CHAPTER 20
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MANUAL RACING WHEELCHAIR

Designers: Group 1 (seating team): Tim Langer, Matt Kent, Paul Boehnlein, Keith Stanney; Group 2 (steering team): Greg Homan, Matt Lewis, Marisa Baysa, Dennis Harrigan; Mechanical Engineering Students
Client Coordinator: Dr. Gregory Nemunaitis, Department of Rehabilitative Medicine, Medical College of Ohio
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INTRODUCTION

The purpose of this project was to design and construct a manual racing wheelchair for one of the racers of a racing wheelchair team. This individual is a male with paraplegia due to a T4-T5 spinal cord impairment. This type of spinal cord injury results in a loss of muscle control and feeling from the abdominal trunk area down, including both lower extremities. Two groups of students were formed to work on this project. The first group focused on the seating. The second group concentrated on the steering and the frame. Both groups worked in synergy to produce a completely functional and ergonomically designed product. Figure 20.1 shows the client using the prototype during the test trials.

Figure 20.1. Client Using Manual Racing Wheelchair with Student Designers.

SUMMARY OF IMPACT

This racing wheelchair prototype provides an active physically challenged individual with an opportunity to participate in a challenging and exciting sport. The seat fixture design allows him to have maximum control of the racing chair while positioning his body for maximum force with each power stroke. The steering mechanism allows him to focus his efforts in propelling the wheelchair with limited concern for the chair's direction. The seat fixture in conjunction with the steering mechanism provides him with state-of-the-art maneuvering capabilities. This prototype will allow him to enjoy the challenges of both road and track competitions.

TECHNICAL DESCRIPTION

A T-frame style design was selected based on its current popularity in the racing wheelchair industry. Most wheelchair athletes prefer to maneuver the chair, while road racing, by simply shifting their weight. To produce this effect the operator's center of gravity must be oriented so its location is mainly a function of the operator's torso angle. Therefore, allowing him/her to control the chair simply by altering his/her torso angle. This ability is directly related to the sizing of the chair. The chair must be designed around the operator resulting in a snug fit. Therefore, the operator can easily direct the chair by applying body forces to the seat fixture members.

Seat Fixture:

An open V-seat fixture, shown in Figure 20.1, was employed to support the racer. Its dimensions were determined such that it snugly fit the operator. A vinyl seat harness was purchased from the Invacare Corporation such that this seat fixture and harness system fixes the operator's upper and lower leg angles at 5° and 35°, respectively, with the horizontal. Therefore the location of the center of gravity (cg) of the operator's body is a function only of the arm and torso angles. A sensitivity analysis was then conducted to determine the effects of these two angles on the location of the cg of the body. It was found that altering the arm angle had minimal effect. On the other hand, the location of the cg was highly affected by the torso angle.

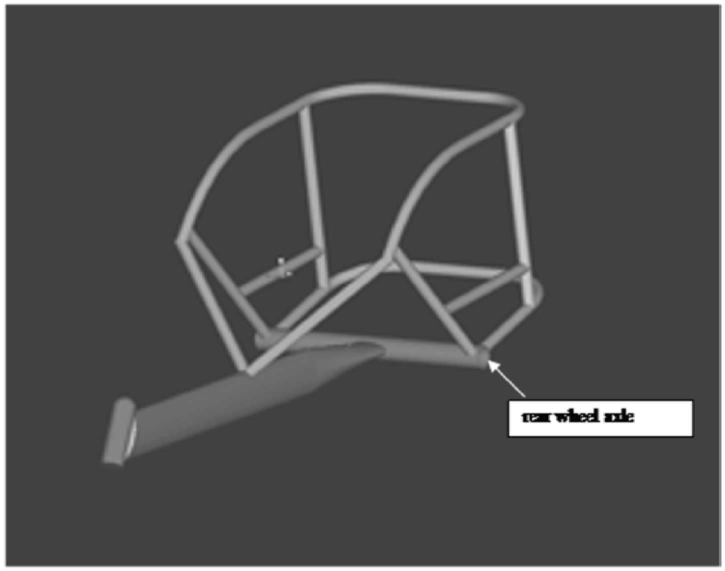

Figure 20.2. Open V Seat Fixture.

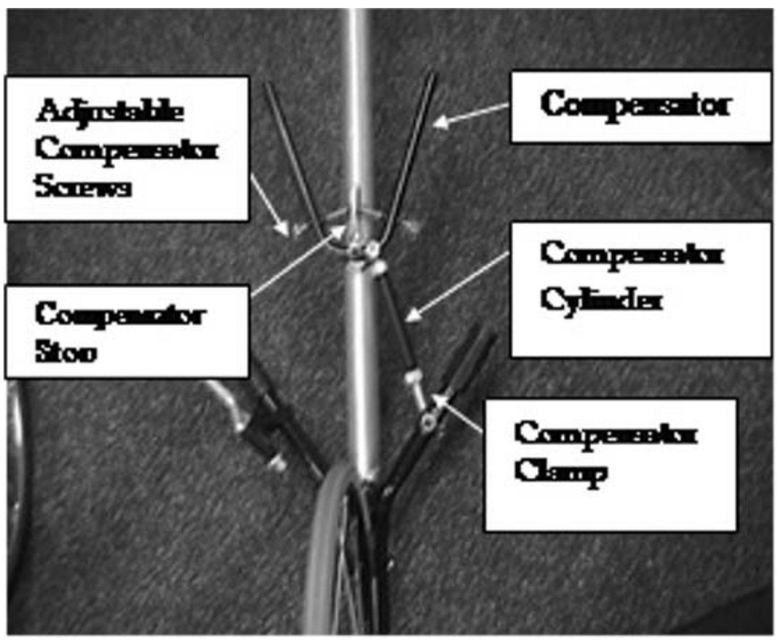

Figure 20.3. Steering Mechanism.

Under normal operating conditions the operator's torso angle will vary between 30° and 40° corresponding to the beginning and end of his/her power stroke. To establish possible static load cases for normal operating conditions moment balances were performed about the operator's hip to determine the forces applied to the seat fixture at the restraint locations for different operator postures. Finite element analysis was then conducted using SDRC I-DEAS to determine the maximum stresses in the seat fixture. Under these conditions the maximum von mises stress was approximately 1.29 x 104 psi. To perform a fatigue analysis additional load cases were established corresponding to the forces exerted by the operator while propelling the wheelchair. The conditions are the same as those for normal operating conditions with the exception of a 145 lb force applied to the fixture to account for the push force of the operator. These applied loads resulted in alternating and mean stress of 500 psi and 11.5 x 103 psi. Using the Distortion Energy Theory of Failure for the static case and the Modified Goodman Diagram for the fatigue case, material selection and member dimensions were determined corresponding to static and fatigue factors of safety of 3. T6-6061 aluminum was selected as the design material due to its weight, strength, and manufacturing characteristics. The seat fixture members for this design have a diameter of 3/4 in and a wall thickness of 1/8 in.

Under normal operating positions the operator's center of gravity was found to be approximately five inches in front of the rear axle. This distance controls the angle that the torso must reach in order to unload the front wheel of the chair. At a distance of five inches in front of the rear axle, the operator will have to rotate his torso angle to 70° to lift the front wheel of the chair. Under normal operating conditions the racer's torso angle will vary between 30° and 40° indicating that the torso angle must be increased 30° in order to lift the front wheel. This amount of angular rotation was deemed optimal through discussions with the client and racing wheelchair professionals.

Steering Compensator Mechanism

The steering compensator mechanism selected for this chair is constructed of four main components: a compensator bar, a compensator cylinder, two compensator screws, and a compensator stop as shown in Figure 20.3.

The compensator cylinder supplies a return force during road racing and also acts as the motion transfer member between the compensator bar and handlebars during track racing. The compensator cylinder consists of an outer casing which encloses a cylinder, bushing, and a standard heavy-duty die spring. The spring has a stiffness of 60 lbf /in. It is pre-compressed inside the casing in order to give the compensator cylinder some initial stiffness. The compensator cylinder can be extended 1.050 inches and compressed 0.625 inches, which creates a change in force of 63lbf and 37.5lbf respectively. Handlebars are two types: straddle-type fork and trailing-arm. Trailing arm design is not recommended to be used with the T-style frame because it produces an undesirable amount of flex in the front end of the chair during racing.

The main function of the compensator bar is to supply a convenient way for the racer to turn during track racing. The compensator bar is made of hollow aluminum tubing that pivots on a threaded stud that is attached to the frame as shown in Figure 20.3. The compensator cylinder is attached to the compensator bar by a threaded stud. Two compensator adjustment screws are threaded into the compensator bar. These screws along with the compensator stop are used to adjust the angle of turn during track racing.

The steering compensator mechanism is used for both road racing and track racing. During road racing the compensator bar is tightened snug to the main frame in order to keep the front wheel straight when the racer is not turning. The compensator adjustment screws can also both be positioned snug against the compensator stop to help keep the front wheel straight during road racing. However, this limits the angle of turn that can be made with the steering device to approximately 15° when turning right and 20° when turning left since the compensator cylinder can only compress 0.625 inches and extend 1.050 inches respectively.

During track racing the compensating mechanism provides a simple way for the racer to turn and to continue propelling the wheelchair during the curved portion of the track. It also helps to keep the wheelchair straight during the straight portions of the track. During track racing, turning is accomplished by the racer forcing the compensator bar into a new position. When the compensator bar is moved to a new position, the offset between the pivot point of the compensator bar and the point where the compensator cylinder is attached creates a linear motion that is transferred to the handlebars through the compensator cylinder. This linear motion causes the steering wheel to be turned. The adjustment screws are set so when one of the adjustment screws is in contact with the compensator stop the front wheel is straight, and when the other adjustment screw is in contact with the compensator stop the front wheel is at an angle of turn that will allow the racing wheelchair to follow the radius of the track. The compensator bar is tightened snug to the main frame in order to assure the front wheel will track straight in the straight portions of the track and will remain at the correct angle of turn during the curved portions of the track. At maximum adjustment the largest angle of turn that could be made using the compensating mechanism in this way is approximately 8°. Using Akerman geometry the turning angle needed for an average track radius of 75ft is approximately 3°. Therefore this compensating mechanism has plenty of turning capability for track racing.

Redesign of Main Frame, Rear Axle and Wheel Mounts

The rear axle width and overall wheelchair length were determined using client dimensions, body position, steering accessibility, and accepted racing standards. Through research and contact with various wheelchair manufacturers, a T-style main frame was chosen for this design. The T-style provided a more stable framework and enabled a broader range of seating positions. T6061 aluminum was chosen as the material for the frame to reduce the weight of the wheelchair while maintaining structural integrity. The frame consists of a 3-inch by 1 ½-inch seamless tube with a wall thickness of 0.065-inches. Using measurements taken of the client's sitting location, arm reach, and body position, an overall wheelchair length of 66-inches was determined to be acceptable. The overall wheelchair length was measured from the front-most part of the front tire to the rear-most part of the rear tire. The front tire had a radius of approximately 9 ¼-inches and the rear tire had a radius of approximately 13 ½-inches. Therefore the frame length was dependent on the ability to reach the steering system and brake while in the racing position.

The rear axle width was determined using the upper inside frame width, the lower inside seat width, and the axle position. These dimensions are dependent on individual measurements of the client and seating position preference. Based on these factors, an axle width of 16 ½-inches was chosen. The rear axle was also made of T6061 aluminum but had a constant 1 ½-inch outside diameter with a wall thickness of 0.065-inches.

The rear wheels were attached to the rear axle by means of ½-20 studs mounted to the center of the wheels. To decrease the possibility of rolling while turning at higher speeds, the rear wheels were angled toward the racer producing a slight camber. Through research and interviews with an experienced racer, 12-degrees from vertical was determined to be the optimal wheel camber angle. If the individual racing the wheelchair had a higher seating position, then this angle would have to be increased. Inserts were designed to act as rear wheel mounts while providing the correct rear wheel camber. T6061 was chosen for the material of these inserts because it is both lightweight and easily machined. Rear wheel stud spacers were also designed and manufactured. These spacers were designed to keep the rear wheel studs from bottoming out in the camber inserts, which will help to keep the studs from turning out of the camber inserts while the wheelchair is being used. These spacers were also made from T6061 aluminum.

Additional components were designed and manufactured for the attachment and use of the steering compensator mechanism. A compensator bar attachment insert was designed and integrated into the mainframe. The attachment insert consists of an inch long, 1.25-inch diameter cylinder with a ¼-28 tapped hole, which will be used to attach the compensator bar to the main frame. The attachment insert was integrated into the frame by positioning it into a pre-drilled hole in the main frame and then welding it solid. A compensator stop, which is one of the main components of the steering compensator mechanism, was also designed and welded to the main frame. The compensator stop was manufactured from 1/8-inch thick T6061 aluminum bar. Again T6061 aluminum was the material used for both the compensator bar attachment insert and the compensator stop because it is lightweight and easily machined.

Finite Element Analysis of Main Frame and Back Axle

The stress analysis of the wheelchair frame was completed using I-DEAS finite element analysis software package. The back axle was modeled exactly as a 16.5-inch long tube with an outer diameter of 1.5 inches and a thickness of 0.065 inches. Since the main frame diameter changed down of the length of the wheelchair, the average diameter was used to model the main frame. The thickness was still 0.065 inches, but the average of the diameter was 2.25 inches. The head tube was modeled as a 4-inch long tube with a thickness of 0.065 inches.

Roll Stability while Turning

As wheelchair racers improve techniques and are able to reach faster speeds, it is important to examine the dynamic stability of racing wheelchairs. As with the design of many vehicles, dynamic roll stability analysis is a standard procedure. Since the client will be starting out in track racing the purpose of this analysis was to determine whether the new wheelchair design can withstand speeds up to 20 mph during track racing without flipping over. This speed is a maximum for world-class athletes and is well above the average speeds of a beginner racer. The analysis was conducted to calculate the roll stability critical velocity. In this analysis the following assumptions were made:

- The chair does not slip radially,
- The track is level, and
- The rider/wheelchair system is rigid.

The roll stability critical velocity can be defined as the velocity at the instant when the torque rotating the racing wheelchair and rider is equal to that of those forces holding it down. The roll stability critical velocity for this system was determined by equating the torques acting upon the center of gravity about a line connecting the outermost rear and front wheels of the racing wheelchair. A radius of 75 ft (900in) was used since this value is an average radius for an oval track. The roll stability critical velocity for the racing wheelchair was calculated to be 24 mph. Since this velocity is greater than the maximum track speed of world-class wheelchair athletes of 20 mph, the design was considered to be stable. .

The new racing wheelchair was designed for a145 lb racer. To test the racing wheelchair a test subject who weighed approximately 170 lb was used. The testing included trial racing to insure that the chair frame would be able to withstand the dynamic loading and to make sure the location of center of gravity of the racer would allow the racer to turn by skidding. Both of these objectives were confirmed by the testing. Figure 20.4 shows the completed racing wheelchair.

The completed prototype was delivered to the client. The total cost of parts and labor was $1,200.00.

Figure 20.4. Final Prototype of Manual Racing Wheelchair.

VERTICAL WHEELCHAIR PLATFORM LIFT FOR HOME ACCESS

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INTRODUCTION

This project involves the design and construction of a vertical wheelchair platform lift to be used by a man with paraplegia and limited use of his arms. The individual used to enter and exit his home using a long ramp in front of the house. This is inconvenient and unsafe for him and his family because he cannot easily exit his home during the winter when the ramp is covered with snow and ice and would be at risk if the ramp would ever be inaccessible during a fire or other disaster.

SUMMARY OF IMPACT

The objective of the project was to safely lift this physically challenged individual 14 inches from the garage floor to the house level. The design meets the client's needs of independent operation and incorporates standard safety features. The lift is capable of raising 1000 lbs (4448 N), which includes the weight of the individual, his motorized scooter and the supporting platform. A dual linear actuator system was incorporated into the design that allowed for minimum platform height at the lowered position. The prototype provides a safe and reliable method of transporting the client between his garage floor and his ranch style home.

TECHNICAL DESCRIPTION

Five methods of driving the lift were investigated, which include using a hydraulics system, linear actuators, scissor lifts, wench and pulley system, and power screws. A dual linear actuator system was selected using a matrix approach based on several design criteria, which include a smooth and independent operation, platform height, design simplicity, safety, and costs. The design parameters included the platform size, the weight to be lifted, and the amount of travel of the lift.

Figure 20.5. Vertical Wheelchair Platform Lift in Use.

The platform size needed to be large enough to fit the wheelchair as well as to have room for the client's arms as he turns the wheels to enter and exit the lift. The rear wheels of the client's wheelchair are 32 inches apart. Allowing for ample room for the client's arms as well as the switch box, the platform was designed to be 42 inches across. The weight of the individual, his motorized scooter, the platform and its holding frame was estimated as 500 lbs (2224 N). A design load of 1000 lbs (4448 N) was used to ensure a minimum factor of safety of 2. The amount of travel of the lift was 14 inches, which is the height of the step between his garage and his home. Also, the platform height at the lowered position cannot exceed two inches from the ground to allow the client to easily roll himself onto the platform. Given that the individual will operate the lift independently, the design must allow him to roll onto the platform using a forward motion from either the garage or his home.

The system, shown in Figure 20.5, consists of two main parts: the fixed outer frame and a part that moves up and down the frame. The platform and its inner holding frame form the moving part. The linear actuators are attached to the holding frame and the fixed outer frame, as shown in Figure 20.6. Steel rectangular tubing was used for constructing both frames. All pinch points on the lift were enclosed to prevent injury and for aesthetics.

A critical component in the system is the pin that connects each frame to the linear actuator. Calculations were conducted to ensure that the pin would not fail due to shear failure, bearing failure, or tear-out. The lowest calculated factor of safety was found to be 4.7.

Finite element analysis (FEA) was conducted using SDRC I-DEAS on the inner holding frame to determine the maximum stresses. Beam elements were used in the FEA model. Three different loading conditions were investigated: a 1000–lb distributed load across the platform, a four-point loading condition of 250 lbs. each, and a two-point loading condition of 500 lbs. each. As expected, the worst case corresponded to the two-point loading situation where forces were applied at the very front edge of the inner frame. In this case, a maximum stress of 23,100 psi was calculated. The lowest yield stress of steel is 24,000 psi. This produces a design factor of safety of 2.08 since the design load is twice the actual load of 500 lbs. This is the worst case and would not occur in normal usage. The client in his chair would need to be more centered on the platform.

The linear actuators are wired to a capacitor and connected to a power source using a regular 110-volt wall outlet as shown in Figure 20.7. The wire routing and electrical boxes were mounted to move up and down with the inner frame so that the only wire that would tighten during travel would be the extension cord to the wall outlet.

Total cost of parts and supplies was $1,200.

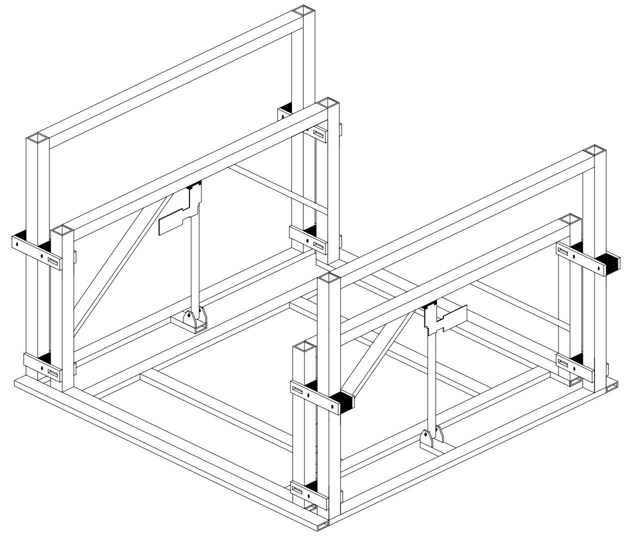

Figure 20.6. Isometric Schematic of the Vertical Wheelchair Platform Lift.

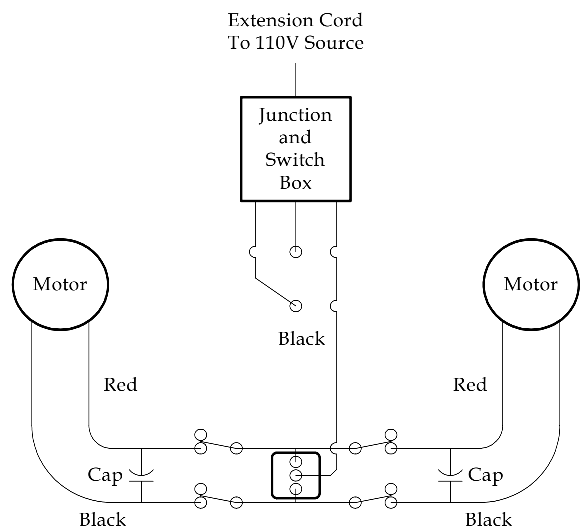

Figure 20.7. Electrical Wiring Diagram .

HOIST MECHANISM TO LIFT LOGS

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Client Coordinator: Dr. Gregory Nemunaitis
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INTRODUCTION

The purpose of this project was to design and construct a hoist mechanism to enable a mushroom farmer with quadriplegia to work independently and reduce his fatigue. The client grows shitake mushrooms on his property. In the spring, the he and his employees cut oak trees into logs that are approximately 4 feet in length. Forty to fifty 3/8" diameter holes are then drilled along each log, filled with spores, and corked. He then applies hot wax over the filled holes to seal the planted spores. The logs are stacked and kept moist on the client's property, and growth of the mushrooms begins around two months after the spores are planted. The logs are transported into the client's barn on a pallet. Logs 4 feet in length (3"-8" diameter) were to be lifted from a pallet on the floor to a table approximately 4 feet in height. Since the client has minimal use of his hands and fatigues quickly, the mechanism was to minimize the amount of input work required. After completion of the drilling operation (see next project), the client needed to be able to use the same hoist mechanism to stack the finished logs onto another pallet located at the end of the work area.

The mechanism selected includes a hoist that is connected to two skates via a mounting plate. The skates roll inside a Unistrut track attached to the ceiling of the client's barn. The hoist raises and lowers a bar and cuff assembly, which was designed to slide over each end of a log and support it as it is lifted to and from the work area as shown in Figure 20.8.

SUMMARY OF IMPACT

The client has poor manual dexterity and tires quickly. Before having this device, the repetitious movements in the mushroom farming process quickly fatigued him. The hoist mechanism allows him to work independently and reduce his fatigue. At no time during the operation of the hoist mechanism is he required to bend over or support the weight of the log. The only work performed by the farmer is to position the bar and cuff assembly around each log, depressing the appropriate button to raise or lower the hoist, sliding the hoist along the track, and taking the cuffs off each log.

TECHNICAL DESCRIPTION

Several ideas were investigated including using a pneumatic device to push the logs up onto the table, a mobile hoist mechanism and a scissor type platform lift. A hoist mechanism mounted to skates that roll along the ceiling in a track was found to be the most cost-effective, easiest to install, and easiest to operate. The hoist will be moved to the front of the table to load the logs, and to the end of the table to unload the logs.

Hoists and winches were considered. A hoist was selected because of its vertical lift design. The Lil' Mule hoist was employed. It offers a lift speed of 12 feet per minute, a maximum load of 500 lbs, and a weight of 16 lbs. Unistrut was used for the ceiling track. Its weight is 1.8 lbs per foot, and can withstand a 1500 lb distributed load when braced every 24 inches. Two skates roll inside the Unistrut track. The hoist was mounted to the skates using a plate. The cuff assembly was made using schedule 40 PVC pipe. Two 1.5" wide circular sections were cut from the pipe, and then machined to specifications.

The mechanism was able to raise logs from ground level to a maximum height of eight feet. The logs were secured by the bar and cuff assembly.

Total cost of this project was $750.00.

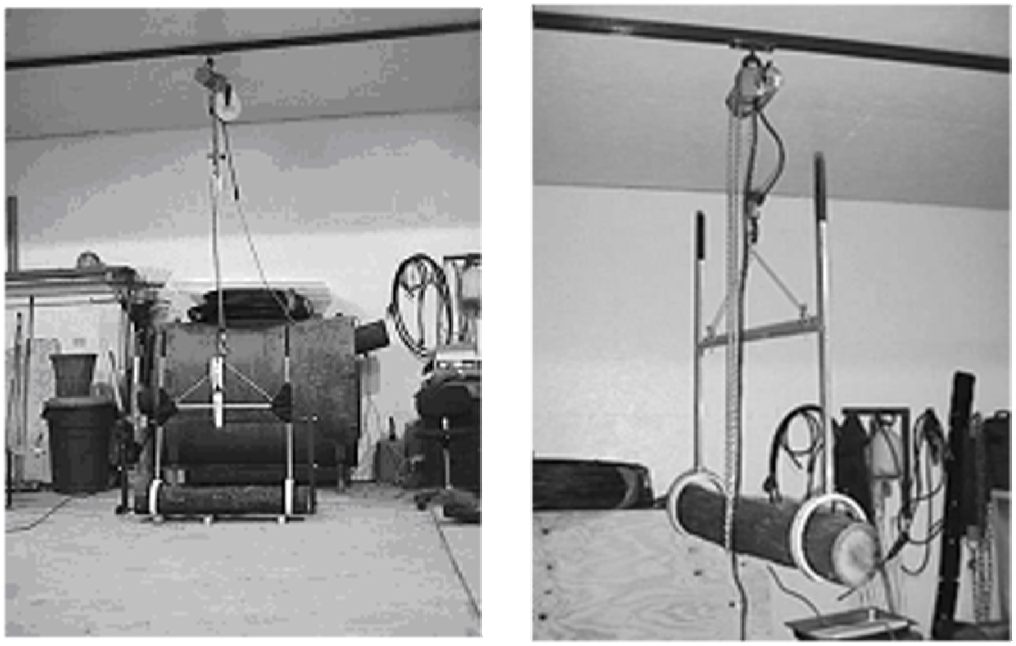

Figure 20.8. Hoist Mechanism Lifting (Left) and Lowering (Right) a Log.

ADAPTIVE DRILLING FIXTURE FOR MUSHROOM FARMING

Designers: Timothy Hartigan, Mark Fenstermaker, Mark Bills, Matthew Miller, Mechanical Engineering Students
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INTRODUCTION

The purpose of this project was to design and construct a drilling fixture to assist a shiitake mushroom farmer with quadriplegia. His preparation of oak logs involves drilling 40 to 60 holes per log and plugging the holes with shiitake mushroom spores. The drill fixture allows the farmer independence during the drilling process, and eases the physical fatigue encountered by holding the drill. A two-axis, vertical drill, utilizing a pre-manufactured drill-press assembly was employed. Figure 20.9 shows the design concept. Figures 20.10 and 20.11 show a front view and a rear view of the prototype, respectively. A lever initiates the drilling action, and the drill moves along the horizontal axis by hand. The log is rotated by hand with the assistance of concave nylon strips located under the drilling fixture. The prototype is made to be compatible with a hoisting apparatus designed and manufactured by another group of students (see previous project).

SUMMARY OF IMPACT

The procedure for impregnating the mushroom spores includes drilling 5/16" diameter holes 3/4" deep, into a 4-foot long by 6" diameter oak log. After the holes are drilled, mushroom spores are inserted into the holes and the holes are covered with a cheese wax coating. The drilling fixture that was designed and constructed is a cost-effective and simple assistive technology device that will allow the farmer to increase his independence and productivity in mushroom farming. The fixture will reduce fatigue and allow the farmer to drill for longer times.

TECHNICAL DESCRIPTION

The design objectives of the drilling fixture were to:

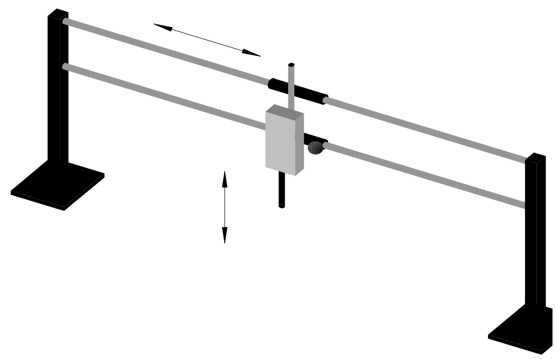

Figure 20.9. Design Concept for Two-Axis Drill Fixture.

Develop a safe fixture to minimize fatigue during drilling by eliminating holding of the drill,

Minimize human-generated forces required to drill into the logs,

Increase the farmer’s independence by making the operation of the drill simple,

Ensure that the drilling fixture is compatible with a hoist mechanism used to lift and lower the logs, and

Implement the design in a cost effective manner

Several ideas were carefully studied, including horizontal and vertical drills, motorized and non-motorized drills, and a zero gravity recoil mechanism. A two-axis, vertical drill, utilizing a pre-manufactured drill-press assembly was employed. The drilling action is initiated using a lever, while the drill is moved in a horizontal direction by hand. The log is rotated by hand with the assistance of concave nylon strips located under the drilling fixture as shown in Figures 20.10 and 20.11.

The fixture includes two linear bearings that allow the drill assembly to slide the full 48″ width of the fixture to allow holes to be drilled at any point along the log. The drill assembly consists of a pre-manufactured holder that accepts any ½″ corded or cordless drill.

The drilling action is initiated by pulling down on the lever just as in a normal drill press. Two seamless steel alloy rods (1″ in diameter and 51″ in length) were used to allow the bearings to slide the length of the fixture. The rods are held in place by a length of ½″ threaded rod that is tightened in place by a washer and locking nut on each end. This was used to allow easy assembly and disassembly. The whole fixture is held in place to a table by two ½″ bolts located on each side of the fixture. These ½″ bolts run through the upright supports and into the table used during the drilling process.

After the fixture is secured to the table, three runners are secured to the table using 5/16″ wood screws. These runners are concave in the center to allow the log to be centered under the drilling assembly. The concave is lined with 1/8″ X 1 ½″ Teflon. The Teflon allows the logs to be easily rolled during the drilling process.

The completed prototype was tested at the client's facility. The prototype was tested by installing the drill used during the drilling operation. The fixture was then used to drill holes in several logs by both the team members and the client. The fixture was then tested with the hoist mechanism (see previous project) and no problems were encountered when the two finished prototypes resulting from the two projects were used simultaneously.

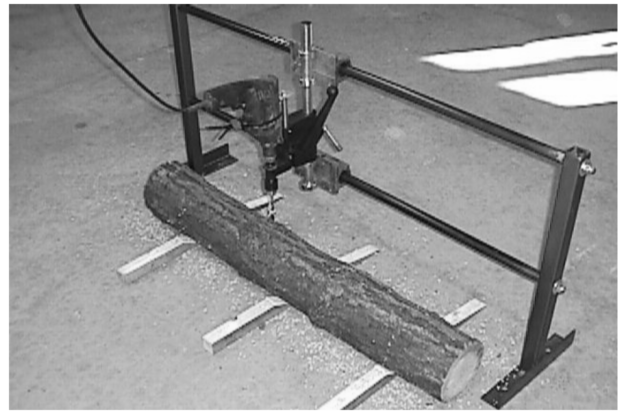

Figure 18.10. Front View of Drill Fixture.

Figure 18.11. Rear View of Drill Fixture.

The total cost of this project was $350.00.

CAMPER ACCESS LIFT

Designers: Colby Benbow, Long Gao, Steven DeWitt, Mechanical Engineering Students
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Rehabilitative Medicine, Medical College of Ohio and St. Vincent Mercy Medical Center
Supervising Professor: Dr. Mohamed Samir Hefzy
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INTRODUCTION

A man who uses a wheelchair and has limited use of his hands and arms wishes to continue camping with his family. Currently, he utilizes a ramp and winch mechanism to gain entrance to the family owned travel trailer. This mechanism requires assistance for setup and operation. The purpose of this project was to design and construct a mechanism to be attached to the trailer, which will allow for its normal use and provide this individual an independent means of access. The system utilizes three actuators and a platform supported by two lift arms as shown in Figures 20.12 and 20.13. The lift arms are attached to a solid shaft, which is attached to two actuators by two cylindrical lever arms. As the lever arms rotate, the solid shaft rotates, causing the lift arms to rotate, in turn rotating the platform to raise it and/or lower it. The third actuator is used to extend and retract the platform from under the trailer.

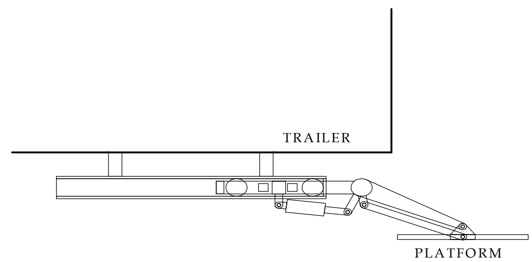

Figure 20.12. Schematic of Attached Lift Assembly.

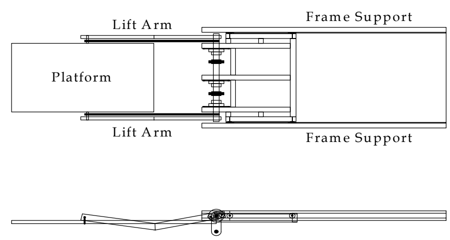

Figure 20.13. Details of Lift Assembly.

SUMMARY OF IMPACT

The successful attachment of this lift mechanism to the family camper allows the client to gain access to this trailer independently.

TECHNICAL DESCRIPTION

Several design criteria were identified. First, the lift needs to be independently operable by the disabled individual. This includes the lift controls, which must be easily manipulated by an individual with limited use of their hands. Second, the lift must be able to accommodate a minimum of 500 pounds. This is the combined weight of the client and his wheelchair. Third, the lift must be completely retractable. The trailer is already 95 inches wide and difficult to manage. Any increase in width will add to this difficulty at best, and at worst create an illegal situation. The maximum legal trailer width in Michigan (where the client resides) is 102 inches. Fourth, the lift must fit under the trailer without ground contact. Fifth, the lift must have a full range of motion. The platform must be accessible to the client if grade slopes to or away from the trailer. These grade conditions will affect the range of motion the lift operates within and must be accommodated. In addition the lift must be able to raise the client to the sill of the trailer door, without contacting the trailer. Sixth, the lift must be safe for the operator. The platform must have devices that keep the client from accidentally rolling off the platform and protected from pinch points. Seventh, the lift must be self-contained. This will allow the lift to be easily transferred to another trailer if required. Lastly, the lift must not interfere with the original factory steps. These factory steps must remain usable when the lift is in the stored position.

The system that was designed and constructed includes three actuators and a platform supported by two arms. The lift arms, shown in Figure 20.14, are attached to the solid main shaft shown in Figure 20.15, which is attached to two cylindrical actuators, shown in Figure 20.14, by two short lever arms, shown in Figure 20.15. Each lift arm is made of welded square tubing (3″ x 1.5″ x 40″). The solid main shaft is 36 ″ long and 2″ in diameter. The short lever arms are made of solid square steel machined to a teardrop shape. As the lever arms rotate due to the actuator forces, the main shaft rotates, causing the lift arms to rotate, in turn rotating the platform, causing it to be raised or lowered. A separate third actuator, also attached to the main shaft, is used to extend and retract the platform. All three actuators are mounted on a carriage that rides on track rollers mounted on the frame support, which is attached to the bottom of the trailer, as shown in Figures 20.12 and 20.13.

The lift was installed successfully on the trailer. The total cost of parts only was $3,500.00. Several corporations contributed to this project by providing $2,500.00 for parts, and the cost of the labor involved in the welding of the different components.

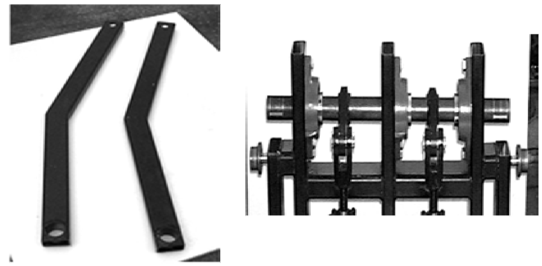

Figure 20.14. Lift Arms Made of Welded Square Tubing (Left) and Main Shaft (Right).

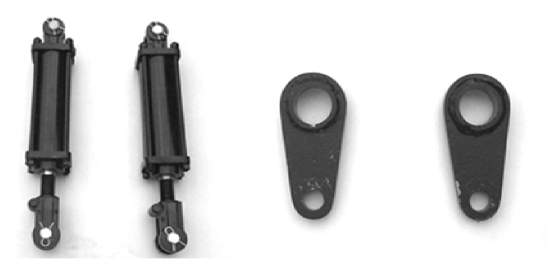

Figure 20.15. Hydraulic Cylinders (Left) and Lever Arms (Right).

FOLDABLE COMMODE SHOWER CHAIR

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Supervising Professor: Dr. Mohamed Samir Hefzy
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INTRODUCTION

An active individual with paraplegia requested a foldable commode/shower chair. Units available on the market are not foldable. The purpose of this project was to design and fabricate a foldable commode/shower chair to be used by this individual. Design criteria were that the device:

- Fit over a toilet to provide support for the trunk and to allow for a level surface transfer from the wheelchair to the commode,
- Have an armrest that is removable to allow for transfer, yet allow for support once the user is on the commode, and
- Be foldable, compact and light enough to allow for transfer into a car.

The fabricated unit includes a removable nylon back for comfort, a standard padded toilet seat, foldable arms with pads, foldable notched legs, rubber feet and round and square aluminum tubing construction, as shown in Figure 20.16. To provide additional stability, the seat was fastened to tabs, which were welded to square tubing.

SUMMARY OF IMPACT

A middle-aged, adult male, weighing approximately 150 pounds hasT-3 paraplegia, possessing normal or near-normal upper limb function and no abdominal muscle function or active trunk movements. He has full use of his arms and hands, but no motor use of his legs or feet. He is an active outdoorsman who enjoys hunting and fishing. The foldable commode/shower chair provides him greater independence. The fabricated unit will not only be used in his home, but also at different public restrooms he may use during his hunting trips. Since the unit is foldable and lightweight, it can be loaded in and out of his van easily.

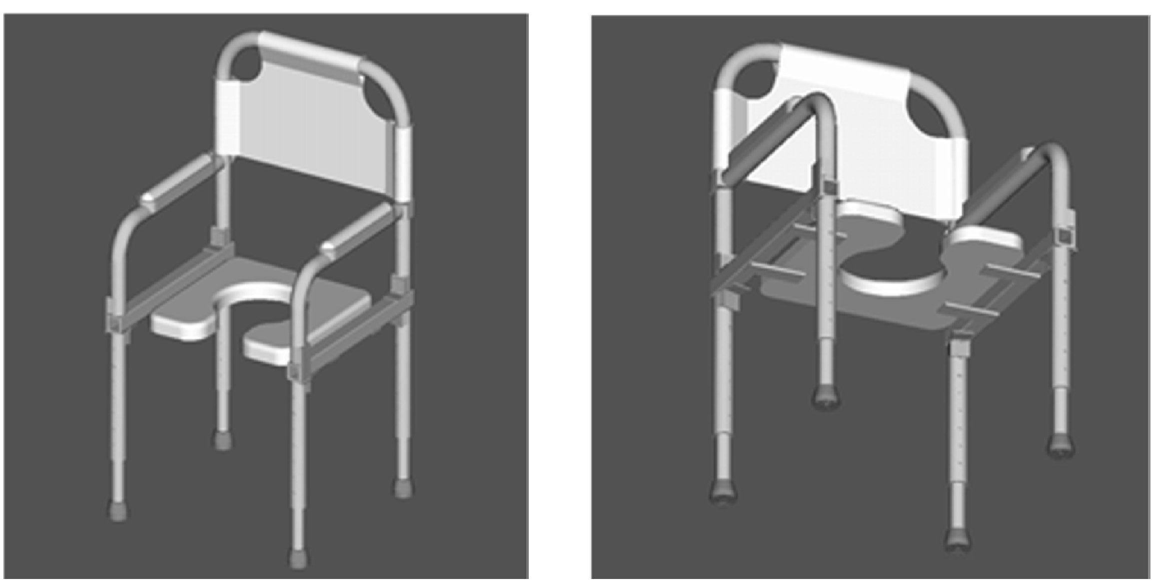

Figure 20.16. Isometric View of Prototype (Left) and Seat with Tabs (Right).

TECHNICAL DESCRIPTION

Existing products available in the market were first benchmarked during the brainstorming process. Figure 20.17 (left) shows an existing stainless steel chair and Figure 20.17 (right) shows a chair made of PVC. Neither design accommodated the client needs.

It was determined at the beginning of the design phase that safety and stability are the primary concerns for the client. Accordingly, the idea of using a soft seat was eliminated because of a concern about stability. In addition, and to improve stability, rubber feet were recommended over wheeled feet that could provide mobility while seated. The armrests were designed to fold completely out of the way to allow for side-to-side and level surface transfer. To enhance versatility, the mechanism of telescoping the legs to adjust leg height was evaluated against a notched mechanism. The notched mechanism was proven to be the stronger and more durable method.

3D modeling using Pro/Engineer was employed to establish fits, interferences and mechanism layouts. The chair has a removable nylon back, a standard padded commode seat, and foldable arms with pads, foldable notched legs, rubber feet and aluminum tubing construction. Twenty feet of aluminum tubing were used in the construction. To provide additional stability, the seat was fastened to tabs welded to square tubing. Figure 20.16 shows a complete virtual model of the chair.

A finite elements analysis FEA of the model was conducted using SDRC I-deas with a design weight of 250 lbs. Three loading conditions were evaluated. The first was a distributed load of 250 lb across the seat to simulate the chair in use. The second concentrated load of 250 lbs at the front of the seat to simulate a person sitting forward on the seat. The final loading condition was a downward load of 250 lbs applied on the arm assembly to simulate a person pushing himself or herself up out of the chair.

The total costs of parts and labor, including welding, was $300.00.

Figure 20.17. Stainless Steel Chair (Left) and Chair Made from PVC (Right).

UNIVERSAL RICKSHAW EXERCISE MACHINE

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Supervising Professor: Dr. Mohamed Samir Hefzy
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INTRODUCTION

The Rickshaw Machine is a piece of exercise equipment that helps develop the muscles in the arms and the sides. These muscles are imperative for wheelchair movement and transfers. This machine is designed to simulate the pushing down motion of the arms such as when one is pushing down on the wheels of a wheelchair. The current design shown in Figure 20.18 (left) is not safe to use when working with heavy weights, cannot be used independently, and is not adjustable. When working with heavy weights, the front wheels of the wheelchair tend to rise and the individual may tip back or fall over. Free weights are currently used and cannot be picked up and placed on the machine by an individual in a wheelchair. The machine's arms are in a fixed position and do not account for individuals of different sizes. The objective of this project was to design and construct a prototype for a new Rickshaw Machine that is adjustable to different sizes. For safety purposes, the prototype was designed to keep the wheelchair stationary. Straps were used to stabilize the wheelchair and the individual. A pulley system with machine weights was selected because of safety and the ease of changing the weights. The arms were made adjustable by sliding in and out allowing for different sizes of wheelchairs; a pin was used to hold them in place. The finished unit shown in Figure 20.18 (right) accounted for safety, independence, and adjustability.

SUMMARY OF IMPACT

Many individuals can use this redesign of the Rickshaw Machine. The new prototype can be used independently and is adjustable. It will improve the quality of life and mobility of individuals who use wheelchairs.

TECHNICAL DESCRIPTION

The following concerns and issues associated with the design of a new Rickshaw Machine were identified as follows:

Safety. This is a primary concern since the wheelchair lifts up from the existing unit when a person pushes down on the arm.

Kind of Weights Used. Exercise equipment is built to use either machine weights or free weights. Machine weight equipment has weights built into it, and the desired weight is selected by changing a pin

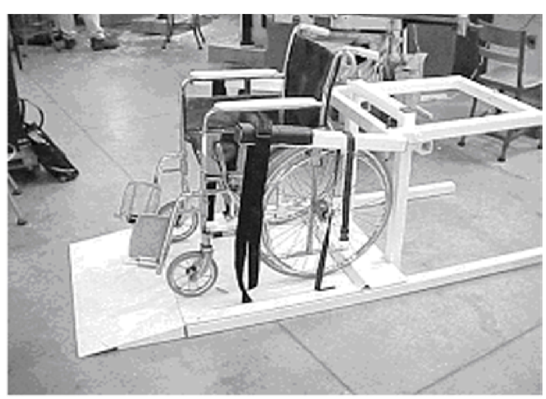

Figure 20.18. Existing Unit (Left) and New Prototype (Right).

in the stack of weights. The user does not have to get up to change the weight. However, the weight can only be added in specified increments of 10 lbs. The latter equipment uses cylindrical disc shapes having certain weight designations. More variations of weight can be used. However, these weights are less stable, and cannot be changed by the user without getting up out of the seat.

Adjustability. The distance between the two arms of the machine has to be directly related to the width of the wheelchair and to the height of the person exercising. A standard width cannot be used because there are wheelchairs of different sizes. The arms need to be as close to the wheels of the chair as possible to simulate the arm extension.

The frame of the new prototype was taken from a butterfly exercise machine. Pulleys were mounted at the bottom and the top of the frame as shown in Figure 20.19. Figure 20.19 (bottom) shows the machine weights used. In order to make the force used to push down the arm equal to the weight stack, the pivot point was located midway between the location where the arms are pushed down and the weight stack.

Steel square tubing (2x2x0.125″) was used for all the sections of the frame. A 7/8″ pin and 7/8″ impregnated bronze bushings were used to construct the pivot point. A stainless steel plate, ¼″ thick, was used as a base plate. The arms were made to slide in and out of the frame allowing for a maximum wheelchair width of 38.5″ and a minimum wheelchair width of 26.5″. The sliding of the arms was made possible by welding a telescoping square bar (1.75″ x 1.75″) to each arm to act as an extension that fitted into the horizontal top tube of the rear arm supporting frame. Three holes were drilled in each of the arm extensions allowing for three possible wheelchair widths. A ramp was

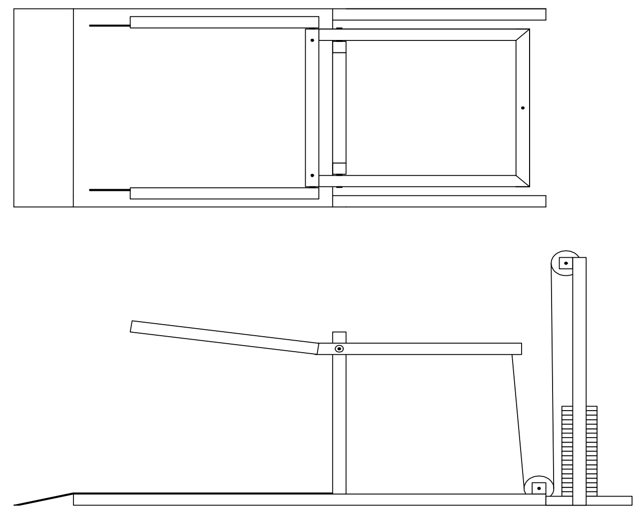

Figure 20.19. Top View (Top) and Side View (Bottom) of Rickshaw Machine.

welded to the front of the base plate, which was welded to the base frame. The wheelchair was stabilized using straps that extend from the base plate and around the chair, as shown in Figure 20.18 (right), thus stabilizing the individual as well as the chair. The problem of the wheelchair tipping back was eliminated since the straps went around the individual's knees. The wheelchair user was able to tighten the straps independently. Long slots were cut in the base plate to allow the

The new design allows for adjusting the distance between the arms (width), but does not allow for adjusting their heights. This is an area of future modifications. Straps to move back and forth for adaptability.

The total costs of parts and labor, including welding, was $825.00.

ADAPTATION OF A ROWING MACHINE

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INTRODUCTION

An active athlete with L4 paraplegia was unable to properly utilize her rowing machine. The objective of this project was to modify her rowing machine to provide adequate support for her lower extremities. The modification process focused specifically on four key issues: stabilization of the client's feet and lower leg, enhancing seat comfort, repositioning of the rowing handle bar to be within reach when the client is seated, and the addition of exercise performance feedback. Figure 20.20 shows two views of the modified rowing machine, including the ankle brace and the wooden foot guard.

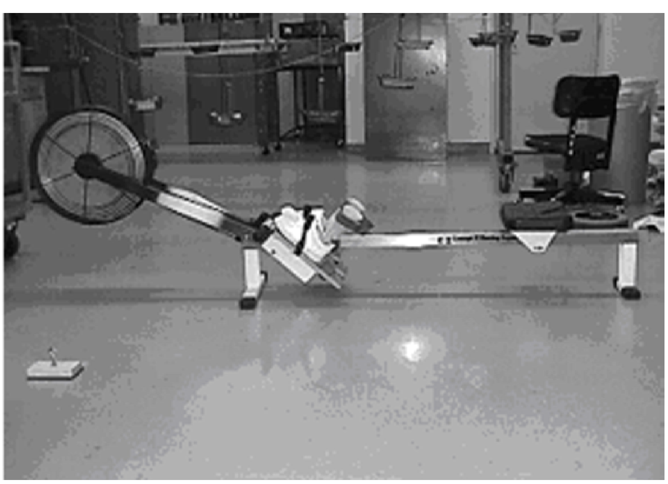
SUMMARY OF IMPACT

The successful completion of this project provided the client with the ability to exercise independently and safely.

TECHNICAL DESCRIPTION

The client was videotaped while exercising to determine the problems associated with her use of the rowing machine. Careful analysis of the videotape revealed that the primary cause of the client's inability to use the machine was because of her feet falling off the platform and the abduction of her right hip. Additional problems were noted with the seat, the handle bar, and a lack of exercise performance feedback.

A foot restraint system was designed to include a formed ankle brace, a Velcro lined shoe sole, a foam pad, and a wooden foot guard. A 5.5″ x 4″ piece of Velcro was put on the bottom of the client's shoes to cover the width of her shoe and was bent down about 5″ to adhere to the wooden platform. The heel stop thickness was increased from 1″ to 2″ to move the position of the client's ankle higher so that it would not contact the chrome monorail. A foam pad was also placed on the sides of the monorail to keep her foot a set distance from the monorail. An ankle brace was constructed out of a composite plastic to provide strength and support to the ankle joint. This was done in consultation with Cole Orthotics, a company that specializes in making



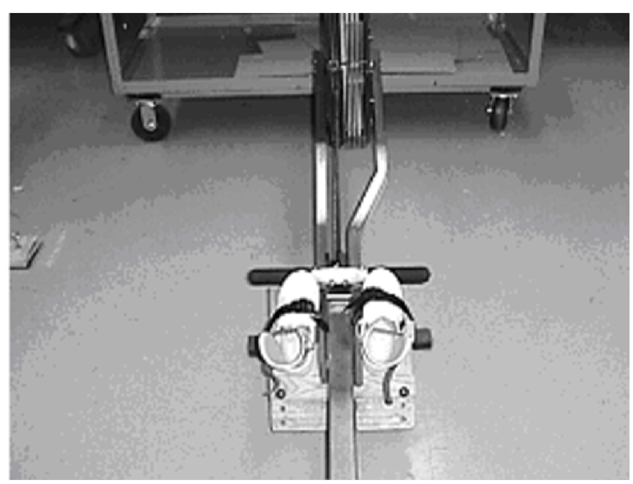


Figure 20.20. Side View (Left) of Rowing Machine and Top view (Right) Showing Ankle Brace and the Wooden Foot Guard.

prosthetics and orthopedic devices for children with disabilities.

The second of the two major issues preventing the client from using the rowing machine properly was the abduction of her right hip, causing her leg to twist outward. A gait belt, made of thick cloth, was used to restrain her thighs where the strength of her left leg was used to counteract the abduction of her right leg.

Secondary modifications included the seat and the handle bar. The seat was modified by adding a foam pad. This alleviated discomfort the client was experiencing during her rowing sessions. Furthermore, it could be seen by inspecting the machine that a bracket was needed to bring the handle bar within grasp while the client was seated in the rowing position. A bracket designed to retrofit the unit was secured from the manufacturer, and installed on the rowing machine. The last of the modifications was the installation of a digital display that relays exercise performance feedback. The client intends eventually to be able to row on water and compete in crew events. An accurate workout-measuring device is thus especially important. The feedback of this device includes calorie expenditure, heart rate, time, target output level, pace, and distance. With its built-in memory function, the client can review the workout when completed. Cosmetic modifications were also made to the unit including installing a new rust-free monorail, new foot straps, and a new paint job.

The client tested the modified unit and was very pleased. The total cost of modifying the rowing machine was $500.

MODIFICATION OFA POWER WHEELCHAIR FOR RACING

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INTRODUCTION

A member of a racing wheelchair team has C6 tetraplegia. This injury prohibits him from moving his legs, hands, abdomen, and trunk, and he has only partial use of his arms. This athlete owns a power wheelchair that he uses in competitive racing. The objective of this project was to modify this power wheelchair to increase its speed capability while maintaining stability for racing purposes. It was also desirable to make the wheelchair lighter. The maximum speed of the wheelchair was increased by modifying the gear box to change the gear ratio. The modified gear box is shown in Figure 20.21. The total weight of the wheelchair was decreased by replacing the original batteries with smaller and lighter batteries.

SUMMARY OF IMPACT

The successful completion of this project allowed an athlete to become more competitive during wheelchair racing. He purchased his power wheelchair with an intention to use it in a competition in which racers dash down a straightaway 60 meters in length. When he used the wheelchair during racing, he found that when he reached top speeds, the front wheels began to flutter, which forced him to reduce his speed to maintain control and stay in his lane. This did not allow him to race at a competitive speed. The modified chair raced at a maximum speed about 60% faster than that the original wheelchair maximum speed. The weight of the chair also decreased, allowing increased acceleration during racing.

TECHNICAL DESCRIPTION:

Time trials were conducted to determine the top speed of the power wheelchair with a 150-pound passenger. The top speed was found to be approximately 4.4 mph. A goal was established to increase the overall top speed to approximately 8 mph.

When the client accelerates and finally reaches top speeds, the front wheels of the original wheelchair start to flutter and vibrate. To keep the chair under control, he has to reduce the speed, causing underachievement of the full potential of the motor. Also, the client sometimes experiences a wheelie effect at the start of the race in this power wheelchair, where the front wheels lift off the ground.

This power wheelchair is propelled via two motors, one hooked to each rear wheel. A controller is used to allow the user to choose high or low speeds and to steer the wheelchair. The front wheels have no steering capability. According to Wheelchair Sports USA, the governing body of the race that the wheelchair will be used in, there are no specific rules about modifications to the power wheelchair. The only guidelines were not to make obvious modifications to the chair thus giving the contestant an unfair advantage. This eliminated the obvious choice of replacing the motors with larger more powerful ones.

The following two modifications were introduced to achieve the goals of this project and improve the racing capabilities of the power wheelchair:

- Changing the gear ratio of the gearbox of the wheelchair to increase its top speed and
- Replacing the old batteries with smaller and lighter batteries.

The gearbox was first disassembled. A schematic showing the interface of the motor, the gears of the gearbox and the output shaft is shown in Figure 20.21. The speed of the output shaft (mounted on gear 2) was measured as 118 rpm. The number of teeth on gears 2 and 3 in the gearbox before modification was 32 and 12, respectively. The speed of gear 3 before modification was thus calculated as 314.67 rpm. Since the speed of gear 3 is the speed of the motor, it was kept constant in the modification process. The number of the teeth on gears 2 and 3 was then varied to allow the speed of gear 2 to become 75% faster, running at a calculated speed of 206.5 rpm. Using a trial and error procedure, the modified number of teeth on gears 2 and 3 was calculated as 27 and 17 teeth, respectively, causing the output shaft to run at 198.1 rpm. Since the diameter of the wheel attached to the output shaft was 12.5 inches, the velocity of the wheel was expected to increase from 4.39 m/h to 7.37 m/h. The two new gears were manufactured professionally. The diametric pitch of gears 2 and 3 was 12.7. Accordingly, the pitch diameters of gears 2 and 3 were established as 2.12598 inches and 1.33858 inches, respectively.

To reduce the weight of the wheelchair, the original batteries were replaced. Two 12-volt batteries connected in series were used to give the power wheelchair 24 volts of power. These batteries were standard wheelchair batteries that were rated at 33 amp-hrs and are heavy, weighing approximately 25 pounds each. The motor draws 3.3 amps, so these batteries would last for approximately 10 hours before they would need to be recharged. Since the client plans to use this wheelchair specifically for racing it is not necessary that the batteries last that long. The original batteries were thus replaced with two 17 amp-hr batteries of the same type and voltage, but weigh about half as much. These new batteries would need to be charged about every 5 hours. This modification allowed plenty of time to complete the race and, at the same time, reduced the weight of the chair since the weight of the original batteries was about half of the overall weight of the wheelchair.

When the modified chair was tested fluttering did not occur. This may have been due to tightening the bolts on the front wheels, which reduced the amount of play in the wheels and reduced the vibration causing the fluttering.

The total cost of modifying the wheelchair, including the new batteries, gears and replacement bearings was $1,150.00. Machining the two new gears was the most expensive item. A part of the cost was absorbed through a donation from Dana Corporation.

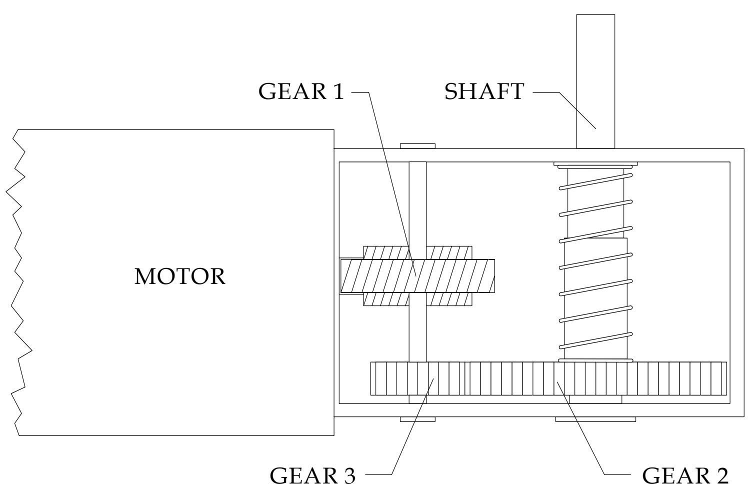

Figure 20.21. Gear Box Modified by Changing Gears 2 and 3.


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