Operations Manual

Team 512: Human Powered Vehicle

1 Project Overview

The American Society of Mechanical Engineers (ASME) host an engineering festival in North America each year known as E-Fest. One of the competitions hosted at E-Fest is the Human Powered Vehicle Challenge (HPVC). The HPVC aims to encourage students to develop practical and sustainable means of human powered transportation. The students' designs are tested using a series of events including speed, endurance, and design. The speed event tests the top speed, the endurance event challenges the efficiency and durability, and the design event evaluates the design. Vehicles are rated against one another using a combined score from each of the three main events of the competition.

There are several constraints specified in the competition rules kept in mind when designing the Human Powered Vehicle (HPV). The vehicle must be able to stop in 6 meters, turn in 8 meters, maintain a straight path and protect the rider's head and shoulders in the event of a collision. These constraints affected how the HPV was designed. The roll protection system consisted of a continuous roll bar that passed over the rider's head and a crossbar that extended past the rider's shoulders. Disc brakes were implemented on two front wheels to stop the vehicle quickly, and a direct steering system was implemented for responsive turning. The vehicle also features a 5-point restraint to ensure the rider is secured within the vehicle. Figure 1 shows a diagram of the final design.

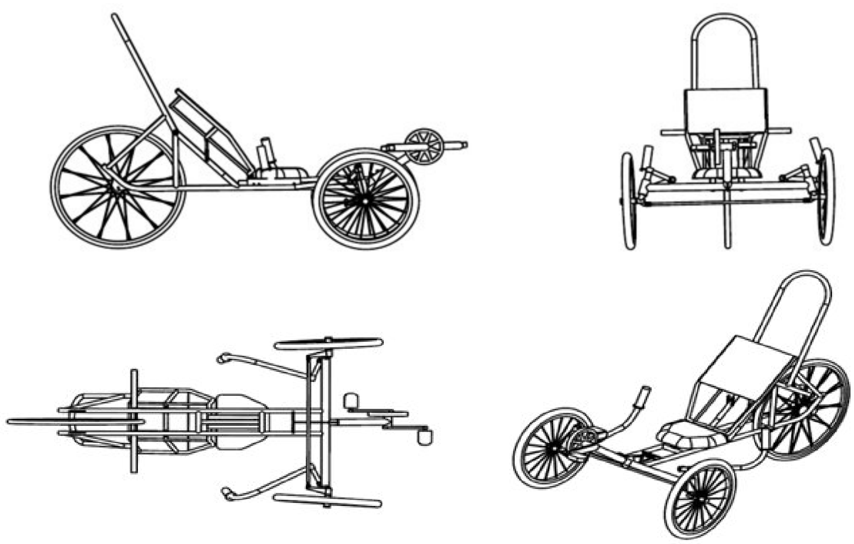

Figure 1: Human Powered Vehicle prototype CAD

The proposed vehicle design consists of two front wheels and a single powered rear wheel, a reclined seating position, 7-speed transmission and low-profile frame. The chain routes underneath the frame to the rear wheel and derailleur. The derailleur picks up chain slack and moves the chain though the 7 different gear settings. The derailleur is actuated using a shifter located on the right handlebar of the vehicle. Front brakes are actuated using brake levers located on both handlebars.

The goal of team 512 is to emulate the 2019 E-Fest competition by producing a vehicle suitable for the competition and testing it in ways like the competition. A good score in the design event will be achieved through successfully completing the deliverables of Senior Design One and Two. The endurance event will be emulated by creating a course in the FAMU-FSU College of Engineering parking lot that is like the course used in the HPVC. The actual endurance course and the emulated course can be seen in figure 2.

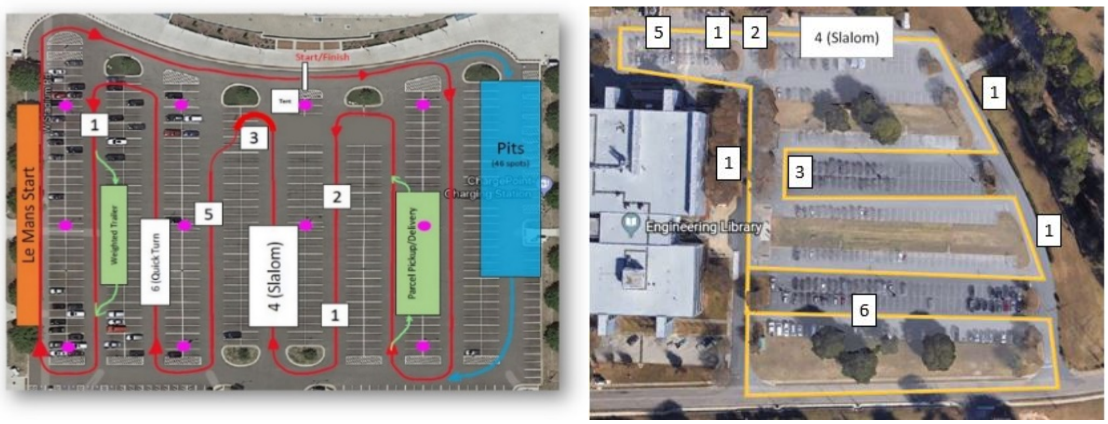

Figure 2: HPVC endurance course (left) and emulated endurance course (right).

These courses are similar in length and include similar features. This allows the team to gauge the effectiveness of the Human Powered Vehicle. The completion time in the emulated course can be compared to the completion times of vehicles at the actual competition. The speed event is emulated using a dash test where the vehicle starts from rest and travels 270 meters as fast as possible. A layout of this timed speed test track can be seen in figure 3.

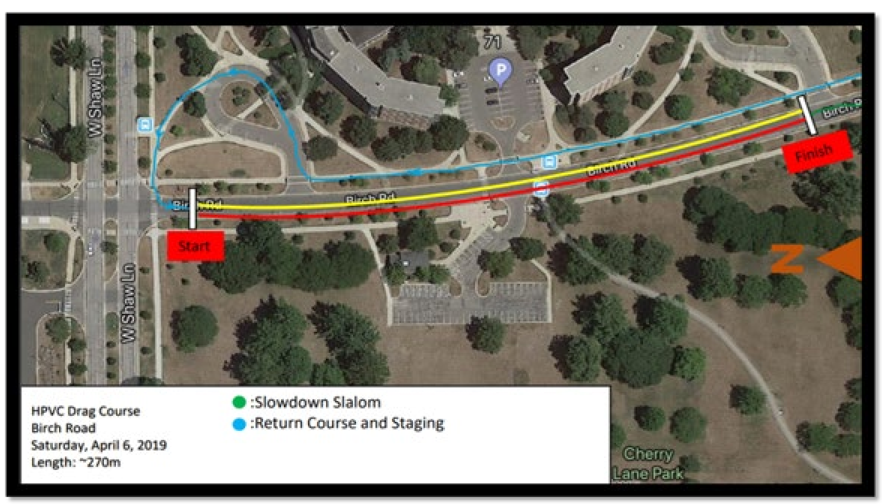

Figure 3: HPVC times dash test

This course is emulated by measuring out a 270-meter straight course and then completing the course as fast as possible with the HPV. The completion time is the compared with those of teams that competed in the HPVC.

2 Component Description

Steering

Handles

The handle and brake assembly shown in figure 4 were recycled from bikes purchased by the previous year's team. The gear shifter is on the rider's right-hand side and brakes attached to each handle. They attach directly to the kingpin axis to achieve the direct steering design choice. This style of steering provides quick response times and low complexity.

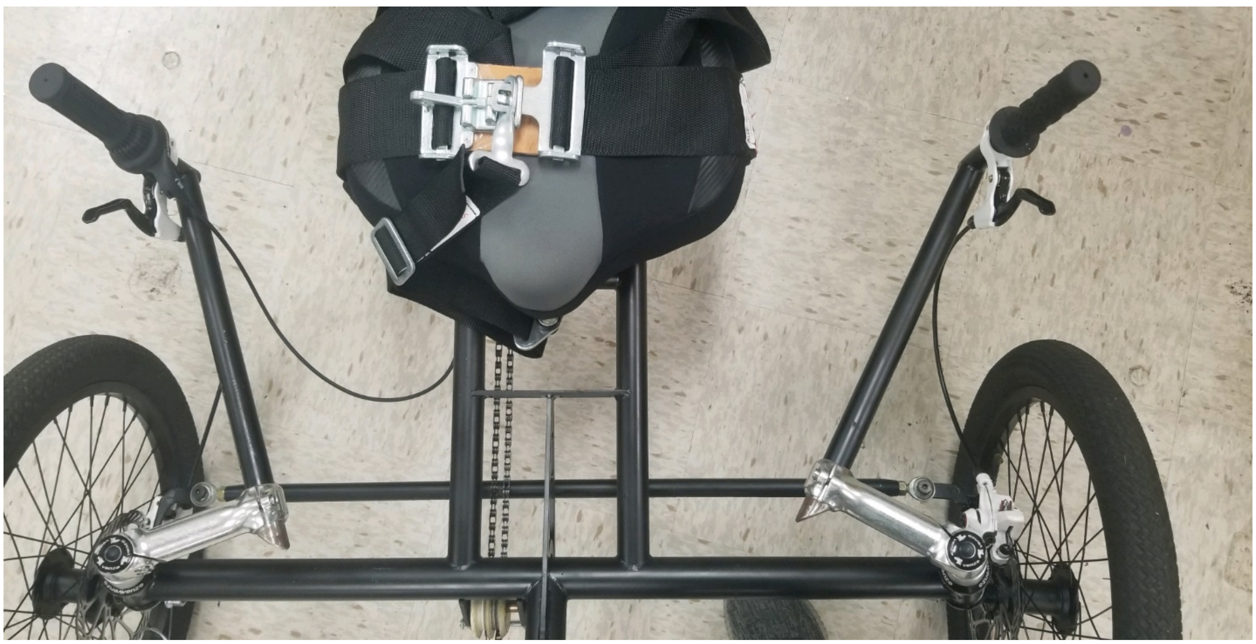

Figure 4: Top View of Steering Assembly

Each handle is an L-shaped piece of aluminum machined from the handlebars of a mountain bike. One end of the handle attaches to the stem via a bolted clamp and the other end is where the grips are located. The handles are positioned at the rider's hips and bump up against the seat during max turning to prevent excessive wheel angle.

Kingpin Axis

The kingpin axis houses the stem, spacer, headset, and steering knuckle together. Figure 5 shows the kingpin axis assembly. The stems were acquired from a local bike shop for free. The spacer was made in-house in the FSU machine shop. The headsets were purchased from Amazon. The steering knuckles were purchased from a Fooldacrow Cycles.

Figure 5: Kingpin Axis

The function of the kingpin axis is to connect the handlebars to the wheels while providing a smooth rotational axis. The headset assembly shown in figure 7 holds the stem, and steering knuckle (which is directly connected to the wheel) together.

Figure 6: Headset assembly

Wheels

The team used two 20-inch wheels for the front of the bike seen in figure 7, and one 26-inch rear wheel seen in figure 8. The two front rims were purchased from Fooldacrow Cycles and are designed for recumbent (reclined) style bikes. The front tires were reused from a purchased BMX bike by last year's team. The rear wheel was fully reused from a mountain bike purchased by last year's team.

Figure 7: Front wheel

Figure 8: Rear wheel

Front wheels are fixed to the steering knuckle via a single locking bolt that passes through both the wheel and steering knuckle. The rear wheel is fixed to two dropouts at the rear of the frame using two lock-nuts.

Braking

Disc Brakes

The disc brakes shown in figure 9 were purchased on Amazon. They were standard sized 160 mm brakes and came with the calipers and brake lines. The brake rotors mount directly to the wheel and brake calipers are attached to the steering knuckle.

Figure 9: Disc Brakes

Brake Levers

The brake lever shown in figure 10 was provided along with the other braking components. The levers are located on each handle and control the brake calipers on the front wheels independently of one another.

Figure 10: Left Side Brake Handle

Powertrain

Pedals

The pedals used on the vehicle were provided to Team 512 from the previous year's design team. The pedals are mounted on a boom that extends out in front of the vehicle and is adjustable. The pedals are connected to a chainring with three gear sizes. The largest and smallest gear sizes were not utilized because the vehicle was not designed for unusually steep inclines. The two other gears were removed and replaced with acrylic plates that help keep the chain on the single chainring as seen in figure 11.

Figure 11: Pedal Assembly

Chain Routing

To connect the pedal gear and rear wheel gear with a chain, the chain had to be routed around the rider. This is because the rider is positioned between the pedals and the rear wheel. To accomplish this, two sprockets were fixed beneath the frame and the chain was routed through these sprockets. One sprocket is located beneath the beginning of the pedal boom and the other is located just before the rear wheel. The layout of the chain route can be observed in figure 12.

Figure 12: Diagram of chain route

Figure 13 shows one of the two chain sprockets. The sprocket consists of a skateboard wheel and bolt. Two grooves are machined into the wheel where the chain runs through. This separates the two segments of chain that are moving in different directions.

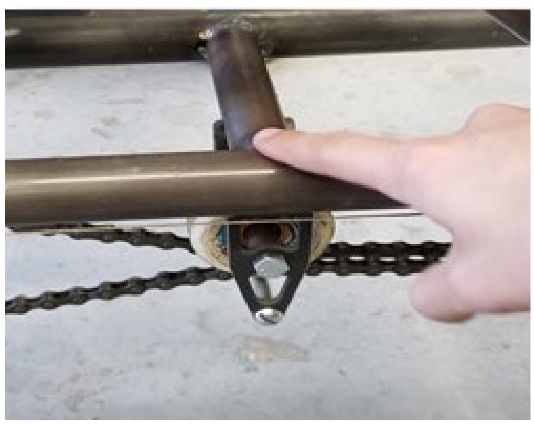

Figure 13: Skateboard wheel sprocket used to redirect chain

Derailleur

The derailleur is responsible for picking up any excess slack left in the chain as well as guiding the chain through the seven different gears. The derailleur is located to the right of the rear wheel and attaches to the frame as seen in figure 14. A cable extends from the derailleur all the way to the shifter located on the right handlebar assembly. The cable is guided through small notches along the length of the frame.

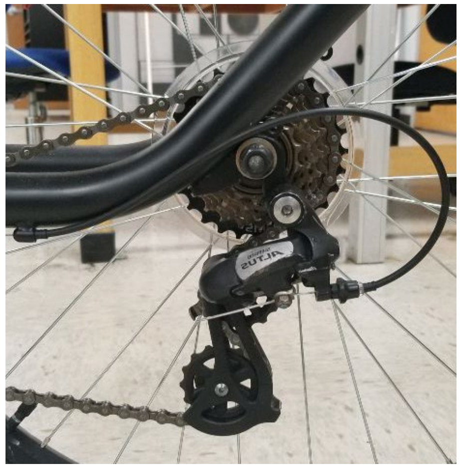

Figure 14: Derailleur assembly

Gear Shifter

The gear shifter is responsible for applying tension to the cable that actuates the derailleur which consequently moves the chain through the seven gears. The shifter is located at the bottom of the right handlebar assembly as seen in figure 15.

Figure 15: Gear shifter

Safety

Seat/Restraints

The vehicle possesses a 5-point restraint harness. This harness is used to ensure the rider is safely attached to the seat and will not be ejected in the event of a crash. Two restraints pass over each of the rider's shoulders, one attaches from between the rider's legs, and an additional is wrapped from the right and left of the rider's pelvis. A buckle locks each of the belts together at a single point on the rider's pelvis.

Figure 16: Four-point restraint harness

The seat is fixed in place at the bottom with three levered bolts that pass through a bracket on the seat and a square tube welded to the bottom of the frame. The back rest is fixed in place using eight bolts and nuts that secure the backrest to the frame.

Roll Protection System

The roll protection system of the vehicle is integrated into the frame. The rider's head is protected using a continuous hoop and the rider's shoulders are protected by a crossbar. These features can be seen in figure 17. The roll protection system is required by the competition to prevent severe injury of the rider's upper body in the event of a rollover.

Figure 17: Roll Protection System (RPS)

3 Integration

Steering

Handles

The handle bars were a combination of 1-inch steel tubing welded to cut pieces of a BMX bike handle bar. They were clamped into the stems that are attached to the kingpin axis via the stem. The stem has bolts on one end that can be tightened around the end of the handlebars to fix them in place. The brake levers are slid onto the handle bars followed by the rubber grips, and gear shifter for the right-hand side of the rider. The layout of the handlebars can be seen in figure 18.

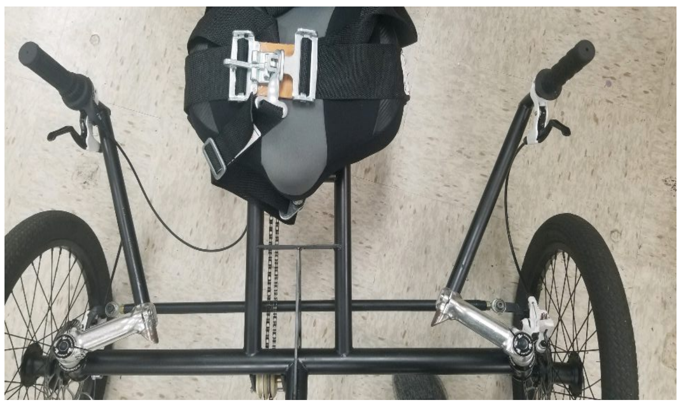

Figure 18: Steering Integration

Kingpin Axis

The kingpin axis houses the stems, spacer, headset, and steering knuckle. The headset tightens everything into place while still being able to rotate about the axis. The spacers were placed to provide elevation to the handlebars. The steering knuckle is fitted inside the entire assembly and provides attachment points for the front wheels. This assembly can be seen in figure 19. The inclination angle was made to account for the design of steering knuckles also having an incline.

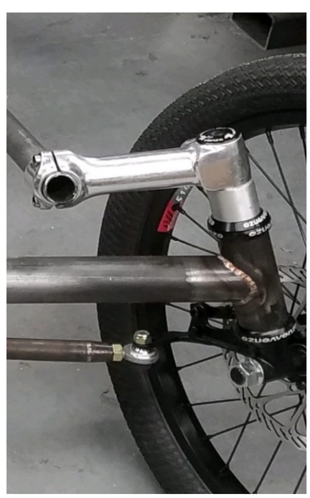

Figure 19: Kingpin Integration

Front Wheels

The front wheels are in position by an axle fitting through the steering knuckles and fixed in place with a nut and bolt as seen in figure 20. The wheels are connected with a tie rod that extends across the vehicle to both steering knuckles. The steering knuckles and tie rod are connected with a bearing and bolt.

Figure 20: Front Wheel Integration

Braking

Disc Brakes

The disc brake rotors should be bolted onto the inside of the front wheels. The brake calipers are bolted onto the steering knuckles. The brake rotor should pass in between the pads of the brake caliper but should not contact the brake pads. The brake cable passes through the whole in the brake caliper and under a bolt as shown in figure 21. The bolt should be tightened onto the cable with the cable tensioned.

Figure 21: Disc Brake Integration

Brake Levers

The brake levers can be slip onto the handles before the grips and gear shifter in the orientation shown in figure 22. The brake levers should face in the direction of the front of the vehicle. Once this orientation is achieved the screw on the clamp can be tightened around the handlebar. The end of the brake line should then be attached to the lever and tightened to the desired tension.

Figure 22: Brake Lever Integration

Powertrain

Pedals

The pedals are threaded into place using a specific tool/key provided by the FSU machine shop. This assembly can be seen in figure 23.

Figure 23: Pedal Integration

Chain Routing

Mounts were fabricated in house in the FSU Machine shop to hold skateboard wheels that redirect the chain. The skateboard wheels had 2 channels grooved into them to allow the chain to be spaced properly. Screws were used to hold the skateboard wheels and chain into place while providing a little slack. The integration of this can be seen in figure 24.

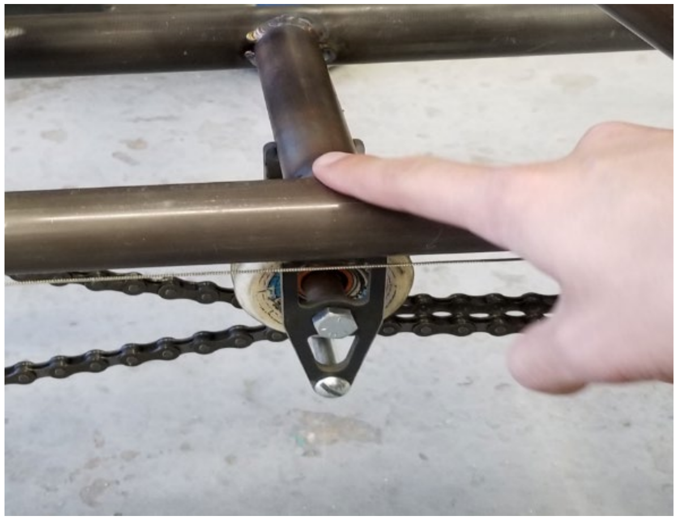

Figure 24: Chain Integration

Derailleur

The derailleur is attached to one of the dropouts of the rear wheel using a single bolt as seen in figure 25. This will be able to pick up the slack created from the chain routing.

Figure 25: Derailleur Integration

Rear Wheel

The rear wheel is attached to the frame through a single nut and bolt through two drop outs as seen in figure 26. The chain should be attached to the seven gear transmission before mounting onto the frame.

Figure 26: Rear Wheel Integration

Gear Shifter

The gear shifter is installed by sliding it onto the right handle after the brake lever is fixed. The numbers on the gear shifter should face the rider. The single bolt on the shifter can then be tightened to fix the shifter in place. The derailleur cable that extends from the shifter can then be guided through the notches on the bottom of the frame to the derailleur near the rear wheel. The cable passes through a hole in the derailleur and underneath a bolt that is tightened onto the cable.

Figure 27: Gear Shifter Integration

Safety

Restraints

The four-point safety harness was integrated by welding the harness brackets (black) directly onto the frame. The brackets that attach the actual belt of the harness (silver) were attached with a bolt that goes through both brackets and are secured with a nut. These are located at four points on the vehicle. These restraint attachment points can be seen in figure 28.

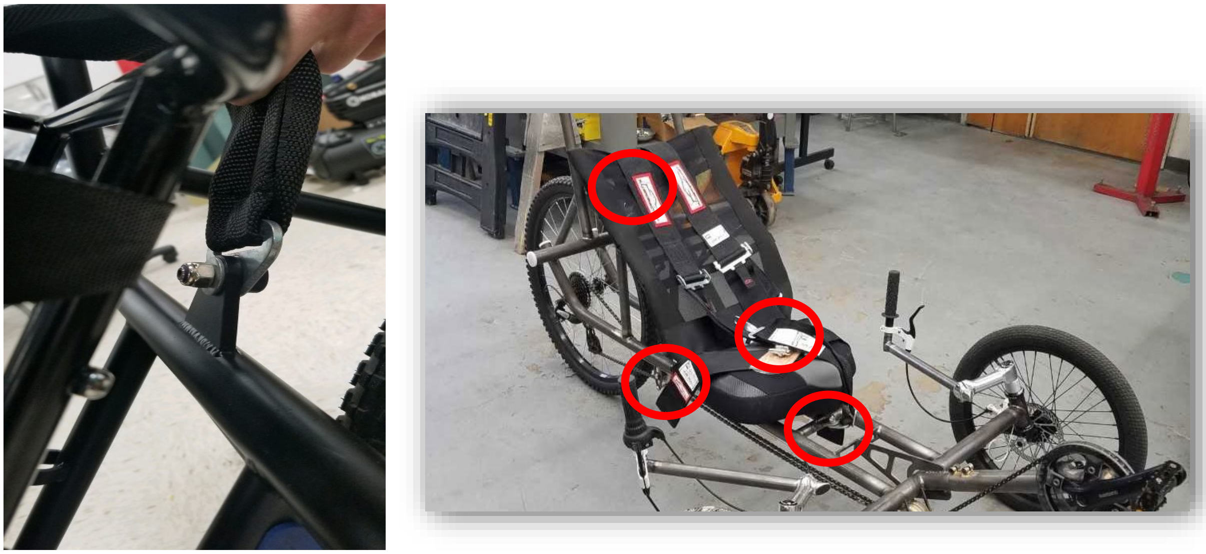

Figure 28: Restraint attachment point and locations

Roll Protection

The RPS was integrated when fabricating the frame. First, the shoulder height bar (horizontal bar the sticks at both sides) was welded onto the middle part of the frame that contains the linkages for the seat. Then the continuous hoop that protects the rider's head was welded onto the horizontal bar. An additional piece of metal tubing was then welded from just above where the shoulder height metal tube meets the continuous hoop to section that bends up (near the rear mountain bike tire).

Figure 29: RPS Integration

Seat

The seat was attached via a piece of 1-inch square tube, that was welded to the bottom part of the frame under the seat, that has holes to match the existing bracket on the bottom of the seat. The seat was attached (on the bottom) via quick release clamps. Posts with drilled and tapped holes were welded on the slanted part of the frame (behind the seat) and linkages were made to connect the mounting points from the chair to the posts on the frame. The seat is fixed to these linkages using eight bolts and nuts that can be adjusted with an Allen key.

Figure 30: Seat Integration

4 Operation

Setting up the Vehicle

Restraints

To be restrained properly, allow for slack in the belt while trying to be secured. Maintain a comfortable seating position while trying to restrain yourself. Make sure the locking mechanism is unlocked (the latch is undone) then go from left to right. Grab the belt to the left of you, then insert the left shoulder strap, middle (between the legs) strap, right shoulder strap, and then secure it all into the buckle on the belt to the right of you. Once all the buckles are in the buckle, push the latch down to secure the buckles in place. Figure x shows how the buckles should be connected. Finally, tighten all of the belts as much as you can without it being uncomfortable.

Figure 31: Restraint buckle assembly

Pedal Boom

If the pedal boom is not at the desired length, loosen the two bolts at the base of the boom. After this, slide the pedal boom in or out to the desired length. Ensure the pedal rotational axis is parallel with the ground and tighten the bolts.

Handles

If handles are not aligned properly, loosen the bolts on the stem connected at the top of the headtube (kingpin axis). Then rotate the stem until the handle is in the desired position. Finally, tighten the bolts again securely.

Propelling the Vehicle

Accelerating

To begin moving, place feet on the pedals and rotate the right pedal in the clockwise direction. If enough leverage cannot be achieved rotate the pedals backwards to a desired position and begin pedaling. To move faster apply more force to the pedals and to move slower apply less force. Be sure not to accelerate to uncomfortable speeds in congested areas because this may increase your chance of colliding with obstacles.

Shifting Gears

To shift gears, the vehicle must be in motion. To shift to a higher gear, rotate the shifter clockwise while pedaling and to shift down rotate the shifter counterclockwise. Be careful not to rotate the shifter passed its extreme positions because this may damage it. Also, it is advised that you shift only one gear at a time to prevent the chain from slipping off the rear wheel gears.

Steering

The vehicle can be steered by moving the handles left and right. To turn the vehicle right push the handles left and to turn the vehicle left push the handles to the right. Be careful when turning at higher speeds because the vehicle is subject to flipping on its side when making sharp turns. It is recommended that the brakes be applied before turning and that the rider lean into their turns to maintain control.

Braking

To slow the vehicle down the brake levers on the handles should be pulled toward the handle (squeezed). This will tension the brake calipers around the rotors fixed to the wheel. It is recommended that both levers be pulled equally to ensure complete control of the vehicle is maintained. Differential braking can be utilized to make sharper turns for expert riders. Be careful when pulling the brake levers at high speeds because the rider may lock up the brakes and cause the vehicle to skid uncontrollably. Light to medium pressure should be applied when trying to stop and the vehicle is in motion.

5 Troubleshooting

Brake rotor rubbing against brake caliper:

The brake caliper can be adjusted using an Allen wrench. There is a small screw located on the side of the brake caliper that will tighten one of the brake pads. Adjust the position of the caliper until the brake pads are centered and then adjust the screw accordingly.

Pedal boom is loose:

Realign the pedal boom and tighten the two bolts located at the bottom of the pedal boom using an Allen wrench.

Brake cables are loose:

Loosen the screw on the brake caliper that presses down on the brake cable. Pull the cable to the desired tension while tightening the screw.

Wheels are flat:

Use a standard bicycle pump and attach the pump nozzle to the tire tube nozzle. Make sure the nozzle is secured and begin pumping to the desired pressure. Recommended tire pressure is 30 – 40 Psi.

Seat is loose:

Tighten the three levered bolts located under the seat as well as the eight bolts behind the back rest. An Allen key is required to tighten the bolts behind the back rest.