CHAPTER 20
UNIVERSITY OF TOLEDO

College of Engineering
Department of Mechanical, Industrial and Manufacturing Engineering
Toledo, Ohio 43606-3390

Medical College of Ohio
Department of Physical Medicine and Rehabilitation
Toledo, Ohio 43614

Principal Investigators:

Mohamed Samir Hefzy, Ph.D., PE. (419)-530-8234

mhefzy@eng.utoledo.edu

Nagi Naganathan, Ph.D. (419)-530-8000

Nagi.Naganathan@utoledo.edu

Gregory Nemunaitis, M.D. (419)-383-3527

gnemunaiti@mco.edu

BACKWARD MOTION CLASS 2L MANUAL RACING WHEELCHAIR

Designers:
Group 1: (frame and seating) Joshua Jurgen, Tamara Vanhoose, Wenquing Su
Group 2: (steering) Sam Studer, Anthony Kledzik, Patrick Mahoney, Michael Wozniak, Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis, Department of Rehabilitative Medicine,
Medical College of Ohio
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory,
Department of Mechanical, Industrial & Manufacturing Engineering
The University of Toledo, Toledo, Ohio 43606

INTRODUCTION

The purpose of this project was to design and construct a backward motion class 2L manual racing wheelchair for a member of an athletic organization. This individual has a double hemiplegia, having partial use of his legs and little use of his arms and trunk. He competes in class 2L (L for lower) races, which is a unique style of racing that requires use of only leg motions to propel the wheelchair. This individual can propel better by using posterior facing - kicking forward leg motions, instead of the traditional 2L propelling technique, which uses anterior facing - pulling backward leg motions. Because of this physical condition, he cannot race as competitively as he could since traditional 2L racing wheelchairs are designed and built only to accommodate the anterior facing racing style. This individual wished to be able to race as competitive as possible, which requires use of a 2L racing wheelchair that allows for a posterior racing style. Design considerations included constructing a unit that is lightweight, aerodynamic, stable, durable, comfortable and ergonomically designed, and that allows easy transfer. These aspects of the design were analyzed using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software) and the 3D-SSPP™ (3D- Static Strength Prediction Program). Special considerations were also given to the steering mechanism and to the seating assembly because of the client posterior facing racing style. The wheelchair was made of lightweight one-inch aluminum tubing allowing for maximum speed and control on the track, as well as an extremely strong design for the client. As shown in Fig. 20.1, it uses three wheels, one front and two rears. The front wheel is used to steer the chair. The steering mechanism was designed to allow the client to adjust the amount of turn desired while also allowing him to easily return the wheelchair to head in a straight direction in both a reliable and repeatable manner. Fig. 20.2 shows the client with the engineering students who designed and built the unit.

Figure 20.1. Constructed Unit.

Figure 20.2. Client with Student Designers.

SUMMARY OF IMPACT

The Toledo Tornados is an athletic organization that is sanctioned by the United States Cerebral Palsy Athletic Association (USCPAA) to encourage persons with physical challenges to compete in track and field events that are tailored to their abilities. This racing wheelchair prototype provides one of the team members with an opportunity to participate and compete in class 2L 100, 200 and 400 meter racing events, where the only method of propulsion is the use of the legs. The chair fits the needs of the client while meeting the standards of the USCPAA. The prototype will permit him to use posterior facing – kicking forward leg motions to propel him, allowing him to effectively compete in future events.

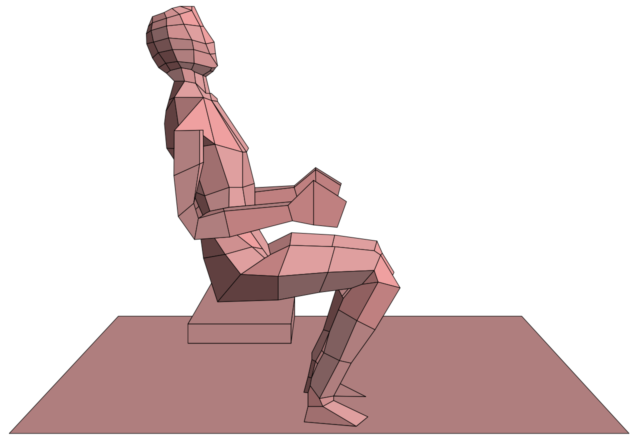

Figure 20.3. Anthropometric Model.

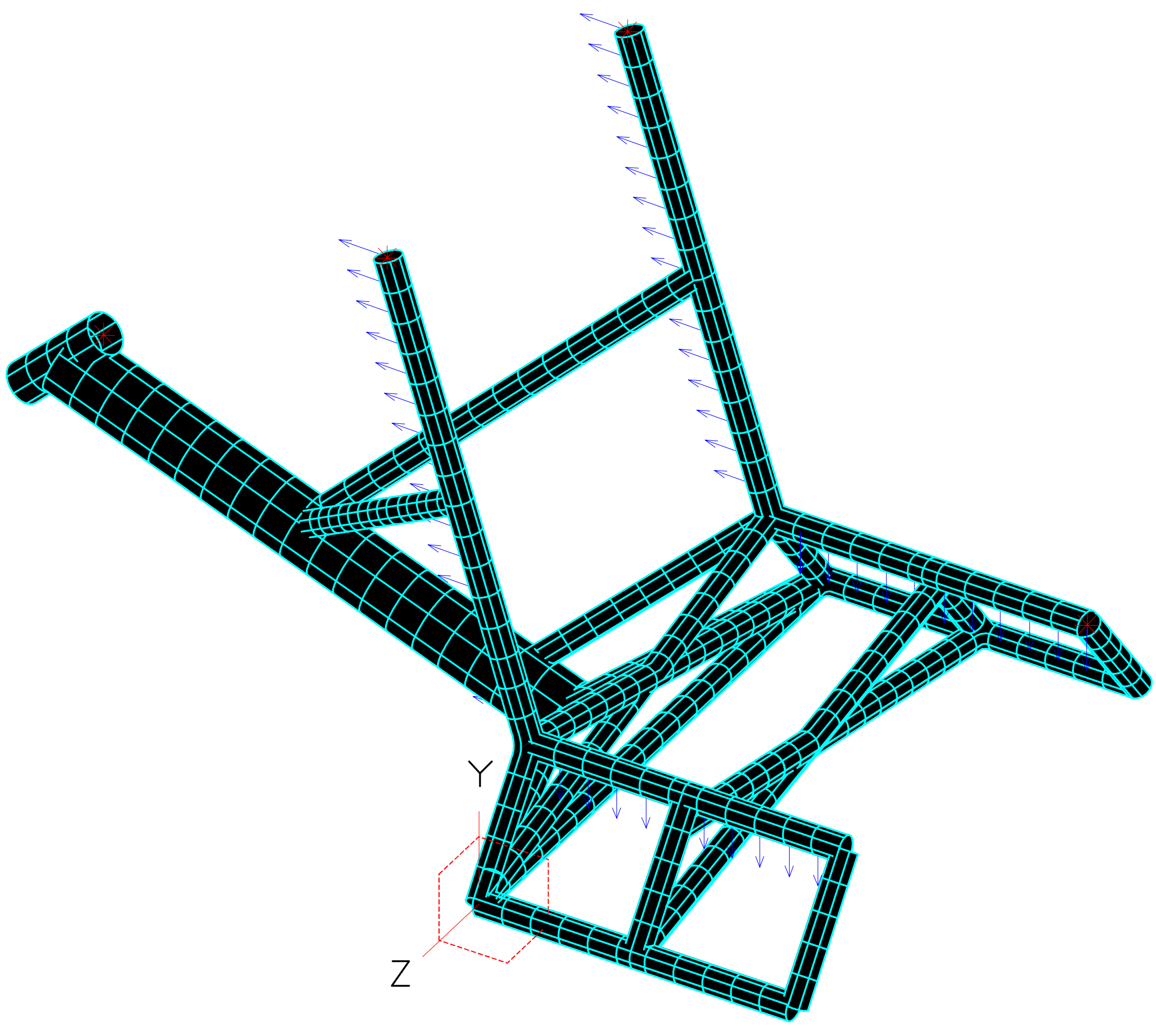

Figure 20.4. Finite Element Model showing Frame and Seating Sub-frame.

TECHNICAL DESCRIPTION

It is mandatory for all wheelchairs and athletes to pass inspection before entering into any competition. In order to conform to the regulations and rules of the USCPAA, the wheelchair must have at least two large wheels and a small one. Other rules and regulations include:

- The maximum diameter of the large wheel including the inflated tire shall not exceed 70cm (27.56 inches),
- The maximum diameter of the small wheel including the inflated tire shall not exceed 50cm (19.69 inches),
- No mechanical gears or levers shall be allowed that may be used to propel the chair,
- Any device of design element that exists for the purpose of reducing air resistance will be permitted provided that said device or designs is limited to the area between the rear wheels and must not extend beyond the lateral edges of the large wheels or extend in front or behind the edges of the tires, except that fenders may protrude two inches past the circumference of the inflated tire,
- Manufactures' labels or trade marks on equipment used within the competition area must be limited to one mark on each piece of equipment and the height of the characters mush not exceed 25mm (0.984 inches), and
- It is the responsibility of the competitor that the wheelchair conform to all the above rules and no event shall be delayed while the competitor makes adjustments to the chair.

The decision was made to use three wheels - one front, small wheel and two large rear wheels - to ensure stability. The front wheel will be used to steer the chair.

Methods and procedures for seating

The first step in the design process was to research and analyze current wheelchair designs and associated features. To complete this task, magazines, the Internet and other athletes with race experience were consulted. The team also reviewed the rules and regulations imposed by the USCPAA. After research had been completed, the design team met with the client to assess his personal needs and to collect his anthropometric measurements. These data were used to develop a customized biomechanical model of the client using the 3D-SSPP™ software. This model is shown in Fig. 20.3.

Several different design proposals were then formulated to evaluate and explore all possible options. The final design was selected using the following three key design criteria:

Posterior facing seat

A posterior facing seat was used in order to allow the client use of his legs for forward propulsion. The seat height was determined using the client's biomechanical model that described his physical profile to include length of legs, seated height, and range of motion. The seat was designed for comfort, functionality and easy transfer into and out of the

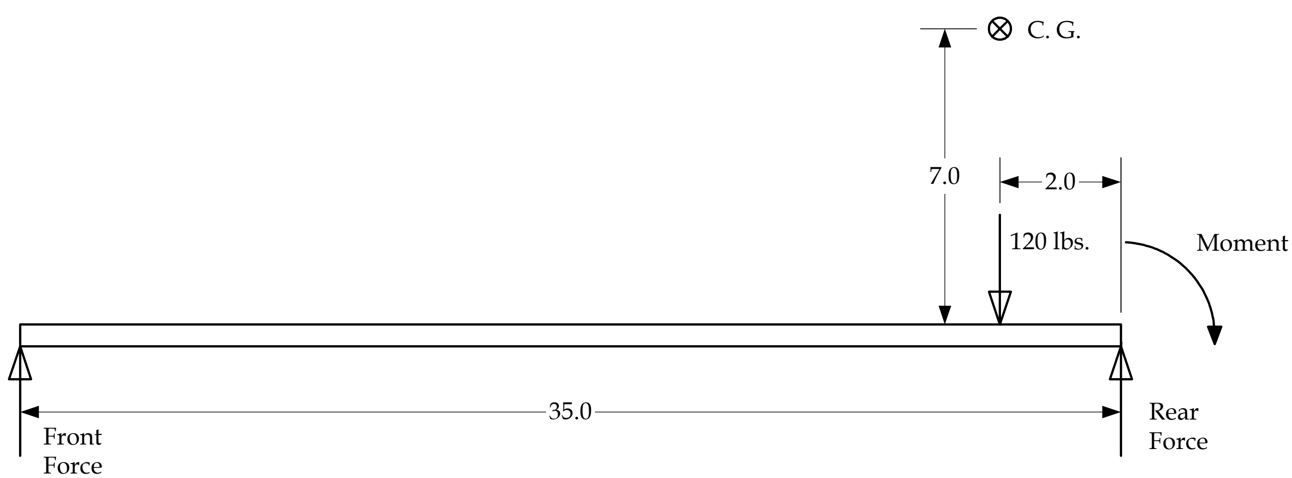

Figure 20.5. Location of the Center of Gravity of the Racer W.R.T. Front and Rear Axles.

racing wheelchair.

Upper body restraint system

The client wanted to be tightly restrained to the chair from the waist up allowing him the mobility of his lower half to adjust his weight in the chair for steering purposes. This also served as a safety feature.

Light weight aluminum frame

A lightweight aluminum frame that directly incorporated a seating sub-frame was used to improve structural integrity of the chair and keep total chair weight to a minimum. Fig. 20.4 shows the frame and the seating sub-frame. This separate seating sub-frame was incorporated into the design to allow a large range of motion of the client's legs. It was decide that the most effective solution to the client's desire to make complete strides beneath the seat was to cantilever mount the axles to the sub-frame.

Biomechanical Model of the Client

Anthropometric data included the seated height of the client, his weight, hip height, the length of his lower and upper legs, the length of his trunk/torso, the length of his upper and lower arms, his shoulder width, and his vertical grip reach in a seated position. These data were used to develop a customized biomechanical model that accurately predicted the client's reach. This model, shown in Fig. 20.3, was employed to simulate the different positions of the client during a race, allowing the wheelchair to be designed around these positions. The optimal seat position for the client was thus determined based on the location of his center of gravity. Anthropometric data indicated that to allow the client to be seated in a comfortable racing position, his upper body needed to be reclined at 108° with respect to the ground, and firmly restrained to the seat back. At the beginning of the stroke, his upper leg needed to be oriented at -15° and his lower leg at 30°. Also, and for comfortable steering, his right upper arm needed to be positioned at -90° and his lower arm at 10°. The anthropometric measurements also showed that the maximum range of motion in the client lower leg was from -135° to -55° with respect to the horizontal. These values were used to determine the clearance needed underneath the chair to permit the proper leg motion, and to design the chair accordingly.

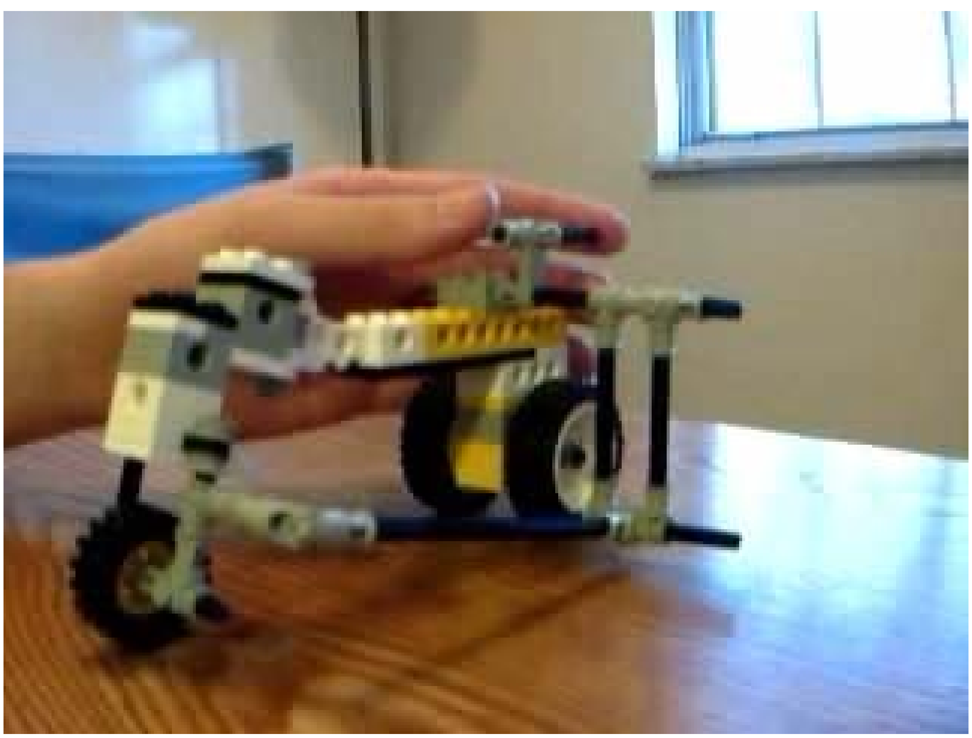

Figure 20.6. Lego Model Illustrating the Level Arm Steering Method.

Stability and Weight Distribution:

Three aspects were considered to allow the wheelchair maximum performance while remaining stable. The first of these aspects was the chair's wheelbase. It had to be long enough to provide stability but at the same time be able to turn effectively within the track dimensions. The chair had an overall length of 60 inches and a wheelbase from front wheel centerline to rear wheel centerline of 35 inches. The design was performed based on a client weight of 120 pounds, and a chair weight of approximately 25 pounds. The client desired to lean forward and apply a moment about the chairs rear axle, allowing him to lift the front wheel off the ground for additional maneuverability. To overcome the weight of the chair, the center of gravity of the seated racer was placed two inches from the rear axle, and seven inches above the rear axle as shown in Fig. 20.5. This allows the client to lean forward in order to assist in steering without the chair being tail heavy and unstable in racing conditions.

Based on the anthropometric measurements, the chair needed to be wide enough to for the client to sit comfortably and stably while staying within the standard lanes of a racing track. The width of the chairs with wheels cambered at five degrees was 29 inches at the ground. The wheelchair frame was made of one-inch T6-6061 aluminum tube, and was ordered from Invacare. The wheels were special ordered bicycle wheels that allow cantilever mounting. The two large wheels were 26 inches in diameter and the small wheel was 20 inches in diameter.

Using I-DEAS™ software, a structural analysis of the proposed wheelchair was conducted using the finite element method. A wire frame, shown in Fig. 20.4 was used to model the frame and the seating subframe using beam elements. Distributed loads were applied to the seat bottom and seat back to simulate those that would be applied during the operation of the chair. A safety factor of three was used to account for any extreme operating conditions, as well as use by a much heavier rider. It was found that the maximum deflection did not exceed 1/100 of an inch.

Seat design and material selection

A posterior facing seat was used in order to allow the client use of his legs for forward propulsion. The seat height and width was determined using the client's anthropometric data such as length of legs, seated height, and range of motion. Taking the safety of the client as a first priority, a single strap, approximately 12 inches long, wraps entirely around his upper body, securely restraining his torso in the chair and permitting desired movement in his lower half

A separate seating sub-frame was incorporated into the design due to large range motion of the client's legs. This allowed mounting the wheels using cantilevered axles, which was the most effective solution to the client's desire to make complete strides beneath the seat. The actual seat itself consists of two separate pieces of canvas for both the seat bottom and the back support. The canvas has the advantage of being more durable and lighter in weight than other materials, while providing a comfort to the racer. The width of the canvas seat was 15 inches. To secure the canvas seat to the chair, .25 inch brass grommets were incorporated into the design. The seat bottom and bask were then affixed to the chair with cord passing through the grommets and around the frame rails. This design was greatly accepted by the client due to its comfort and lightweight design.

Steering Mechanism:

Four different ideas were developed in the brainstorming sessions which involved steering the wheelchair: a swivel chair method, rack and pinion steering, hydraulic actuated steering, and the lever arm steering method. The swivel chair method had the client's seat geared to a third wheel in the back of the chair allowing the client to change direction by shifting his body. This method would allow the client a full range of turning ability but restrict his nature use of body weight to stabilize and adjust the wheelchair during the race. The client preferred mobility in the seat during the race, so any steering mechanism involving the seat would not be very effective. The rack and pinion steering method involved a lever that would be geared to a rack on a third wheel in the back of the wheelchair. This method would deliver a full range of steering ability but scaling from its current automobile use to wheelchair use would be difficult, and added weight to the chair is also a negative feature. The hydraulically actuated steering method would require the client to pull a lever which would compress a piston causing fluid to flow out of the piston and into another piston connected to a third wheel in the back of the chair. By moving the lever up and down the client could then turn left and right by compressing and decompressing these two pistons. While this method would provide full range of steering ability it is complicated by nature and carries a potential for fluid leaks and frequent maintenance. The lever arm steering method would again require the client to steer by pulling on a lever that would be connected in a three bar linkage pivoted by the seat and attached to the supporting fork of the front wheel. The lever would provide feedback to the client and allow the ability to adjust the heading of the wheelchair during the race environment. This design is lightweight and provides a simple and realistic approach to the problem yet lacks the full range of motion the client will be able to use in normal use. However, the normal use and nature of the racing event did not require a full range of motion in order for the client to safely maneuver the race. The client only needed to turn left and a few degrees to the right, which is significantly supplied by this design. Adaptations of this design may involve the ability to switch sides in order to provide for large right turns or clockwise racing events. This is the method chosen for the steering of the racing wheel chair. A simple model of this lever arm mechanism was constructed prior to fabrication using Lego as shown in Fig. 20.6.

The total cost of the material was $1500.00. Time for machining the different parts was donated.

ADAPTATION OF A WHEELCHAIR FOR HUNTING

Designers :Jerome Dorlack, Robert Andrews, Todd Bradford Pausche,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory
Department of Mechanical, Industrial, and Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

The goal of this project was to adapt a wheelchair to allow an individual with a disability to hunt using a shotgun. The adaptation consisted of attaching a turret to the chair on which the shotgun was secured. A Sip and Puff system (S&P) was used as triggering device. The client blew into the S&P system to activate a solenoid, which in its turn actuated a cable to pull the trigger as shown in Fig. 20.7. The client wears this Sip and Puff (S&P) system. The turret was mounted on the left leg post of the wheelchair, and was made to pivot to allow easy access to and from the wheelchair as shown in Fig. 20.8. During operation, the shotgun is clamped in a support block that pivots only in one plane on the turret. The solenoid is powered from the wheelchair's battery. A safety toggle switch was also integrated into the system to prevent misfiring of the shotgun by preventing current to be drawn from the battery.

SUMMARY OF IMPACT

A person with C6 tetraplegia had no use of his legs and minimal use of his upper body. He had poor tricep strength but good bicep strength. Before using a wheelchair, he was an avid hunter. His wheelchair was adapted to allow him to hunt. The final product delivered to the client was a shotgun turret and a firing system operated using an S&P device. The turret can be used to support different models of shotguns, which was convenient to the user. The turret allowed him to have a larger shooting range and more mobility. The unit was easy to disassemble which was also convenient. The client also had greater control over the firing of the weapon due to the S&P device. The safety toggle switch that was integrated into the system provided a higher safety level.

Figure 20.7. Cable Used to Pull Trigger.

TECHNICAL DESCRIPTION

Adapting the client's wheelchair to allow him to hunt successfully involves the design and construction of a stable shooting turret and a firing mechanism. The turret needs to withstand the significant dynamic forces that accompany the firing of a shotgun, and the firing device must be able to actuate the trigger successfully and repeatedly. The firing device is also required to operate as effortless as possible to allow the client to hunt successfully. A Sip and Puff system is used to activate a solenoid, which in its turn actuates a cable to pull the trigger. The turret is mounted on the left leg post of the wheelchair, and is made to pivot to allow easy access to and from the wheelchair. To resist corrosion, the turret is made of aluminum making it more suitable for hunting in the outdoors. It is also designed so that it can be easily removed and disassembled and can be fitted to different rifles and shotguns. The uprights of the turret, both top and bottom, and the support arm are fabricated from one-inch machined rounds.

During hunting, the shotgun is to be clamped within a support block that pivots only in one plane on the turret. The solenoid is mounted on the left side of the wheelchair, and draws its power from the wheelchair's battery. The client wears the Sip and Puff (S&P) system during hunting. This system includes a head set, a puffing tube, and a control box that attaches to the client's waist. This control box is wired with the wheelchair battery and with the solenoid. As this individual blows into the S&P system, an air pressure activated photo diode, housed in the control box, allows the current to pass from the battery to the solenoid, which pulls a cable to actuate the trigger. This cable connects the solenoid plunger to the trigger on the shotgun and allows the solenoid to pull the trigger. This cable was obtained from a bicycle hand brake cable and made up of two parts. One part is a Teflon coated stainless steel cable, and the other part is a flexible plastic conduit through which the cable runs. Using this particular cable has several advantages. The stainless steel Teflon coated cable allows the cable to survive the elements of the outdoors without corrosion, and Teflon coating reduces friction and allows the cable to easily slide in the housing.

A one-inch stroke solenoid rated at six pounds with an internal resistance of 100 ohms was used. It was purchased from McMaster-Carr. The solenoid is adequate enough as it delivers the required force to pull the trigger, and allows the necessary travel to fully actuate it. The shotgun has a trigger stroke of .225 inches, as measured with a set of calipers. A 5.25 pound load is required to pull the trigger as measured with a fish scale. This solenoid is also compact in size, which allows an easy mounting on the turret: it measures two inches long, 1.75 inches wide and 1.75 inches deep.

Due to the relatively high current, a relay is used to transfer the current from the battery to the solenoid, which protects the sip and puff device from any possibility of overload. The relay has a rating of 20 amps and is small enough to fit in an inconspicuous place on the wheel chair. The interface between the cable and the solenoid is held in place with a cotter pin. This allows the cable to be pulled through the conduit with minimal resistance.

Figure 20.8. Turret Mounted on Wheelchair.

A safety toggle switch is also integrated into the system to prevent misfiring of the shotgun by preventing current to be drawn from the battery. The toggle switch is a simple single pole, single throw toggle switch, rated at 10 amps. The switch also lights up red when it is armed, thus providing a visual notification to the user that the system is armed and ready to fire. The switch also has a large toggle, making it easier for the client to use.

The interface between the shotgun trigger and the cable must be strong enough to hold the cable firmly in place, but free enough to allow the cable to slide with minimal friction in the conduit. To allow this, the cable is fastened to the gun using a picture-hanging clamp, and a hole is drilled thru the trigger to rout the cable. A cable crimp is used to tie the end.

The total cost of the material was $450.00.

AUTOMATIC FISHING ROD AND REEL

Designers: Thomas Badman, Nick Rowland, Timothy Ravas, Michael Crum,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory,
Department of Mechanical, Industrial, Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

The goal of this project was to design and construct a fishing rod and reel system that would allow an individual with a disability to fish for a long time with relative ease and comfort. This person has a C5 tetraplegia with good use of biceps and shoulders but no use of triceps and limited use of hands. He desired a fishing rod and reel system that would allow him to retrieve the line without any exertions on his hands. Adapting a system for casting was not necessary since this individual is able to cast seventy feet with an open-faced reel, which is not uncommon for the average fisherman. Also, for securing the rod to the body, the client preferred to use custom fitted plastic molded braces attached to his wrist. Therefore, design objectives were focused on line retrieval. The retrieval system used a small DC motor controlled by a linear rheostat to bring the line in; the motor was mounted to the reel. The rheostat could be retracted either automatically via a linear spring attached to it or by use of an on/off button. Two small clutch bearings were integrated within the system to allow the client either to retrieve the line manually using a hand crank as he presently does, or by activating the DC motor. A removable plastic guard was installed to cover the hand crank to protect his hands in case of malfunction. Fig. 20.9 shows the reel assembly unit that was constructed, and Fig. 20.10 shows a client demonstrating how the unit is used when attached to a fishing rod.

Figure 20.9. Completed Reel Assembly.

Figure 20.10. Reel Assembly Unit Attached to a Fishing Rod.

SUMMARY OF IMPACT

An individual with a C5 tetraplegia has been an avid fisherman for over forty years, but now he can not fish for a long periods of time. As he uses the fishing reel, he turns a hand crank to retrieve the line. His hands tire quickly from the repetitive rotational motion required to reel in the fishing line. A state of the art spinning reel was adapted with high quality mechanical products to allow this individual to fish with very little effort. He has tested the unit and found it efficient and convenient to use.

TECHNICAL DESCRIPTION

Design objectives were focused on line retrieval and securing the fishing rod. The design included using a small DC motor controlled by a rheostat to retrieve the line. The motor was mounted on the reel. The rheostat allowed the client to adjust the speed of the motor. In order to allow the client to retrieve the line either manually as he is accustomed to doing or automatically using the motor, two small clutch bearings were placed on the sides of the central drive shaft in order to disengage either the manual hand crank or the motor, depending on which retrieval method is being used. This eliminated rotation of hand crank as the motor is powered.

In order to estimate the torque required to turn the reel, an experimental approach was used. In this experiment, the crank torque and the bail torque radii were first determined by attaching a container to the bail and a second container to the crank and measuring the distances from the crank's and bail's axes of rotation to the respective masses. The second step of the experiment consisted of adding a known mass to the lever arm of the bail and then adding masses to the lever arm of the crank until equilibrium was attained. The ratio of the bail torque relative to the crank torque was thus calculated.

The minimum load was simulated using a worm made of rubber with one ounce weight, 0.25 inch diameter and a length of three inches. The maximum load was simulated using an eight-pound large mouth bass 24 inches long and with a head approximated as an oval with diameters of four inches and six inches. This fish was then modeled as a streamlined strut. It was estimated by an experienced fisherman that light lure should be reeled in at a rate of eight revolutions per 10 seconds (this would vary per reel but the client decided that this was a good rate for this particular reel). As the radius of the spool used in the constructed unit was 0.875 inches, the specified luring rate resulted to a line speed of 4.4 in/s, which represented the velocity of the worm or the fish. In order to calculate the minimum and maximum torques exerted on the bail, Reynolds numbers for the worm and the fish were calculated using 50o F fresh water. The corresponding drag coefficients were then found from the appropriate charts, which allowed calculation of the drag force on the worm and the fish. Using these drag forces, the weight of the fish and the worm, and the radius of the bail, the maximum and minimum torques exerted on the bail were calculated. Using the value obtained for the ratio of the bail torque to the crank torque, the maximum and minimum torques needed by the motor were estimated as 1192 oz*in and 9 oz*in.

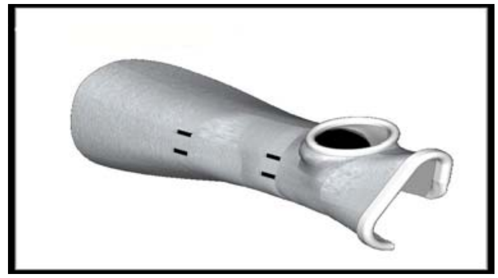

Figure 20.11 Custom Molded Arm Brace.

Due to size limitations, a smaller motor was purchased from Merkle-Korff Industries. It is a 12-volt DC gear-motor with a maximum torque of 6.6 in.lbs and rated at 105 rpm. This motor was not powerful enough to retrieve anything larger than a half-pound fish. The motor was secured to the reel itself using an aluminum bracket and two M2.5 machine screws as shown in Fig. 20.9. This design allowed for the new modified reel to be switched to another rod with no more effort than would be required in switching an unmodified reel. This is an important aspect because it is not unusual for a fisherman to switch rods when on a fishing trip either for fishing conditions or because of a broken rod. The motor's shaft was then assembled into a bearing adapter and then into a clutch bearing. The bearing was then attached to a hex shaft that ran into the reel from one side and then out the other to another clutch bearing. This clutch bearing was then pressed into a manual hand crank. The purpose of these clutch bearings was to allow one retrieval method to act independently of the other. This was an important part of the design because it was deemed unsafe by the design team to have the manual hand crank spinning while the motor ran and it was found to be impossible to turn the motor's shaft by hand.

The client has been using a custom plastic molded brace, shown in Fig. 20.11, to mount the rod. The mold partially encloses the forearm and upper hand with a hole for the thumb. It is secured to the arm using a two Velcro straps, one at the wrist and the other close to the elbow. The brace is mounted to the rod with two hose clamps. The client prefers this mounting due to its reliability and effectiveness.

The total cost of the material was $250.00.

BEACH WHEELCHAIR

Designers: Mark Swallen, Todd France, Robert Hiss, Matthew Motil, Daniel Widman,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory
Department of Mechanical, Industrial, Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

Standard wheelchairs have narrow wheels that easily sink in the sand. This does not allow individuals in wheelchairs to access the waterfront and prevents them from enjoying the beach. A client who is active but cannot move her body from the waist down desired to use a custom made beach wheelchair that would allow her to access the waterfront. She cannot enjoy the beach while in her conventional chair.

The frame of the prototype was made of lightweight Polyvinyl Chloride (PVC) pipes to prevent corrosion as shown in Figures 20.12 and 20.13. Wide tires were used to prevent sinking in the sand. The design differs from conventional chairs in that the large wheels are the front wheels. These large wheels were 12 inches wide. Smaller six-inch wide wheels were used as the rear wheels. Having the large wide wheels in the front made pushing the wheelchair in the sand easier. Seat and chest straps were incorporated in the design to ensure safety. Ease of entry was enhanced by not including armrests on the seat, thus enabling the client to be set into the chair from the front or sides, or through use of a transfer board. A folding footrest was also incorporated into the design.

SUMMARY OF IMPACT

In the summer, the client with paraplegia likes to go with her family and friends to the beach. However, her conventional wheelchair does not allow her to access the waterfront because it sinks in the sand when pushed. The beach wheelchair meets her wishes by allowing her to access the waterfront and enjoy the beach. It is portable and equipped with large diameter wide tires, which prevents sinking into the sand, thus granting mobility when pushed. A sticker reading: "DO NOT USE IN WATER" was mounted on the back of the chair to ensure safe operation and discourage misuse. The client is pleased with the safety feature of chest straps and a seat belt, preventing her from falling out.

Figure 20.12. The UT Beach Wheelchair.

TECHNICAL DESCRIPTION

Safety, portability, and ease of entry were three important design considerations. The final design utilized a combination of large and small diameter, wide tires. The tires selected were specifically designed for beach wheelchairs and beach applications. The large diameter wheels were placed just below the seat. The small diameter tires were located in the rear under the wheelchair handles. The frame of the wheelchair was made of lightweight Polyvinyl Chloride (PVC) pipes. The advantages of PVC are its availability, ease of machining, corrosion resistance, price, and low weight. The disadvantages are size, aesthetic appearance, and difficulty of integrating metal components (i.e. bearings, swivels). Since the material properties of PVC change with exposure to ultra violet rays from the sun, conventional PVC becomes more brittle and prone to fracture over time. To inhibit this deterioration, furniture grade PVC pipes and joints were used. Furniture grade

PVC contains a special UV inhibitor to prevent its deterioration due to from the sun. Steering and maneuverability were two issues that needed to be addressed. Conventional wheelchairs have two small narrow wheels in the front that swivel, thus increasing the ease of turning. Large wide tires require a large radius to swivel and if located in the front, may hinder entering and exiting the chair. Ease of entry was enhanced by not including armrests on the seat. The larger turning radius was not a major concern because the beach wheelchair would primarily be used on the open beach.

The rear swivels for the chair were purchased from Deming Design. The rear castors were press fit into a 90˚ schedule 80 L-shaped joint. These castors can easily be removed to enhance wheelchair portability. An added benefit of this design was the ability to remove the castors and change the bearings should a failure ever occur. A one-inch diameter hollow cylinder with a wall thickness of 0.065 inches and made of 4130 normalized steel was taken as the main axle supporting the two large tires. This axle was attached to the frame with plastic inserts. Custom inserts were designed and turned enabling the main shaft to be supported throughout its entire length. Custom castor inserts were also used to serve as spacers on the rear swiveling castors. These inserts prevented excessive play between the shaft and the castor bracket. The castor inserts also prevented the tire from traveling back and forth on the shaft thus rubbing against the bracket. The bar supporting the rear castors was reinforced to prevent failure. To achieve this, schedule 80 pipe and fittings were used in this location. Running a section of schedule 40 pipe through the piece from elbow to elbow reinforced this rear assembly. Adapters were made to attach the schedule 80 back section to the schedule 40 frame. Press fitting the schedule 40 into the schedule 80 members constructed the members in compression. Gluing and press fitting the schedule 80 into the schedule 40 constructed the section in tension.

Extended handlebars were incorporated into the design to keep the pusher further away from the swivel wheels to prevent possible injury. To support the additional length of the handle, a support piece running from the bottom of to the handle was installed. This feature greatly improved the rigidity of the handle.

A footrest was used to support the entire length of the foot. It folds up to allow greater ease when entering and exiting the beach wheelchair. Straps were installed from the front of the footrest to the base of the chair seat to ensure that the angle of the footrest remained at 90˚ to the chair frame. The front bar of the footrest has an embroidered piece of cloth attached stating that the footrest is not a step. This feature will help encourage proper usage of the beach wheelchair.

The design incorporated several safety features. Individuals with paraplegia often have little control of their upper torsos. Adjustable chest straps and seatbelts were installed to prevent an individual from falling out of the beach wheelchair. Using I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software), a structural analysis of the proposed beach wheelchair was conducted. The analysis showed that the design was safe.

The total cost of the material was $850.00.

Figure 20.13. Client Response.

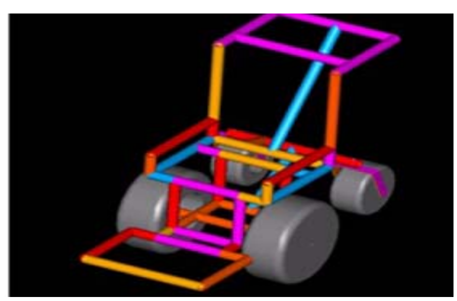

Figure 20.14. Beach Wheelchair Design.

AUTOMATIC WATER HYDRATION SYSTEM FOR MUSHROOM FARMING

Designers: Travis Buddlemeyer, Jeff Kremer, Robert Danyluk, Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Department of Mechanical, Industrial, and Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

A farmer with a C-4 incomplete tetraplegia grows shitake mushrooms. He has limited mobility and tires quickly. This individual is in need of a new hydration system to assist him in mushroom farming. The procedure for impregnating the mushroom spores includes drilling 5/16 inch diameter holes ¾ inch deep, into a four-foot long by six inch diameter oak log. After the holes are drilled, Shitake mushroom spores are inserted into the holes and the holes are covered with a cheese wax coating. Logs are placed in rows in a 1500 square foot open area to be mist hydrated. Three sprinklers are mounted on steel posts that are manually moved from one location to another to allow for irrigation of the different sections. Also, water is turned on and off manually using shut off valves.

During the irrigation process, this farmer, when moving a post from one location to another, manually removes it six inches from the ground, transports it to a new location, and then inserts it six inches underground. These tasks are physically demanding and require assistance from another individual since the limited mobility of this farmer prevents him from pulling out and digging these posts. This does not allow him to irrigate independently his mushroom farm. The objective of this project was to design, construct and install an automated mist hydration system for this farmer to allow him to irrigate his farm independently.

SUMMARY OF IMPACT

The system that offers adaptability for water supply to all or a group of specified sprinkler heads to cover a specified area with the option for future expansion if desired. It enables a mushroom farmer with a disability to irrigate independently his farm and reduce his fatigue. The new system ensures that the whole mushroom growing area will be hydrated sufficiently, in a timely manner, and according to the farmer's needs. The timer allows the farmer to program it according to the necessity to open and close specified valves to irrigate specific areas for specified times. With the touch of few buttons, the farmer will be able to irrigate his farm without any additional effort.

Figure 20.15. Mushroom Farm with Automatic Water Hydration System

TECHNICAL DESCRIPTION

The main components of the mist hydration system include automatic programmable timer and automatic shut off valves with additional posts, hoses and sprinkler heads. Hosing was run from the main water line to an intermediate valve assembly. From this assembly, hosing was run to six mounted sprinkler head assemblies. Hoses were used instead of PVC pipes since the farmer did not want to dig his farm to install the pipes. The automatic timer was installed in the farmer's barn for easy access. The automatic shut off valves were mounted on the outside of the barn and near the main water valve. Fig. 20.15 shows the mushroom farm with the newly installed automatic water hydration system.

The entire mushroom farm is 1620 square feet of open area that must be mist hydrated. An above ground water system that allows for future expansion was selected. An electronic programmable timer was the main component that needed to be evaluated. A 5006-1 Six Station Independent Program AC Controller from Drips Plumbing and Sprinkler Supplies was selected. This timer was able to open and close specified solenoid valves for specified periods of time. It works by sending an electrical signal to a valve, telling it to open or close. The watering period can range from one minute to twelve hours with an option for four different start times per day. A specified watering program can be cyclical from one day to thirty days. It was found that the timer was constrained to only open two valves at one time. This constraint was easily overcome to complete the project objective by using tee and elbow fixtures so that one valve will control three sprinkler assemblies, as shown in Fig. 20.16. This gave the farmer the ability to hydrate 810 square feet or all 1620 square feet at one time.

Compatible automated valves were used with the timer to control the flow to the sprinkler head assemblies. Five-volt signals from the timer to the lead wires for each valve open and close the valves. The controlled capacity of the automated timer was a total of six automated valves. These six solenoid valves were CP-075 Automatic Sprinkler Valves from Rain Bird. Additionally, these valves were rated for a pressure range from 15 to 150 psi and a flow rate range from 0.2 to 40 gpm, which was sufficient for this system. Currently only two of these valves are used as shown in Fig. 20.16. The other valves will be used to satisfy the client's plan for future expansion. The timer sufficiently works with the six valves and no changes to the timer will need to be made. Sprinkler heads were needed to provide a fine mist, which is required for mushroom farming. A sprinkler head assembly consisted of one ¾ inch male adapter, one ½ inch to ¾ inch reducing female adapter, one ½ inch male base and one Dramm Nifty Nozzle. The sprinkler heads formerly used by the mushroom farmer were chosen; they were rated for 100 psi and 2.2 gpm.

Mounting posts were needed to mount the sprinkler head assemblies at a specified height that allowed for optimum misting radii. The posts chosen were 5/8″ cold rolled painted tubing that came in standard lengths of 22 feet. Three posts were cut in half, resulting in six 11 feet posts. One end of each post was milled to a V-shape to allow for easy insertion into the ground. In order to design the lay out of the posts, the effective misting radius needed to be determined. A three-foot Plexiglas plate was used for this purpose by placing it near a sprinkler assembly. The transition from a fine mist to water droplets on the plate established the misting radius. It was assumed that all six valves would be open at a given time.

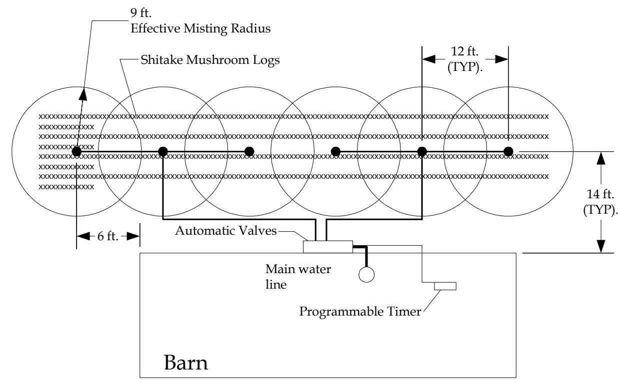

Figure 20.16. Water Hydration System Layout.

Sprinkler height was adjusted by moving the assemblies up and down the mounting posts. It was found that a misting radius of nine feet was measured for a sprinkler height of nine feet; all posts were thus inserted two feet into the ground. The posts were then inserted according to the specified locations shown in Fig. 20.16, where an overlap in the misting areas was necessary in order to ensure complete coverage of the farming area.

Miscellaneous components such as hosing, installation fixtures, clamps, and quick disconnects were needed to install and tie together the main components of the system. These components simply needed to be compatible and durable for completion of the system. The system was installed at the mushroom farmer's place of residence and found to work properly.

The total cost of the project was about $560.00.

DESIGN AND CONSTRUCTION OF A MANUAL RACING WHEELCHAIR

Designers: Jonathan Blevins, Brian Schimmoeller, Kent Sxhlatter, Joshua Dusseau,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory
Department of Mechanical, Industrial, Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

The purpose of this project was to design and construct a manual racing wheelchair for a 10-year-old individual with paraplegia who has spinal bifida, a congenital defect in the spinal column, and scoliosis, an abnormal lateral curvature of the spine. The unit that was designed and constructed is shown in Fig. 20.17. The prototype satisfied the design constraints of being lightweight, aerodynamic, stable, durable, comfortable, and ergonomic. Special considerations were given to the steering mechanism and to the seating assembly because of the client's small size and physical limitations in the inability to lean forward.

SUMMARY OF IMPACT

The client is a team member in an athletic organization formed to encourage persons with physical challenges to compete in track and field events. He has paraplegia, scoliosis and spina bifida, which limits his forward leaning motions. He is also very small. He is not able to purchase a manual racing wheelchair because none is commercially available in a size that will accommodate him. During competitions, he uses his own manual wheelchair, which is not practical for racing. The unit that was constructed was tested by the client who found it very efficient. Fig. 20.18 shows the design team and the client as he first tried the unit. The prototype will allow him to compete in future racing events because he found it more efficient for racing purposes than the wheelchair he had been using.

TECHNICAL DESCRIPTION

Three proposed designs were considered to include: modification of an existing Y-type frame, a customized A-type frame, and a customized T-type frame. The customized T-type frame was the method of choice since it was easier to tailor based on the client's dimensions, limitations of movement, and weight. Using AutoCAD, a stick figure diagram was used to estimate the location of the center of mass of each of the client's limbs with respect to the back of the seat of the wheelchair at three common positions: an upright position representing the client resting in the chair, the position at the beginning of the power stroke, and the position at the end of the power stroke. Using these data, the dimensions of

Figure 20.17. Racing Wheelchair.

Figure 20.18. Design Team with Prototype.

the frame were established. Stability of the chair was determined by verifying that the chair would not tip over while the client was using it. The speed at which the client could take a turn of a given radius was also calculated. Using I-DEAS™ software, a structural analysis of the proposed wheelchair was conducted using the finite element method. The frame was made of T6511-6061 aluminum. A factor of safety of 3.4 was estimated.

A 16 inch wheel was used as a front wheel; this was smaller than the typical 20 inch wheel found on most manual racing wheelchairs. A commercially available fork could not be obtained, and a custom-made one was used to fit the 16 inch wheel. The seat design was based on the dimensions of the wheelchair, the limited range of motion of the client, and a preference of the client of not sitting on his legs as many racers do. A seat that places the client in an upright seating position was chosen. The seat wrapped around the horizontal bars of the frame and the two adjacent vertical bars. String was fed through the holes much like shoelaces and was tied to secure the seat to the frame.

Side guards were placed in the open area of the frame between the racer and the wheels to prevent the racer's clothing or hands from getting caught in the spokes of the wheels. Typically these side guards are plastic. However because of the small size of the wheelchair, side guards could not be purchased. Therefore a fabric side guard was designed that would provide protection for both sides of the chair, as well as serve as fenders. The side guard goes underneath the seat, over the fender rails, and attaches to itself by means of button snaps. Fenders cover the wheels to prevent chafing of the racer's arms against the tires and are typically metal. Due to difficulty in having fenders fabricated, two fender rails, covered with the side guards, were used.

The steering system consisted of a stem, handlebars, and a compensator. The handlebars were held in place by the stem. Although the compensator device was not directly connected to the handlebars, it did control the angle at which the handlebars can be turned because both the compensator and the handlebars are connected to the fork. The compensator device allows the racer to take a turn, while not having to steer the wheelchair, so the racer can concentrate on propelling the wheels. It did this by applying a force to the front wheel that

Figure 20.19. Compensator System.

counteracted the wheel's tendency to turn to a straight path. The compensator device was made up of two components, a compensator bar and a compensator cylinder as shown in Fig. 20.19. The compensator bar was located on the top of the main tube to allow the racer to have easy access to it for adjustment while using the wheelchair. The compensator cylinder, which normally attaches to the compensator bar and the handlebars, was attached to the compensator bar and the fork because of complications of attaching it to the handlebars. To attach the compensator cylinder to the fork a threaded stud was welded to the left side of the fork.

To complete the design, it was required to determine whether or not the compensator bar allowed the front wheel to turn sharply enough to allow the racer to take any turn that he may encounter while racing. The effective turning angle for given radii can be calculated; the larger the angle, the smaller the turning radius. Since the compensator bar turned at an angle equal to the effective turning angle, the maximum angle that the compensator bar would turn was then measured as 30°, which corresponded to a turning radius of approximately 6.6 feet. This angle can be adjusted using two setscrews. A padded strap that wrapped around the client's torso was included as a protective restraint. This strap allowed the client to rest while in the racing position, which relieved stress from his back and permitted him to conserve his energy for racing. Also, this restraint reduced the possibility of the client sliding out under heavy breaking, making the wheelchair safer to operate.

The different components were painted and the wheelchair was tested by the client to find if further modifications were needed. It was determined that a foothold, instead of a leg strap, should be used to support the client's lower legs and feet.

The total cost of the material was $650.00.

MOBILE COMPUTER TOWER ELEVATING UNIT

Designers: Troy Dunbar, Jasper Crispen, Mike Meadows, Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory
Department of Mechanical, Industrial, and Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

A man with C6 tetraplegia cannot move his legs, hands, abdomen, or trunk and has only partial use of his upper arms. He owns a desktop computer with a tower. This tower sits on the floor. As this individual is working from his wheelchair, he cannot reach the different disk drives on his computer, and requires assistance in order to insert and eject disks from drives. This individual desires to be able to reach independently all disk drives while working from his wheelchair.

The purpose of this project was to design and construct a unit that will elevate and lower the computer tower to allow this individual to reach all disk drives independently while sitting in his wheelchair. This elevating unit was constructed as a mobile unit with wheels attached to the base to allow access for repairing the computer tower and access underneath and behind it for cleaning purposes. The elevating unit includes a base that supports the computer tower. This base is elevated and lowered using a linear actuator, the motion of which is generated using a motor mounted on a fixed base that is attached to the mobile frame of the unit. Wheel locks allow the mobile frame to remain stationary. Two control buttons are used to lower and raise the moving base.

SUMMARY OF IMPACT

While seated in his wheelchair, the client is now able to reach all drives and bays independently. Easy access was also made possible because the unit is mobile. Using push buttons to control the height of the disk drives allowed the unit to be easily and independently operated by the client

TECHNICAL DESCRIPTION

The client uses a table that serves as a desktop for the monitor of his computer. The computer tower, which was located to the right of the desk, sat on the floor. It was noted that the table supports were near each end of the table, but were not located at the edge of the table. The horizontal distance from the support legs to the edge of the tabletop was approximately a quarter of the overall length of the table. It was thus apparent that building a computer tower-elevating unit that would attach directly to the desk would be difficult. This type of unit would need to be located at the end of the table so that it could elevate to the proper height above the desk surface. However, at such a lengthy distance from any support leg of the desk, it would not be feasible to stabilize the unit. Additionally, the client did not want any attachments to the desk. For these reasons, the two best options to fulfill the client's needs were to build an entirely new desk, which would include the computer elevating mechanism, or to build a separate tower elevating unit that would sit between the current desk and the printer stand located to the right of the table. It would be very costly to design build a new desk. The client indicated that he prefers a mobile elevating unit since he is already satisfied with the current desk. This unit would only be big enough to hold the computer tower. The merits of this idea include; lower cost, increased mobility and access for client, decreased manufacturing time, and greater

Figure 20.20. Tower assembly.

accessibility for computer tower servicing and repair. One demerit of this idea was that the unit would not be as stable as a single desk unit.

The dimensions of the computer tower were measured as 18 inches high, 7 ¾ inches wide, and 24 inches deep including two inches for connection wires located on the back. The overall dimensions of the elevating unit were specified to be 26 inches high, 16 inches wide, and 26 inches deep to allow for increased stability. The frame of the unit was made of one-inch square, AISI 6063 aluminum tubing.

The computer tower was secured to the moving base using two pieces of angle iron, one on each side of the computer tower. Adjustable cam-style clamps were used to attach the angle irons to the moving base of the elevating unit. An electrically powered linear actuator was used to raise and lower the moving base. The linear actuator moved vertically at a speed of 19.4 inches per minute. The overall travel of the linear actuator was modified to eight inches (from 12 inches) so that the moving base would not be raised more than 36 inches above ground, which will allow the client to access all drives while seated in his wheelchair. Limit switches were used to control the maximum and minimum heights of the moving base, which were established by measuring the distances between the bottom of the computer tower and each disk drive. A 3/8 inch diameter pin, made of mild carbon steel, was used to attach the linear actuator to the platform and to the frame. The frame of the unit also supported a lower fixed base where the motor used to drive the linear actuator was mounted. The moving base rode along vertical rails mounted on the side of the frame of the elevating unit. Wheels were attached to the bottom of the unit to allow mobility. Wheel locks were used to allow the mobile frame to remain stationary when needed. Finally, two control buttons were used to lower and raise the moving base. The control buttons were connected to a six-foot flexible wire so the client could place the controls in an accessible location. A removable wood casing was constructed with a walnut colored veneer finish to match the client's desk.

Using I-DEAS™ software, a structural analysis of the proposed elevating unit was conducted using the finite element method. The frame was found to be safe. An analysis was also performed on the pins that attach the linear actuator to the frame and to the platform. The unit was tested and evaluated by the client. He found that the casing around each button represented a problem as they interfered with operation. This issue could be resolved by purchasing a different style of button. During testing, it was also found that the moving base appears to wobble slightly from side to side as it raised and lowered. This appeared to be due to a slight bend in the linear actuator shaft. This problem could be resolved by replacing the current rails with slotted rails. The moving plate would then have to be attached to these slotted rails by means of shoulder bolts and vinyl washers. However, even with the current wobble, there is no concern for safety. The clamps on the moving base will hold the computer tower securely so it will not fall off.

The total cost for all individual parts of the unit was $550.

WHEELCHAIR GARAGE ACCESS SYSTEM

Designers: Stephen Gallat, Christian DelBoccio, Jeremy Bechtol, Jason Holmes,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory
Department of Mechanical, Industrial, Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

The purpose of this project was to modify the entryway to the first floor from the garage of an individual's house and to design and construct a lift system that would safely lower this person twenty-three inches from the garage floor to the first floor level. This individual has paraplegia with full use of his arms. The house is a tri-level where the main door opens to the second floor, and the garage door opens to the first floor, which is below ground by approximately two feet as shown in Fig. 20.21. This person currently enters and exits the home from the main door using the long ramp in the front of the house. This is highly inconvenient for him and his family since he must enter the house from the second floor, which consists of only a living room, dining room and kitchen. No bathrooms are available on the second floor. Because of this, his family would like to move him to the first floor where he can have his living room and bathroom contained in one area. The only way the client can access the first floor independently is through the relatively elevated garage. In order to accomplish this goal, the entryway to the first floor from the garage needed to be modified. The first floor was accessible from the garage via two steps as shown in Fig. 20.21. Modification of the entryway required removal of these steps and additional concrete from the garage floor in order to enlarge the first floor stairwell area. A lift system was then designed, constructed and installed in the newly enlarged pit (it is called a pit since the two steps will no longer exist). The lift resembles a "forklift" design that consists of a steel platform powered by a single linear actuator, mounted on one side of the platform as shown in Fig. 20.22.

SUMMARY OF IMPACT

The client found the prototype to be convenient for his everyday use. This project allowed the client to live more independently and enter and exit the house through the use of a lift. This was not only important to improve the client's independence, but also a safety factor in case of emergency. The system efficiently raises and lowers the client to and from his garage to the first floor of his house.

Figure 20.21. Entryway to the First Floor from the Garage Before Modification.

TECHNICAL DESCRIPTION

Many factors and limitations had to be fully understood in order to identify the most appropriate lift system. The number one concern was the safety of the client, so all possible safety issues needed to be addressed when considering solutions. In addition, it was required that the lift system be easily used by the client and accommodate his needs as well as those of his family. A "forklift" design was adopted. Such a system uses very little material, is compact, allowing space saving, and would be very efficient in operation. A linear actuator was mounted on the side of the lift next to the wall of the garage. The actuator that was used is self-contained, where the oil reservoir, motor, microprocessor, bore, and stroke are all contained within the same unit. The actuator was powered by a twelve-volt car battery, which was housed away from the unit. The battery was to be connected to an automatic battery charger at all times, providing continuous power to the actuator. The battery will supply power to the lift in the case of a power outage. An automatic locking mechanism was contained within the actuator. When the lift stops, a series of check valves automatically close it to stop fluid flow. This kept the actuator locked in its current position and also allowed it to act as an emergency stop. As an added safety feature, two limit switches, placed at the top and bottom of the stroke of the lift, were added in order to ensure that the lift stopped at the correct location in the up and down positions. This ensured that the client would not stop the lift too high or low from the desired location, which would give him easy access on and off the lift.

This design also required some home modifications. The first floor was accessible from the garage via two steps. Modification of the entryway required removal of these steps. In addition, the final layout of the modified entryway must allow this individual to access the platform using a forward motion from either the garage level or the first floor level. Additional concrete from the garage floor was thus removed to enlarge the first floor stairwell area. Also, to allow access for his family, more concrete was removed to construct two steps to the side of the entry door as shown in Fig. 20.22.

The wheelchair lift system included a mast that acted as a support and was made up of two, one-inch diameter, six-foot long, 1060 hot rolled steel rods that were attached to a base plate. The linear actuator was located midway between these two steel rods and was also mounted to the base plate- the only portion of the lift in contact with the ground. The moving part, namely the platform, was powered by the linear actuator. The platform was made of 1.5 inch x 1.5 inch x 0.1875 inch 1020 steel tubing welded together to resist deflection as shown in Fig. 20.23. Aluminum diamond plating was attached to the frame of the platform to allow the client a non-slip surface in which to position himself for safe operation of the lift. The platform was welded to two vertical pieces of 2 inch x 2 inch x 0.1875 inch square tubing. Two oil-impregnated bronze flange sleeve bearings were mounted inside these vertical pieces using custom designed adapters. The bearings allowed the platform to move smoothly and quietly while guided by the vertical steel rods and also maintained a very low coefficient of friction. SolidWorks® software used

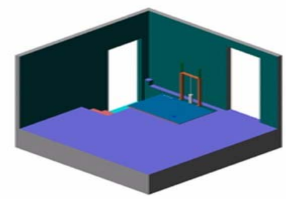

Figure 20.22. Modified Entryway Showing the Lift Raised to the Garage Level.

in the design process for visualization purposes as shown in Fig. 20.22.

The lift was designed to withstand at least 400 lb. Using the I-DEAS Master Series™ Software (Integrated Design Engineering Analysis Software), finite element analysis (FEA) was performed to determine the deflection of the platform and the stresses at critical welding points. The 400 pound load was placed on one corner of the platform to simulate a worst-case scenario. Joint stresses for this situation were found almost equal to the yield strength of the material, which corresponded to a factor of safety of two since the weight of the client was 160 pounds. Angle brackets were added to these joints for additional reinforcement. To simulate the most common scenario, two 200 pound loads were distributed over the two middle beams of the platform. Very small stresses were obtained at the joints in this situation; the corresponding maximum displacement of the platform was calculated as 2.13 millimeters.

The total cost of the project was about $3,200.00. The cost for concrete removal and work was $2,000; this was covered through donations secured from the local community.

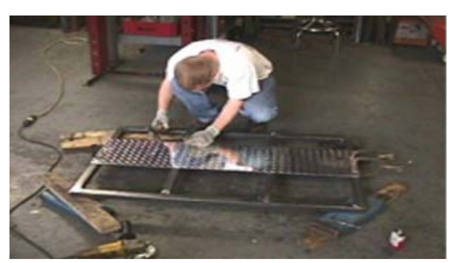

Figure 20.23. Assembling the Platform.

WHEELCHAIR WHEEL WASH SYSTEM

Designers: Jared Bright, Jay Lake, Jeff Raymond, Gregory Seth Turner,
Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis
Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
Biomechanics and Assistive Technology Laboratory,
Department of Mechanical, Industrial, and Manufacturing Engineering
The University of Toledo, Toledo, OH 43606

INTRODUCTION

An individual with T-3 paraplegia uses a wheelchair. He has good use of his upper body, but cannot move his lower extremities. He is active and seeks a high level of independence. As he moves in and out of his house, his floor gets dirty. This is because dirt such as sand and mud stick to the treads of the rear and large wheels of his wheelchair. This presents an additional burden to his family since they have to clean the carpets and the floor of the house each time he goes in and out from his yard.

The purpose of this project is to design and construct a manually activated wheelchair wheel wash system that allows this individual to clean the wheels of his wheelchair before going into his house. The system includes a fixed horizontal platform with a center-raised section as shown in Fig. 20.24. This construct allows each rear wheel of the wheelchair to back and roll into individually. Once a wheel is confined to the platform, it sits on two rollers and backs against a third one as shown in Fig. 20.25. This third roller acts as a stop to limit the backward motion of the wheel. Brushes are installed on the raised section of the platform. As the user manually rotates the wheel confined in the platform, the brushes will scrub the dirt and sand off the wheel. A garden hose water supply line and a water valve are attached to the platform. As the brushes scrub the dirt, water is sprayed down onto them, cleaning the wheel and brushes. To get out of the platform, the front roller is allowed to rotate only in one direction, namely a direction that allows the wheel to move backward. As the client is ready to move away from the platform, he pushes the wheel of his wheelchair forward causing the front roller to lock in place and his wheelchair to climb the front roller.

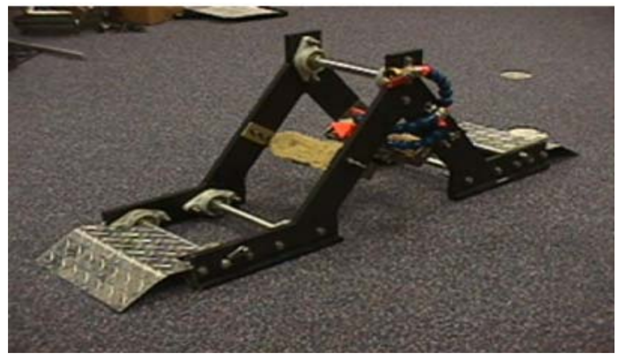

Figure 20.24. Wheelchair Wheel Wash Prototype.

SUMMARY OF IMPACT

Many individuals using wheelchairs use rags to wipe the wheels off before entering their houses so that the floors do not become dirty. This technique is inefficient because the users are unable to remove all of the debris. The unit that was designed and constructed allows an individual with paraplegia to clean the rear wheels of his wheelchair with little effort. The unit is compact in size, and when rigidly attached to the home entrance ramp, it is narrow enough to allow for a wide passing area by the wheelchair when the unit is not needed. The unit is also portable, which allows for seasonal use. No similar products are available in the market. The successful completion of this project allows for an increased level of independence and self-reliance for the client.

TECHNICAL DESCRIPTION

The main design consideration was that the unit had to be mounted on a flat surface. It also had to be narrow enough so that when it was not being used it would not intrude in either the walkway of non-users, or the path of a wheelchair. The other parameters considered were that the system had to be lightweight, corrosive resistant, used predominately during the warm seasons, low cost, easy to use, and low maintenance.

The unit consists of a frame with a raised center section. Fig. 20.24 shows a picture of this frame. Only one rear wheel of a wheelchair is cleaned at a time by rolling backwards into the unit as shown in Fig. 20.25. Once a wheel is confined to the unit, it sits on two rollers and backs against a third as shown in Figures 20.24 and 20.25. The third roller acts as a stop to limit the backward motion of the wheel. Two stationary brushes are installed, one on each side of the raised section, as well as a garden hose water supply line and a water valve. Before the system is used, the water supply may be turned on by a manual shutoff valve that is located on the frame. If the shutoff valve is put in the open position water flows through two adjustable hoses that spray water on the brushes. As the wheel rotates against the brush, dirt is scrubbed off the wheel and flushed away by the running water.

The rollers are made of 6061-T6 aluminum and are ¾ inch in diameter. This diameter is small enough so that the wheelchair would not be unstable while the rollers support the wheel. Once in the unit, the wheelchair wheel is elevated only 1-5/16 inch off the ground. The 6061-T6 aluminum is lightweight and offers good corrosion resistance. Rollers design was performed based on two loading conditions simulating the two most critical situations. The first situation is that the client will enter the unit directly in the center of the roller, creating maximum bending stress, which was calculated to be 5,690 psi. The second situation is where the client enters the unit with his rear wheel as close as possible to the bearing housing. This results in the maximum shear force, which was found to be 96.5 pounds.

The frame is also made of 6061-T6 aluminum due to its resistance to corrosion and its low density. Each side of the frame consists of five pieces, each three inches wide and ½ inch thick, that are welded together using double vee pass butt weld. In order to extend the life and intervals of maintenance of the wash system, the design utilizes two-bolt composite flange bearings developed for the food service industry. These sealed bearings are stainless steel, surrounded by a composite body. They are rated at a static radial load of 1,470 pounds, which is well above the maximum load of 96.5 pounds that the bearing was found to sustain. No dynamic loading was considered due to the slow speed at which the roller will be rotating.

Figure 20.25. Unit in Use.

To get out of the unit, the front roller is allowed to rotate in only one direction, namely the direction that allows the wheel to move backward.

As the user is ready to move away from the unit, he will push the wheel of his wheelchair forward causing the front roller to lock in place and the wheelchair wheel to climb over the front roller and onto a diamond plate access ramp. This ramp is attached to the frame at 30 degrees with the floor, allowing a smooth entry and exit to and from the unit.

The unit was tested and appears to function appropriately. The system of rollers allows the rear wheel of a wheelchair to be pushed against the brushes and to rotate only in one direction – backwards as it is cleaned. Cleaning dirt from the rear wheel is accomplished by a combination of water being sprayed onto the brushes and the rear wheel being rotated. As a user exits the unit, the roller locking mechanism effectively locks the front roller, allowing the rear wheel to rotate forward. The unit access ramp is effective in allowing easy entry and exit to and from the wheel wash unit.

The total cost of the parts was about $800. This could be drastically reduced in mass production. The unit includes 10 bearings, each costing about $50.00. If this product is commercialized, the costs of the bearings will be drastically reduced, reducing the total costs to manufacture the unit.