

Introduction

Over the course of four months I successfully manufactured and assembled a fully operational electric scooter without the use of welding and under a \$200 budget. This was a personal project fueled by my own problem of transportation between classes to be able to save time traveling from place to place on campus. My learning goals for this project included understanding the design, fabrication and assembly processes that Mechanical Engineers experience when completing a project. This included knowledge of Solid Works, the Lathe, Bridgeport Mill, Band Saw, Waterjet, Drill Press and proper Engineering Design which accounted for the manufacturability of each part.

Key concepts

Key concepts this project included started with the Design Process. I did extensive research on each part of commercial electric scooters to understand how they worked and made my own design decisions to implement aspects of those features into a 3D model on Solid Works. This process took about two months and contained multiple iterations to achieve a model which accounted for the proper load amount which the scooter would be required to carry. Due to not having access to a welding shop, I needed to find a way to make the scooter frame with as little material as possible to account for the budget and strain on the motor, but in such a way that there would be little to no shear stress on the bolt fasteners I would be using to put it together. My goal was to create a model which put the majority of the load directly onto the frame. Due to some parts being pre-existing or cut from other objects the design needed to seamlessly integrate both the newly made and pre-existing parts together in a way that was structurally sound.

The next concept I focused on was learning the proper machining techniques necessary to create each part I intended to manufacture. I learned how to use several machines and wrote down a manufacturing plan for each part I intended to create. I learned how to use each machine to a high enough skill level where I never needed to recreate a part to not waste any money in my budget.

Another concept involved in this project was learning how to purchase, program, and wire electronics that could effectively spin a 500W DC motor. This involved creating wiring diagrams and navigating product data and manuals to create and program an effective electrical system. This system has the capability to be turned on and off by a key while using the twist of a throttle to control voltage allowed to the motor from the lithium ion battery.

Also, proper calculations needed to be performed to know what motor would be strong enough to move the scooter, what gear ratio was needed for the motor to spin the wheel below the speed limit of 20mph, what diameter bolts would be able to resist the braking force, and what thickness the floor plate needed to be to be able to hold my weight.

Additionally, this project honed my skills in project management. Having to balance a full time internship, college football training and work on this project around the limited open hour

availability of the fabrication shop at my school called for my skills in organization, time management and information gathering to increase exponentially. With only about an hour and a half a day for four days a week to work in the shop after work, I needed to have a plan each day for the operations I was going to perform in the shop to stay on track. So, I created a Notion page which put each part in order of when it would be fabricated and how many shop days it would take to make it to serve as a schedule I could stick to that prioritized the most technically challenging parts to fabricate as the first priority. I also had to time the purchasing of materials to deliver exactly when needed to not extend the lead time of completion.

Bill of materials

(green: available in shop, red: unavailable in shop, yellow, not enough available in shop)

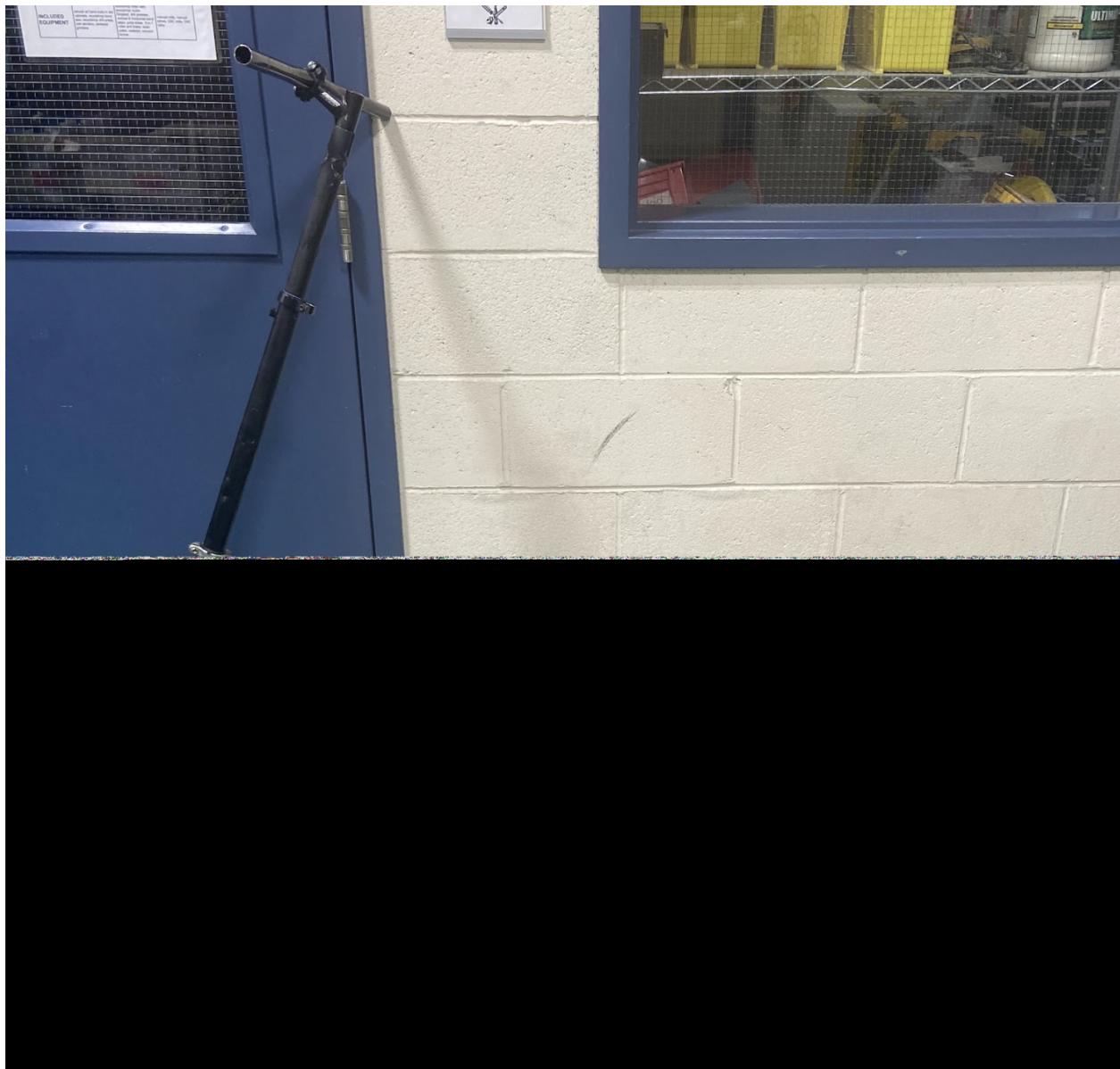
ITEM NO.	Raw Material	DESCRIPTION	QTY	Material In Shop	Manufacturing Plan	Phase
1	12" Long .86" Diameter Aluminum Rod	Harris Bar - no additional features Steel rod - hollowed threaded cylindrical cut 1" diameter 6" deep up through the bottom of the rod, Hole .86" diameter through the side of the rod near the top.	1	Yellow	Lathe will be used if aluminum raw material provided is thicker than .86"	4
2	19" Long 1-1/2" Diameter Aluminum Rod		1	Yellow	Lathe will be used to create a hole penetrating up through the bottom of the rod that is threaded and if the aluminum raw material is too thin	3
3		Bike Steering Mechanism (Mode)	1	Green		
4	6" long .63" Diameter Aluminum Rod	Front Axle - middle section kept .63" diameter 3.2" long, from the mid section to the ends each end has a .39" diameter sections that are threaded.	1	Green	Lathe will be used to make fabricate the correct diameter thicknesses and threading of the aluminum rod at the proper distances along it	2
5		Pipe Frame (Mode)	1	Yellow		
6	1/4" Thick 4" x 14" Aluminum Plate	Movement Blocker - 1/8" thick, 4 through holes total, two of them are 1.315" diameter 12.25" apart and the other two are centered near the middle of the plate face and are 1.5" in diameter and 1.75" apart	1	Yellow		
7	1/4" Thick 16" x 32" Aluminum Plate	Floor Plate - rectangular through hole at the back middle of the plate 6" x 8"	1	Yellow	Water Jet will be used for the four holes in the plate at the appropriate diameters and distances as per the part drawing on solidworks.	1
8	1/2" Thick 5" x 3" Aluminum Plate	Back Axle Holder (Gearside) - 1.315" through hole on the top middle of the back face of the holder and .39" diameter through hole threaded near the bottom of the skinny face	1	Green	Water Jet will be used for the one rectangular hole at the back middle of plate as per drawing on solid works	1
9	16" long .63" Diameter Aluminum Rod	Back Axle - mid section .63" and 3.2" long smooth, then from that mid section to each end .39" diameter and threaded	1	Yellow	Water Jet will be used to cut the shape and top hole of the part and CNC or Drill will be used to make the axle hole that is threaded	2
10	6 X 1/8" Thick Aluminum Plates	Battery Box -	1	Yellow	Lathe will be used to make fabricate the correct diameter thicknesses and threading of the aluminum rod at the proper distances along it	2
11	1.5" Thick 2" x 9" Aluminum Block	End Plate - organism Top - 3" x 1" block of aluminum with two 1" by .35" prongs with .5" bolt holes(2 each) attached to a rod 1" diameter 4" long with a through hole .75" in diameter, end of rod cut at 45 degree angle to fit with bike part	1	Yellow	Water Jet will be used to cut the shape of the box and the metal sheet bender will be used if necessary to overlap metal sheets to make box	4
12		Front Wheel (Mode)	1	Yellow		
13	1/2" Thick 6" x 4.15" Aluminum Plate	Back Wheel Hub (Breakside) - has a through hole .1315" diameter at the top right and a threaded hole through the skinny side .39" diameter	1	Green	Water Jet will be used to cut the shape and top hole of the part and CNC or Drill will be used to make the axle hole that is threaded	2
14	1" Thick 6" x 3.5" Aluminum Plate	Folding Mechanism Bottom - 1" diameter rod with a through hole through the bottom .75" diameter and a semicircular block of the rod with three through holes that are .15" apart, end of rod cut at 45 degree angle to attach to bike part	1	Green		
15		Back Wheel (Mode)	1	Green		
16	2.1" Thick 4.5" Diameter Aluminum Cylinder	Wheel Hub Gearside - 4.5" diameter cylinder of aluminum 1.6" thick with a semicircular cutout around the sides to allow the wheel hub to fit around it with a .63" diameter hole through the center and 8 .25" threaded holes for bolts on the on the larger surface.	1	Green	Lathe will be used to create proper thicknesses of the aluminum cylinder and axle hole. And Mill will be used to make gear connection holes	2
17	2.2" Thick 4.5" Diameter Aluminum Cylinder	Wheel Hub Breakside - 4.5" diameter cylinder of aluminum 1.6" thick with a semicircular cutout around the sides to allow the wheel hub to fit around it with a .63" diameter hole through the center, hole just out .195" diameter extrusion with 5 screw holes in it for the break disk and 4 other .25" threaded holes for bolts on the on the larger surface.	1	Red	Lathe will be used to create proper thicknesses of the aluminum cylinder and axle hole. And Mill will be used to make break connection hole	2
18	1" Thick 1.75" x 3"	Break Mount - elbow style joint with 2 plate surfaces 3" x 1", one of those plates has two .25" holes for bolts to connect to the break mount body, other one on the other has two .75" long jut out cylinders that are .5" diameter with .38" threaded holes through the middle to mount break caliper on.	1	Green	Lathe will be used to make the cylindrical jut outs and Mill will be used to make the aluminum plates according to solid works dimensions	3
19		Caliper (Mode)	1	Green		
20		Break Disk (Mode)	1	Green		
21		Gear (Mode)	1	Green		
22	1/2" Thick 3" x 3" Plate of Aluminum	Under Support - 3" diameter semi circle cylinder with 1.315" diameter hole cut in a semicircle in the top center with a .5" away from the top edge the hole goes .10" into the 3" diameter aluminum semi circle cylinder that is revolved around the center point of the 3" diameter circle and stops .5" away from the end. It has holes on the side ends .25" diameter.	9	Green	CNC machine will be used to cut the shape and thickness of all 9 parts out of an aluminum block and to make the holes in them	1
23		Motor (Mode)	1	Green		

Methods

My methods for design and assembly were thought of in four phases. I thought of the basic frame body, floor plate, and undersupports as phase one due to their importance and ease of

manufacturing. Phase 2 included the manufacturing of the back wheel accessories that would mount the brake disk, gear hub, and wheel to the body. Phase 3 included creating the collapsable shaft up to the handlebars of the scooter. Phase four included mounting of the electronics and braking components.

Results



The Electric Scooter can fully support my weight and roll forwards and backwards with ease. The steering mechanism works well to provide the rider with maximum control of the vehicle. Through this project I learned skills in design, manufacturing, the mechanical engineering process, electrical systems, load analysis, gearing, material selection, and project organization.

Future

In this project I could've created a system that could fold rather than collapse but was limited to due constraints. I plan to improve this project by adding a phone holder, water bottle holder and stereo system. This project has helped me learn about my style of design and consider how manufacturing is important when designing a project and allowed me to see through the perspective of all roles when completing this electric scooter.