E-Baja Conversion Team

Operation and Assembly

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1. Disclaimer

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions. Furthermore, the project was cut about four weeks short due to the COVID-19 pandemic. The final parts of this project were not completed. Sections of this intended report were either omitted or theorized.

2. Vehicle Overview

The vehicle that has been created is a highly advanced off-road automobile that is powered solely using electricity. The vehicle has been designed by a team of 5 mechanical engineers (ME) and 4 electrical engineers (EE). The car uses a 23 hp motor to power both of the rear wheels together. The car was started with the use of the frame from a previously built gas-powered vehicle. Using the frame, the team reverse engineered the car to upgrade old components and add new components. The vehicle did not get completely finished due to the loss of access to the car and the shop that was used to fabricate parts. The following manual goes over how to operate the car and the components on the car. Also included in this manual is how to completely build the car as if the team was doing it themselves.

3. Safety Equipment
The car is equipped with several different items to keep the driver safe during the operation of the car. Without these items it would greatly increase the chance for the driver to get hurt while driving.

3.1. Seat
The seat is used to keep the driver in the middle of the vehicle. Without the seat, the driver would not have a place to be secured in at. The seat locates the person in the middle of the car so that they don't get hurt if the car rolls during driving.

3.2. Harness
The driver harness must be attached to five different points of the vehicle. There must be two shoulder attachments, two lap attachments and at least one submarine attachment. The submarine attachment will prevent the driver from sliding from under the lap belt. All the attachment points must then connect into one buckle, creating a safe web for the driver.

3.3. Firewall
The firewall separates the cockpit from the motor and batteries. It must be electrically insulated and in accordance with UL94-V0 or FAR25. This means it will be a plastic sheet that must be at least .02in thick.

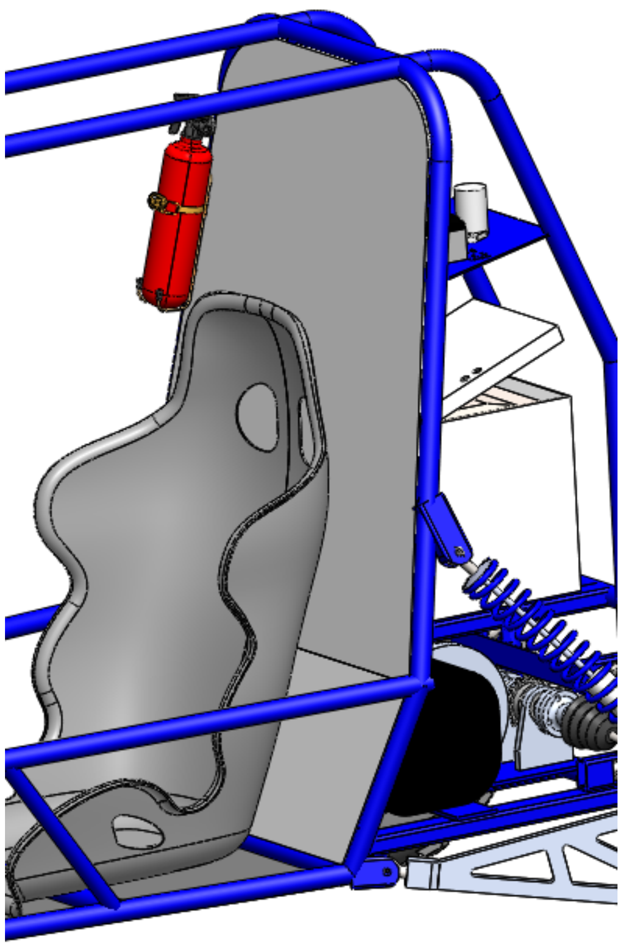

Figure 1. Firewall

3.4. Fire Extinguisher

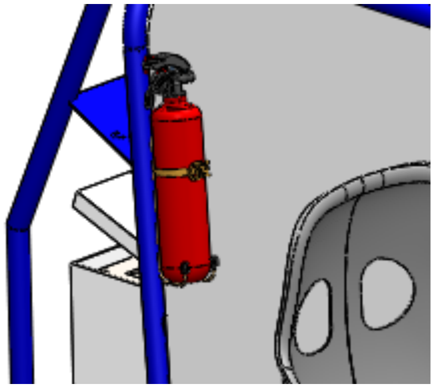

Figure 2. Fire extinguisher

Fire extinguisher of class D is used for electrical fires. Mostly sold in 30lb quantities in any online fire safety store to prevent the spread of electrical fires in case of catastrophic failure in the electrical components during operation.

4. Vehicle Operations

There are several parts to the vehicle that each play a vital role in the operation of the car. These components all together ensure that the car can operate at maximum performance. These items are all connected using various methods to the frame of the car. Without even one of these subcomponents, the vehicle would not run properly.

4.1. Car Frame

The car frame is the base to the entire system. All of the other components that make the car run and drive properly are attached to the frame. The frame also plays a crucial part in making sure the driver stays safe while driving. The frame acts as a cage that protects the driver if the car crashes or rolls during operation. A strong frame is required when building and designing the car. All suspension and drive systems are connected to the car.

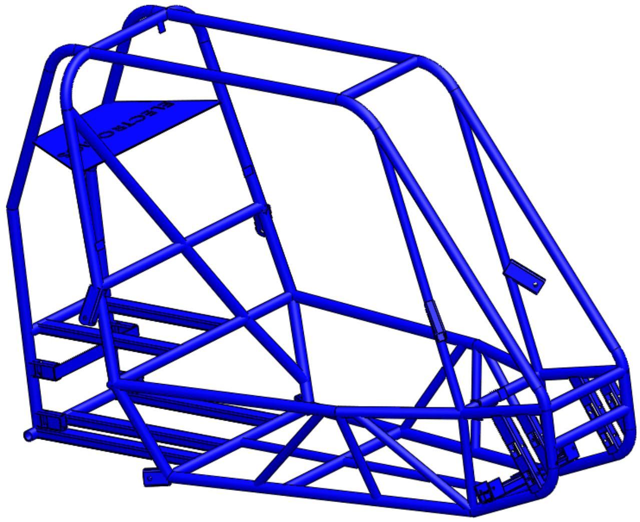

Figure 3. Car frame

4.2. Front Suspension

The front suspension helps to keep the wheels in contact with the road. One of the main components in the front suspension is the stabilizer because it makes the wheels more stable with the road. Also, the sway bar in the front suspension helps with transferring the movement of the wheels when the car is not going on s straight road (off-roading). Moreover, The A-arm helps with having a more powerful suspension. Lastly, we have the heim joints which holds the front suspension and helps with locating the wheels if one of the wheels is not on the ground which make it more safe for the driver.

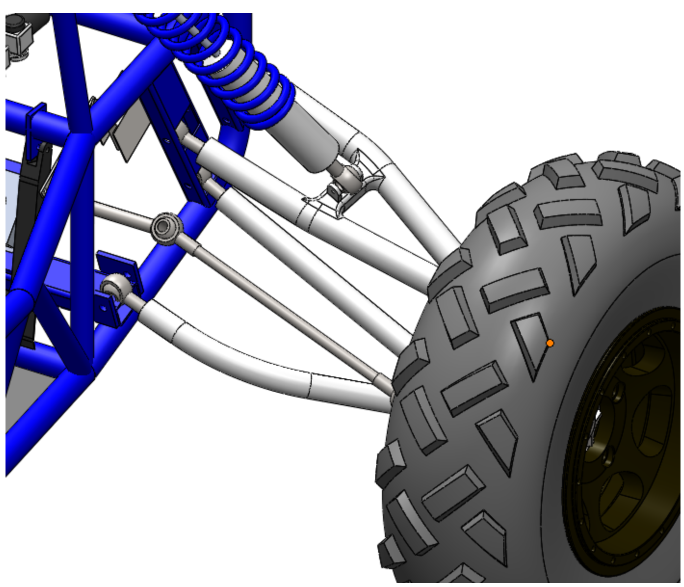

Figure 4. Front suspension

4.3. Rear Suspension

The rear suspension consists of four components which bring together the frame and the wheel. The five components are the supports, the trailing arm, the hub link, and the shock.

4.3.1. Supports

The supports are attached to the frame via female heim joints. This makes them into a hinge which can move in the Z direction. The heims are then connected to a metal bar that leads to another heim joint on a bolt. This part is connected to the top part of the rear hub. The second support is the same except smaller. below the top support bracket in parallel fashion. The second support bracket connects to the bottom of the rear hub. These supports must be sure to not interrupt the drive lines or wheel.

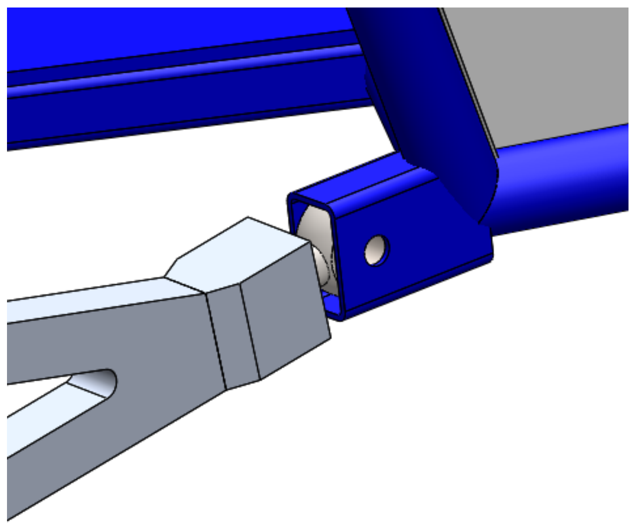

Figure 5. Trailing arm connection

4.3.2. Trailing Arm

The trailing arms also connect the frame to the wheel and allow for impact to be absorbed into the shock. The trailing arm is connected to the frame via a male ____ heim ball joint on a bolt between two metal plates. This heim is inserted into the trailing arm. The trailing arm then runs to the rear hub link where it is connected with bolts. The shock connects to the trailing arm on top with two metal plates on either side and a bolt to hold the shock in place.

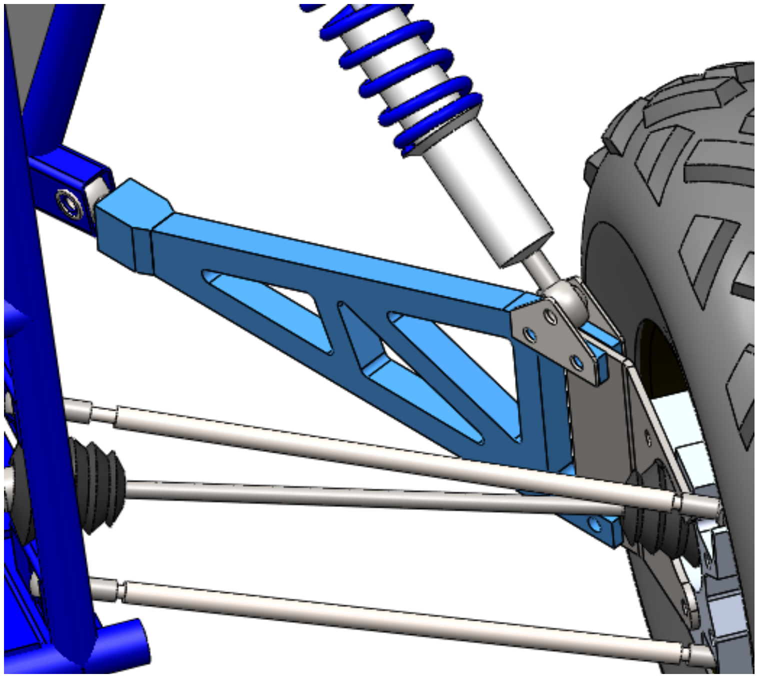

Figure 6. Trailing arm

4.3.3. Hub Link

The hub link is a metal plate that connects to the rear hub by forming around the drive line entry point and attaching to the hub with four bolts. Then the other end inserts between two plates (on top and bottom) then bolted in to attach on the trailing arm. This part cannot interfere with the drive line or the supports.

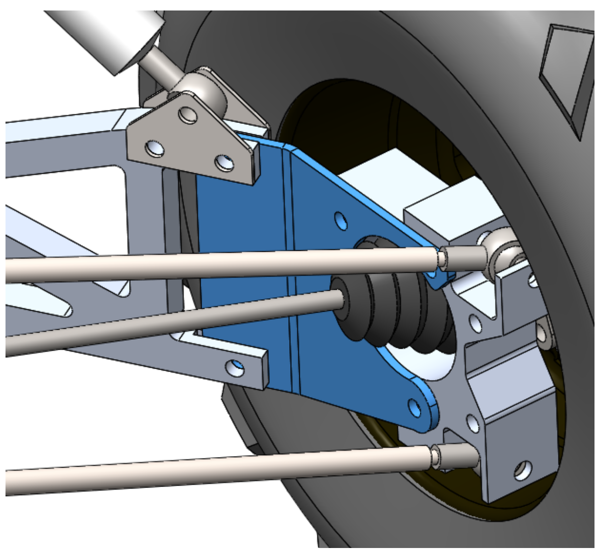

Figure 7. Trailing arm hub link

4.3.4. Shock

The shock is another connection to the frame. The frame has a metal, hollow, and protruding square where the top of the shock is bolted into. The bottom of the shock is connected similarly onto the trailing arm. Two metal plates bolted onto the trailing arm is where the shock is inserted and bolted in.

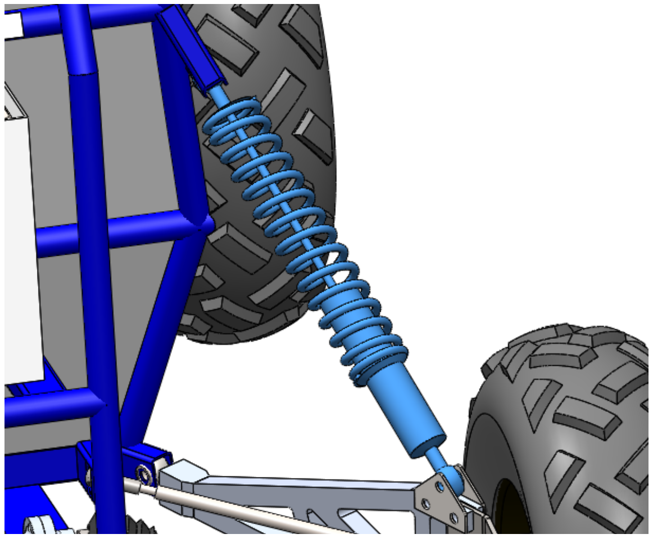
Figure 8. Shock

4.4. Steering

The steering controls the direction the car should turn. The steering components consist of the steering wheel which is connected to the frame of the car and mounts towards the driver for control. The steering wheel turns steering shaft, rotating the pinion gear connected to the steering rack. The steering rack moves side to side pulling and pushing the tie rods, causing the tires to rotate about an axis on the steering knuckle. In between the tie rods and steering knuckles, is a steering link producing an ideal Ackermann angle for smoother turning. The steering knuckle is connected to the front suspension A-arms for stability.

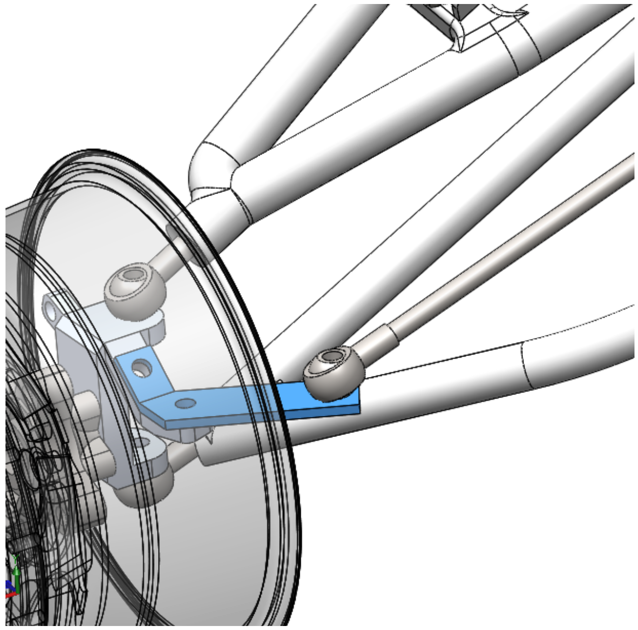

Figure 9. Steering hub link

4.5. Throttle

The throttle was provided to us from the EE team. This throttle will be controlled using the foot of the driver and is used to control the acceleration of the vehicle. The electronic throttle is a potentiometer that controls how fast the motor spins. The throttle switch is wired directly to the motor controller which is what controls the output voltage from the battery to the motor.

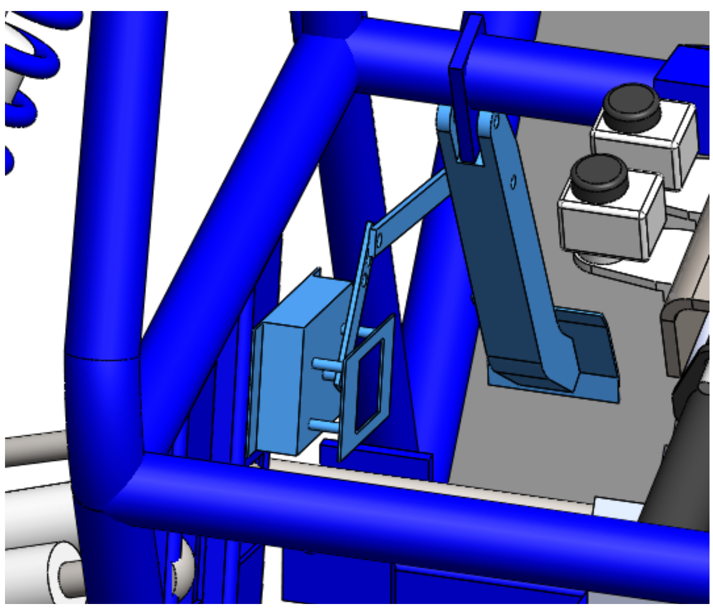

Figure 10. Throttle system

4.6. Brakes

The brakes are connected to the hubs of each wheel. The brakes are used to stop the vehicle when coming up on an obstacle or just to slow the vehicle down when coming to a stop. The brake system is connected to the brake pedal which is controlled by the foot of the driver. Once the brake pedal is pressed, it activates the brake cylinders which close the brake calipers resulting in the car slowing down. The brake cylinders are located, one on each hub for maximum stopping power. The brake system in the back will not be utilized as much as the motors in the front as the motor will do a lot of the braking on the back wheels.

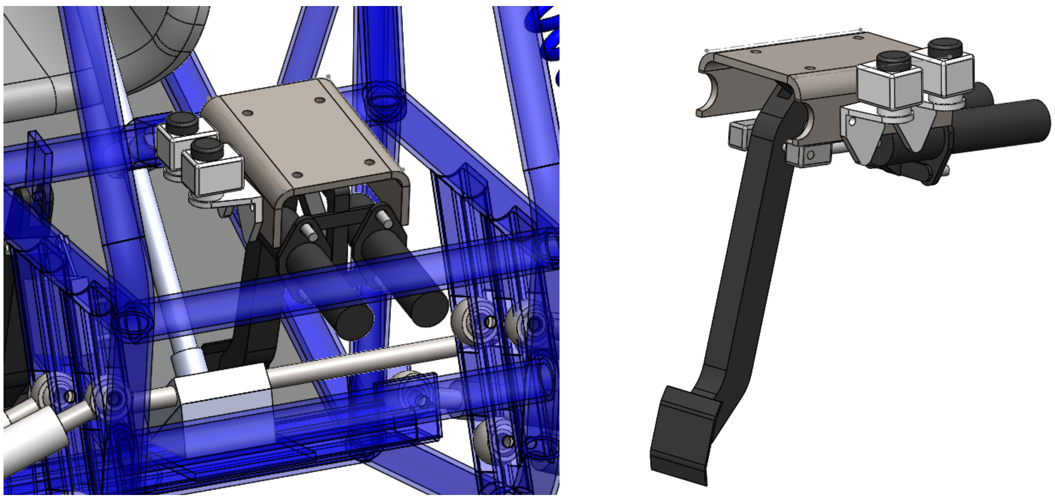

Figure 11. Brake system

4.7. Motor

The motor is located at the back of the car and is attached to the frame of the vehicle. The motor is where all of the power comes from that drives the car. The motor is directly connected to the gearbox which turns the wheels. The motor is also connected to the motor controller and other electronics provided by the EE team. The motor controller is connected to the battery which sends current to the battery to drive the car.

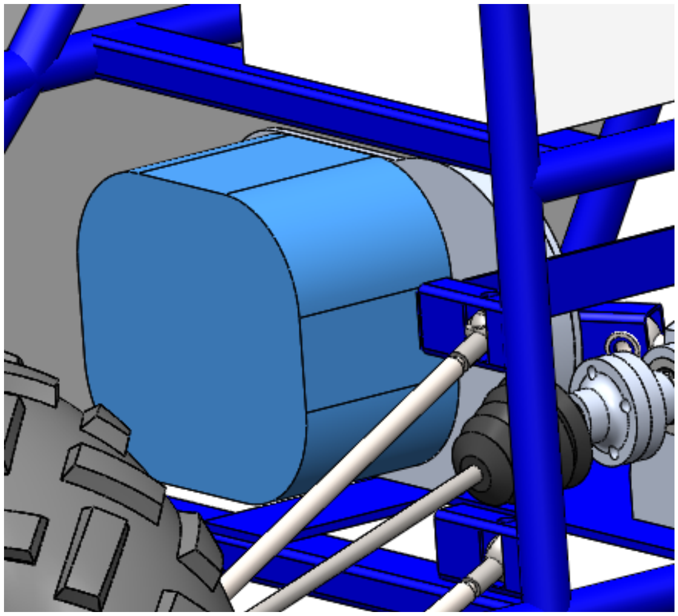

Figure 12. Motor

4.8. Battery

The battery is attached to the rear of the vehicle. The battery is one of the heaviest parts on the vehicle which is why it is located in the rear. The car is designed to have more weight in the back to help with controlling the vehicle. The batteries are attached to a drawer slide allowing the battery box to slide in and out of the car. This allows for easy removal by the EE team when it is time to charge the battery. The battery is also installed inside of a watertight case that keeps the external elements found while driving to hit the sensitive electronics. The battery is connected to electronic components provided by the EE team that control the battery and receive signal from the throttle.

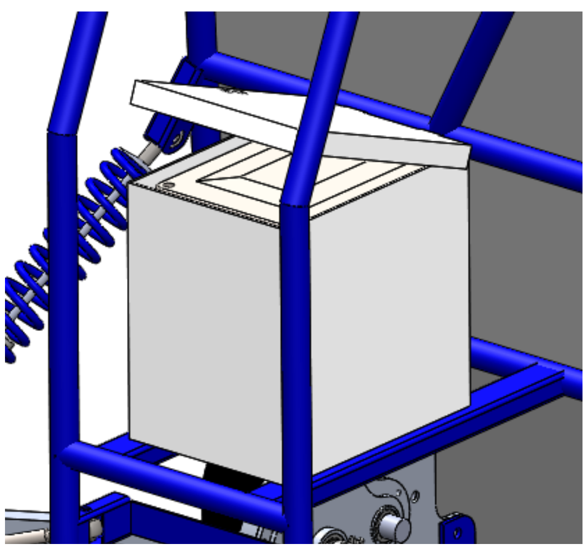

Figure 13. Battery bank

4.9. Gearbox

The gearbox is a major component that connects the motor to the rest of the drive system. The gearbox is used to step down the rotations of the motor into more power to drive the car. The gearbox is bolted directly to the motor and is also attached to the frame. The gearbox is what is used to fasten the motor to the car. The gearbox drives another sprocket in a set of bearing blocks which is attached to the CV axles. Once the motor rotates in the gearbox, it drives the CV axles which turn the rear wheels of the car.

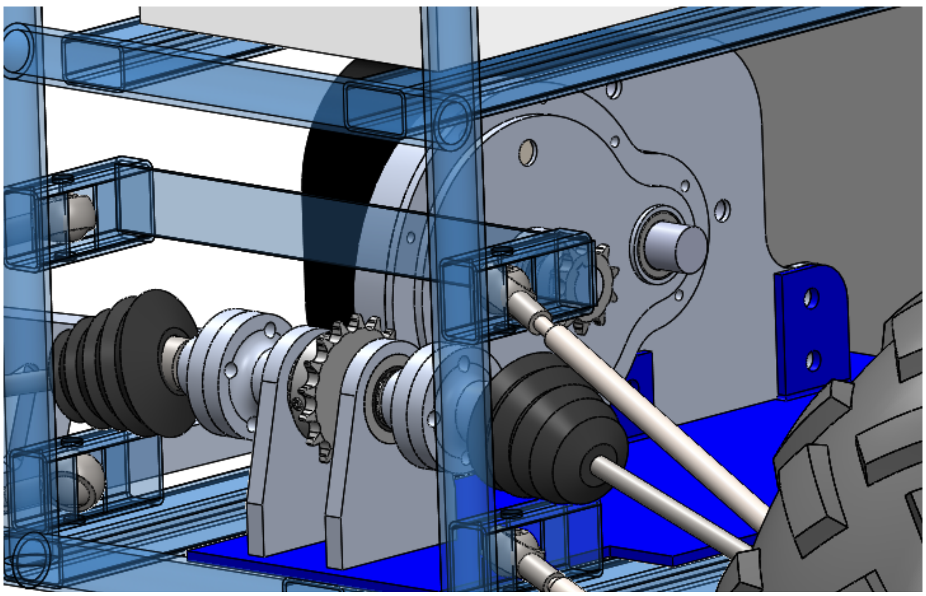

Figure 14. Gearbox

5. Assembly/Disassembly

There were several methods that were used to manufacture parts for the car. One of the main ways that parts were made was with a hand grinder. Due to the lack of proper steel cutting machinery at the machine shop, the team had to resort to handle tools to create their parts. When attaching parts to the car, most of the brackets were made out of steel and were welded on to the frame of the vehicle.

5.1. Car Frame

There is no additional assembly required to the car frame. The car frame was required to have minor changes done to it to match up with new designs and remove old parts. There were several brackets removed using an angle grinder. These brackets were used in the old design to hold the gas engine and certain components that were no longer being used by the Electric Baja Team. There were no other support members added to the frame by the EBaja team. The team used all the old support members for any components added.

5.2. Front Suspension

The team did disassemble the front suspension to start manufacture it. The team decided to use the old suspension and change the heims and bolts to avoid the snapping on the car. The old heims size were Hm6 and the team will replace it with Hm8 heims on the top and Hm10 rod ends on the bottom. The heims were bought from Homeco and we took the bolts from Copper sate. First, the team did drill the old arms and used the tapping tool to tap it in the machine shop to fit the new heims. Then, we did some grinding on the car to make the suspension flat and cut the steel that we will use before welding. The size of the steel that we will weld on the front was 3x2inch and the holes diameter was 0.5 inches for the top and 0.625 inches for the bottom arms. After that, the team did some welding in the machine shop for the steel that cut to place the new heims and bolts. Lastly, the team did assemble the front suspension after finishing from manufacturing the parts.

5.3. Rear Suspension

The rear suspension consists of three main parts. First the trailing arm. The trailing arm is made of 6061 T6 Aluminum. The trailing arm will have a series HMX, size 12G heim screwed in the bottom of the trailing arm. The heims will attach to frame. Second, the rear attachment. The rear attachment will angle the trailing arm towards the wheel hub the angle is 30 degrees. Then the attachments will correctly fasten by a 9/16 in screws to the wheel hub. The attachments are made by bending steel sheet metals by a hydraulic press then for precision will use the mill to drill the 9/16 in holes and do the C cut on it. The rear suspension system will require one avocado (2 C shaped metals attached to a screw) on each side to attach the heims that are installed to the trailing arm to the frame. The length of the heim-avocado connection should be 4 inches from the center. Third the two stabilizers. The stabilizers are two rods with a diameter of ½ inch and a length of 18.75 inches. They need to be parallel to each other they will be extended from the back of the vehicle and fastened to the wheel hub using an 0.5 in screws. The stabilizers will control the wheels camber at a maximum of ±5 degrees.

5.4. Steering

The steering components were reused from the original parts, the steering wheel, steering shaft, rack and pinion, tie rods, steering knuckle, heim joints, and bolts. The steering link was designed and made by the team, manufactured using a ¼ inch sheet metal. The sheet metal was cut with a grinder, 5/8 inch holes were made on the drill press, and bend on the hydraulic press to 45 degrees in the middle. The steering knuckles are connected to the lower heim joints on the front suspension's A-arms. The steering links are connected to the steering knuckle by bolts and connected to heim joints on the tie rods. The other end of the tie rod connects to the steering rack, the rack fits with a pinion gear in its on assembly. The rack and pinion assembly connects to the steering shaft, which is mounted to the steering wheel.

5.5. Throttle

The throttle was provided to the ME team from the EE team. The only part that the ME team had to deal with was how to activate it. The team had to install a pedal that would attach to the throttle. This throttle pedal was never installed on the vehicle. The pedal was going to be attached to the same member as the brake pedal. The throttle was going to be attached behind the pedal and was going to be attached using a link. The throttle was spring loaded which would return the pedal to the original position when force was taken off the pedal. There were two minor brackets that needed to be welded to the frame to mount the pedal. These mounts would hold the pedal and be routed back to the throttle.

5.6. Brakes

The braking system was mostly attached to the vehicle. The team mounted the bracket to the vehicle prior to the lockdown. The team had also purchased all of the required components for the braking system at the start of the semester. All of these components were bought from "Wilwood Brake Components" online. This mount had all components on it that needed to run brake the car. The only part that needed to be done on the brakes was attach the rear hubs (which already had brakes on them) and attach lines to each of the calipers. The team had brake fluid lines on order to install on the car once they got back from spring break. The team simply had to attach the lines from the front master cylinders and run them to each of the brake calipers. The rear lines were going to run along the frame and the trailing arm to the brake calipers. The front brake lines were going to run along the front A-arm to the front calipers. Once the lines were attached, fluid could be added to the reservoirs. With the fluid in the reservoirs, the lines needed to be "bled". This process simply takes the air out of the lines which allows for maximum force when the brake pedal is pressed. The braking system would be complete after the lines were bled.

5.7. Motor

The motor was provided to the team from the EE team. This motor was bought online from a Go-kart company. It was a 23 hp motor that was more than enough power for the car. This motor came with holes in it already for easy mounting.

The motor only had to be mounted to the gearbox. Once the motor was mounted, the car would be ready to drive. The only part that needed to be done with the motor once it was mounted was to be wired up. This was to be done by the EE team. The gearbox has holes pre-machined into the face and a grove to locate the motor mount which allows for easy mounting of the motor. There were three bolts to install into the face of the motor to hold it and the motor shaft just slide right into the gearbox.

5.8. Battery

The battery that was to be used on the car was provided by the EE team and was composed of ten power cells from a Nissan Leaf. This battery pack put out about 78 volts which was exactly what was needed to run the motor at top rotational speed.

The battery was almost ready to be mounted on to the vehicle. There were a few tasks that needed to be done to get the battery mounted. The first part that needed to be done was for a watertight case to be created. This case was going to be created using plastic sheeting and then rubber seals to keep water out. The only requirement for the battery box is that it needs two outlet holes for power cables to come out of the case to charge the battery and connect to the motor. This case was going to use weather stripping and silicone caulking to seal up the box. Angle iron with bolts was going to be used to hold the plastic sheets together. The top of the box will have a hinge on it, allowing for access to the battery if needed.

The bottom of the battery case would be attached to two slides which are connected to the car frame. These slides make it easy for the battery to slide in an out of the car. The EE team needs easy access to the battery for removal in order to charge it after each use. These slides would lock into place using a bolt that goes into the frame of the car to the slides.

5.9. Gearbox

There were several components on the gearbox that still had to be created in order to complete the gearbox. The gearbox was designed from scratch and was going to be machined by a local machine shop. The gearbox needed to have a gear ratio of about 6.5:1 in order to get the right amount of torque and speed that the team needed.

The gearbox was designed using gears from the previous gearbox that was already on the car. Using the old gears, it saved the team money and made the design simpler. These gears did require some adjustments on the hubs in order for them to work properly with the new car. The pinion gear needed to have the bore expanded from 1 in to 1.125 inches to fit on the motor. This process was to be done on the lathe using a boring bar. Once the bore was enlarged, a broach was to be used to create a keyway to mesh with the motor. The larger gear had an extremely large hub that was designed to have a custom hub created to match whatever was needed. The hub was designed in SolidWorks and needed to be cut out using a CNC Mill. This was going to be created at the same time as the rest of the gearbox. With this hub created, it simply needed to be bolted to the gear and the gears were ready to be installed in the gearbox once it was created.

The gearbox itself was ready to be machined. The case was designed SolidWorks and was started to be machined before the lockdown happened. The case was going to be machined out of 1” thick Aluminum plate. Both sides of the gearbox were going to be machined on a CNC Mill at a local machine shop. Once the two sides of the case were machined, it simply needed to be assembled. Using 1/4-20 bolts, the case could be bolted together. With the gears inside and the motor attached, the bolts could all be put in. Lastly, oil could be poured into the case through the inlet hole and plugged with a pipe screw.

The last part of the gearbox that needed to be created was the bearing blocks for the sprocket and CV axles. The bearing blocks were to be machined out of 1/2” Aluminum plating. The bearings would then be pressed in with the shaft running through the bearings and the sprocket. The CV axle hubs would then be attached to the shaft which would drive the rear wheels.

The gearbox could then be mounted to the rear of the car. There were mounts that needed to be welded to the frame. The mounts were going to be “L” brackets that the case could be bolted to. The brackets were going to be 1/4“ thick steel brackets because they were going to be holding a lot of force from the motor. With these brackets welded on, the motor could be attached using bolts. The bearing block could be attached to rear of the car as well. The bearing block was going to be mount about 6 inches away from the gearbox. This aligned the CV axles parallel to gain the most amount of torque and proper travel. The two sprockets are attached with a chain that was not purchased yet. The team was waiting to see approximately how long was needed before purchasing. This chain could then be mounted to the two sprockets which would result in the gearbox being fully complete.

6. Maintenance

The car was not designed to last for a long time but for a few high-performance drives. Due to this, there are not a lot of areas on the car that are in need of maintenance. What this does mean though is that a lot of the parts are not made for longevity so they may need replacing after a given amount of driving. There are also certain areas, due to the driving that was going to be done by the car, was designed with a higher factor of safety than the client asked. This makes it so that the car will handle hard terrain better.

6.1. Troubleshooting

The throttle, motor and battery are the only components of the car that would need troubleshooting, due to the amount electrical parts within these components. The ME team was not in charge of these components, for troubleshooting the throttle, motor and battery, look for the Operation Manual from the E-Baja EE team.

6.2. Potential Failures

The trailing arm will break when is impacted in a T-bone position by another vehicle. If the trailing arm will fail and will have to be replaced then best source of replacement is sending the part drawing from Solidworks to Marzee Waterjet services in Phoenix, Arizona. The part costs $100 for both to manufacture.

The steering link will bend when hit from the front of the car into the wheel with a force of 1,000 lbs. This will cause the steering to be out of alignment and the car will not turn proper. The steering link part can be remade out of metal material to have a better quality and to last longer.

The heims joints on the front suspension may bend if the load exceeds more than 9500 lbf. This will result of losing the linkage between the suspension and the A-arms. If that happened, the A-arms can be re-installed with the suspension and buying stronger heims which can hold out the total load.