MAE 4291: 3 Credit Senior Design – Spring 2021

Final Report: Electric Motorcycle

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1 Introduction

To fulfill the senior design requirement for Mechanical Engineering students, we designed and built an electric motorcycle under the supervision of Professor Andy Ruina. This report is intended to document and justify our design process, and serve as a tentative guide for those interested in building their own electric motorcycle. A link to the final product videos can be found in the appendix, subsection 10.1.

2 Project Objective

Our project objective was to design and build a high-performance electric motorcycle that is appealing to a new demographic through its performance and ease of use. This student motivated project is independent, and we set out to built something that works. Building something that works requires all of the trial and error, hypothesis testing, and generalized problem solving methods of scientific research - learning was a central objective of the project.

We set out to install an electrical powertrain into the frame of an existing gas-powered motorcycle. We anticipated the main work to be in sizing, selecting and fitting together the various components which were not designed to work together. This necessarily involved many calculations, including optimizations, as well as various trial and error experiments with the dozens of design choices.

3 Project Constraints

3.1 Cost

Being mostly a self-funded project, we wanted to constrain ourselves on the total cost of the electric motorcycle. Additionally, we felt that adding a cost constraint would help guide some of our design decisions and also make the project more enticing to future students interesting in pursuing a similar project. The total cost target that we set for the entire electric motorcycle was $1000. This figure of course excludes the labor cost that would normally be associated with hiring a design engineer or machinist to design, build and assemble the product.

3.2 Time

As mentioned in section 1, this project ultimately fulfills the senior design requirement for all Mechanical and Aerospace (MAE) students, and is a 3 credit course taken during the spring semester. Therefore time is a large constraint in the creation of this project as we only had the duration of the spring semester to build and assemble the entire electric motorcycle. As will be discussed later in the report, this caused component lead-time to be a deciding factor in some of our ultimate design choices. We did however, start working on the electric motorcycle during the fall semester to try to ensure that we would be able to jump right into the project in the spring. In the fall semester we acquired the donor gas-powered motorcycle, began our frame ideation process, designing select parts as well as honing in on our desired performance metrics.

3.3 Ease of Use

Although we set out to build a high performance vehicle, we also wanted to keep usability in mind. Many people are apprehensive of typical motorcycles because they are loud, heavy, and relatively complicated. Our goal was for anyone to be able to get on the bike and intuitively know how to ride it.

In addition to using a different power source, electric motorcycles can have many benefits from a rider's perspective. There is currently a significant barrier to entry for potential motorcycle owners. Gas-powered motorcycles require routine maintenance, the ability to operate a manual transmission, and frequent handling of fuel. Electric motorcycles can appeal to new demographics that may be less mechanically inclined. When compared to the typical motorcycle controls (left hand clutch, right hand throttle and front brake, left foot shifter, right foot rear brake), electric motorcycles are very user friendly. They only require a throttle and two brakes, so anyone who has ridden a bicycle can pick up on it quickly. They also require minimal maintenance and can be significantly lighter than their internal combustion counterparts.

3.4 Tools

We were fortunate enough to have access to the Cornell University Baja garage throughout this project, although due to the mandated covid-19 shift system, we had to be very efficient with the time we had. We primarily made use of the garage to weld the new frame members onto the bike. The rest of the work was done in our apartment, and while we had to purchase a few specialty tools (chain breaker, electrical connectors, etc.), most of the project could be accomplished with basic tools we already had.

4 Project Overview

Our finalized electric motorcycle features a modified Suzuki GS450 with a cafe racer style frame, with a minimalist, modern design approach. It weighs approximately 185 pounds, sports dual shock rear suspension, and 33 mm air assisted forks for the front suspension. It is powered by a 3 kW brushless DC motor, and 6 12V 8Ah Absorbed Glass Mat batteries. The motor is controlled by a 24 Mosfet 50A Controller, and features forward and reverse functionalities in three different speeds. The motorcycle has newly installed hydraulic front brakes and has a 1.4 meter wheel base, and overall length of 2.07 meters. The entire project was completed using $928.53.

Figure 1: Completed Electric Motorcycle (Labelled)

5 Alternative Concepts Considered

Since Professor Ruina is very experienced in locomotion, dynamics and bicycles, we briefly considered converting a bicycle into an electric bicycle. We would have likely tried to pursue a stealth build for the added design challenge, by trying to fit all the components in the electric bicycle such that it would look like a normal bicycle at first glance. This could have been achieved by concealing a small motor in the downtube of the frame for example, which has actually been done by some professional cyclists, deemed "mechanical doping". Ultimately however, we decided that converting a gas powered motorcycle to an electric motorcycle would be more technically challenging and the final product would be something we would be more excited about.

Once we made the decision to electrify a motorcycle, we also considered different types of motorcycles, with the broad categories being dirt bikes, sport bikes, dual sport, and retro motorcycles. While we liked the aesthetics of a sport motorcycle, we felt that the design and culture associated with this type of motorcycle would require motor and battery performance metrics that we would simply not be able to afford. Building an electric dirt bike or dual sport bike would have been more feasible especially if we optimized for lower weight, but we felt that this type of bike with its more sensitive suspension would not satisfy our "ease of use" constraint. We felt that it might be slightly more intimidating for the average person. We eventually decided that a retro style motorcycle would lend itself well to electrification. For one, we thought that we would have a better chance of finding a cheap donor retro/cruiser motorcycle than some other motorcycle types. Additionally, we felt the generally open frame design of these types of motorcycles would allow us to make significant frame modifications and still have it fit with some of the existing motorcycle components.

6 Design and Fabrication Procedure

6.1 Donor Motorcycle

Choosing the donor motorcycle is a very important step in the procedure as it places broad constraints on the overall look and specifications of the final electric motorcycle. There is also a general trade-off to consider between price and functionality. Of course, anything related to the original engine in the donor motorcycle such as the engine itself, gas tank, etc. does not need to be functioning as it will be stripped. However, the better shape the rest of the motorcycle is in, the less restoring or repairing will have to be done. Our criteria for the donor motorcycle was anything under $500, with minimal damage and preferably a cafe racer style motorcycle, which are often known for their design minimalism and rear-set footrests. The best places to find a donor motorcycle are used or second hand product sites such as Facebook marketplace, eBay, or craigslist. We suggest browsing these sites frequently and remaining patient when looking for a donor motorcycle.

For our donor motorcycle, we purchased a 1980 Suzuki GS450 for $300, which had not run in many years but had functioning brakes and a fairly intact frame. The GS450 has a dry weight of 385 lbs, sports dual shock rear suspension, and 33 mm air assisted forks for the front suspension. It has a 1.4 meter wheel base, and overall length of 2.07 meters with a width of .72 meters [1] [2]. Figure 2 shows the donor motorcycle in the condition we purchased it. The seat was not attached, and the high-handle bars and clunky exhaust did not fit the style we had envisioned for our electric motorcycle.

Figure 2: Donor Motorcycle: Suzuki GS450

We began stripping the donor motorcycle, starting with removing any wiring related to the combustion engine, and removing the exhaust, fuel tank as well as engine (Figure 3). Stripping the motorcycle to its naked frame allowed us to quantify our dimensional constraints and give inspiration for possible frame design changes. Additionally, we removed the seat mounting plate (still present in Figure 3) which had been roughly welded on by the previous owner.

Figure 3: Removing exhaust, fuel tank and wiring

6.2 Motor

In selecting the right motor, the first broad choice we had to make was whether we wanted to use a brushed or a brushless DC motor. Brushed motors use a pair of carbon brushes to transfer DC power to the commutator of the armature, which creates an electromagnetic field, repelling the permanent magnets surrounding the wound armature (see Figure 4). This causes the armature to rotate, and as it rotates, the polarities of the rotor windings are constantly being reversed such that the armature continues to be repelled in such a way that it can continue rotating [3]. The commutation of the windings is done mechanically, meaning that brushed DC motors are much simpler and are thus cheaper. However, since the brushes and commutator are in constant physical contact with the shaft, more energy is lost to heat, and the lifespan of a BDC motor is reduced, and potential for motor maintenance is introduced. Brushless DC motors on the other hand do not have brushes and a mechanical commutator but instead use a controller to rotate the shaft. This means that in general, brushless motors tend to be more expensive, but are smaller and more efficient [4].

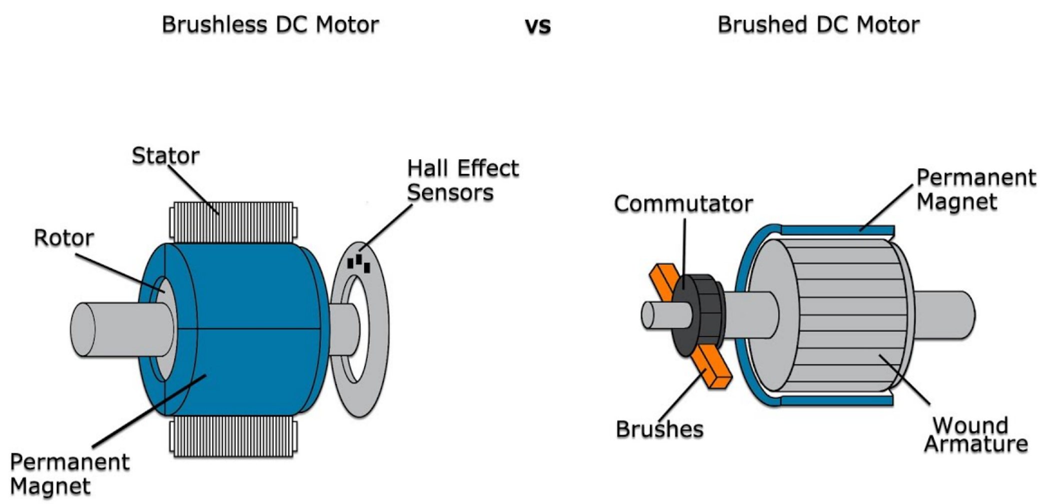

Figure 4: Brushless DC Motor versus Brushed DC Motor

Since the frame without the massive combustion engine and fuel tank leaves ample space, the size benefit associated with a brushless motor did not really factor into our motor selection decision. Additionally, both motors are capable of speed control and regenerative braking, although a brushless motor is likely to be more precise considering the sensors and controller associated with it are more complex. Our main criterion then was the efficiency of the motor, as well as ease of controller compatibility. Since we had originally planned to program the controller ourselves, we ultimately decided to select a brushless DC motor. We also found that for the power range requirements we were considering, going with a brushed motor did not make a significant enough monetary difference for it to be worth the potential headache in designing a controller for it.

The next consideration we had to consider for our motor was what performance we desired. Ultimately we wanted to design a motorcycle that would be to accelerate fairly well up a steep hill, and reach top speeds comparable to a scooter. Our desired performance prioritized peak torque and power over endurance and ride time.

The motor that we selected for our electric motorcycle is a 72V 3kW brushless DC motor. The motor is rated for 45A, and has a maximum RPM of 5800. The motor has an aluminum body and comes with a pre-welded mounting plate (Figure 5).

Figure 5: 72V 3kW BLDC Motor with Mounting Plate Included

The final factor in our motor selection decision was simply the part lead time. We had found more powerful 5kW or even 8kW motors that exceeded our performance requirements, and would have resulted in a more powerful overall motorcycle, but all of these possible motors had lead times of between 3-5 weeks, and the timeline for our motorcycle build that we had in mind did not allow for such a large lead-time. In retrospect, if we had done the motor selection sooner, we would have been able to take this lead-time into account, and could have obtained a more powerful motor. However, these more powerful motors would have also been significantly more expensive.

6.3 Motor Mount

Since the 3 kW motor that we purchased arrived with a pre-welded mounting plate, we designed our motor mount to use the same bolt pattern. We wanted to make the aesthetic of the mounting system match the lower frame of the motorcycle so that it would be difficult to discern that any modifications had been made. Thus we used 1 inch outer diameter tubing and welded this to a .09 inch thick sheet metal plate. The mounting plate has to withstand significant torque loading from the motor, so we performed finite element analysis before fabricating the part and welding it to the frame. The mounting plate was recessed into the tube in order to increase weld area and provide a larger lever arm to withstand torque. The weld bead was modeled with a fillet in CAD.

The analysis was set up to simulate the most extreme load case: the full torque of the motor (7Nm) being applied while the rear wheel remains stationary (Figure 7). Ideally this scenario would never occur during operation, as our calculations show us the motor has ample torque to climb steep hills without stalling. However, we wanted to ensure no damage would occur to the motor mount if it did. Fixed supports were applied to both ends of the tube that will be welded to the frame and a remote force was applied at the top of the motor sprocket (where the chain would be in tension resisting movement). This remote force is transmitted through the two mounting feet of the motor.

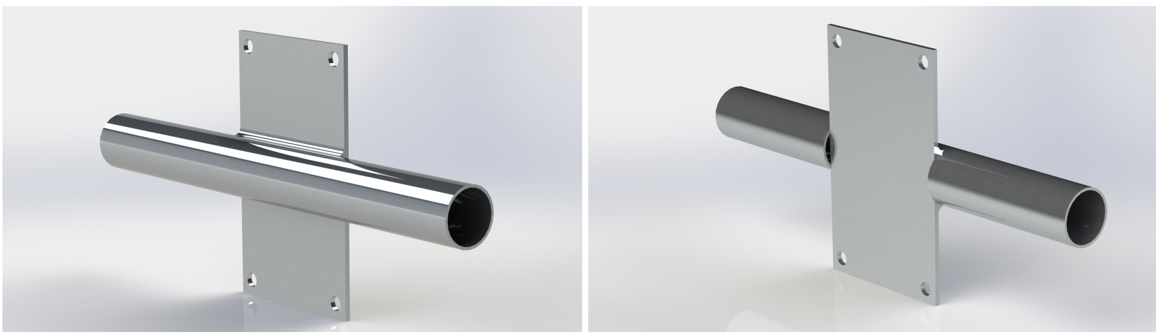

Figure 6: SolidWorks Custom Motor Mount Renders (Front and Back)

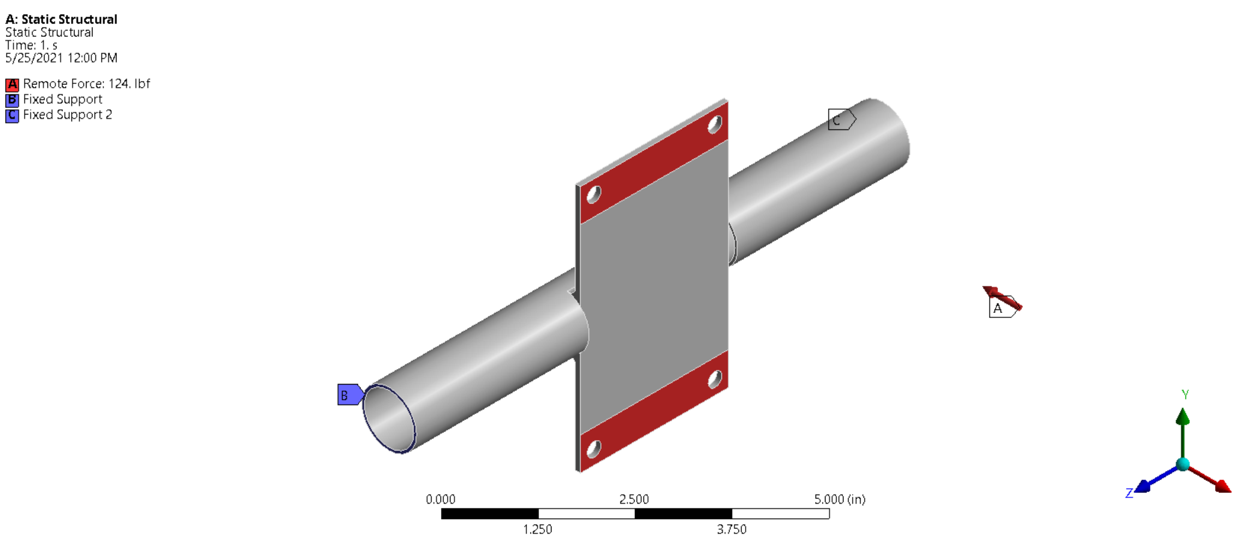

Figure 7: FEA Setup in ANSYS

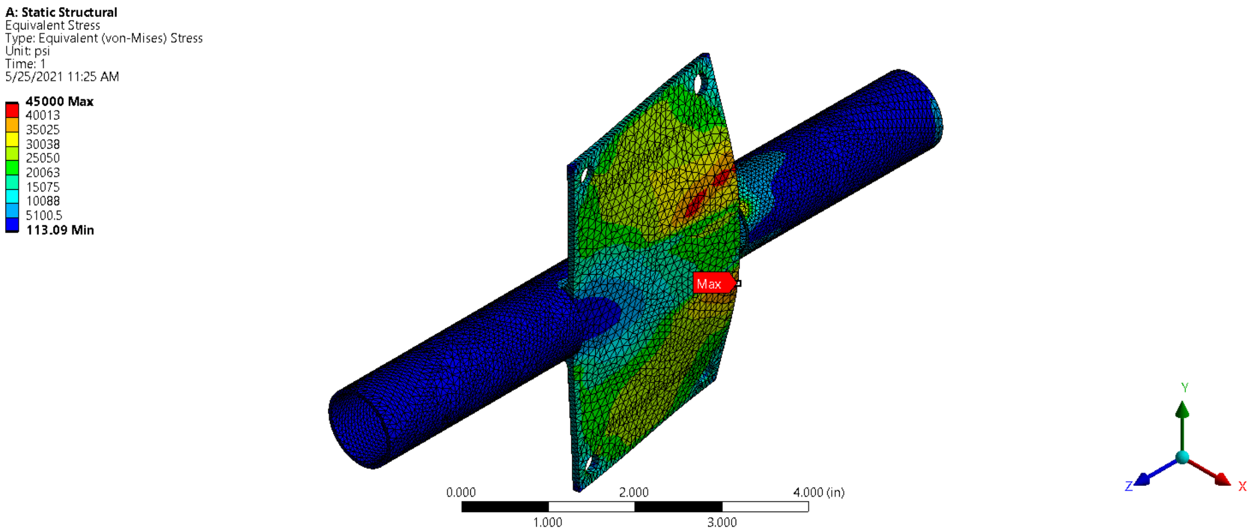

Figure 8: Stress Results in ANSYS

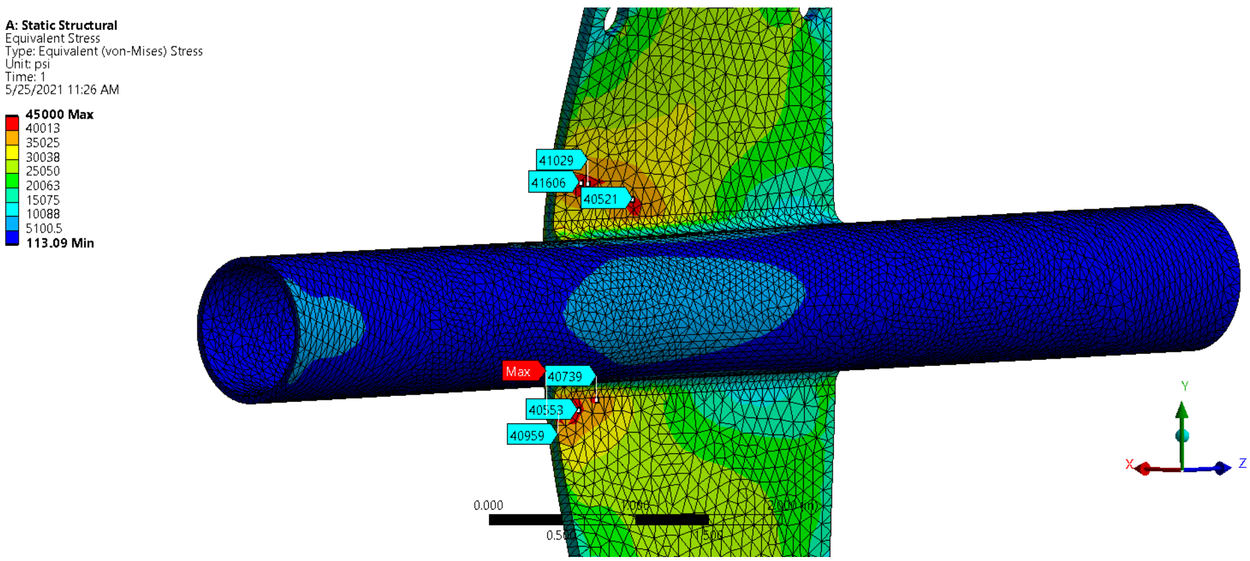

Figure 9: Max Stress Location with Additional Probes

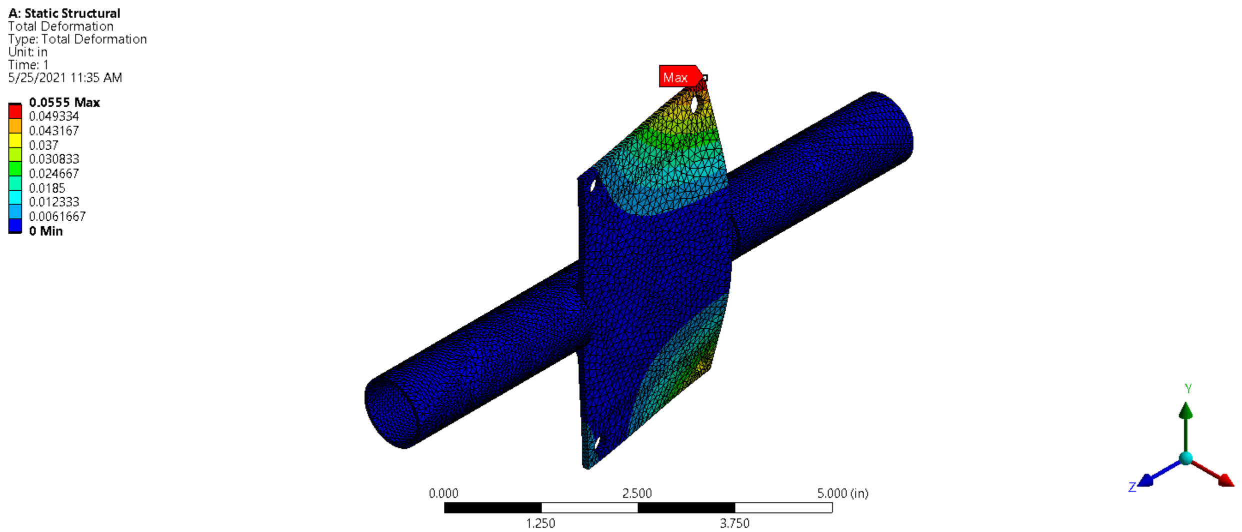

Figure 10: Deformation Results in ANSYS

Results seen in Figure 8 suggest that the maximum stress seen by the motor mount is around 45ksi, but the point of maximum stress is on a corner and may be artificially high. Additional probes in the areas of highest stress showed that the maximum realistic stress may actually be closer to 41ksi. Considering the yield strength of our steel is 53.7ksi, the motor mount has a factor of safety of 1.31. Results shown in Figure 10 show a maximum deformation of .055in, which we deemed an acceptable margin. Performing this analysis gave us confidence to proceed with our design.

Once we verified that the mounting system would be sufficiently stiff to withstand the load from the motor, we fabricated the motor mounting system, making sure the motor fit correctly (Figure 11), and then welded the custom motor mount to the motorcycle frame (Figure 12).

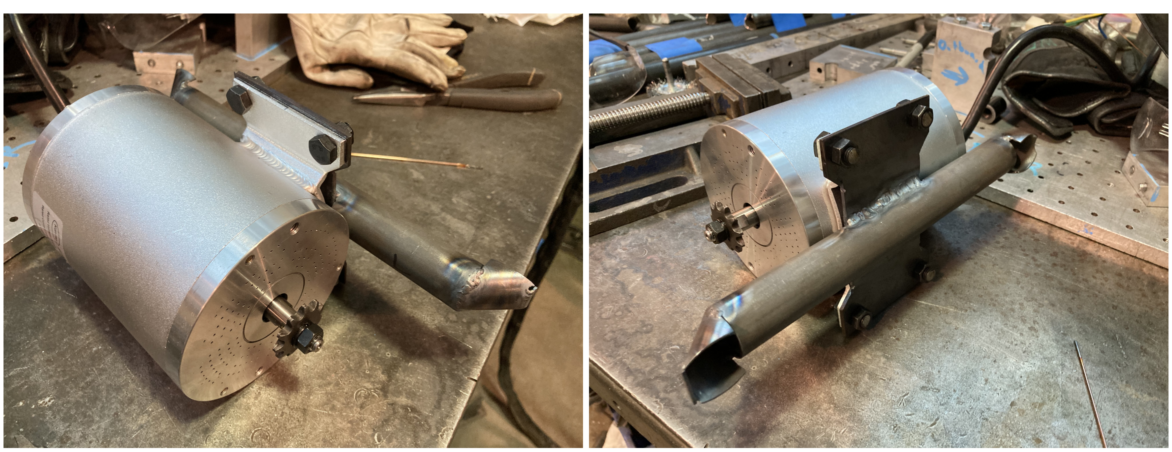

Figure 11: Custom Motor Mount

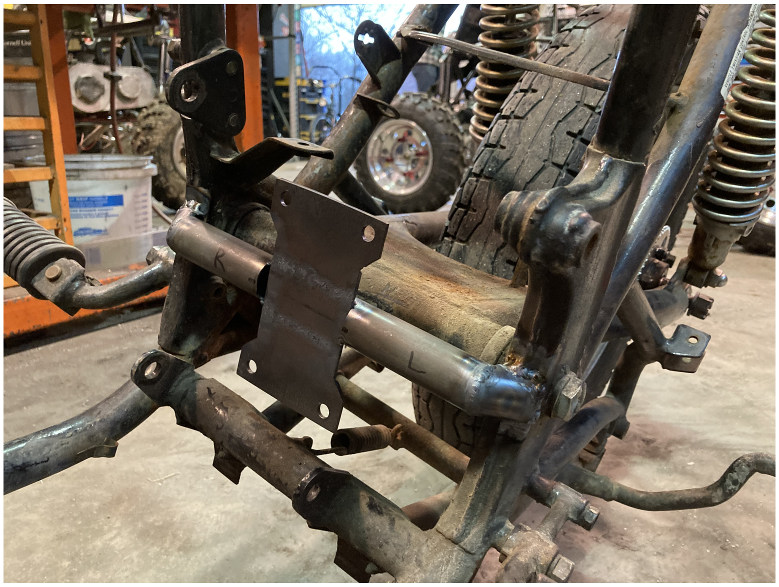

Figure 12: Custom Motor Mount on the Frame

Figure 13: Custom Motor Mount & Motor on the Frame

6.4 Final Drive

Figure 14: Final Chain Drive Configuration

Because the new motor is less powerful than the gasoline engine it was replacing, it uses a smaller chain to connect the motor and the rear wheel. 8mm chain, also known as T8F, is commonly used for small vehicles such as electric scooters and go karts. The motor came with an 11 tooth front sprocket and a 44 tooth rear sprocket, but the gear reduction was not as large as we desired.

We purchased the largest rear sprocket available to increase torque output to the wheel, and although we wanted to install a slightly larger front sprocket to improve chain clearance with the swing arm, we could not locate a supplier that could ship one in a timely manner. This means that the chain occasionallly comes into contact with the swing arm, which would not be acceptable for a production vehicle.

The 11 tooth front sprocket and 72 tooth rear sprocket used gives us a final drive reduction of 6.55:1. Although this may compromise our top speed, we wanted to prioritize acceleration and torque. In order to fit on our bike, the rear sprocket was match drilled to match the bolt pattern of the rear hub (Figure 15).

Figure 15: 72 Tooth Rear Sprocket Mounted to Hub

6.5 Controller

The controller we used for this project was purchased directly with the motor and was thus pre-programmed. This controller is 209 mm x 117 mm x 60 mm (L x W x H) and supports up to 50 Amps, and has voltage and power specifications compatible with our motor. It has forward and reverse functions and three speed settings. The wires are managed through a singular wire grommet and are color coded (Figure 16). The controller also sports lateral flanges to help with mounting, which we had to widen slightly for the bolts we used.

Figure 16: 24 Mosfet 50A Controller

To mount the controller to the frame of the electric motorcycle, we used 4 square weld-nuts welded underneath the central frame tube. This allows the controller to be easily be removed in case any re-wiring needs to be done, and also allows the controller and the subsequent wiring to be conveniently located in relation to the motor and the electronics enclosure. The controller can be seen on the frame in Figure 17, with the 4 weld-nuts boxed in white.

Figure 17: 24 Mosfet 50A Controller on Frame

6.6 Batteries and Enclosure

For the batteries, our main criteria were price, resistance to vibration and motor compatibility. The broad choices of batteries available for our purposes were either lead-acid batteries or lithium ion batteries. Lithium ion batteries have specifications that are almost always superior to lead-acid batteries. They are much lighter, have a higher energy density, and usually last longer than lead-acid batteries. Understandably, this makes lithium ion batteries significantly more expensive than lead-acid batteries. Since we did not design the bike for longevity, and the weight of the bike had been significantly reduced by removing the combustion engine and fuel tank, we felt that we could afford the extra weight incurred by using lead-acid batteries. Additionally, since space in our frame was also not an issue, the much higher energy density of lithium ion batteries would not have been necessary.

Within the category of lead-acid batteries there is also room for selection. Flooded lead acid batteries are reliable and are one of the cheapest batteries on the market. However, we desired batteries that would be shock and vibration resistant due to the nature of their application. For this reason, we chose Absorbed Glass Mat (AGM) batteries. In AGM batteries, the sulfuric acid is absorbed by a fiberglass mat rather than being flooded. This makes AGM batteries incapable of spilling, and means they can be stored in any orientation. This was also an important criteria for us when selecting a battery because we had considered storing our batteries vertically rather than horizontally, and wanted to have that option available to us. AGM's also do not require maintenance and charge up to five times faster than flooded batteries [5].

Our final battery selection was 6 12V 8Ah. Each battery is 5.94 inches x 2.56 inches x 3.94 inches, weighing 4.96 lbs. Thus the total weight of the batteries is just under 30 pounds, at 29.76 lbs.

To house the batteries, we designed an enclosure that would be able to be removed without specialized tools or very much effort to allow for easy charging after the batteries had been depleted. To do this, the battery enclosure is fixed to the tubular frame using two-piece shaft collars. One larger steel shaft collar, seen on the top of the enclosure lid in Figure 18 and two lateral steel shaft collars keep the enclosure centered and support the weight of the batteries.

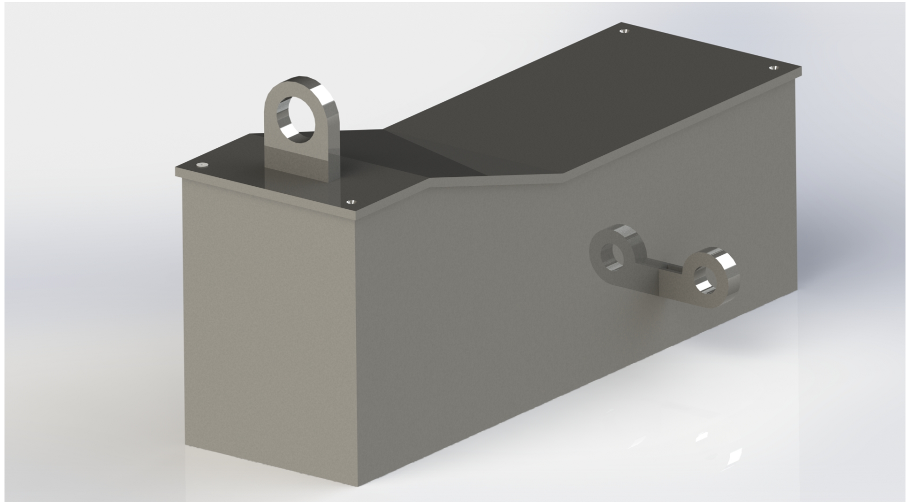

Figure 18: Battery Enclosure: SolidWorks Render

We designed the battery enclosure to consist of sheet metal parts that would be able to be welded together. We used 16 gauge low-carbon steel for the entire battery enclosure. We first cut out all of the sheet metal components using an angle grinder and a foot shear, spot welded the walls of the enclosure in place, making slight adjustments and finalized the welds. We carefully measured the required lengths for the shaft collar struts extruding from the sides of the enclosure so that they would be able to line up with the frame. The entire battery enclosure is 7.44 inches in height, 18.57 inches long, and 5.57 inches wide, allowing the batteries to fit snugly within the enclosure. To ensure minimal jostling of the batteries, we also incorporated lateral foam strips within the battery enclosure. The empty enclosure and lid weighs approximately 10.2 pounds, meaning the entire enclosure and battery array weighs about 39.96 pounds. Below, in Figure 19 is the finished battery enclosure, with the top half of the shaft collars completely separated.

Figure 19: Battery Enclosure

Figure 20: Weld Nuts Used in Battery Enclosure for Lid Fixture

To demonstrate the functionality of the shaft collars, see Figure 21, below.

Figure 21: Battery Enclosure fixed to Frame Only using Shaft Collars

6.7 Frame

Very early on in the design process, it became clear the existing frame would be excessively large for the components we planned to install. Even with our motor, controller, and relatively large lead acid battery pack, the frame would have been mostly empty. In addition to improving the appearance of the vehicle, we decided to modify the frame in order to decrease weight and increase rigidity.

There are three basic types of motorcycle frame: backbone, cradle, and perimeter. The backbone frame is the cheapest and simplest option, using one large, mostly horizontal tube/beam to connect the steering tube back to the seat and then a vertical section to mount the engine. In this design, the engine hangs on the bottom of the frame. The cradle frame has one or two bars going down from the steering tube to support the engine. In this configuration the engine is within the frame and can be mounted in many spots. Finally, the perimeter frame connects the steering tube as directly as possible to the rear swingarm mount point for minimal weight and maximum rigidity. The engine sits higher in the frame in this configuration, as the members go around its perimeter. This is commonly done with small tubes in triangulated arrangements (trellis frame).

Figure 22: Backbone Style Frame

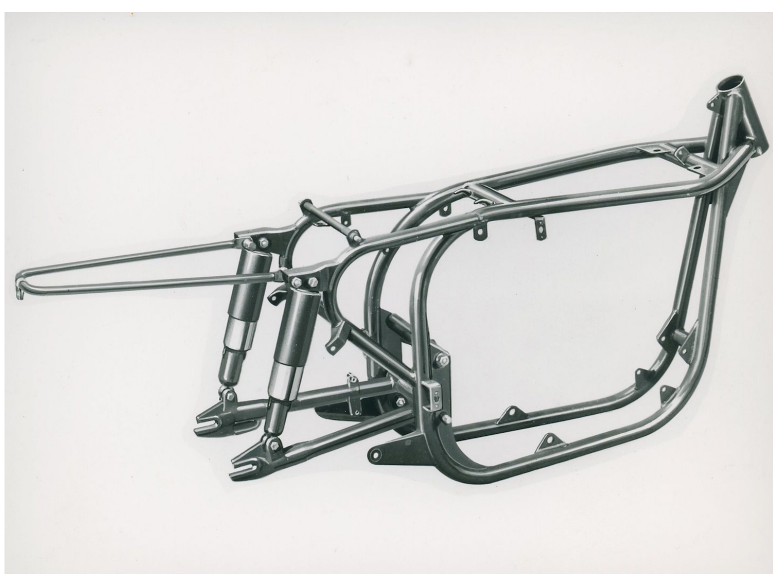

Figure 23: Cradle Style Frame

Figure 24: Perimeter Style Frame (Trellis)

We iterated through a few frame designs getting inspiration from these three basic motorcycle frame types. Below are the CAD renders for different broad frame design choices we considered.

Figure 25: Trellis Frame Design v1

Figure 26: Trellis Frame Design v2

Figure 27: Trellis Frame Design v3 (part of minimalist concept using rear monoshock)

Our stock Suzuki utilized a double cradle design that had two members going under the engine to support it. We wanted to eliminate these two bars in order to give the bike a sleeker, taller look as well as getting rid of the image of an "empty" frame. This essentially left us with a backbone frame, but because it was not designed as a backbone frame we anticipated the top tube wasn't strong enough to keep the frame rigid. We took cues from the perimeter frame, except instead of the engine we routed the new tubes around the battery pack (our motor is small enough that no major packaging issues were encountered for that component). We also ran bars to enclose the motor, both for aesthetic reasons and protection. This design lightened our frame, allowed us to create good mounting points for the battery pack, and maintained rigidity. It also dramatically changed the look of the vehicle so it appears smaller, lighter, and more manageable.

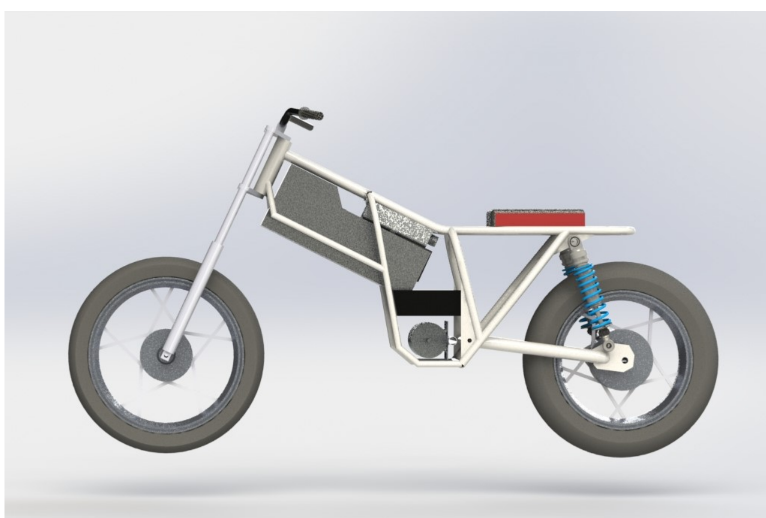

Figure 28: Final Frame Design (Backbone/Perimeter)

Figure 29: Bare Frame after Power-washing

6.8 Brakes

Our donor motorcycle had functional brakes when purchased, which was one of the main reasons it was selected. The foot-actuated rear drum brake required a bit of adjustment but worked fine. The hydraulic front disc brakes worked well, but we wanted to ensure they were bled properly before our first test drive. During this process, we found that the master cylinder was incapable of transferring brake fluid from the reservoir into the pressurized system, so although the brakes functioned, we were not confident in their continued operation and decided to purchase a new master cylinder and brake line. The caliper and brake pads were in good condition so they were not replaced. We flushed and re-bled the system with DOT3 brake fluid. The new master cylinder provides very good pressure and the hand lever is much more firm and responsive than the previous setup.

Figure 30: Purchased Front Master Cylinder

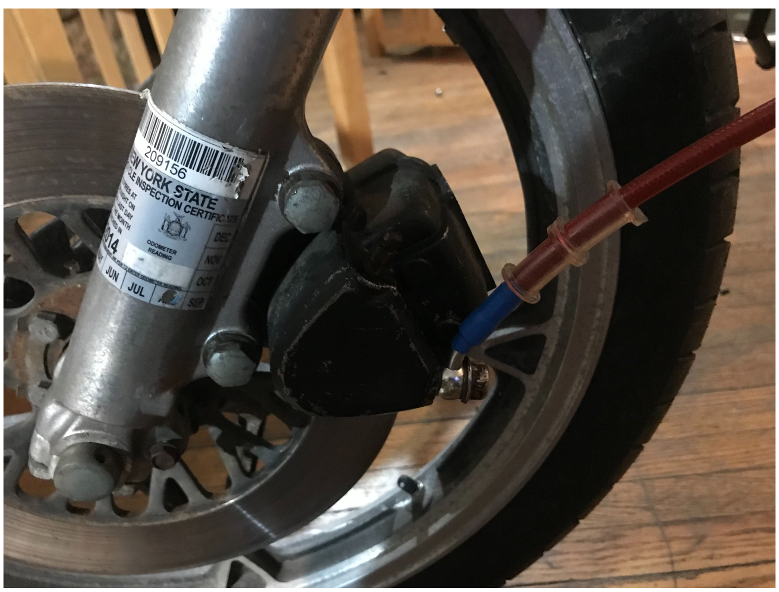

Figure 31: Original Front Caliper

6.9 Wiring

As mentioned above in subsection 6.5, we placed our controller such that the wire grommet would be we facing towards the motor, batteries and the electronics enclosure to allow for easier wire management. We also made a small incision in the rear wall of the battery enclosure for ground and power. All of the wiring is fed into the electronics enclosure, which can be easily accessed by loosening a few screws. Figure 32 shows the open electronics enclosure, where all the wires from the controller are connected to those of the motor. The electronics enclosure itself is bolted onto the motorcycle using two parallel steel strips just above the motor.

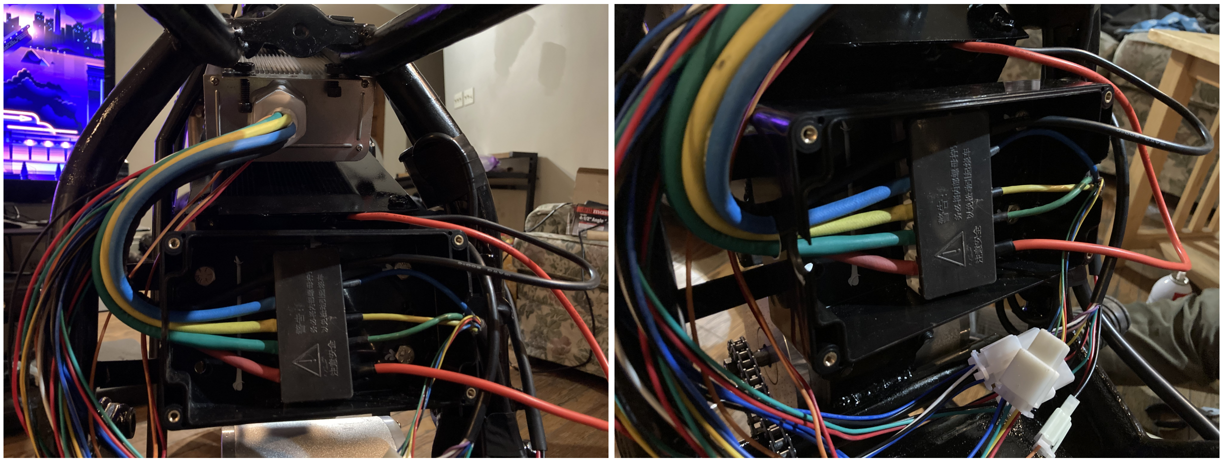

Figure 32: Wire Management in Open Electronics Enclosure

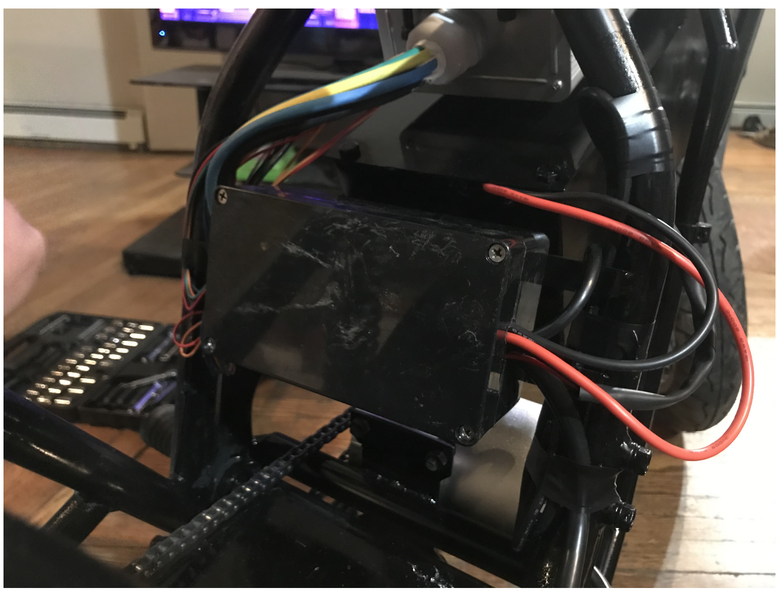

Figure 33: Closed Electronics Enclosure

7 Design Evaluation

Now that the prototype vehicle is fully assembled and functional, we can reflect on some of the design choices that we made. The most obvious oversight that we discovered during the first drive was the chain selection. Our motor came with 8mm roller chain sprockets, so we continued to use this size. However, the nature of motorcycle swing arms is such that the distance between the front and rear sprockets changes slightly. With larger chain typical of full size motorcycles, this change in tension is perfectly acceptable without the chain skipping any teeth or falling off the sprockets. However, the relatively long length of our chain coupled with the small size makes it prone to falling off the sprockets under sudden acceleration or braking. Over-tightening the chain may result in it snapping, so we also want to avoid that. Our chain selection was somewhat constrained because the only sprockets available with the proper mounting holes for our engine are for smaller chain sizes. We did not take this fully into account when selecting our motor. Given more time, our preferred solution would be to manufacture a custom front sprocket for a larger chain size. Given the time left in the semester and the resources available, we will be installing a chain tensioner/guide to keep the chain on the sprockets.

We were generally pleased with our frame modifications and packaging. We decreased the weight of the vehicle by over 190lbs while maintaining frame rigidity and mounting all necessary components in a secure and appealing manner. One fundamental way we would change our approach is choosing a donor vehicle closer to our desired end product. We were slightly constrained during our selection process because we needed the bike quickly and had a low price cap, but choosing a lighter, smaller motorcycle instead of a large cruiser like the GS450 would have resulted in less frame work and a lighter and nimbler motorcycle. Additionally, given more time, it would have been interesting to design the controller from scratch so that we could have made finer adjustments to the desired motor modalities.

8 Acknowledgments

We would like to thank Professor Andy Ruina for his financial support and guidance in this project. He kindly covered the costs of the 3 kW motor, motor controller and the 6 12V batteries.

9 References

[1] http://www.suzukicycles.org/GS-series/GS450E-S_specs.shtml#gsc.tab=0

[2] https://www.motorcyclespecs.co.za/model/suzu/suzuki_gs450s%2080.htm

[3] http://ww1.microchip.com/downloads/en/appnotes/00905a.pdf

[4] https://www.digikey.com/en/articles/an-introduction-to-brushless-dc-motor-control

[5] https://batteryuniversity.com/learn/article/absorbent_glass_mat_agm

10 Appendix

10.1 Final Product Videos

Please click the link below for the final product videos.

https://drive.google.com/drive/folders/1-8Dka1XHYBUpVysn_SAnSM9yykS_Md_u?usp=sharing

10.2 Parts List

Sub-system	Part	Vendor	Unit Cost	Quantity	Total Cost	Link	Notes
Frame	Suzuki GS450 Donor Motorcycle	Craigslist	$300.00	1	$300.00	N/A	
	Frame Tubes	McMaster	$9.78	1	$9.78	https://www.mcmaster.com/tubing/steel/multipurpose-low-carbon-steel/od~3-4/wall-thickness~0-049/	.049" wall thickness, low carbon steel
	Seat Fabrics and Foam	Joann Fabrics	$35.40	1	$35.40	N/A	
	Paint	Home Depot	$9.50	2	$19.00	N/A	Gloss black
	Weld Nuts	McMaster	$9.93	1	$9.93	https://www.mcmaster.com/93975A100/	
	Electronics Enclosure	Amazon	$8.99	1	$8.99	https://www.amazon.com/dp/B08TR2C42F?psc=1&ref=ppx_yo2_dt_b_product_details	
Brakes	Master Cylinder	Amazon	$16.59	1	$16.59	https://www.amazon.com/dp/B08CZWG8VD?psc=1&ref=ppx_yo2_dt_b_product_details	
	Brake Line	Amazon	$13.00	1	$13.00	https://www.amazon.com/dp/B086J96VXD?psc=1&ref=ppx_yo2_dt_b_product_details	
Drivetrain	Replacement Rear Sprocket	Electric Scooter Parts	$19.95	1	$19.95	https://cart.electricscooterparts.com/74-tooth-sprocket-for-8mm-chain	72 tooth sprocket for 8mm chain
Battery Enclosure	Sheet Metal	Steel Weitsman steel downtown	$69.50	1	$69.50	N/A	2x5ft 16 Gauge
	Weld Nuts (Steel nuts)	Home Depot	$2.10	1	$2.10	N/A	
	Shaft Collars (Lateral)	Amazon	$9.99	1	$9.99	https://www.amazon.com/gp/product/B07GT9QXS3/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1	
	Shaft Collars (Top)	Amazon	$6.85	1	$6.85	https://www.amazon.com/gp/product/B001VY05AO/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1	
	Hardware	Home Depot	$3.48	1	$3.48	N/A	
Powertrain	BLDC 72V 3000W Brushless Motor Kit with 24 Mosfet 50A Controller and Throttle	Amazon	$299.00	1	$299.00	https://www.amazon.com/Brushless-Controller-Throttle-Motorcycle-Conversion/dp/B07KR2FN89/ref=cm_cr_arp_d_product_top?ie=UTF8&th=1	Ensure in the "style" dropdown that "6 part in 1 and motor with foot" is selected
	Universal Power Group 12V 8Ah Battery for Razor MX350 MX400 Electric Dirt Bike - 2 Pack	Amazon	$34.99	3 packs of 2 (6 batteries total)	$104.97	https://www.amazon.com/Battery-Razor-MX350-MX400-Electric/dp/B019S0K9S0/ref=sr_1_1?dchild=1&keywords=electric+motorcycle+battery&qid=1605157810&sr=8-1	
				TOTAL COST:	**$928.53**		

Below is the link to the master parts list on google docs.

https://docs.google.com/spreadsheets/d/1P3MOt-qtrYnLcQdFNzfAKmcsv34QnxlDNj0he-nrTeM/edit?usp=sharing