CHAPTER 10
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Tilting Platform For Wheelchair Access To Dental Surgery

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INTRODUCTION

The objective of this project was to redesign, reconstruct, and install a second-generation working prototype of a lifting and tilting platform in a dental suite at The Medical College of Ohio (MCO) in Toledo. The platform was designed to accommodate a wheelchair or a regular dentist's chair, and is to be lifted and tilted to a prescribed position and orientation. The design is to be fabricated, installed, and used in a hospital setting. This project was started during the winter and spring quarters of 1995; a prototype was designed and constructed, with details reported in the 1995 book of engineering design projects (pp. 226-227). The first-generation prototype used a power screw that was driven by a gear motor, and was allowed only to tilt. The new prototype employs two pairs of scissors arms and a system of three hydraulic cylinders that allow lifting and tilting of the platform. This prototype is being evaluated for final installation.

SUMMARY OF IMPACT

Since its founding, the Department of Dentistry at MCO has treated patients in wheelchairs. The department treats an average of three patients a day who are wheelchair-bound. Many such patients arrive directly from the hospital, some having intravenous tubes in both arms, with the tubes tied down to the wheelchair. Other wheelchair-bound patients do not feel comfortable being moved from their wheelchair to the dental examination chair. Still others, due to their general health, are not able to sit in a dentist's chair for the duration of an examination. It is thus much more practical for the patient and staff if the patient can stay in his or her wheelchair during the examination.

There are products currently on the market that allow patients to remain in a wheelchair and still be examined in a position that is suitable for the dentist. However, they only accommodate wheelchairs. Since wheelchair-bound patients constitute only a fraction of the total number of patients treated per day in the department, it is not economical to devote an entire suite to wheelchair-only use. Therefore, an apparatus that lifts the wheelchair and tilts it backwards, yet still accommodates a regular dentist's chair, is an appropriate solution. A adaptive dental platform was thus designed, built and evaluated.

TECHNICAL DESCRIPTION

The main components of the system include bottom and top frames, a platform, a ramp (for rolling a wheelchair up on to the platform), a cart (to make the existing dentist's chair mobile), and a hydraulic system. The materials used to construct the components were selected for low cost, cleanliness, and performance. The fact that the system is going to be used in a hospital setting necessitates that all materials be kept clean and sanitary. The materials are also expected to carry various loads and be able to handle points of high stress.

The bottom frame, which is in direct contact with the floor, is made of four by four-inch stainless steel angles. Due to the routine cleaning of the dental suites, this material must be resistant to rust and strong enough to hold large loads. The top frame is made from four by four-inch hot rolled carbon steel angles. This material was chosen because it is potentially in less contact with water and is much cheaper than stainless steel, thus keeping costs down. The carbon steel is strong enough to meet specifications; it is painted to make it aesthetically pleasing. The top frame is kept level while being lifted by two pair of scissors arms as shown in Figure 10.1. The tilting platform is made from half-inch thick T6061 aluminum plate and is 30 inches wide by 40 inches long. T6061 aluminum is chosen because it is clean, corrosion resistant, lightweight, relatively inexpensive, and is strong enough for the expected loads. The ramp and cart are also constructed from T6061 for similar reasons.

Due to the need for head and back support for the patient while tilted backwards, a backrest was constructed. It consists of two components: a pad and a frame to support the pad. The frame is made of one by one by 1/4-inch thick T6063-T52 extruded aluminum. The pad is upholstered plywood.

The mechanism used to produce the motion for the dental platform is one of the major aspects of the project. Cost, efficiency, cleanliness, noise, and overall performance were considered. In the first generation prototype, a power screw and a gear motor were selected (1995 NSF Senior Design Projects to Aid the Disabled, pp. 226-227). Evaluation of the first-generation prototype indicates that its overall performance was not satisfactory since it allowed only tilting of the platform. In this second-generation prototype, a hydraulic system was employed.

Because the overall height of the platform is one of the primary concerns, finding hydraulic cylinders that can fit into the platform and still perform the desired task is challenging. The cylinders must be small enough to fit into the initial height of the platform. At the same time, the initial angle of the cylinders must be great enough to withstand the force provided by the cylinders. Therefore, platform design entailed consideration of the dimensions of the hydraulic cylinders.

The major advantage of hydraulic cylinders is that they can perform all modes of motion with one power assembly. Because motors are expensive, the number of motors must be minimized. The first-generation prototype employed a power screw and a gear motor, but allowed only tilting of the platform. Another motor would have been required to allow for the additional lifting motion. An additional advantage of hydraulic cylinders is that they do not have an oily surface exposed except during the relatively brief times they are extended. Therefore, they are appropriate for a dental suite, in which cleanliness is of utmost concern.

The dental platform has two modes of motion. The first mode is in the vertical direction. The second allows a rotation, or tilt, about a fixed point. Three cylinders were used to accomplish the total motion. Figure 10.2 illustrates the layout of the three cylinders employed in this prototype.

Two hinges at the fixed end and one cylinder midway out, on the free end (Figure 10.3) support the tilt platform. The initial angle on the tilt cylinder is approximately three and a half degrees. The initial angle is large enough for the cylinder to easily tilt the load. The two other cylinders and the two sets of scissors arms perform the lifting of the structure. The purpose of the scissors arms is to provide stability and to limit the motion of the platform in the vertical direction. The purpose of the cylinders is to lift the load. Two cylinders, instead of one, were used because stability is a larger concern for the lift platform.

Both lift cylinders must extend the same amount at the same time regardless of load or initial positions. If, at any time, the cylinders are at different angles, or if the load on one cylinder is less than on the other, they still have to extend together. Therefore, series cylinders are being used. Series cylinders entail two cylinders, a master and a slave. The fluid from the out port of a pump travels into the in port of the master cylinder. Then, the fluid from the out port of the master cylinder travels into the in port of the slave cylinder, and the fluid from the out port of the slave cylinder travels to the in port of the pump. There is also a bypass valve in the master cylinder, which allows the pressure in the overall line to equalize. Whenever the master cylinder reaches full stroke, the fluid from the pump is able to travel directly into the slave cylinder. Therefore, if the slave cylinder is a little behind in stroke length, the stroke is then equalized.

The cylinders are also double acting. If the cylinder is to be extended, fluid must be fed into the in port of the cylinder. To be contracted, the fluid need only be fed into the out port of the cylinder. Thus,

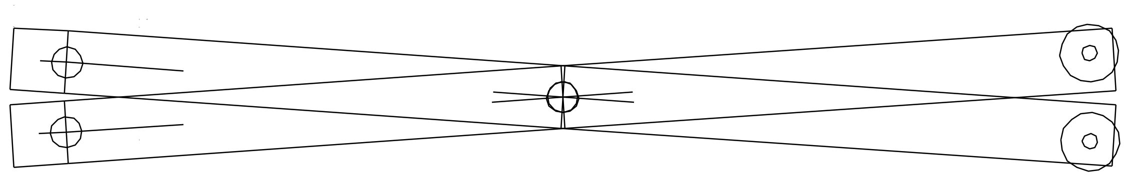

Figure 10.1. The Scissors Arms.

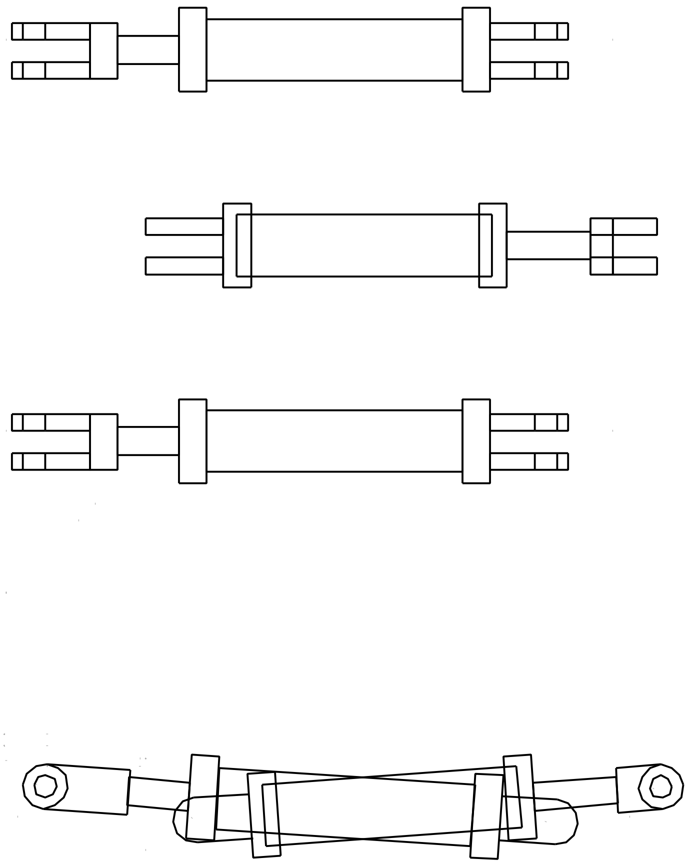

Figure 10.2. The Hydraulic Cylinders.

gravity does not help or hinder the operation of the cylinders. The major reason for selecting this type of cylinder is the amount of control gained. If a single acting cylinder were used, the lowering of the platform would have been dependent on gravity. Also, the speed at which the platform was lowered, or the angle of tilt, would not be able to be controlled. With double acting cylinders, the speeds of the cylinders are able to be set by the operator.

Figure 10.4 shows a flow diagram of the hydraulic system. The fluid from the pump is fed into a manifold, which then divides the flow between two valves. These two valves control the flow of fluid to the lift and tilt cylinders. Thus, the cylinders can be run all at once, or more preferably, one at a time. A manifold makes the hydraulic circuit cleaner and allows for better operation. The valves are three position valves. One position directs fluid from the pump back to the reservoir. The second position directs fluid from the pump into the in-port of the hydraulic cylinders. The final position directs fluid from the pump into the out-port of the hydraulic cylinders. The valves also have control dials to control the speed of the fluid. There are separate dials for each position so that, for example, the speed for lifting the platform can be slow and the speed to lower the platform can be fast if desired.

Deflection of loaded dental cart: The calculations for the deflections of the dental cart include a 450-pound dental chair and a 442-pound person. The cart is made of T6160 aluminum and is 0.75 inches thick. The cart's dimensions include a lowered level that runs 26 inches long and 26 inches wide. This lowered section allows the dental chair to rest closer to the ground while the raised ends allow for more space for more efficient casters. The base of

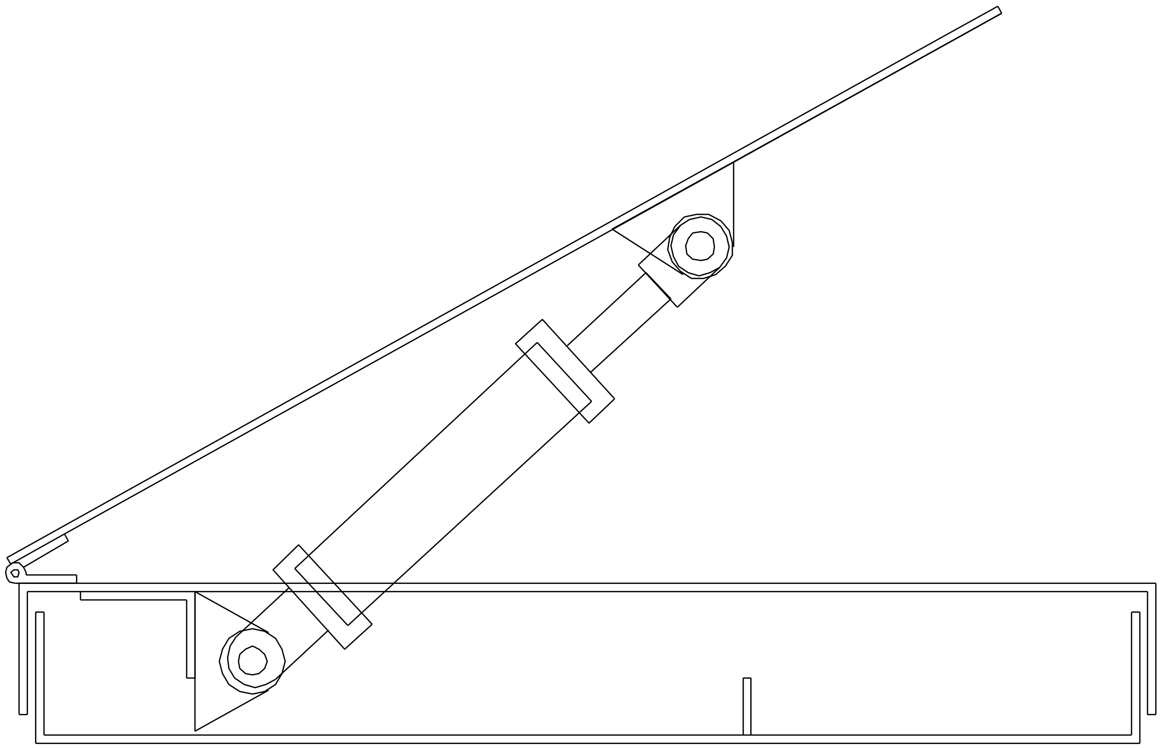

Figure 10.3. The Platform Tilted.

the dental chair measures 25 inches in diameter and because of this, simple supports and a uniform load are assumed for the calculations. For a total load of 892 lbs., the maximum deflection at the center of the cart was calculated as 0.581 inches, and the maximum normal stress was calculated as 7370 psi. These calculations indicate that the maximum deflection is in the center of the cart at slightly more than one-half inch. The value of the maximum stress of 7370 psi is much less than the proportional limit of aluminum. The cart will thus not be permanently deformed when subjected to the load, and will return to its original flat shape when the load is removed.

Dental cart clearance over ramp: When choosing the length to height ratio for the ramp leading up to the dental platform a minimum ratio was desired to reduce the floors space and the weight of the ramp. The length to height ratio used is eight to one. This ratio was chosen to confirm with the *U.S. Department of Transportation's Guideline Specifications for Passive Lifts, Active Lifts, Wheelchair Ramps, and Securement Devices*. This ratio is equivalent to a ramp angle of 7.125 degrees. Figure 10.5 shows the dental cart clearance over a 7.125 degrees ramp. The height of the platform is five inches, and the height of dental cart clearance over the ramp was calculated as 0.8093 inches.

Maximum deflection of platform: The maximum load that the tilting platform will be subjected to will occur when the dentist's chair and portable cart are loaded on to the platform and the patient is resting in the chair. A total load of 1000 pounds was used in the calculations including a 450-pound dental chair, which is the heaviest of possible chairs, 108 pounds of 0.75-inch thick aluminum used for the portable cart, and a 442-pound person. The aluminum that was used in the platform was 0.5-inch-thick T6061 Aluminum. The calculations assumed simple supports and two symmetrical point loads, 500 lbs. each. The length of the platform was 40 inches, its width was 30 inches, and each point load was 4.5 inches from the corresponding end supporting point. The maximum deflection of the platform was calculated as 0.106 inches.

Initial force required for lifting the platform: The dental platform is supported by a frame made from four by four-inch steel angle bars. Two pair of scissors arms, which are two inch by one half-inch steel bars, support the frame. The frame and platform are lifted by two hydraulic cylinders, which act on the end of the top frame. The downward force

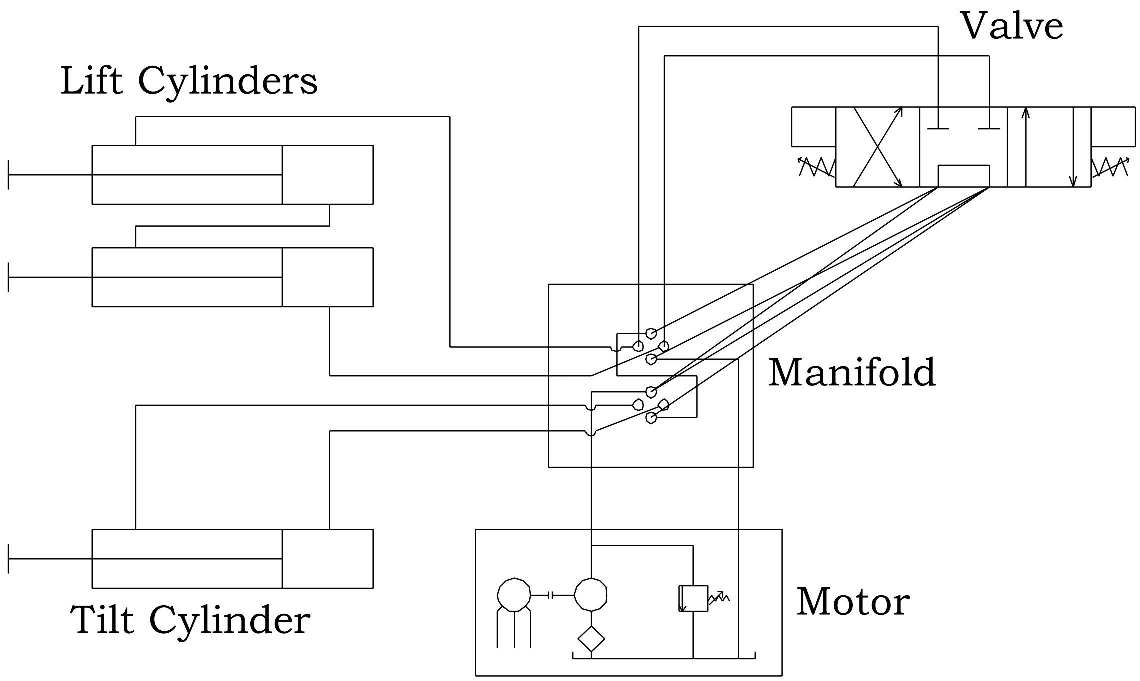

Figure 10.4. Flow Diagram Of The Hydraulic System.

upon the cylinders includes the patient, the wheelchair, the lift platform, and the lift support frame. The initial angle of the hydraulic cylinders is calculated to be three and a half degrees. Seventy percent of the patient's weight will be located on the back wheel while the remaining thirty- percent will be located on the front wheel. The weight of the patient and wheelchair is 472 pounds. The back wheel of the wheelchair is located eight inches from the scissors arm closest to the hinge. The weight of the tilt platform and the steel frame is 72 pounds. The center of the scissors arms, when the platform is down, is located 14 inches from the supported end of the scissors arms. Using the principle of virtual work, the force required from each cylinder to lift the platform was calculated as 9828 pounds. Each cylinder has a maximum operating pressure of 2500 psi and a bore diameter of 2.75 inches, providing thus a force of up to 14849 lbs., which corresponds to a factor of safety of 1.51.

Initial force required to tilt the platform: The dental platform will be tilted by one hydraulic cylinder based close to the hinged end of the platform and extending out to the middle of the platform. The moment calculations for the amount of force needed to tilt the platform are made around this end. The forces involved in the calculations include two forces that are created by the wheelchair and the patient in the wheelchair. These two forces are located 16 inches apart from each other because this is the average distance between wheels for different types of wheelchairs. It is also assumed that the wheelchair and patient will weigh 400 pounds maximum and that the back wheel will support 70 percent of this weight as the center of gravity of the patient will be located toward the back of the wheelchair. A third force consisting of 72 pounds of platform material acts downward against the hydraulic. This force is considered to act at the center of the 40-inch platform. The hydraulic unit will be acting at an initial angle of no less than 2 degrees from the platform and the force will be located 25.5 inches from the hinged end of the platform. Calculations were performed to determine how the force required and exerted by the hydraulic unit is affected by the angle at which the hydraulic cylinder is acting, and by the distance between the hinge on the platform and the location of the rear wheel of the chair. Distances ranging from 5 to 15 inches and angles from 3.5 to 5.0 degrees were considered. The maximum value of the minimum force required by the hydraulic unit to tilt the platform was calculated as 6012.5 pounds, which corresponded to a distance of 15 inches and an angle of 3.5 degrees. The tilting cylinder has a maximum operating pressure of 2500 psi, a bore diameter of 2.5 inches and an 8- inch stoke, thus providing a force of up to 12272 lbs., which corresponds to a factor of safety of 2.04.

The prototype is presently being evaluated. Re-wiring of the electrical system as well as completion of fabrication of the cart and the ramp still must be done before it is to be installed.

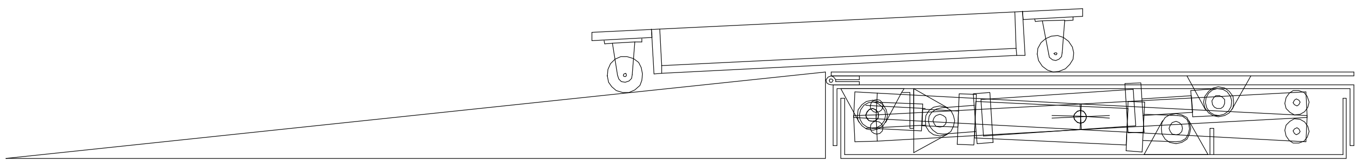

Figure 10.5. Dental Cart Clearance Over Ramp.

Prototype For A Prosthetic Hand

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INTRODUCTION

The purpose of this project was to design and build a prototype for a prosthetic hand that would provide a lower-arm amputee with a replacement appendage. The project was limited to the mechanical workings of the hand; the interface of the actuating electrical signals will be developed later by another group of senior design students. The design of the hand centered on functionality and appearance.

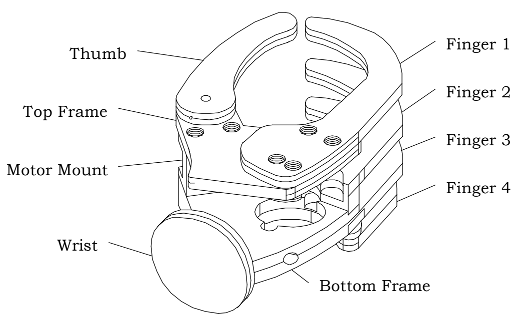

Figure 10.6. Prosthetic Hand in a Pincher Grip

The prototype consists of an economical mechanical linkage with two degrees of freedom allowing for a pinching grip, a large-radius cylindrical grasp, and a small-radius cylindrical grasp. A model, constructed from wood and controlled by an electric motor, was tested for functionality and appearance. The prototype, shown in Figure 10.6, includes four parts: the thumb and its drive train, and the finger and its sliding drive train. A cosmetic outer covering of the hand was incorporated into the prototype.

SUMMARY OF IMPACT

Lower-arm amputees have a limited number of reasonably priced options for a prosthetic hand. One option is a hand with one degree of freedom, known as a gripper or hook. This is a mechanically actuated device in which the user operates the hook by moving his or her good arm. This device costs about $360; while is functional, it is not very natural in appearance. The second option is a myoelectrically controlled pincer-rip prosthetic device. Although this option has a natural appearance, it has limited functionality and costs about $5,000. The third option is a myoelectric hand with multiple degrees of freedom, which looks natural but costs $30,000. The goal of the current project was to design a hand that: 1) provides a pinched grip of 20 pounds; 2) carries a transverse load of 50 pounds across the four fingers; and 3) could be marketed and sold for around $7,000.

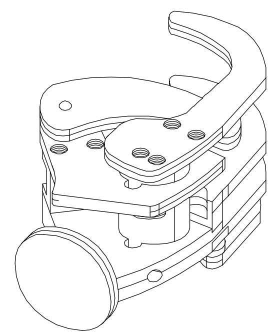

Figure 10.7. Prosthetic Hand When Fully Closed.

TECHNICAL DESCRIPTION

Functionality, weight and appearance were the three primary design criteria. With regard to weight, the prosthetic hand was to be comparable to the weight of a human hand, or possibly less. With regard to appearance, it was decided that the hand should closely resemble a human hand including size, weight and general appearance. Cosmetic glove and inner plastic shell from Otto Bock (a German company) were incorporated in the prototype to cover the prosthetic hand. The cosmetic glove has four fingers and a thumb, and is made to resemble human skin color. It is long enough to fit on a human arm. In the inner shell glove, two fingers are movable and other two are rigid.

The functionality of the hand depends upon degrees of freedom and weight. The prosthetic hand was designed to have three grips using two motions:

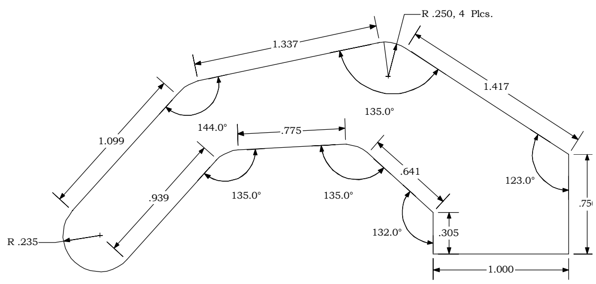

Figure 10.8. Geometrical Details Of A Finger Pro-

thumb rotation and finger translation. The first grip is a pincher grip used to grasp small objects; it involves bringing the fingertip to the thumb tip, as shown in Figure 10.6. The second grip is a large-radius cylindrical grasp; it is accomplished by cupping the fingers and thumb around a larger object, such as a pop can. The third grip is a small-radius cylindrical grip. In humans, this grip is also called a lateral pinch; it is made by cupping the fingers around the object and sliding the thumb along the first finger, as one would do when carrying a suitcase (see Figure 10.7). In the prosthetic hand, the first finger is driven to allow the thumb to pass between the first and second fingers.

The prosthetic hand was designed using IDEAS Master Series 2.1. This software was chosen due to its accessibility, dynamic viewing capabilities, and finite element analysis (FEA) features. The fingers and thumb profiles shown in Figures 10.8 and 10.9 were derived from direct observation. The fingers were shaped to have a matching internal curvature, to facilitate the grips and to distribute the loads; however, external curvatures and tips were shaped variably for a more realistic cosmetic appearance. Using IDEAS, it was found that the largest stresses occurred along the internal curve.

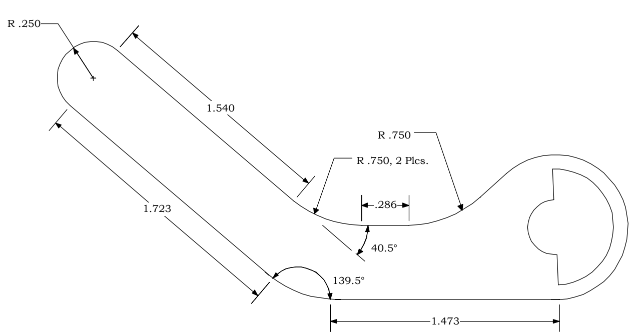

Figure 10.9. Geometrical Details Of Thumb.

The main drivetrain of the prosthetic hand drives the thumb, which does the work of the hand by opening and closing to accommodate the various grips. The motor and drivetrain were obtained as a set. However, bevel gears were used to accommodate the orientation of the motor and drivetrain. In order to accomplish the design objective of a grip force of 20 pounds, the drivetrain would have to be custom made. However, due to financial constraints, a smaller gearbox that was able to provide a grip force of only one pound was selected. The sliding finger drivetrain generates a translation motion, requiring no to resistance to a load beyond its own inertia force. Since it is an all-or-nothing motion, no middle stops were needed, and a push solenoid is used to drive the finger. The frame was designed to hold these parts together and connect the hand to the prosthetic attachment via the wrist. The frame was designed to withstand the forces of the hand and to provide much of its shape. After the hand was designed in IDEAS as a solid model, a FEA was undertaken to show that the design could withstand the forces applied to it. The model has two different load cases: 1) a pinched grip with 20 pounds of force between the first finger and thumb tip; and 2) a 50-pound transverse force across the four fingers for load support. Thin shell elements, beam elements, and three-dimensional brick elements were employed in the analysis.

While the fingers and frame of the final prototype are to be made of aluminum, a first prototype made of wood and powered by an electric motor was constructed to simulate the mechanical motion of the hand. The objectives met include design for strength, weight and appearance. Concerning functionality, the thumb drive train used did not provide adequate pinched grip force. Incorporating a planetary gear drive or other suitable mechanism may rectify this. It is anticipated that the goal of a $7,000 price tag could be readily achieved in reasonable production quantities.

Based on a peer review, this work has been chosen as one of the winners of the 1996 Young Design Engineer's Paper Competition from the American Society of Mechanical Engineers (ASME). The paper was presented at the ASME International Congress held in Atlanta in November, 1996, and received a prize of $500, plus a certificate. This project was one of four projects in the United States to be recognized with this award for 1996.

Rearward Viewing Device

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INTRODUCTION

The purpose of this project is to design and build some type of rearward viewing device for a patient who is confined to a wheelchair and head and neck brace due to a neck injury. This patient used a halo-brace system to immobilize his neck and head to prevent further injury. He was not able to see around himself since his neck is immobilized in the system. Figure 10.9 shows the prototype and Figure 10.10 shows the patient using it.

SUMMARY OF IMPACT

The rearward viewing device was developed to enable a stationary person with an immobilized neck to see side to side, down, and behind without moving his head or wheelchair. Immobilized patients often feel uncomfortable when another person is present but cannot be seen. Since such patients often have full movement of their hands and arms, the device was designed to be controlled by the hands. Adjustability was a primary consideration. The prototype was designed for people of all sizes. The only other such device on the market is a pair of prism glasses, with two critical limitations: 1) it merely allows the patient to view the frontal area;

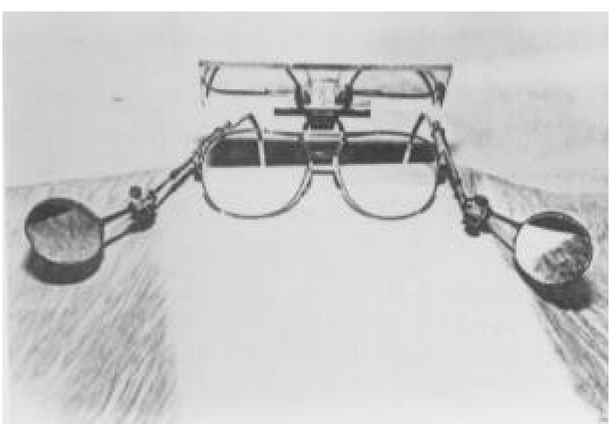

Figure 10.9 Front View of the Rearward Viewing Device for Non Prescription Glasses

Figure 10.10. The Patient Using The Prototype While Wearing The Halo Device.

and 2) it is weighty, hurting patients' noses if worn for long periods.

TECHNICAL DESCRIPTION

Immobilization of the head and neck is often required for a limited time, averaging about six months; thus, cost should be low to take into account its limited period of use. Other design criteria include: 1) allowance for the patient to see side to side, down, and behind without moving his head or wheelchair; 2) weight as light as possible; 3) ability to be attached to a pair of prescription glasses; and 4) adjustability, such that it could be used by a variety of people.

The device combines mirrors, a telescoping tube, and glasses, to enable the patient to see in all directions. It was designed for a patient who wears prescription glasses, but may be used by patients who do not. The device includes two telescoping arms that are connected with a metal wire and monofilament line wound around the glasses and arms.

Each arm carries a convex mirror that allows the patient to see behind himself, and a flat circular mirror (glued to the convex mirror with a hot glue from a glue gun) that allows to see in front. Additionally, a rectangular flat mirror allows the patient to see downward. This flat mirror is clipped to the central upper portion of the frame of his prescription glasses.

The telescoping arms are antennae that were cut to length and drilled to receive a spring-loaded holding clip. An aluminum slug was then used to cap the cutoff end of each antenna to prevent dirt from collecting and to protect the ends.

The ball portion of a flexible ball joint was obtained from a telescoping inspection mirror, and the socket was welded onto the end of the antenna. The flexible joint grip plates from the inspection mirror were modified by drilling a larger hole in them to accommodate a thumbscrew that was used for tightening the ball joint. One of the ball joint grip plates had a nut welded to it to provide threads for the thumbscrew. The ball arm portion of the inspection mirror was altered to receive the convex and flat mirrors for looking in the rearward direction. The ball arm was crushed into the form of a spade to provide a flat surface on which to glue the mirror.

The convex and flat mirrors had to be cut to size. The convex mirrors were cut by turning them on a lathe. The mirrors were wedged between rubber and paper in a wood chuck in order to prevent the metal backing from scratching off the mirrors. The flat and convex mirrors were then attached to the device by sandwiching the spade between the two mirrors and gluing them together. The telescoping arms were connected to the glasses with a metal wire and monofilament line wound around the glasses. This is considerably stronger than a spot weld would have been; the device is not likely to break if it is dropped.

It was verified that the convex mirrors allowed the patient to see a person who is standing six feet behind him and 16 feet to his right or left. The patient can see anything that is more than a foot away from his head, thus delimiting thus the blind area for the device. Figure 10.11 illustrates the rearward viewing area for the device using the convex mirrors. Figure 10.12 shows the frontal viewing area using the flat mirrors.

The material cost to build the prototype for the patient who wears prescription glasses was $35.00. For the patient who does not wear prescription glasses, an additional $10.00 is required to purchase wire frame glasses.

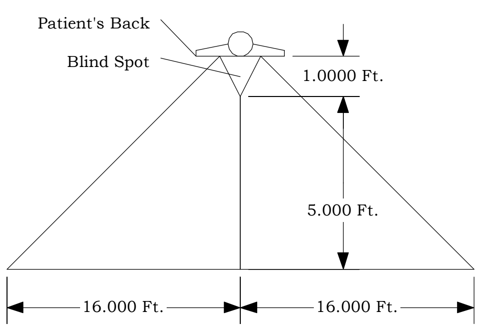

Figure 10.11. Rearward Viewing Area With Convex Mirrors.

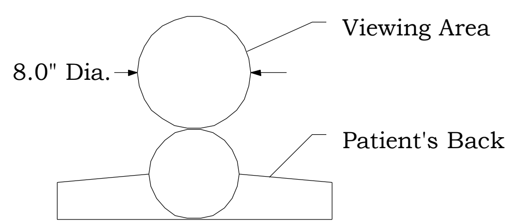

Figure 10.12. Frontal View ing Area With Flat Mirrors.

Wheelchair Lift For Independent Home Access

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INTRODUCTION

The objective of this project was to design, build and install a lift that allows a woman with double amputation of the legs to enter and exit her home in a wheelchair, without the assistance of another person. The basic principle of the design is that of a forklift. A hydraulic cylinder pushes up on two chains that are connected to both a fixed point and a platform. This allows the platform to move twice as far as the cylinder head. The moment created by the platform is absorbed by guide rails that are attached to it and to the frame of the lift. The wheelchair lift is located beside the client's front porch.

SUMMARY OF IMPACT

A physical therapist referred the client, who had both of her legs amputated due to complications associated with diabetes. Her left leg was amputated at the knee while her other leg was amputated approximately halfway between the knee and hip. She is learning to use a prosthesis on her left leg; however, this does not give her enough mobility to enter and/or exit her house. A wheelchair lift was designed, built and installed at the client's home, allowing her independent access in and out of the house.

TECHNICAL DESCRIPTION

The primary design criteria were that the lift: 1) safely lift the client from the ground to the level of her porch; 2) be operable in any weather, as it will be located outside; and 3) have a long life expectancy with either no or low maintenance requirements. The design concept was to use the same basic principle that a forklift uses, as illustrated in Figure 10.13. The basic design involves a cylinder with idler sprockets on the head, extending 10 inches. Two chains were attached to the frame and also to the platform, causing the platform to move 20 inches. A guide rail system was designed to absorb the moment produced by this style of lift. Attached to the platform are two support arms with cam followers. The frame has two 3 by 1.25-inch steel beams that act as guides. The rest of the frame is composed of 1 by 1-inch steel tubes. A plastic plate covers the frame to protect it in bad weather. To keep the platform from rusting, all metal was

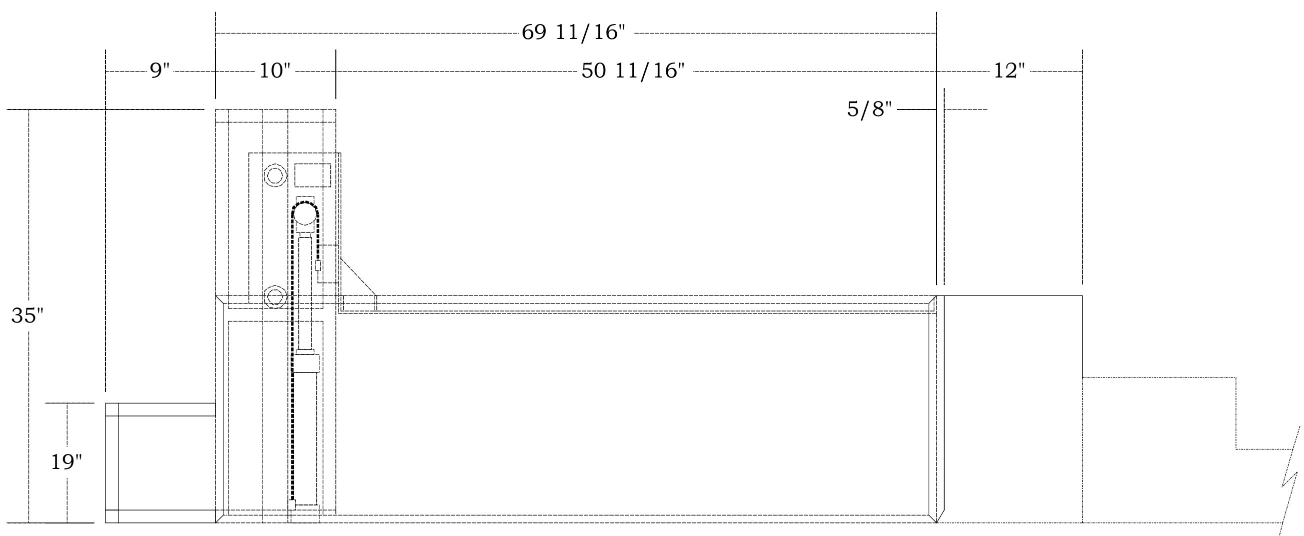

Figure 10.13. Design Concept for the Wheelchair Lift.

coated with primer and then painted.

Four major points of concern were identified in the design. The first is that the platform must not yield or deflect very much. The second is that the connection between the platform and the supporting arms be made with complete welds and with 45 degrees corner gussets, such that it is able to withstand the moment load combined with the shear force of the design load applied at the extreme edge of the platform. The third was that the shaft go through the cylinder head and hold the idler sprockets while not yielding or deflecting to any great extent, still remaining narrow enough to fit both the cylinder rod eye and the idler sprockets on both sides. The last major point of concern is that the guide rails, 3 by 1.25-inch steel beams on the frame, be strong enough to withstand the force caused by the cam followers.

The control system for the lift is composed of three parts. The first part consists of three separate boxes that house the temporary contact switches. These switches are designated as up, stop and down. The switch box is then connected to the terminal box that houses two four-pole double-throw relays. These relays are the primary component in the control system and act as a switching mechanism. The

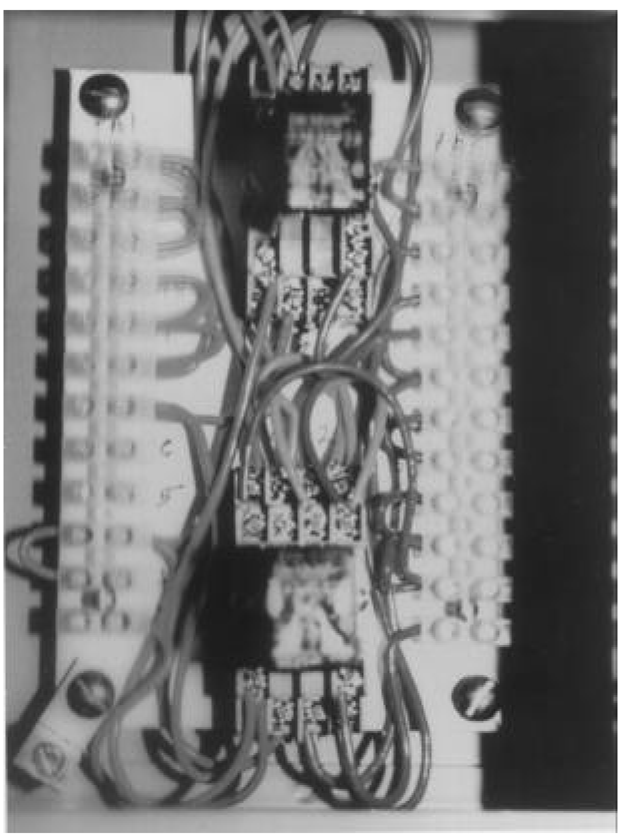

Figure 10.14. Control Box

Figure 10.15. Frame Assembly Housing the Motor and the Cylinder.

third component is the limit switches. These switches are mounted to the frame and indicate to the control system when the lift is completely up or down. The limit switches are also connected to the terminal box. Originally, connection of the relays to solenoid valves on the hydraulic system was considered; however, solenoid valves were not used in the final design. It was decided that a reversible pump/motor system would be used to provide the correct flow rate, thus, eliminating the need for the solenoid valves. With the relays directly connected to the motor, the relays trigger the pump to let fluid lower or raise the cylinder. The other connections of the relays to the motor allow for the automatic start and stop of the system in conjunction with the limit switches. The control box is shown in Figure 10.14. Figure 10.15 shows the frame assembly housing the motor, the cylinder and its connection assembly

Because the design was kept simple, the wheelchair lift was relatively easy to manufacture. The platform, support arms, and most of the frame were made of 1020 steel. The first thing that was constructed was the frame to house the cylinder and pump, along with the platform itself. The frame was then painted to prevent any rust from occurring. At the same time, a six-inch concrete slab that serves as a foundation for the lift was poured at the client's residence. The motor/pump assembly and the cylinder were then mounted to the frame. The plastic sheet stock was cut to fit the dimensions of the frame. Once the front plastic sheets were installed, the platform was connected to the frame by connecting the cam followers to the guidepost on the frame and connecting the chains over the sprockets. The hydraulic cylinder was then connected to the pump and the control system installed. The remaining exposed frame was covered with the plastic sheets. To ensure safety, a railing was used on the lift's platform to box in the area that will be used to transport the client. Side arms were utilized as another safety precaution. These side arms provide not only extra support against the moment of the system, but also a barrier so that nothing can get under the platform. With the lift fully operational and tested, the entire system was transported to the site and installed by bolting the frame into the concrete.

The total cost of the system was a $1,600, all of which was donated by a charitable organization. This cost is far less than the price of $10,000 to $15,000 quoted for building a ramp to the client’s house.