CHAPTER 19
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COLLAPSIBLE WHEELCHAIR WITH DETACHABLE COMPONENTS

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INTRODUCTION

Wheelchair users must take their wheelchairs with them when they travel. Airlines have limited or no space available for storing standard folding wheelchairs in the cabin of the airplane. The closet, in which the wheelchairs are stored, is filled on a first come first serve basis. If the closet is filled or no closet space is available, the wheelchair is then considered as checked luggage. In the baggage hold, it is unprotected from falling items, can be thrown or dropped, or sustain damage that may arise from carelessness of airline employees. If extensive damage to the wheelchair occurs, it may become inoperable. The wheelchair can also become lost luggage and not arrive at the correct final destination. A lost or inoperable wheelchair is an extreme inconvenience to the wheelchair user.

There are a few existing wheelchair designs on the market that are considered to be collapsible. These designs collapse smaller than standard folding wheelchairs but are not small enough to fit in carry-on luggage. Some of the designs are heavy and bulk and none of the existing designs feature collapsing wheels. Other collapsible designs collapse to a small dimension but require someone to push the wheelchair from behind because the wheelchair utilizes four very small caster wheels, which does not allow the user to independently propel it. This requires the wheelchair user to depend on someone else to assist in their mobility.

The purpose of this project is to develop a collapsible wheelchair, with detachable wheels, backrest and seat. When detached and collapsed, all components of the wheelchair fit in carry-on luggage with dimensions of 22″ x 14″ x 9″. The developed unit is constructed using a standard folding manual wheelchair frame that was modified to make the backrest and seat detachable from the frame. The unit includes two 20 inch wheels; each one is detached into two semi-circular parts. The

Fig.19.1. Final assembled prototype.

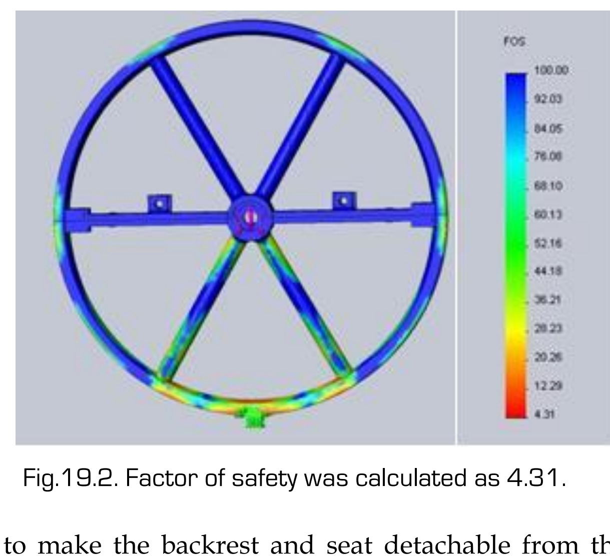

Fig.19.2. Factor of safety was calculated as 4.31.

foot rest and the two front caster assemblies are modified to allow them to fold up into the wheelchair frame. The unit is assembled and disassembled with minimal time and effort. Fig. 19.1 shows the prototype assembled, and Fig. 19.3 shows all the components when detached.

SUMMARY OF IMPACT

A collapsible wheelchair with detachable components is developed to allow a wheelchair user to store it in the overhead carry-on luggage compartment when traveling by airplane. This design saves space, prevents damage to the wheelchair by the airlines, and enables wheelchair users to travel with greater ease. The developed unit can be disassembled and reassembled quickly and easily yet it is still durable and reliable enough for everyday use. The developed unit thus provides wheelchair users with greater independence as They can independently disassemble the unit, store it in a carry-on luggage compartment, and reassemble it when they arrive at destination. Also, the small collapsed size of the wheelchair makes storing it in a vehicle easier.

The developed prototype was evaluated by a wheelchair user as shown in Fig. 19.4 The Quebec User Evaluation of Satisfaction with assistive Technology (QUEST 2.0) tool was used as an outcome measurement instrument to measure satisfaction with the unit. The eight QUEST items that are assessed include a) comfort, b) dimensions, c) simplicity of use, d) effectiveness, e) durability, f) ease in adjusting, g) safety, and h) weight. Each item scored with a 5-point satisfaction scale ranging from a score of 1 denoting "not satisfied at all" to a 5 indicating "very satisfied". A score of 4 was obtained for simplicity of use, ease of adjusting, and weight, and a score of 5 was obtained for each of the other five items.

TECHNICAL DESCRIPTION

Design requirements include 1) a wheelchair that fits within a 22" x 14" x 9" suitcase, 2) a wheelchair that is durable, 3) a wheelchair that can be assembled and disassembled easily and quickly, and 4) a wheelchair that allows independence in mobility when assembled.

The greatest challenge to overcome was to design the largest diameter wheel to fit into the desired dimensions. Carry-on luggage allows a maximum solid wheel diameter of 14 inches, which is 10 inches smaller than a standard wheelchair wheel (24"), the wheelchair remained easy for its user to independently propel.

Fig. 19.3. Components of the wheelchair when disassembled.

Fig. 19.4. Prototype being tested and evaluated by a wheelchair user

Several frame design areas were also considered and it was decided to modify a donated wheelchair frame for this project. In order to make the collapsed frame fit within the desired dimensions, the back rest and seat sections of the frame are removed and the front casters needed to fold into the frame. The front casters are modified to swivel upwards towards the chair for storage. Replacing the lower caster mounting bolt with a quick disconnect pin allows the caster to swivel up and into the frame for storage yet remain locked in place when assembled. The seat support bars and the back rest support bars are modified to become removable as well. Quick disconnect pins are used for this purpose.

SolidWorks® 2009 finite element analysis software is used to conduct a structural analysis on the wheelchair wheels and a factor of safety of 4.31 was calculated with a one hundred pound load applied at the center hub of each assembled wheel as illustrated by Fig. 19.2.

The cost of the parts is $400.00. The time for machining and welding of the wheel was donated to the team by the University of Toledo machine shop. The students working on this project posted a detailed description of their design and analysis in the World Wide Web at the following address:

http://www.mime.eng.utoledo.edu/design/clinics/2009/Fall/sites/2009-04-02/

This work was also presented at the 2010 Rehabilitation Engineering Society of North America annual conference and was one of five winners of the student scientific paper competition.

EXTENDABLE "EASY REACHER"

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INTRODUCTION

Our client was born with Ehlers-Danlos Syndrome, a group of inherited disorders that affect connective tissue. As a result, she has lost strength in her joints and uses a wheelchair for mobility. In order to grab everyday items from in and out of reach places she uses two types of reachers: a low-grade suction cup reacher, offering a hard-to-squeeze gripping mechanism, and a low profile jaw reacher for around the office. However, she is not satisfied with these commercially available reachers because of the manual grip controls and the lack of an extension mechanism. The purpose of this project is to develop a reacher that can be extended to a comfortable distance and with a more versatile gripping mechanism to allow someone with limited range of motion to reach items are inconvenient distances. There are no similar devices presently available on the market. The unit that was developed can extend up to 5 feet in length and easily grip a two pound object up to 4.5" in diameter. Power screws are used to control the extending and gripping mechanisms. Fig. 19.5 shows the developed prototype next to the commercially available "Easy Reacher". Fig. 19.6 depicts the client holding the developed prototype.

SUMMARY OF IMPACT

Our client was born with Ehlers-Danlos Syndrome and is confined to a wheelchair. She enjoys cooking and other household activities, but usually has to rely on her husband or someone else to help her. The newly designed device allows her to reach items that were still out of reach with her original "Easy Reacher". Additionally, the motor-controlled gripper makes it easier for her to grasp heavier objects. This lightweight prototype provides her more independence in her daily living activities. Although this device is designed for one person in particular, it could be beneficial to many wheelchair users.

Fig. 19.5. Developed prototype (to the left) next to commercially available Easy Reacher (right).

TECHNICAL DESCRIPTION

The design process started with evaluating multiple ideas for extending mechanisms and gripping mechanisms. The first extending mechanism idea utilized a tube with several holes along it. As the device extended or retracted, a spring-loaded button on a second internal tube would snap into one of the holes on the external tube, holding the reacher at a specific length. Depressing the button and sliding the internal tube until the button locked in another position would allow for length adjustment. The second extending mechanism design used a similar concept to that of a camera tripod. To change the length of the device, a knob attached to a set screw on outer tube is loosened, allowing the inner tube to slide easily within the outer tube. The knob is tightened at the desired position to fix the length. However, the first two extending ideas were too labor intensive to operate. The third and final design utilizes a power screw driven by a small electric motor to adjust the length of the two telescoping tubes.

The first gripping mechanism idea consisted of a rod connecting the trigger to two parallel jaws using linkages. Squeezing the trigger would cause the rod to move and close the jaws to clasp an object. This design was unacceptable because it could grasp only a limited number of object shapes. The second gripping mechanism idea featured scissor-hinged jaws that were spring-loaded to keep them closed. Two cables attached the jaws to a trigger on the handle. When squeezed, the handle opened the jaws to grab around and object. Releasing the trigger allowed the jaws to firmly grasp the object. This design required too much grip strength to open the jaws deeming it unacceptable. In the final gripping mechanism design concept, a second power screw and motor are used to control the gripper. The power screw threads through a nut fixed to a scissor-like mechanism. The jaws open or close depending on the direction of rotation of the screw.

The final prototype was thus developed using two power screws and motors. The extending mechanism consists of two square aluminum tubes that slide within each other controlled by a 6-32″ threaded rod attached to a small motor and gearbox mounted in the tubing near the plastic handle. When the power screw turns, a nut fixed to the extending section forces the tube to extend or retract depending on the direction of rotation. The power screw is self-locking allowing the device to maintain a specific length even under load. The gripper mechanism consists of two tw0-bar linkages attached to a 2-56″ threaded rod. This second power screw is actuated via a small gearbox and motor mounted in the inner extender tube. Memory foam on the grippers allows for improved gripping of a variety of different objects. A plastic handle houses batteries and two switches to actuate the motors controlling gripping and extension. The gripper motor is connected to its control switch and battery by an insulated self-retracting cord.

The developed prototype was tested by the client who was pleased and found the device to be suitably light at just over two pounds and fully functional with the ability to extend up to 5 ½ feet and grip a two pound object up to 4 ½ inches in diameter. Motors were selected to allow for approximately 7 to 10 seconds for a time to full extension and have the gripper close in about two to three seconds.

The total cost of the parts is about $200. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:
http://www.mime.eng.utoledo.edu/design/clinics/2010/Spring/sites/2010-01-02/

Fig. 19.6. Client holding the developed prototype.

A WALKER TO ASSIST BARIATRIC PERSONS WITH WALKING

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INTRODUCTION

Currently, our bariatric client uses a commercially available four wheeled walker as an assistive device as depicted in Fig. 19.7. However, this unit is not suited to his needs. This is because a seat for resting is located directly in the center of the walker's frame. The location of the seat forces the user to stand behind the walker. When the user applies a force to the handles while moving, the walker can become extremely unstable and possibly tilt on either side, as well as falling completely backwards. The purpose of this project is to develop a safe walker to assist this individual with walking, as well as exercising. The new design is a three-wheeled walker that includes two front wheels and a rotating caster rear wheel as shown in Fig. 19.8. The walker has a tee-shaped frame that trails between the legs of the user and the handlebars closer to the front of the unit. Since a bariatric person has a wider stance, the trailing rear wheel, located behind the user's feet, will not only centralize his weight, but make the model less of a tripping hazard when making turns. Also, at the front of the walker, a tray is mounted into the frame to support the user's abdomen. This tray will support a large portion of the user's weight and make it much easier to walk longer distances. Also, the model is constricted to an overall width of 30 inches which is the standard width for most doors.

Fig. 19.7. Client using the old walker.

Fig. 19.8. Developed three wheeled walk.

SUMMARY OF IMPACT

Our client is a bariatric person who uses a commercially available four-wheeled walker. Even though it is one of the best walkers on the market, the client finds it difficult to control and does not feel safe using it because it is unstable. The developed unit was tested by the client and found to serve his needs and to provide a comfortable and functional walker that can be used on a consistent basis. It makes walking for him much easier while still functioning as any other walker would. This is because the design allows centralization of the weight of the user which make the model less of a tripping hazard when making turns. Also, adding a tray to the developed unit alleviates some of the weight carried by the user. This allows the user to walk longer distances, which provides him with additional exercising opportunities.

TECHNICAL DESCRIPTION

Design requirements include developing a walker that keeps the center of gravity of the user closer to the center of the entire walker and allows supporting much of the weight of the user's abdomen. When the client uses his old walker, his center of gravity is located behind the center of gravity of the walker, causing the front wheels to leave the ground when a large force is applied to the handlebar. Several designs were considered including a three wheeled walker, a four wheeled walker with inward bent handlebars and a four-wheeled box frame walker. The three wheeled walker design concept was selected based on a house of quality analyses that include the design considerations of safety, stability, portability, cost, size, weight, and comfort.

The three wheeled walker allows the client's center of gravity to be closer to the walker center of gravity. However, the main concerns with this model are stability and safety. To demonstrate that a three-wheeler is stable, a prototype model of the walker was created. The prototype was tested by use in a similar manner to how the actual final product would be walked around. It exhibited no issues with tipping and the wheels rolled without much difficulty. Although the prototype was a crude model, it provided a proof of concept.

The next step was to develop a frame design that would be able to support the weight of the client or other bariatric persons, as well as being comfortable. Since bicycles have been proven to be strong and still lightweight, a frame made of carbon steel and similar to that of a bike was selected. The front of the frame uses a fork similar to that of a bicycle. However, it is split in a semicircle shape to support two wheels instead of one as shown in Fig. 19.8. This fork cannot rotate to the left or right to steer. This is because if the front wheels were able to rotate, it would cause a greater risk of the walker falling over. Instead, the trailing wheel, which is located behind the client, is a rotating caster wheel which allows the frame to move left or right. Hand brakes are also attached to each of the front wheels, which assist in turning as well as overall control of the walker. The stem and handlebars are standard bike parts that were purchased separately and attached to the frame. This allows the handlebars to be adjustable in both height and angle to account for different users.

Finally, a series of vertical slots are included along the middle of the steel frame in which a tray or seat, depending on the location and the person, may be added. A tray may be used for the client to place his abdomen on, thus alleviating weight from his legs/feet. In decreasing this weight, the client will be able to walk for a greater length of time. A seat may be used for resting only and may not be used while moving.

Both hand and computer calculations are used to assess the structural integrity of the unit. A model of the walker was created in SolidWorks® and a Finite Element Analysis was performed. The loads include 50 pounds on each handle bar and 100 lbs on the tray. A factor of safety of 2.19 was calculated for the frame for this loading condition which resulted in a maximum stresses of 14,600 psi at the edge of the holes for the tray and a maximum deflection of about 0.05" in the handlebars. In order to simulate a falling situation, loads of 100 pounds were applied at each handle and 150 lbs on the tray, which resulted in a factor of safety of 1.2 for the frame and a deflection at the handlebars of about 0.1 inch. An additional benefit of the walker is the ability to change the position of the tray to put it back on the walker as a seat. In order to simulate this situation, a load of 300 lbs was placed on the tray alone and a factor of safety of 2.8 was calculated at the support by the caster wheel.

The cost of the parts is $195. The three wheels, the tray and the braking system are donations. Labor for machining and welding is outsourced for $325, making the overall total cost of the project $520. The students that completed the work and analysis on this product posted their work at the following URL address:
http://www.mime.eng.utoledo.edu/design/clinics/2009/Fall/sites/2009-04-04/

ADAPTATION OF A CAMPING TRAILER TO ALLOW WHEELCHAIR ACCESS

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INTRODUCTION

The objective of this project is to provide a means for our client, a person with limited mobility, to gain easy and independent wheelchair access to and from their camper trailer. The trailer has a large door on the front side that is hinged at the bottom and folds down to be used as a ramp for motorcycles and all-terrain vehicles. When folded down into a ramp, the door is too steep of an incline for the client's electric wheelchair to climb. In order to access the trailer, the client has someone lower the door down onto two wooden blocks, about a foot tall, and place another ramp off the end of the door as depicted in Fig. 19.9. Our client is not able to set this up on her own. The purpose of this project is to adapt the current door with a secondary ramp to make the incline less steep, and to allow our client with independent access. A six foot ramp is hinged to the existing six foot door, and a cable driven system is installed in the camper to raise and lower the door and the attached ramp as shown in Fig. 19.10. The ramp folds out as the camper door lowers. The developed system provides a total of 12 feet of ramp surface and is fully automated as it is deployed by the push of a button.

SUMMARY OF IMPACT

Our client uses an electric wheelchair and was not able to independently set up and take down the ramp system that allowed her access to her trailer. She wanted to keep the ramp system and did not want to use a lift system. The ramp provides a more convenient and less expensive solution to a lift system. However, there is not a ramp system that is readily available for camper trailers that will meet our client's requirements. The developed ramp system provides the user with independent and safe access to the trailer. Fig. 19.11 depicts the client using the developed ramp system.

Fig. 19.9. Previous Trailer Ramp Setup.

Fig. 19.10. New Trailer Ramp Setup.

TECHNICAL DESCRIPTION

An electric winch and cable lift system is developed to raise and lower the existing 6 foot door and the attached 6 foot ramp. The ramp is hinged to the top of the door on the outside. This design allows gravity to assist the ramp in deploying and still allows the client to have a ramping surface that is 12 feet long and safe to use. The fold out ramp is a pre-fabricated all-terrain vehicle ramp, made of lightweight aluminum and rated at 1200 pounds. It is designed for loading motorcycles and heavy four-wheeled vehicles in the bed of a pick-up truck.

The lifting system includes a sub-frame that rests inside the camper to support a mounting shaft. The fully welded frame with a height of approximately 74″, is made of 1″ x 2″ x 0.125″ rectangular steel tubing. This is bolted inside the trailer to the wall and floor using 4″x 4″ x 0.125″ flat square foot plates. Three cable drums, each with a diameter of 4.75″, are mounted on the shaft. Two of the cable drums have cables attached to the door and the third has a cable attached to an electric winch which is used to turn the shaft. This shaft raises and lowers the door and the attached ramp. Aircraft grade cables are used due to their high strength. Two adjustable support legs, one on each side, are attached to the main camper door. Two more adjustable support legs, one on each side, are attached to the top of the foldable 6 foot ramp. Wheels are mounted on the bottom of the 6 foot ramp to allow it to roll across the ground providing a smooth operation. Each of the two wheels of the 6 ft ramp is mounted on a 4.75″ long solid shaft with 0.75″ in diameter. Two wheel brackets are mounted to the side of the 6ft ramp, one on each side and cantilevered off the front of the ramp. Each wheel bracket is drilled through and the corresponding wheel mounting shaft is inserted and welded solid. Two small ramps are developed and placed on the ground for the 6 foot ramp to land on. The wheels of the 6 foot ramp land on these smaller ramps which will move it away from the camper. This system is depicted in Fig. 19.10. A full size wooden prototype was first built as a proof of concept.

The winch needs to pull out at least 200 pounds since the weight of the door is estimated at 100 pounds. The winch selected is rated at 3000 pounds, runs on 12 volts DC, and comes with a wireless remote control. This winch is chosen because of its low price of $75.00. Support leg assemblies made of nestable tubing are bolted to the main door and fold out ramp. Each assembly is composed of upper and lower parts. The upper part of each support leg assembly consists of 1.5″ x 1.5″ x 0.11″ CRS nestable tubing, 4″ x 2″ x .19″ CRS flat bar and a 1.5″ flange x 0.125″ pin x 0.5″ flange CRS piano hinge. The lower part consists of a 6″ x 1.75″ x 0.1875″ thick CRS plate and a 1.75″ x 1.75″ x 0.11″ CRS nestable tubing. Pins, 0.375″ in diameter, are used to secure the nestable tubes to each other. The tubing of the upper part of the fold out ramp leg assembly is cut at an angle.

Fig. 19.11. Client using the ramp to access her trailer.

Finite element analysis using SolidWorks® and hand calculations are used to perform structural analyses on the system and its components. A factor of safety of eleven was calculated for the mounting shaft which was made of cold drawn 1018 steel with a diameter of 1″ (solid shaft) and 54″ long. Each of the two wheel brackets mounted to the side of the 6 foot ramp is designed to support a weight of 360 pounds and the corresponding critical factor of safety was calculated as 4.5 in the wheel mounting shaft. Each support leg assembly is designed to support a weight of 500 pounds and the corresponding factor of safety was calculated at 12.3.

The cost of the parts is $965.00. The time for machining and welding of the different components of the system was donated to the team by the College of Engineering machine shop. The students working on this project posted a detailed description of their design and analysis in the World Wide Web at the following address:
http://www.mime.eng.utoledo.edu/design/clinics/2009/Fall/sites/2009-04-05/

DEVICE TO LIFT A PERSON FROM THE GROUND TO WHEELCHAIR HEIGHT

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INTRODUCTION

The goal of this project is to develop a device to assist a paraplegic or quadriplegic in moving from the floor to a wheelchair with the assistance of only one person. There are times when an individual using a wheelchair may fall out of the chair, or exit the chair to rest on the ground to enjoy a picnic or to play with a child. When the individual tries to return to the chair it can be very difficult, and requires a great deal of strength from the individual or from an assistant to lift them into the chair. A collapsible and portable device resembling a chair into which the individual can be strapped is developed for this purpose. The device separates into four pieces: the high back, the right leg with an attached foot rest, the left leg with an attached seat, and the top handle. The right and left legs are curved. Two ratcheting rear legs are placed on the back side of the unit for additional support. The device and its components are shown in Figs 19.12 and 19.13, respectively. The unit is collapsible into 40” by 18” as shown in Fig. 19.14. During use, the client lies on their side on the floor with their legs bent as if sitting in an imaginary chair. The unfolded and assembled chair is then placed next to them and safety straps are placed around the client’s chest, waist, and shins. The client and chair are then rolled so that the client is lying on their back. Once in this position, the assistant lifts the tall back of the chair to bring the client to an upright sitting position at wheelchair height.

Fig. 19.12. Final prototype.

Fig. 19.13. Components of the prototype.

Fig. 19.14. Prototype in a stacked position.

SUMMARY OF IMPACT

It can be difficult, for an individual who is paralyzed below the waist, to return to their wheelchair from a ground position. There is currently no available device to assist in lifting our client aside from a Hoyer lift which is expensive, heavy, and generally a stationary device. A light-weight, portable device does not exist. As a result, our client chooses not to exit his chair if it is not necessary, limiting what he is able to do and to enjoy, including playing with his son. The device developed allows our client's wife to assist him in returning to his chair with limited effort. This makes the prospect of sitting on the floor much more appealing and less of a chore. He is also pleased that the chair can be disassembled quickly and easily for compact storage, and is lightweight and easy to carry.

TECHNICAL DESCRIPTION

Design requirements include the development of a device to allow someone to lift and lower a person from the ground to wheelchair height, or vice versa, while expending limited effort. From this height, the individual can easily transfer themselves to the wheelchair. The device needs to be capable of lifting an individual weighing up to 300 pounds, portable and lightweight, and be able to fold down to 40" x 18" in order to easily fit in the trunk of the car. The device also needs to be easily operable, and be able to be assembled and disassembled by the assistant and the individual.

Two designs were explored. The first was a tripod which utilizes a winch to hoist the individual from the floor. This design was not used because it requires a large area in which to set up the device due to the large reach of the tripod legs. Also, it would be difficult to put a wheelchair beneath the tripod due to interference with the tripod legs. The second design was simply a collapsible chair with a tall backrest that could be used for leverage. To use this design, the individual is strapped into the chair while it is lying on its side. The chair is then tipped to its backside and lifted into an upright position. At this point, the individual is sitting in the chair normally. In order to minimize the large force required to lift the chair into the upright position, the bottom of the chair is curved as shown in Fig. 19.12. This curve relocates the location of the fulcrum as the chair is being lifted into its upright position. This reduces the force required to perform this lift by approximately 50%.

The frame of the chair is made using 4130 Chromoly steel round tubing. This through-hardened, chrominum-molybdenum alloy tubing is used extensively in the aircraft industry, and anywhere light and strong structural tubing is needed. It also costs less than aluminum and is much easier to weld. The chair is made to separate into four pieces as shown in Fig. 19.13: the high back, the right leg with an attached foot rest, the left leg with an attached seat, and the top handle. The top handle is used when lifting the chair, and is angled upward at ten degrees. This handle increases the lever arm which reduces the force required to lift the chair by about 10%. The right and left legs are curved. Two ratcheting rear legs are placed on the back side of the unit for additional support.

Assembly and disassembly can be completed easily by one person within a matter of minutes. Four screws are used to attach the seat to the right leg, two pins are used to hold the legs in place and attach each leg to the chair back, and two cotter pins are used to attach the top handle to the chair back.

Finite element analyses using SolidWorks® and hand calculations are used to perform a structural analysis on the chair and its components. Two cases are studied: the chair being lifted and the chair resting on its ratcheting legs. When the chair is lifted, the following four positions of the chair were investigated: 0°, 30°, 60°, and 90° with the ground. When the chair is resting, the following four positions of the chair were investigated: 10°, 30°, 60°, and 90°with the ground. In the case simulating the lifting of the chair, the lifting force is applied perpendicular to the back of the chair. For each of the two cases that were studies, the weight of the person is distributed on the back of the chair and on the seat. This distribution changes with the chair position. When the chair was at 0° with the ground, the total weight of the person (300 pounds) is applied to the back of the chair. At 90°, the total weight is applied to the seat. A minimum factor of safety of 4.0 was calculated. This corresponds to the case simulating the chair being lifted at an angle of 30° with the ground. At this position, the lifting force is at a maximum of 80 pounds and the maximum stresses are located in the pins joining the extension handle to the back piece. When the chair is resting on its ratcheting legs, a minimum factor of safety of 5.0 was calculated when the chair was at 10°with the ground. In this case, the maximum stresses are located in the ratchet handles. The unit when assembled is 71" in height and around 40lbs in weight. When disassembled, the chair takes up a volume of approximately 40"L x 20"W x 4"H as depicted in Fig. 19.14. The total cost of the parts is about $500.

ADAPTATION OF A LAWN MOWER TRACTOR WITH HAND CONTROLS

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INTRODUCTION

A paraplegic individual has full range of motion and dexterity in his upper body. He currently owns a White Outdoor Hydrostatic Lawn Tractor Model LT 165, but is unable to depress the foot-pedal brake lever. The purpose of this project is to adapt his lawn mower to allow him to control the brake lever via hand controls, while maintaining the original operation of the foot-pedal for other users. The developed system includes a cable drawn device that includes two sheathed cables, a tensioner and a handle. One cable is attached to the brake/clutch foot pedal and the second to the handle. The device allows the user to pull the handle to depress the foot-pedal. The tensioner system consists of a spring loaded piston that is used to absorb slack in the cable allowing for normal operation of foot-pedal, depressing directly by foot. Fig. 19.15 depicts the system in use, and Fig. 19.16 shows the tensioner system mounted under the floor plate.

Fig. 19.15. Cable drawn device in use.

Fig. 19.16. Tensioner unit installed under floor plate.

SUMMARY OF IMPACT

A paraplegic individual uses his riding lawn tractor to mow several acres of land. Since he has no leg movement, he was previously using a shovel handle to depress the brake lever when needed. The device developed in this design is user-friendly and allows the client to depress the brake lever by pulling a handle mounted on the top of the rear fender of the tractor. The client tested the developed unit and found it to be easy to use, un-obstructive to wheelchair transfer, and adaptable to various lawn tractors which use similar brake pedal mechanics. He is also pleased that the unit is capable of accommodating normal foot operation.

TECHNICAL DESCRIPTION

Design considerations include developing a device that does not hinder or prevent normal brake operation by means of foot and requires little or no permanent alterations to the tractor. The client transfers from his wheelchair to the lawn tractor on the same side that the brake lever is located. Therefore, any device designed to control the brake lever should provide sufficient clearance for transfer and the operator's legs during use. A rigid bar may be bolted directly to the clutch/brake foot pedal. While this design is simple and economic, it presents complications with functionality since it is necessary to keep the hand control device within close reach of the user, while not interfering with transfer on and off the mower. Therefore, a cable drawn system design is selected which consists of two sheathed cables, a piston style spring tensioner, and a handle as illustrated in Fig. 19.17. The piston-style spring tensioner is designed to absorb slack cable for normal operation. The cables are guided via sheaths similar to bicycle brake cables. The system uses two cables. One cable is attached to the brake lever shaft by means of a clamped shaft collar. The other cable is attached to the underside of the handle. Both cables are joined by the tensioner unit. The handle is supported by two bearings that are mounted to a base plate bolted to the mower body. A collar is mounted to the foot-pedal to provide attachment for the cable.

When the handle is pulled, the cable travels through the sheath and completely depresses the foot pedal. In this case, the tensioner acts as a rigid member traveling a distance equivalent to the length of cable drawn. A challenge arises when the foot pedal is operated normally. If the foot-pedal is depressed directly by the foot, tension in the cable is lost allowing the cable to bend and twist upwards. This could potentially allow the cable to get caught on other parts not allowing the pedal to return to its neutral position. The piston-style spring tensioner system is designed to maintain normal brake operation and its mechanism is illustrated in Fig. 19.18. Under normal operating conditions and as the foot pedal is depressed, the compressed spring extends due to the drop in the cable tension, thus raising the slider tube and drawing excess cable into the tensioner. When the pedal is completely depressed, the slider tube is extended to its maximum displacement position (Fig. 19.18 View

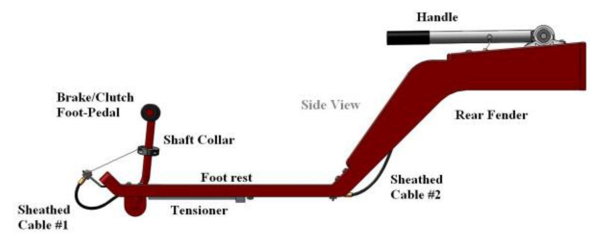

Fig. 19.17. This figure shows the different components of the cable drawn system.

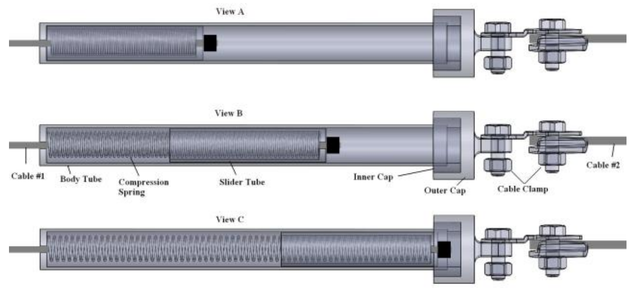

Fig. 19.18.Tensioner assembly.

C). This allows the excess cable to be pulled into the tensioner while maintaining cable tension.

The cable travel is used to select the appropriate compression spring and design the piston and cylinder. The force required to completely depress the pedal is determined experimentally to be from 3.5 – 4.5 pounds and used to estimate the maximum tension in the cable at about 70 pounds. A braided cold-drawn steel cable having 19 strands, each with a diameter of 0.014 in is selected resulting in a factor of safety greater than 2 in the cable. A handle length of 13 inches is used to maximize mechanical advantage and avoid interfering with the client's transfer space. Finite element analysis is used to perform a structural analysis on the different components of the system which are found to have a minimum factor of safety of 2.6. The total cost of the parts is about $310.00. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:
http://www.mime.eng.utoledo.edu/design/clinics/2010/Spring/sites/2010-01-03/index.htm

HAND CONTROLS FOR A UTILITY TERRAIN VEHICLE

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INTRODUCTION

The objective of this project is to develop hand controls to allow an individual paralyzed from the waist down to independently operate his Utility Terrain Vehicle's (UTV) accelerator and brake pedals. A device that can be completely operated with the use of one hand is developed for this purpose. The device includes a handle mounted on the right side of the steering wheel. The handle uses a series of linkages to push the brake and throttle pedals down. If the operator pulls the handle back the brake will engage. If he pushes the handle forward it will engage the throttle. Fig. 19.19 shows a schematic of the system and Fig. 19.20 shows the system installed in the UTV.

SUMMARY OF IMPACT

An individual was involved in a hunting accident that left him paralyzed from the waist down. He is still an avid hunter and uses his Kawasaki Mule to travel to various hunting locations. He previously relied on a long object, such as a stick, to push and operate the foot pedals. The developed device allows him to independently and safely operate his UTV. The client tested the device and found it to be easy to use, durable, safe, and comfortable. He is also pleased that the unit has made no permanent alterations to the vehicle, which will help the vehicle retain resale value.

TECHNICAL DESCRIPTION

Several criteria and guidelines are considered when designing a hand control mechanism that allows the client to independently operate his UTV. The device needs to control both pedals using only one hand since the other hand needs to be on the steering wheel to safely operate the Mule. The device cannot be intrusive, and must be within the driver's reach.

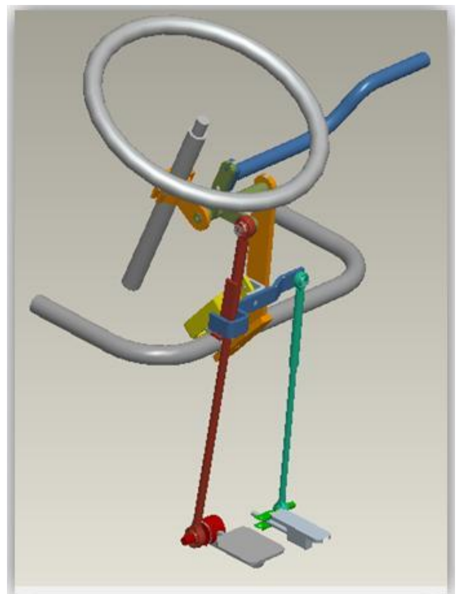

Fig. 19.19. Schematic of the device.

The client requested that the device be located to the right of the steering column for more personal ease of use. Another consideration is that the pedals need to remain functional to someone operating the vehicle with their feet while the device is installed on the Mule. Also, the design needs to be robust and sturdy since the Mule will be driven in fields and on uneven ground which will cause the device to vibrate. All of this needs to be considered while keeping in mind that the device needs to be removable, leaving no permanent alterations to the Kawasaki Mule that would violate the warranty or depreciate the value of the vehicle for future resale. It is also desired that the device be transferrable to another UTV if the client chooses to purchase another model.

SolidWorks® and Professional Engineer® are used to draw a 3D model for the device shown in Fig. 19.21. The existing parts on the SUV that are used to attach the hand control mechanism are clearly shown in Fig. 19.21 and include the steering column and wheel (the top of the figure), the U-Shaped lower UTV frame (in the middle of the figure), and the brake and throttle pedals (at the bottom of the figure).

This design is very simple to operate. It consists of two directions of motion of the hand control located at the upper right of Fig. 19.20. When the operator is facing the steering wheel, the hand control is pushed forward to engage the throttle. Likewise, the operator can pull the handle towards their body to engage the brake.

The forward and backward hand control operations cause the brake and throttle to engage through a series of mechanical linkages. The handle is directly connected to the crank arm with two bolts as shown in Fig. 19.21. This crank arm is supported on both ends so it rotates on an axis that is parallel to the handle. The crank arm is also connected to the brake arm assembly (located at the left of Fig. 19.20) as shown in Fig.19.21. A pivot arm detailed in Fig. 19.22 connects the brake arm assembly to the throttle arm assembly (located at the bottom right of Fig. 19.20 and at the right of Fig. 19.21). The upper part of the brake arm assembly slides in the upwards direction on its lower part when the handle is pushed in the forward direction. This results in rotating the pivot arm in the clockwise direction. which moves the throttle arm assembly in the downward direction applying a force on the throttle clamp, thus engaging the throttle. With the handle bolted directly to the crank arm, the backwards motion of the handle results in an opposite rotation of the pivot arm pushing down on the brake arm assembly which directly applies a force on the brake clamp, engaging the brake.

Finite element analysis is used to perform a structural analysis on the unit. Calculations are done only for the braking because the accelerator pedal takes only a fraction of what the brake pedal takes to fully compress. It was determined experimentally that an average of 12 pounds force is needed to be applied to the handle to fully compress the brake pedal. AISI 1020 cold rolled steel is used to fabricate the system and a minimum factor of safety of 8.5 was calculated with the maximum stresses occurring in the crank arm near the bottom hole where the handle attaches. The total cost of the parts is about $400. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address:
http://www.mime.eng.utoledo.edu/design/clinics/2010/Spring/sites/2010-01-0

Fig. 19.20. Device installed in the UTV.

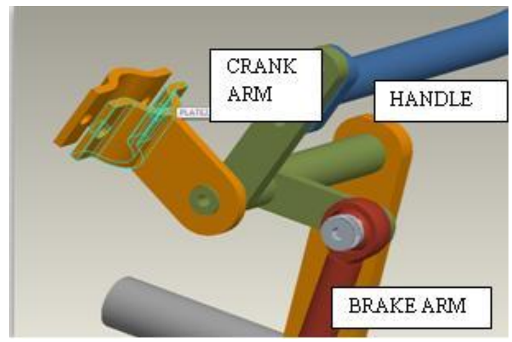

Fig. 19.21. Close-up view of the crank shaft

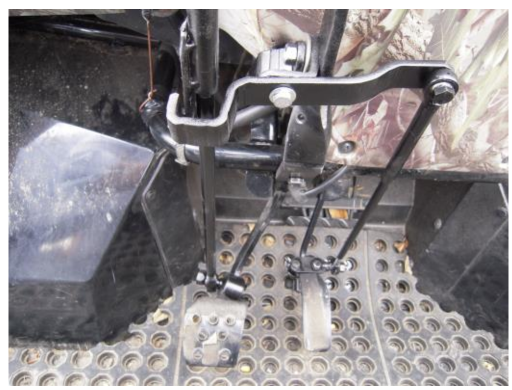

Fig. 19.22. Close-up view of the pivot arm.

ASSISTED FEEDING MECHANISM

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INTRODUCTION

The goal of this project is to develop a mechanism that will help an individual with cerebral palsy eat more independently. A robotic arm is developed in this design for this purpose. The device consists of a base and three arms made of PVC pipe and joined together with sleeve fit joints. The unit includes four motors, one housed inside each of the three joints and one inside the base. A utensil attachment is located at the end of the robotic arm to allow the user to retrieve from his plate. Two motors are controlled via a joystick that is mounted to the table using a clamping fixture. The other two motors are controlled by two foot pedals. When eating, the robotic arm is placed directly on the table to the left of the plate. The joystick is controlled with the chin of the user while the pedals are controlled with his feet. Fig. 19.23 depicts the developed robotic arm.

Fig. 19.23. Developed Robotic Arm.

Fig. 19.24. Client using the arm.

SUMMARY OF IMPACT

An individual with cerebral palsy would like to be able to eat independently when in a restaurant or at home. Since he has minimal control of his hands and fingers he is not able to pick up a fork or spoon and eat with a utensil. The developed device allows this individual to operate a robotic arm that can pick food up from a plate and place it in his mouth. The unit was tested by the client and he was able to both stab and scoop food when using it. The client has indicated that he was very pleased with its performance. Fig. 19.24 depicts the client using the robotic arm to feed himself. The mechanism could also be used in other applications such as with the elderly.

TECHNICAL DESCRIPTION

The client has a motorized wheelchair that is controlled with a joystick located on a hinged bar under his chin. It is desired to operate the feeding mechanism with controls similar to those of the client's wheelchair. Other design criteria included the ability to pick up a wide variety of food, portability, and ease of use. Several design ideas were considered including an indexing or rotating plate that an arm would scoop food from while fixed to a predetermined track, a design similar to a three axis mill where a central utensil attachment would be able to move in space, and a power screw to move an arm fixed in a horizontal position up and down and radially. These designs were not pursued because of the client's mobility constraints and because of their inconveniently large sizes. The selected design is a four-degrees-of-freedom robotic arm that is controlled by a joystick and foot pedals. This design is chosen because it allows a wide range of movement, has the ability to stab and scoop food, and is not very distracting when used in a restaurant setting.

The robotic arm consists of three pieces of ¾" Polyvinal Chloride (PVC) pipe that are joined together with sleeve fit joints. The robotic arm is mounted on a turntable base. Four motors are used, three to control the rotations of each of the three arms and one to control the rotation of the base. A motor is housed inside each of the three sleeve joints, and the fourth one inside the base. Each joint consists of an inner and an outer insert; a motor is mounted inside of the inner sleeve using a custom designed plug and its shaft rotates the outer sleeve.

At the end of the robotic arm is a utensil attachment which is used to stab or scoop the food on the plate. Two motors are controlled via a joystick that is mounted to the table using a clamping assembly. The other two motors are controlled by two foot pedals. The joystick is controlled with the chin of the user while the pedals are controlled with his feet. In order to easily control the device, the joystick needs to be mounted so that the client can easily reach it with his chin. This is accomplished by welding a clamp with a T-handle to an adjustable clamp in which a PVC arm coming off the joystick box attaches.

Four gear boxes are also used since the motors need to be geared down to a slow speed of 3 rpm. Most of the rotations in the eating process will not exceed 120 degrees and take only five to seven seconds to be performed. A 12 volts lead acid battery with 4.5 Amp.hr of energy capacity is used as a power supply. This allows running three motors simultaneously for an hour. A turntable with ball bearings is used to rotate the robotic arm at its base which is used to house the battery and wiring. A junction box is used as the base.

Fig. 19.25. Robotic arm with controls.

The total cost of the parts is about $500. The students working on this project posted a detailed description of their design and analysis on the internet at the following URL address: http://www.mime.eng.utoledo.edu/design/clinics /2010/Spring/sites/2010-01-01/