Project Summary
Pull-Lever Wheelchair

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Abstract

Team Leverage was formed to address the needs of a young adult male, a man with quadriplegia who maintains some strength and control of his arms but has little strength and control of his hands and fingers. The team was tasked with designing and creating a manual wheelchair that would allow the subject, a high functioning quadriplegic, to exercise outdoors and participate in long distance events. The design needs to compensate for his lack of fine motor skills in the hands and fingers and also take into consideration weaker-than-typical muscle groups that have been under-utilized for many years. All-terrain use is not a priority of this design given the subject's desired applications. After considering the needs of our client, the team has proposed a user-centered design that will incorporate lever-propulsion achieved by a pulling/rowing motion rather than by pushing forward. The design will have one gear ratio and will allow the subject to adjust the mechanical advantage by moving his hands up or down the lever. In addition to flexibility with speed and torque, the team has prioritized braking ability and safety measures within the design. Although reverse gearing capability was initially included in the design, the subject's feedback at the oral presentation indicated that this is not a priority given that this wheelchair would only be used when a companion is present. The team has developed the following design proposal, although we will continue to make improvements throughout the design process to incorporate feedback from our client.

Design Criteria

The customer requirements were determined based on the desired functional goals gathered from meeting with the project sponsor. The requirements fall under three categories; physical operation, physical considerations, and non-movement related design. Table 1 lists and categorizes these requirements.

The most important requirements were determined to be:

- Allows manual wheelchair propulsion
- Accounts for lack of triceps strength
- Utilizes biceps and deltoids
- Accounts for lack of hand strength/ wrist control
- Accommodates customer's specialized cushions

Final Prototype Design

The final prototype includes much of what was presented in the midterm design, with minor changes resulting from discrepancies in projected assembly plans. These changes and clarifications are explained in the following sections.

Frame

The frame for the final design concept has remained the same since the preliminary design. As previously proposed, a standard wheelchair was used and modified to accommodate the additional and modified components. For the final prototype, a Ki Mobility Catalyst 5 made out of lightweight 7000 series aluminum wheelchair was used. This was beneficial to the design as the additional components added a moderate amount of weight to the original chair.

Forks and Support

As proposed in the midterm design concept, chromoly forks were chosen to support the axle of each wheel. These forks were bolted directly to the wheelchair frame in order to minimize the final chair width as much as possible. The forks were bolted to the chair instead of welded, which was previously proposed, in order to give the client the option to revert the chair to its original factory assembly. The bolt shear strength was calculated to be appropriate for the loading conditions of the product, but in order to reduce torsion along the length of the forks, a support structure was added to the back of the chair and pinned to the upper shafts of the forks in order to reduce significant twisting of the wheels under load, which was achieved. Figure 1 shows the basic fork and a posterior view of the forks and the back support structure.

Figure 1: Chromoly Steel Bike Fork (left) and Bike Forks on Wheelchair with the Anti-Rotation Support Bar Structure Connecting them.

<u>Wheels</u>

As stated in the midterm design, standard 700c make model road bike wheels were selected. Previously, a left-hand-drive freewheel was ordered without the need for custom BMX-hub/road bike-rim wheels because they were specified as right-hand threaded. This left-hand freewheel was needed in order to mirror the left wheel, and allow the drive train to function on the inside of the wheels on both sides. However, when the part was received it was actually found to be left-hand threaded. In order to resolve this issue, the part was rethreaded with right-hand threads over the existing threads, and due to the decreased surface area caused by the cross-threading, JB- weld was used to ensure a strong attachment to the axle. Figure 2 shows the wheels on the final prototype.

Figure 2: Wheel on Final Prototype

Tires

The tires for the final design are 28c width tires that are lightly treaded. A wider tire was chosen in order to increase the user's comfort, at a lower pressure of 130 psi. This lower pressure allows the tires to run smoothly over uneven surfaces, and the light tread provides additional fluid motion while still being able to channel moisture outward if riding over a wet surface.

Levers

The levers for the final prototype were made out of hollow aluminum with a one-inch outer diameter. These were located in the forward position on the chair to allow for the widest range-of-motion possible for the client, as positioning the levers in the forward position as opposed to the axle was found in testing to increase the range of motion for the client 20 degrees. The levers were attached to the bottom shaft of the drive train using custom-made clevis joints manufactured in the KU machine shop, as off-the-shelf components that allowed for the width of the shaft as well as utilized the pin-size needed for the design were not available. CAD drawings for this component are located in Appendix E. Unlike previously proposed, the levers on the final prototype were located on the outside of the wheels to resolve gear train spacing issues, while the gear drive system remains located on the inside of the wheels. Levers were wrapped in bike handlebar tape to maximize the grip of the user. A view of the lever is located in Figure 3.

Figure 3: Front View of Right Lever

Drive Train

The final drive system included much of what was described in the midterm design. Major components of the final drive train design included an aluminum plate, two spur gears, a bike sprocket, thrust bearings, a bike chain, and bike chain tension adjuster, bearing housings, and two solid aluminum shafts. The aluminum plates were made from 0.25 inch wide aluminum plating, and holes were drilled in order to secure the bearing housings and shafts onto the plate. Roller bearings were JB-welded into the lower bearing housing in order to allow for a secure connection and for rotation of the lower shaft with the lever motion. As stated in the midterm design, the front spur gear is attached adjacent to the lever, and the idler gear that converts this pulling propulsion into reverse motion is located on the upper shaft in linear mesh with the lower gear. These are both 16 tooth, steel 14-1/2 degree pressure angle spur gears, and have a pitch diameter of 0.8" and a ⅜" bore diameter. The driving spur gear was fixed to the lower shaft with a setscrew. The upper shaft was press-fitted into housings on either side of the aluminum plate, and a gear set including the driven spur gear and sprocket were pinned onto the upper shaft. These rotated around the shaft freely via roller bearings press-fitted into the axle of the spur gear. Thrust bearings made from low-friction brass were placed on the shafts between the gears and shaft pins to ensure a prolonged life of the gear system by reducing friction and wear from metal-on-metal contact. The bike chains used in the design were single-speed SRAM chains, which incorporate a “power link” which allows the chain to be installed onto the freewheel and front sprocket with ease. The final gear train set-up is shown in Figure 4.

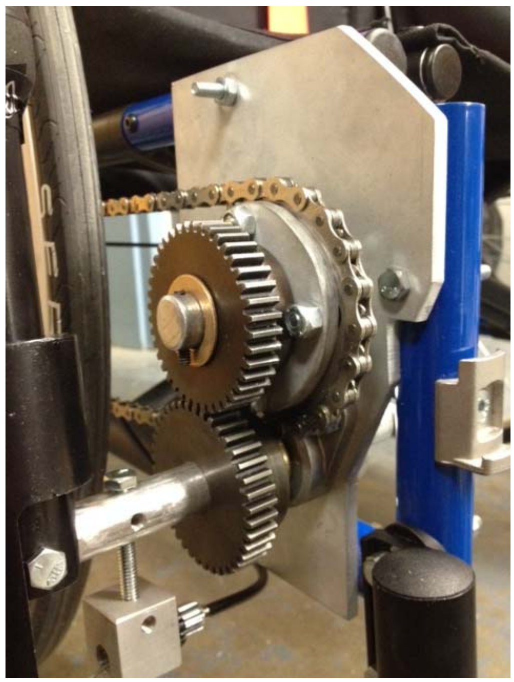

Figure 4: Drive Train on Final Prototype

<u>Braking</u>

Shimano V-brakes were used in the final design. They were chosen because they were low cost, easily maintained parts that provided the braking power needed for the design loading conditions, as well as were compatible with the wheel rims purchased for the design. The major components of the braking system were the Shimano brake sets including the braking cables (Figure 5), the rim tension adjuster utilizing the fine-tune adjustment component from the original hand-brake set, and the brake cable pull attached to the lower end of the lever that was manufactured in the KU machine shop (Figure 6).

Figure 5: Posterior View of V-brake Rim Clamp

Figure 6: Brake Cable Pull and Fine Adjuster

Assistive

The assistive components of the final design included the restraint harness (Figure 7), canvas side guards (Figure 9), and quad gloves (Figure 9). The restraint harness used was a four-point harness, and was a cam lock seat belt that is Department of Transportation compliant with a single buckle design for comfort and ease-of-use. Due to the fact that the armrests were removed from the original frame in order to allow for maximum range of motion for lever-use, side guards were crafted in order to provide protection from the spokes of the wheel for safety measures. These are attached the frame using Velcro, and can easily be removed from the seat in order to be repaired or modified. The gloves chosen for the design comprise of wrist bracing and finger support features in order to compensate for the lack of grip and wrist strength of the client. Gloves were found specifically for the use of gripping handcycle pedals or handlebars for quadriplegic users. These gloves use a simple strap and Velcro webbing system and do not require any additional modifications to be usable for this wheelchair application.

Figure 23 shows the harness secured to the final prototype.

Figure 7: The 4-Point Restraint Harness

Figure 8: The Triangular Canvas Side Guards

Figure 9: Quad Glove

Final Budget

The final budget for the design was divided into system sections as the previous budget format shows. For the frame and wheels system, the total cost was $737.88, for the lever and drive system, the costs totaled $259.96, for the braking system, costs totaled $88.37, and for the assistive components, the cost was $105.00. The grand total for the prototype was $1,191.21.