaching shelves while shopping alone. Several companies currently produce such a chair, but they are quite costly and usually not covered by insurance. Unfortunately, the client's insurance is unable to cover the cost associated with this kind of wheelchair. After completing the chair, Jill has tested it and found it exceeded all her expectations. It has met all her goals and she is now able to do the things she requested. She is delighted to use the chair on a regular basis.

TECHNICAL DESCRIPTION

One of the main preferences of the client is a mechanically operated lifting mechanism rather than an electrically operated one. Due to the size of the van owned by the client and the existing lift mechanism used, the wheelchair design should not be any wider or longer (front to back) than her current manual wheelchair. The existing wheelchair lift mechanism also has weight restrictions that must be considered.

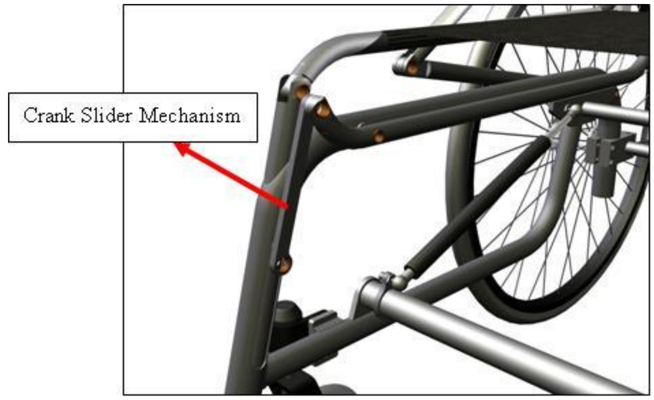

Fig. 14.2. Crank slider mechanism.

Several design options were considered, including using a hydraulic lift assist mechanism, an electric power screw mechanism, a lever assisted mechanism, and gas springs. Hydraulic systems are expensive and have a slow response time. Electric power screw mechanisms are also expensive and bulky. Using a house of quality, it was determined that a gas spring lift assist mechanism is simpler and safer. Through the use of gas springs, all of the client's requirements are met. Gas springs allow for a fully mechanical mechanism. Two gas springs are utilized with one placed on each side of the seat. These springs are attached to the wheelchair frame on one end and the seat bottom on the other. For optimal operating conditions of the gas springs, they are mounted in a nearly vertical position when the chair is in the seated position with the springs compressed. These gas springs are fully adjustable to achieve the required lifting force for the client. They are also relatively small, as well as more cosmetically appealing as compared to other lifting mechanisms. Since the gas springs operate within small spaces and tolerances, size constraints are easily met.

A locking mechanism is used to hold the chair in the seated position during normal operation. When the client desires to transition into the standing position, this latch or locking mechanism is released. The user then applies a force using her arms to initiate motion into the standing position using her arms.

Coupled with the input force of the gas springs and the initial applied force of the user, which is minimal, the chair transitions into the standing position. The standing position is defined as the seat bottom making an angle of 75° with the horizontal. This design requires the seat bottom be hinged at the front of the frame. The use of another hinge also requires a space between the seat bottom and seat back to allow the two parts to become aligned.

While in the standing position, the seat back is supported in one of two ways. A four-bar linkage is used to rotate and raise the chair, supporting the seat back. Another potential design option is the use a telescoping bar. This locks into place when in a standing position, and is easily released by the client. A similar mechanism is used to support the seat bottom if necessary. Using the house of quality, it is determined that using a four bar linkage is the preferred method.

The crank slider mechanism shown in Figure 14.2 is used to lift the chair caster wheels off the ground. This enables the chair to form a wider base for support, while letting the client exert most of her body weight on the front support.

Other considerations include the stability of the wheelchair, as well as leg and upper body supports for the user when in the standing position. There are a variety of ways to stabilize the chair while in the standing position. Prior to elevating in the standing position, the rear wheels are locked into place to prevent any rolling movement of the wheelchair while in the upright position. Any linear motion while in the standing position creates a potential tipping hazard due to momentum generated from the movement. This is accomplished using a standard braking mechanism similar to what is used on most wheelchairs today. To support the legs while in the standing position, padded rests are used that rotate off of the foot rests and lock into place just below the knees. The armrests also rotate prior to transitioning the chair to the standing position. The armrests move from a position at the user's side to a support position just below the user's elbows when in the upright position.

Kinematic Analysis

The modeling for the current design of the wheelchair is done using Autodesk Inventor. By drawing in a fully 3D world, the 4-bar mechanism and the crank slider mechanism that lifts the client out of the seated position are confirmed to function as designed. The basis of the lifting mechanism rests on the design of the 4-bar mechanism that lifts the client into the standing position, while changing the

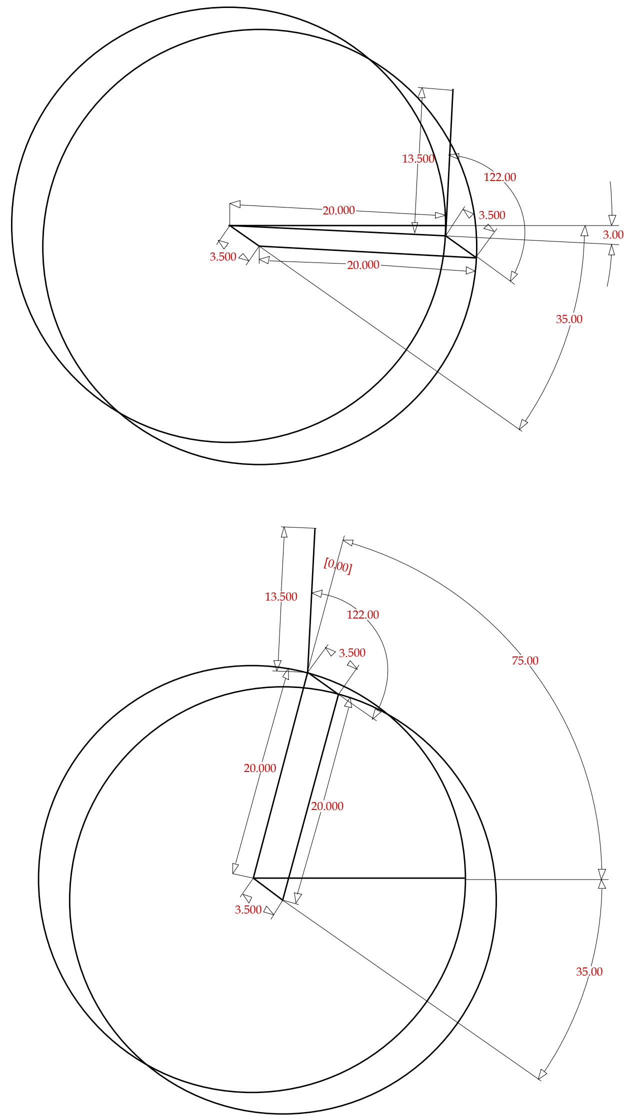

Fig. 14.3. Four bar mechanism moving from the seated position (top) to the standing position (bottom).

seat angle relative to the ground. It is designed using a graphical solution method as seen in Figure 14.3.

The final angle of 75 degrees for the seat relative to the ground is chosen based on existing sit to stand wheelchairs. It provides the safety of keeping the client's center of gravity closer to the center of the supports of the chair. The seat back angle does not change relative to the ground. This makes the seat back perpendicular to the seat in the seated position and at a twelve degree angle when in the standing position as shown in Figure 14.3. The twelve degree angle is necessary to support the client's upper body when standing. Figure 14.4 show images of the design modeled in Autodesk Inventor. Pictured are the seated position, half-way standing, and fully standing positions, respectively.

Design Calculations and Finite Element Analysis

First, a fairly rough stress analysis was completed on the chair in each of its positions. These included the seated, intermediate position just before the foot rests hit the ground, and the full standing position. This is done to identify which position held the critical, or highest, stresses. Thus, a more detailed stress analysis needs to be completed only in that position. The reaction forces for each case are calculated, and the highest stresses are identified for each position. The highest stress is found in the seated position; therefore it was identified as the critical position.

A detailed stress analysis on each member of the frame in the seated position was then conducted. Four members in the frame are analyzed. These are identified as members A, B, C and G. Free body diagrams of these members are shown in Figure 14.5. The estimated weight of the finished sit-to-stand wheelchair is around 40 lbs. The frame is made of Aircraft Grade Chrome-Moly 4130 Steel with a yield strength of 63 MPa. Wall thickness of members A and B are calculated as 0.065”, corresponding to a factor of safety of 5.1 and 3.4, respectively. The factor of safety for members G and C are calculated as 11.6 and 14.9, respectively. The welds on member C are also analyzed and found to be very safe with a high factor of safety.

Gas Spring Calculations

The placement of the gas springs is critical in the final design. The moments about the hinge connecting the seat bottom to the frame are taken into consideration in order to determine the optimal placement of the gas springs in the frame. The moment caused by the body weight of the user acts in the opposite direction caused from the gas spring input force. The moment caused by the gas springs must be greater than that caused by the distributed load from the user’s body weight on the seat bottom. Also, as the input forces change from the gas springs, the moment about the seat bottom hinge changes accordingly. It is important to note that as gas spring placement changes, the extended and compressed lengths of the cylinders change. This

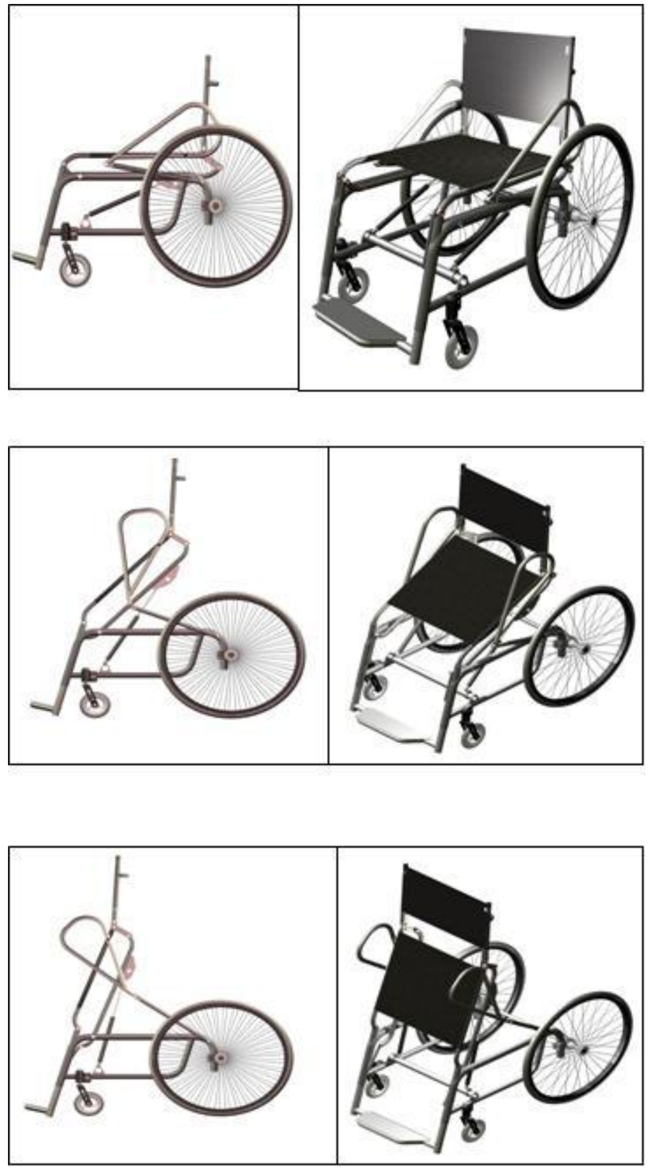

Fig. 14.4. Computer rendering of the final design; the seated position (top), half-way standing (middle), and fully standing positions (bottom).

had a large role in determining a supplier for the gas springs.

To have the gas springs custom made is not only very costly, but also require a great deal of lead time due to the processing of the parts. For the given application, accounting for the timeline and budget allotted, a supplier was found that stocks gas springs with the desired input force and extended and compressed lengths as close as possible to those calculated to be the optimal conditions. Once this was determined, the wheelchair design had to be retrofitted in order to accommodate the changed dimensions and placement of the mounting brackets.

The selected gas springs have an adjustable linear force. This was accomplished by bleeding off pressure from them through a release valve until the desired input force was achieved. The gas springs that were thus ordered had initially a much higher than needed input force. Through testing with the client, the supplied force was adjusted to the best working condition.

Machining and Fabrication

Frame material was ordered from Airparts Incorporated. Saxon Products Inc. completed the required tubing bending for the final design. All bent tubing pieces were bent with excess material left at the end to aid in the bending process. After cutting all of these pieces to the required length, the necessary holes were drilled in the tubing in order to make the desired connections.

All flat plate pieces welded onto the frame material that were used to make connections were cut out using a CNC plasma cutter. Sperling Heating & Ventilating Company donated their services and equipment for completion of this task. After getting all the necessary parts machined, the frame was welded together by Bruce Welch and group member Jake Welch. They also handled all other welding, including various parts on the frame. Then all the parts were powder coated, and then assembled. After completion of assembly of the prototype model, extensive testing took place to make adjustments to best fit the client. This included making any necessary alterations that included gas spring adjustment. Testing was conducted to make sure the lifting device worked properly and ensure it met all the clients' expectations. The client was extremely satisfied with how the final product turned out and is looking forward to using it.

Donations were obtained from a titanium wheelchair manufacturer, TiLite, consisting of front wheels with tire and casters, rear wheels with tire and axle bolts, brakes, and a footrest. These donations have been priced out at a value just under $1400. MTS Seating donated their powder coating service on all the steel pieces of the wheelchair. These donations helped the group to stay around the $850 approved budget.

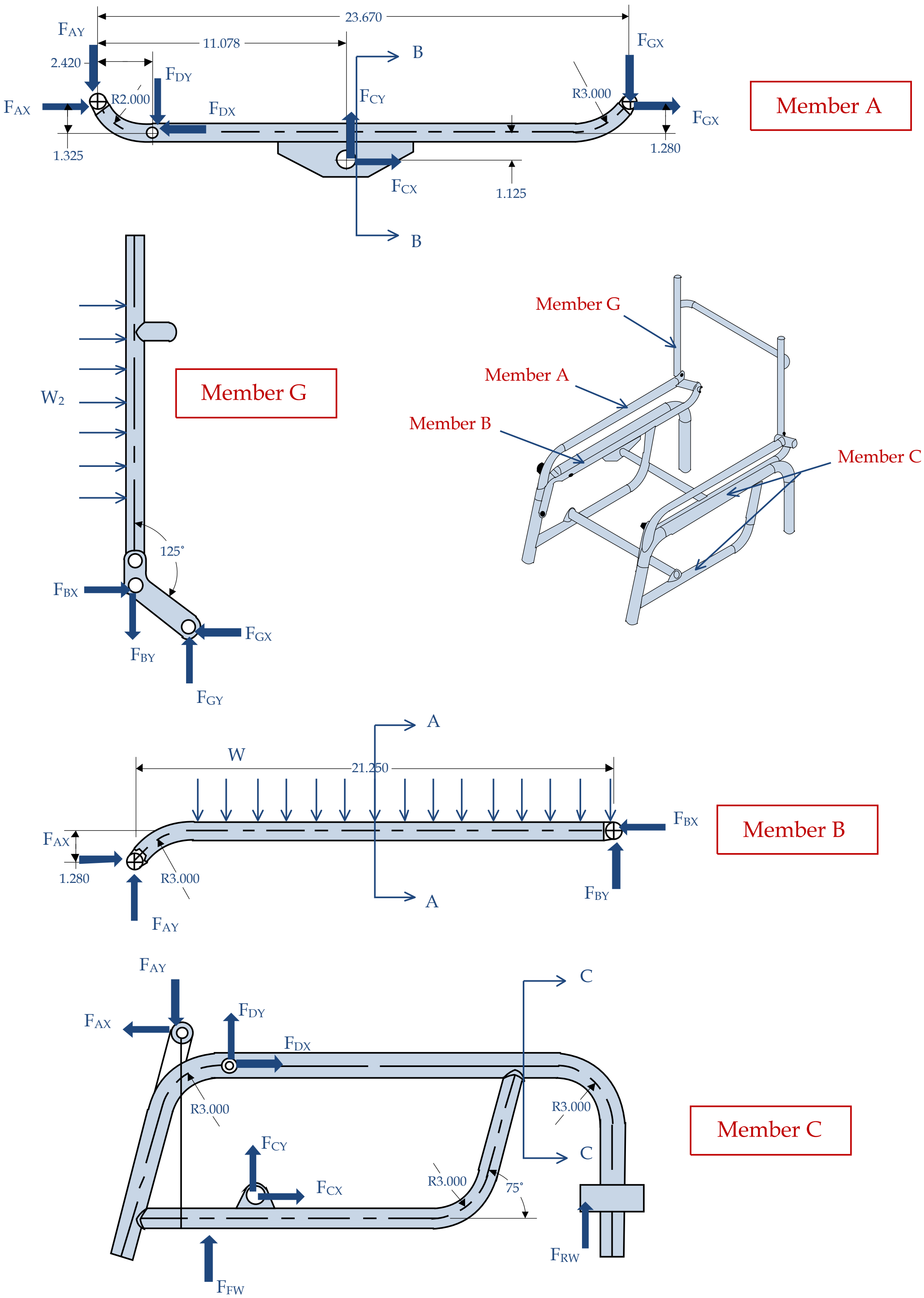

Fig. 14.5. Free body diagrams for members A, B, C and G.

ADAPTATION OF A WHEELCHAIR TO MOUNT A 16MM FILM CAMERA

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INTRODUCTION

The goal of this project is to adapt a wheelchair to allow an individual with a disability to operate the main functions of a Bolex 16mm film camera. This individual is a C5 quadriplegic, with limited use of the shoulders and biceps, but no use of triceps or hands. He is a student at the University of Toledo majoring in film. To complete his major he needs to take FILM 2130. This course requires students to learn about and use the Bolex 16mm film camera. Design objectives focused on allowing the client to tilt and pan the camera, as well as lining up a shot, and running film. A frame that attaches to the client's wheelchair made of aluminum and steel, acts as a platform for the camera. The camera is attached to the frame via a quick release mechanism with a tilting base. A remote viewing system is attached to the eyepiece of the film camera and allows the client to easily see what he is filming. Buttons are placed according to the clients request to operate the camera. Figure 14.6 shows the client using the camera, while seated on his wheelchair, and Figure 14.7 shows a conceptual rendering of the system that was developed.

SUMMARY OF IMPACT

An individual with disability is aspiring to complete a degree in film at the University of Toledo. One of the requirements of the degree is to complete the FILM 2130 course. This course involves the use of a Bolex 16mm camera. The successful completion of this project allowed this individual to operate the film camera independently. After testing the system that was developed, the client found he is easily able to operate the main functions of the Bolex 16mm film camera.

Fig. 14.6. Client using the Bolex 16 mm film camera.

TECHNICAL DESCRIPTION

Adapting the client's wheelchair to allow him to use the Bolex camera involves the design and construction of a stable platform and controls to run the camera. The platform needs to withstand the weight of the camera and also any external loads applied by the client. A steel block clamping system was devised to easily attach the "L" shaped support arm to the wheelchair. The support arm is bolted to the clamping system and is made of extruded aluminum profiles. The profiles are used because of their light weight and rigidity. Also, the aluminum profiles allow for easy attachment of buttons and controls.

Attached to the top of the support arm is a lever locking tilt device. This allows the client to lock in different angles of vision when he is shooting film. Mounted on top of the tilt device is a quick release system. It consists of an aluminum T-slot and locking pin. A T-block is bolted to the bottom of the Bolex camera, and this block then slips into the T-slot on the tilt mount. After the block is inserted, a locking pin is pushed across the front through two holes drilled in the T-slot to hold the camera in place.

To allow the client to see what the camera is actually filming, a digital viewing system is included in the design. The Zigview S2 Digital Eye Piece viewing system is chosen for its remote operation capabilities. Zigview mounts to the eyepiece of the Bolex through a custom Delrin adapter, as shown in Figure 14.8. The adapter presses onto the eyepiece for a secure fit and transfers the image seen through

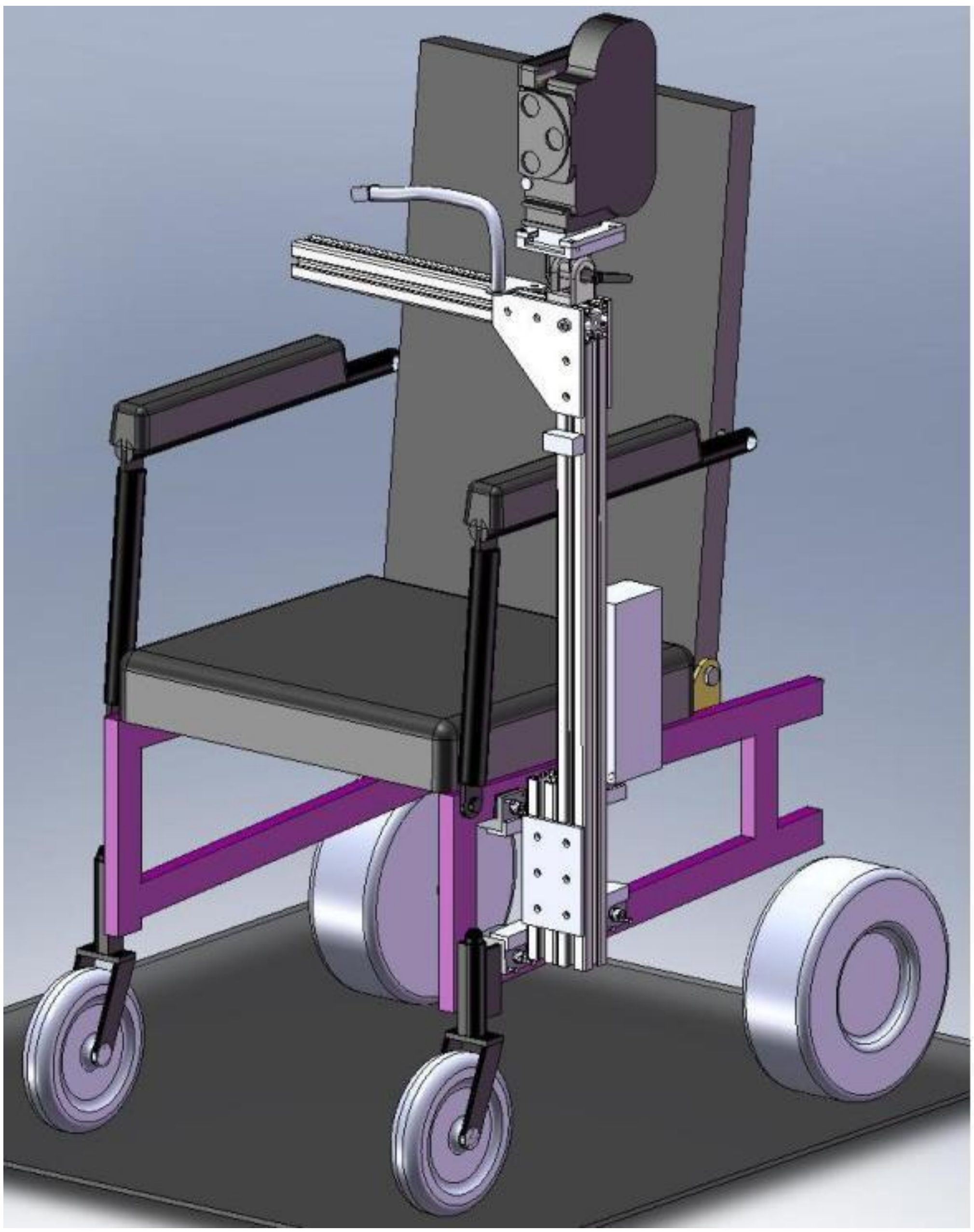

Fig. 14.7. Conceptual rendering of the system.

the eyepiece to a viewing screen. The Zigview's remote 2.5" LCD viewing screen is mounted, via a Velcro strip, on the end of a flexible metal tube that allows adjusting the screen's position. The remote viewing screen allows for the Bolex to be mounted away from the client, and still allows the client to instruct an assistant in accurately tilting the camera. The digital eyepiece captures the image seen in the Bolex eyepiece and displays it on an LCD screen. The LCD screen is attached to the support arm as shown in Figure 14.9 via a flexible tube, which the client can move to position the viewing screen in a convenient location. The power button for the Zigview, which is located on the viewing screen, was modified by making the button larger and also slip-resistant, giving the client the ability to activate the button. A sunshade was also constructed that mounts onto the viewing screen, helping to reduce glare from the sun when filming outdoors.

The Bolex camera runs film in two different modes, continuous run and single shot. To give the client the ability to use the continuous run function, an electric motor made for the Bolex camera is used. It mounts to the side of the Bolex with three screws. A momentary push button switch is wired to control the motor. When the client wants to start filming, he pushes and holds the button down and then releases it when he wants to stop. This switch is mounted on the inside of the support arm upright, which allows for easy access and meets the client's preference.

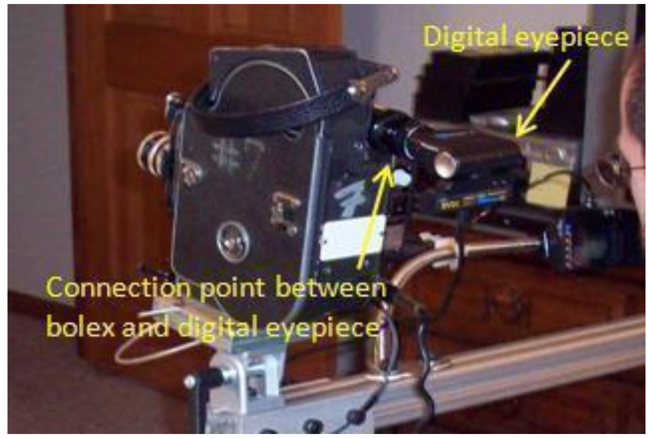

Fig. 14.8. Zigview adaptor.

To take film one frame at a time, the motor is removed and a plunger cable is attached to the single shot button on the Bolex camera. This cable is being borrowed from the UT Film department. The cable is mounted to the side of the support arm in a place denoted by the client. To take a single shot, the client pushes the plunger in until the camera advances the film by one frame. The tips of the buttons have a rubber pad placed on them to help the client push them in and to keep his hand on them.

COSMOL, a finite element package, was used to perform the structural analysis of all the components of the unit. The total cost of the material is about $560.

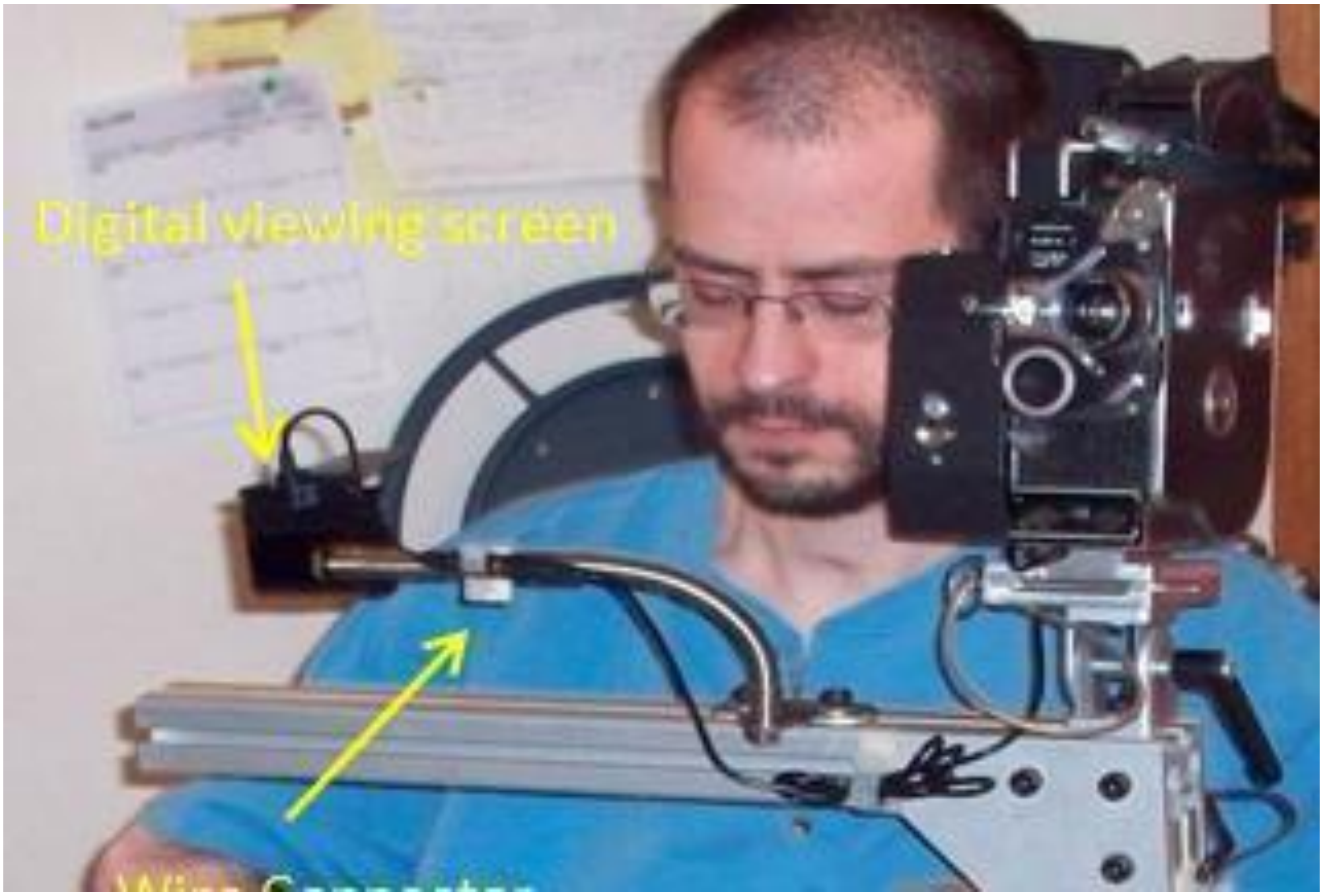

Fig. 14.9. Zigview remote viewing system.

DEVICE TO ASSIST A PATIENT OUT OF A HOSPITAL BED

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INTRODUCTION

The purpose of this project is to design, analyze, build and test a mechanism that assists a patient out of a hospital bed. This device is not focused on a patient with a specific disability but rather any patient that has difficulty getting out of bed independently. After discussing the scope of the project with physical therapists, it was decided that the shoulder would be lifted to help the patient grab the opposite hand rail and swing their legs over the side of the bed. Once the patient achieved sitting position, the rear is be lifted and pushed in a lateral motion to help the patient stand up. This is accomplished by using two air cylinders that would lie under the left shoulder and the right rear of a patient, and inflate to provide lift assistance. The design concept and lift process is depicted in Figure 14.10.

SUMMARY OF IMPACT

Many patients in a hospital have difficulty getting out of bed independently for many reasons. Whatever the case, this device allows the patient to stand independently. This device is also beneficial to hospital personnel because any patient that needs assistance from someone to get out of bed is able use the device instead. The Leadership Team at Flower Hospital, a member of Promedica Health System, assessed the final product and found it novel and useful.

TECHNICAL DESCRIPTION

Two cylinders are used: one for the shoulder with a diameter of 8″ and one for the rear with a diameter of 12″. A pump designed to inflate air mattresses was found to be adequate. A total of three solenoids and three switches are used to direct the air flow properly. Two of the switches are Double Position Single Throw switches; the third one is a Three Position Single Throw (3PST) switch connected to all three solenoid valves. To operate, a patient flips the shoulder cylinder switch that turns on the pump, and opens the first solenoid allowing air to pass to just the shoulder cylinder. Similarly, the rear cylinder switch is flipped to turn on the pump, and open the second solenoid to allow air to pass just to the rear cylinder. To evacuate the cylinders, the 3PST switch is flipped to open the third solenoid (which is open to the atmosphere) as well as the other two solenoids. An analog timer is added to prevent prolonged use and damage to the pump. The patient flips the switch to turn on the pump, and begins inflating the cylinder; the timer turns the pump off after one minute regardless of whether the patient flipped the switch back off. The switches are housed in a small plastic enclosure and wires are run to a wooden box made of 0.75″ treated plywood that contains the three solenoid valves, the safety shut-off timer, the air pump and air tubing. Carpeting is attached to the inside walls of the box to absorb sound. Metal brackets are used to hang the box off the back side of the hospital bed headboard, as shown in Figure 14.11. Stress analysis was conducted to estimate the hoop and longitudinal stresses in both cylinders and a minimum factor of safety of 4 was calculated. Also, the amount of head loss in the system was calculated and the total pressure loss in the system was estimated at .874 psi from the pump outlet to the entry of the cylinders. Despite this head loss, the pump is still capable of achieving sufficient pressure.

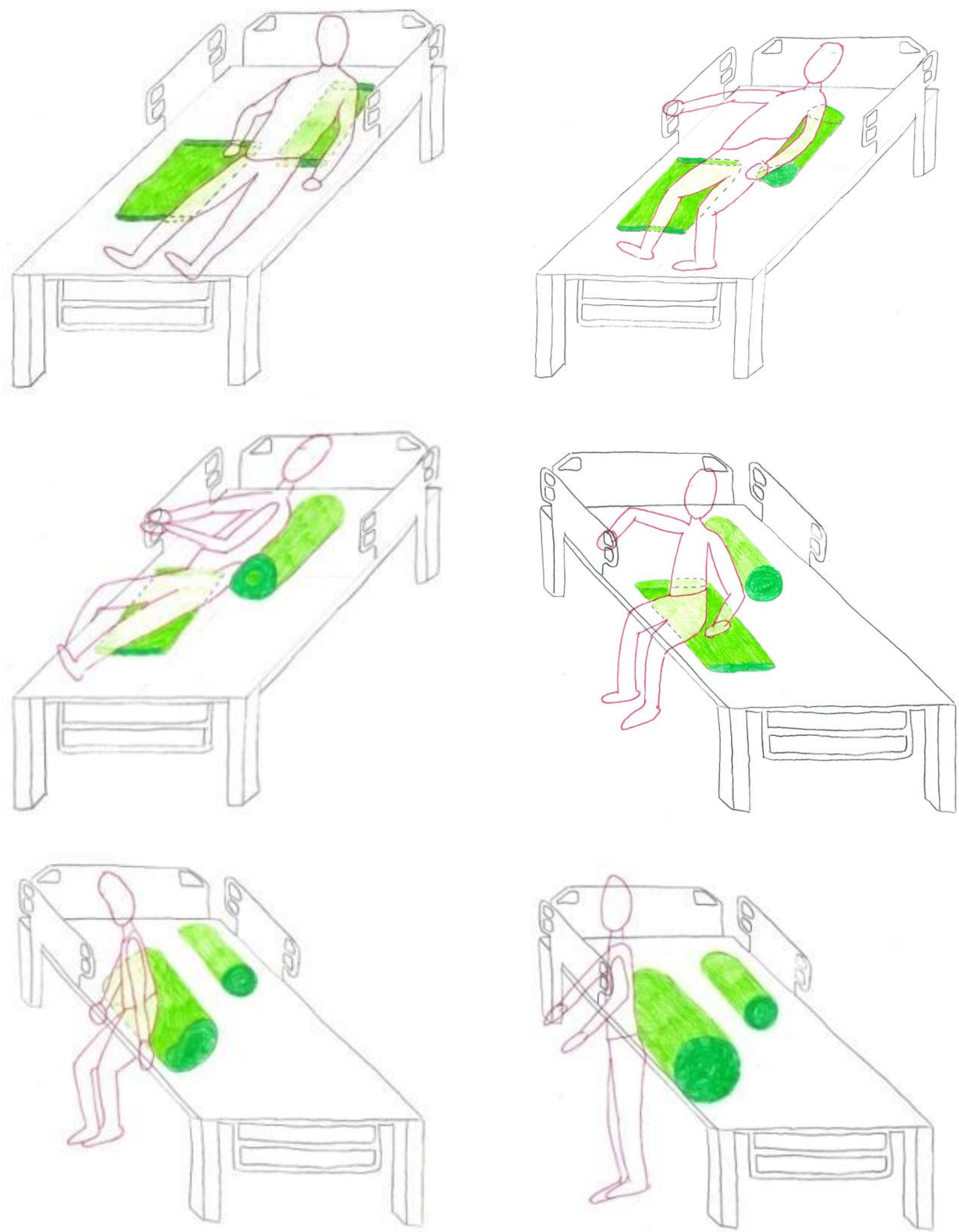

Fig. 14.10. Design Concept (from left to right; begin with both bags deflated, shoulder bag slowly inflates, when shoulder bag inflation is completed, the patient is sitting and the rear bag slowly inflates).

After testing the lifting ability of the rear cylinder, it was decided to place a board on it to provide stability while inflating as shown in Figure 14.12. Without the rigidity, the patient needed to use their abdominal muscles to balance themselves on the flexible cylinder. As the cylinder inflates, one side of the board rises with the cylinder to simulate a wedge. As well as providing stability, the board provides a lateral motion that helps push the patient forward, as opposed to lifting the patient straight up. Each cylinder has its own bolster bag with a pull cord to close the bag. The two bolster bags are sown to a mat, and the board placed on the rear cylinder is attached to the mat made from 100% cotton. The mat is then attached to the longer blue fabric, draw sheet, which is placed crosswise underneath the patient and used to assist in moving a patient from bed to bed or repositioning a bedridden patient.

The total cost of this project is $500.

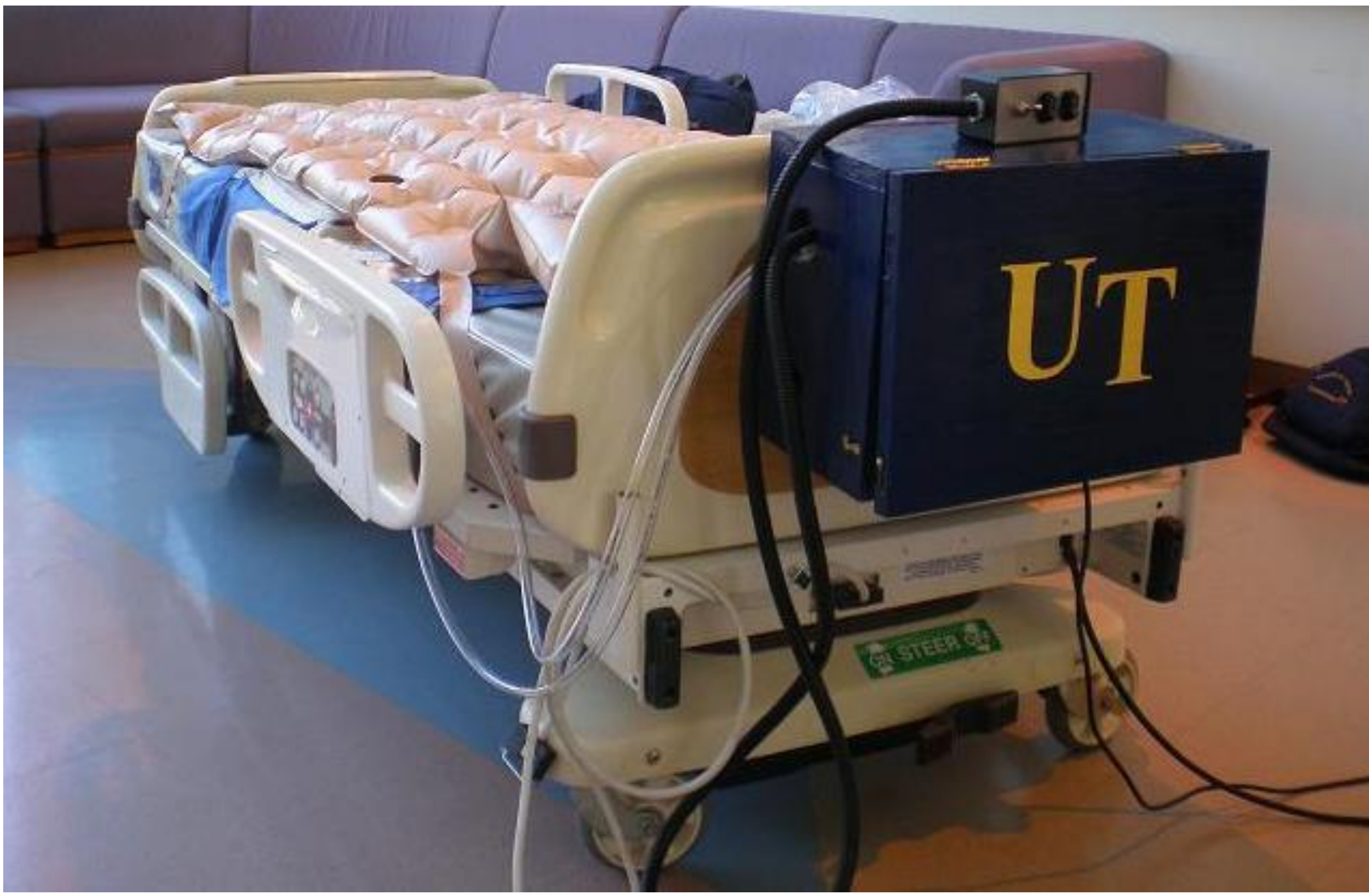

Fig. 14.11. Control box attached to a bed.

Fig. 14.12. Board attached to the rear cylinder

A DEVICE TO ASSIST A CLIENT TO BUCKLE HIS SEAT BELT

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INTRODUCTION

The goal of this project is to design a system to assist an individual with a physical disability to buckle his seatbelt. The client has a limited range of motion and needs a system that requires minimal exertion to operate. A fully automated system is developed for this purpose that utilizes an auxiliary belt and a motor assembly to buckle and unbuckle the client's seatbelt. The auxiliary belt is attached to both the male end of the client's existing seatbelt, and the motor assembly. To have his seatbelt buckled, the client simply presses a pushbutton switch which activates the motor assembly. The motor assembly rolls up the auxiliary belt and the male end is guided to the female end and locked. When the client is ready to exit the vehicle, another pushbutton switch is pressed that activates an actuator. The actuator depresses a release mechanism that unlatches the seatbelt, and allows the client to exit the vehicle.

SUMMARY OF IMPACT

As a result of having Cerebral Palsy, the client is physically unable to buckle/unbuckle the seatbelt of his car. The client drives to and from work, and either relies on the assistance of others to buckle his seatbelt, or simply forgoes the usage of his seatbelt. This situation presents an obvious problem for the client with regard to safety. This problem is resolved by developing a system that assists the client in buckling his seatbelt independently. The device was successfully tested by the client as shown in Figure 14.13.

TECHNICAL DESCRIPTION

A fully automatic design is created that works by utilizing an auxiliary belt that is permanently attached to the male end of the existing seat belt.

Fig. 14.13. Client successfully using device.

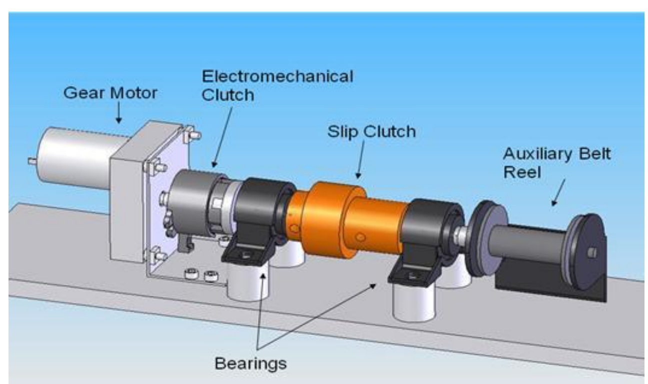

Fig. 14.14. Motor assembly.

The auxiliary belt is kept slack to allow the user to slide underneath it, and into the seat. A 24 volt gear motor with a maximum torque output of 50 in-lb. at 25 rpm is used to provide the force necessary to buckle the seatbelt. The motor assembly, shown in

Figure 14.14, is comprised of the motor, an electromechanical clutch, a slip clutch, two bearings and the auxiliary belt reel. When the seatbelt latch is released and the client wishes to exit the vehicle, the driveshaft of the device must fully disengage so that the existing seatbelt retracts properly. Because the output shaft of a gear motor cannot free-spin when there is no power, an electromechanical clutch is used in line with the output shaft. When the switch is pressed to engage the gear motor, power is also delivered to the clutch allowing the reel to spin and retract the auxiliary belt. When the switch is released, thus disengaging the motor, power is removed from the clutch causing the reel and belt to spin freely. The safety of the client is of prime importance, and the inclusion of the slip clutch helps to ensure it. If for some reason the client are becomes entangled in the belt, the slip clutch slips and allows the motor to free spin without transmitting any more torque to the reel.

Figure 14.15 shows the belt attachment and release fixture. It is made of ABS plastic and is used to connect the auxiliary belt to the existing male end of the seatbelt. The release mechanism is made of aluminum and is engaged by the linear actuator. The belt guide is used to align the male and female ends of the seatbelt, and also used to house the release mechanism.

A motor assembly cover is used to prevent any entanglement of foreign objects in the motor assembly. The design requires electronic control of both the seatbelt fastening mechanism and release mechanism. The user operates both of these systems via an electronic control box shown in Figure 14.16. The electronic control box, has two momentary pushbutton switches, one to operate the seatbelt fastening device, the other to operate the release mechanism. Momentary switches are used for safety reasons; they require the user to depress each switch for the entire duration of operation. Should any problems arise, which may compromise the user's safety, the user can let go of the button causing operation to cease. A green indicator lamp illuminates when the seatbelt fasten switch is depressed to alert the user the seatbelt fastening

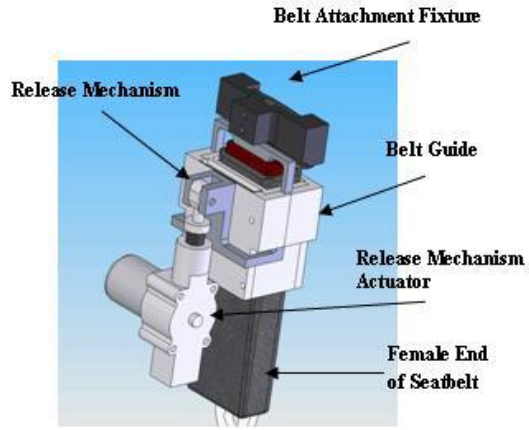

Fig. 14.15. Belt attachment and release fixture.

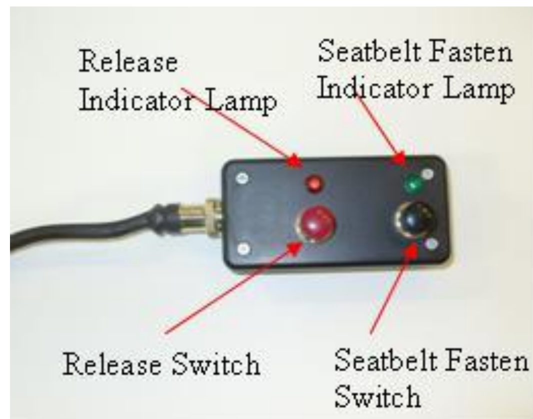

Fig. 14.16. Belt guide control box.

mechanism is in operation. A similar red indicator lamp illuminates when the release switch is depressed. The system is powered by the 12-volt accessory outlet of the client's vehicle. A step up converter is used to transform the 12-volt supply to the necessary 24-volts for the motor. The release mechanism also manually releases to allow for a quick release in the event of an emergency or power failure.

The total cost of the parts of the system is $547.02.

CUSTOMIZED RACING WHEELCHAIR

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INTRODUCTION

The purpose of this project is to design and assemble a fully customized racing wheelchair for an individual using a wheelchair for daily living activities. An I-cage design is used in the construction of the racing wheelchair. An A-frame is employed. Special attention is used in the design of the compensator and steering linkage to allow proper and safe steering during both track racing and road racing. Figure 14.17 depicts the client with the racing wheelchair along with the team of students who worked on this project.

SUMMARY OF IMPACT

The client was born with Spina Bifida. He is a twenty-three year old theatre major at the University of Toledo. He enjoys a wide selection of music and working at the Toledo Zoo, in addition to physical activities, including tennis and biking with a borrowed racing wheelchair. This individual required a customized racing wheelchair with a seating position that allows for maximum performance, with minimal contact points, which may produce pressure sores. He requested a position with the feet and lower legs in front of him, for comfort and circulatory purposes. A racing chair

Fig. 14.17. The client on the racing wheelchair.

is designed and fabricated for use in both competitive and non-competitive environments. The unit was successfully tested by the client. The successful completion of this project allows the client to engage in beneficial overall physical health and weight loss activities, as well as being able to leisurely enjoy the outdoors, away from everyday wheelchair.

TECHNICAL DESCRIPTION

The client requested an open front to the cage, a footrest, and use of the chair on both track and street courses. Two possible cage designs were identified, including I-cage and V-cage designs. Also, three frame designs were identified including T-frame, A-frame and V-frame. To meet the client's needs, an I-cage and an A-frame were selected. Aluminum tubing, ½" (0.125" thick) for the cage and 2" (0.25" thick) for the frame, was used to construct a three wheel racing wheelchair. Standard bicycle components are used that include: front fork and tire, hand brake and rear wheels.

The front steering system consists of several parts unique to a racing wheelchair. One of these ancillary components is a compensator. To keep the front wheel under control while the client powers the rear wheels, a compensator system is needed. A compensator is part of the front steering system and consists of a spring loaded damper to keep the front wheel turned at a specific angle. Without this, the wheel turns freely and prevents the chair from functioning properly.

Given a 3-wheel, I-cage, A-frame, the main calculations determine the center of gravity (CG), the impact load, the critical roll velocity and the force and moment for the compensator. The client's anthropometric data are used in these calculations. The impact load is calculated as 2500 lbf. This is calculated using a mass of 225 lb., which includes the estimated weight of the chair and the rider, and a velocity of 30 mph and an impact time of 91 ms. A critical roll velocity of 23.5 mph was calculated as the highest velocity that can be achieved before the chair overturns as it negotiates a 60 ft. turning radius.

Two sets of handle bars are used: one for steering and the other for track use. The two handle bars are connected with the compensator, as shown in Figure 14.18. The front fork caster angle is 45 degrees.

Fig. 14.18. The two handle bars connected with the compensator.

Design considerations for the steering included allowing the wheelchair to be able to turn on a track, as well as on a road course. The effective steering angle to turn a radius of 60 ft. is calculated as 3.7 degrees. The corresponding angle that the steering handlebar turns is calculated as 5.25 degrees. This angle is used to calculate the force that the user needs to apply on the rear handle bar to maneuver the wheelchair.

I-DEAS, a finite element analysis software package, is used to perform the structural analysis of the cage. A maximum acceptable stress of 12.7 kpsi and a maximum acceptable deflection of 0.06" are found in the cage.

The students working on this project were able to secure a donation for the labor and materials for the aluminum A-frame and I-cage, as well as other support materials. The costs of the other parts of the wheelchair including the rear wheels, compensator cylinder, front wheel and fork and push rims and rubber were $750. The team members posted a detailed description of their design and analysis on the World Wide Web at the following URL address:

http://www.eng.utoledo.edu/mime/design_clinic/design_expo/Fall07Pages/2007-04-07/Home.html

BEACH WHEELCHAIR

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INTRODUCTION

The purpose of this project is to develop a manually propelled beach wheelchair that a user propels by themselves without assistance on a beach or any sand terrain. The unit is designed and assembled consists of a frame made of furniture grade, ultra violet light resistant Polyvinyl Chloride (PVC) pipe with mountain bike tires mounted on standard rims because of their thick tread. This increases surface area and grip in the sand. The PVC frame is light enough so that the user can easily load and unload the wheelchair into a vehicle, which greatly facilitates transportation. The rear wheels are doubled, two on each side, for a total of four rear wheels. The outer wheels on each side are removable to reduce the overall width to a manageable transportation width. The front two caster wheels are pre-manufactured beach ready balloon wheels. Figure 14.19 depicts the final product.

SUMMARY OF IMPACT

The Ability Center of Greater Toledo (ACGT) is a non-profit organization in northwestern Ohio assisting people with disabilities in living, working, and socializing within a fully accessible community. The ACGT has a beach wheelchair they allow their patrons to rent out, but the wheelchair is very heavy, must be pushed by another individual, and cannot be transported without the use of a trailer. Due to the need of trailer, this wheelchair is rarely used. The successful completion of this project has allowed any client to use it independently. The design of the new chair allows for a variety in customer size, yet still is user-propelled.

TECHNICAL DESCRIPTION

Safety, lightweight components, and transportability are the three main design considerations. The beach wheelchair had to be less than 26″ wide, 42″ long, 48″ high and less than 40 pounds. These criteria are specified to allow the chair to fit in a standard minivan and be lifted by existing wheelchair lifts into the van.

Fig. 14.19. Picture of the actual prototype.

The final design implemented two standard wheelchair rims retrofitted to connect to one another, for a total of two tires on each side. These rims are fitted with large treaded mountain bike tires to increase surface area and traction in the sand. The four rear wheels have axles placed just below the seat. The rear axles are ½ inch steel axles held in place by PVC bushings inserted into the PVC fittings. The front caster wheels are pre-manufactured beach ready caster wheels. Caster housings are fabricated by Unique Fabrications, Inc., using thrust bearings, steel plating, a few bolts and some spacers. The wheelchair frame is constructed with lightweight furniture grade PVC pipe. Furniture grade pipe has an UV inhibitor to disallow the molecular breakdown of the PVC that UV light causes.

The inner wheels rear wheels are secured to the PVC frame easily. The existing hand rims attached to the procured wheels were removed and angle irons attached to the outer wheels are used to bolt the rims together. The angle iron is cut into small pieces that are bolted onto the frame through holes drilled into the tube race of the rim. Holes were then drilled perpendicular to the wheel through the angle iron, and bolts are inserted through these holes and bolted to the hand rim holes on the inner wheels. Figure 14.20 depicts a picture of this assembly. Brakes, footrests and backrest are hard mounted to the frame. Plywood square is hard mounted to the frame, on which the seat pad was secured.

The location of the seat with respect to the rear axle is determined taking into account rear stability and ergonomic considerations. Weight distribution in the sand is a major design consideration as the wheelchair must be maneuverable in the sand. The wheel surface area contacting the sand is calculated at 300 pound load in the seat and equal weight distribution among the four tires. With those values, the wheelchair sinks in the sand less than one inch. Further calculations demonstrate the chair can be propelled by the client. Structural analysis determined the maximum stresses in the PVC frame, and a factor of safety of over 6 was calculated.

The four rear wheels were donated by Gilligan's Health Aid of Ohio, Inc. The cost of all other parts is about $450.00. The students working on this project posted a detailed description of their design and analysis on the World Wide Web at the following URL address:

http://www.eng.utoledo.edu/mime/design_clinic /design_expo/Fall07Pages/2007-04-08/home.html

Fig. 14.20. Picture of the rear wheel connection assembly.

ADAPTATION OF PIANO PEDALS FOR AN ADULT – THIRD GENERATION

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INTRODUCTION

A pianist usually needs two functional feet to play the piano correctly. A music instructor at The University of Toledo and pianist has Multiple Sclerosis (MS) and has been fitted with a motorized wheelchair that allows her to position herself in many different ways so that she can perform many of the essential everyday functions. With the aid of her wheelchair, she can situate herself in the desired position to play the piano with her left foot. The objective of this project is to develop a pedal adaptation device that gives our client the ability to use her left foot to play two piano pedals at one time. The design allows the client to use her left foot to control her piano's right damper pedal. The product developed incorporates a mechanical component that allows the playing of the original damper pedal, with a transposed pedal to the left of the current pedals and an electric solenoid to depress the Una Corda (left most) pedal whenever desired. The device developed is portable and adaptable to different pianos. Figure 14.21 shows the adapted piano and Figure 14.22 depicts the client using the unit.

SUMMARY OF IMPACT

Having to use piano pedals with limited mobility is a considerable challenge. For more difficult music pieces, the use of the damper (right) pedal is essential. The client has MS that has taken her ability to use her right leg and right foot away. Attempting to operate the pedal with the left foot is uncomfortable at best, and considering the client's needs, unacceptable. As demonstrated, she can turn her motorized wheelchair enough to allow her left foot to play the damper pedal. However by moving her body to the right caused an undesirable change in her posture and playing technique. Moving the chair and the client in such a way is neither practical

Fig. 14.21. Adapted upright piano.

nor safe. The successful completion of this project allows this music instructor to play the damper and the Una Corda pedals at the same time using her left foot. She successfully tested the units on different pianos which positively impacted her profession, and hence her life.

TECHNICAL DESCRIPTION

This project was attempted twice in the past by two previous teams, and both devices have resulted in unsatisfactory results. It has been emphasized by the client that gaining the ability to use the damper pedal is vital. A hybrid design that uses both mechanical and electric components to perform the desired actions was selected. The final design of the system is comprised of a hollow steel rod 95/8" outer diameter and ½" inner diameter) that has two new pedals semi-rigidly affixed to it. One pedal sits to the left of and at the same height as the three existing piano pedals, while the other pedal is positioned directly above the piano damper (right most) pedal. Levers are used so when the client presses the new left pedal downward, the motion is transferred to the pedal above the damper pedal. While playing this portion of the device, the Una Corda (left most) pedal can be played at the same time using a solenoid. A switch has been fitted to the side of the new manufactured left pedal for the client to push on and off by rotating her feet, thus activating and deactivating the Una Corda as she wants.

A continuous duty 120 VAC solenoid, 18P-C-120A solenoid from Guardian Electric Manufacturing, is used in the design. The solenoid can be plugged into any grounded wall outlet without any additional sources needed. It has a maximum stroke length of one inch, while producing 60 ounces of push force. Overall, it is small enough to fit into the designed system, less than 2 inches wide by 2.093 inches thick by 2.5 inches tall. Sponges and insulation are used to dampen the electrical noise that is produced by the solenoid.

A hollow rod is attached to bearings at both ends, allowing for the rotation in the system. The bearings inside their brackets are press fitted into them, and placed at each end of the rod. This bearing-bracket assembly allowed the rod to be attached to the external frame of the device, while still allowing the rod to rotate as needed. The frame, which serves as the support structure for the apparatus, is constructed from hollow aluminum square tubing. Spring locking mechanisms on the outer frame of the device are used to allow the client to change the height of the new pedals as she deems necessary, so that the device can be used on many different pianos. Overall, the finished product weights less than ten pounds. A carrying case has also been fitted to the final product so that the client will have an easier time taking the device from work to home and back. The unit is also made esthetically pleasing by powder coating most of the device black. This helps the device blend in with the black baby grand piano that she plays on both at school and home.

Static and fatigue design were conducted on the hollow rod. A factor of safety of 1.8 was calculated

Fig. 14.22. Client playing a baby grand piano using the unit.

for a maximum force of approximately 93 pounds of cyclic loading, while maintaining an infinite life. This is acceptable since the maximum force applied by the client does not exceed 50 pounds. Also a factor of safety of 7 was calculated in the cross beam of the frame under 1000 lbs. load; a larger load causes the piano to be lifted.

The total cost of the material is $400.00. The students working on this project posted a detailed description of their design and analysis in the World Wide Web at the following URL address:

http://www.eng.utoledo.edu/mime/design_clinic/design_expo/Fall07Pages/2007-04-06/home.html