MONTANA STATE UNIVERSITY

Department of Mechanical and Industrial Engineering

ETME 499R Capstone: Mechanical Engineering Design II

TECHNICAL ADDENDUM

Battlebot Team 3

By:

Nishagar Raventhiran

Ivan Albert

Cole Trugman

For: Robb Larson, Dr. David Miller, and Dr. Craig Shankwitz

Prepared to Partially Fulfill the Requirements for EMEC 499R

Department of Mechanical and Industrial Engineering

Montana State University, Bozeman, MT 59715

April 29th , 2019

Manufacturing and Assembly

The manufacturing plan for the current model is provided below. First instructions will be for individual parts, followed by instructions for sub and final assembly.

Section B-1: Armor plate Bottom (AP1)

|  |  |  |  |
| --- | --- | --- | --- |
| AP1 | Process | Tool | Time |
| 1 | Cut 2 pieces as shown in the AP1 drawing from the plywood | Laser cutter | 5 minutes |
| 2 | Drill the 11 M6 clearance holes along the edge of the piece as shown in the AP1 drawing | Mill | 40 minutes |
| 3 | Drill 4 more M6 clearance holes in the rectangular pattern shown in the AP1 drawing | Mill | 20 minutes |

Section B-2: Armor Plate Top (AP2)

|  |  |  |  |
| --- | --- | --- | --- |
| AP2 | Process | Tool | Time |
| 1 | Cut 2 pieces as shown in the AP1 drawing from the plywood | Laser cutter | 5 minutes |
| 2 | Drill the 11 M6 clearance holes along the edge of the piece as shown in the AP1 drawing | Mill | 40 minutes |

Section B-3: Electronic Mounting Plate and Assembly (EM1/EMA1)

|  |  |  |  |
| --- | --- | --- | --- |
| EMA1 | Process | Tool | Time |
| 1 | Cut 4.375" by 3.375" square of 1/4" aluminum | Bandsaw | 10 minutes |
| 2 | Tap 4 M6x.5 mm threads | Mill | 15 minutes |
| 3 | Drill 8 6 mm holes | Mill | 30 minutes |
| 4 | Insert 4 M6 press-in nuts into the 4 corner holes of part AP1, all on the same side. | Press | 10 minutes |
| 5 | Insert 8 M6 press-in nuts into the 8 remaining holes of part AP1, all on the same side as each other, opposite the previous press-in nuts. | Press |  |
| 6 | Secure the Raspberry Pi Zero to part EP1 using the small electronics mounting hole pattern with 4 10mm M6 bolts. | Screwdriver | 5 minutes |
| 7 | Put one 40mm M6 screw through each corner of one of the motor control boards so that the components on the board are facing up and the bolts extend down. |  |  |
| 8 | Flipping the motor control board over so that the bolts point up, add one 10mm aluminum spacer to each bolt. |  | 5 minutes |
| 9 | Slide another motor control board onto the bolts facing the same direction as the previous one. |  | 5 minutes |
| 10 | Repeat step 5. |  | 5 minutes |
| 11 | Repeat step 6. |  | 5 minutes |
| 12 | Use the large electronics mounting hole pattern to secure the stack to part AP1. | Screwdriver | 5 minutes |

Section B-4: Frame Back (FR1)

|  |  |  |  |
| --- | --- | --- | --- |
| FR1 | Process | Tool | Time |
| 1 | Cut 2x1 aluminum rectangular tube to a length of 13" | Bandsaw | 5 minutes |
| 2 | Drill M6 clearance hole (3.4 mm) on centerline of tube and 3.5" from end | Mill/3.4mm drill bit | 5 minutes |
| 3 | Drill M6 clearance hole (3.4 mm) on centerline of tube and 6" from first hole | Mill/3.4mm drill bit | 5 minutes |

Section B-5: Frame Side (FR2)

|  |  |  |  |
| --- | --- | --- | --- |
| FR2 (2x) | Process | Tool | Time |
| 1 | Cut 2x1 aluminum rectangular tube to a length of 13" | Bandsaw | 5 minutes |
|  | Perform operations 2-6 on 1" wide face |  |  |
| 2 | Tap M6x.5" thread on center line .5" from both edges | Mill (M6x.5 Tap) | 5 minutes |
| 3 | Cut 7.32" x .75" rectangle (starting 2.68" from the same edge the first hole was drilled on | Mill (.25" bit) | 5 minutes |
| 4 | Tap M6x.5" thread 4.25" from same referenced edge | Mill (M6x.5 Tap) | 5 minutes |
| 5 | Tap M6x.5" thread 8.75" from same referenced edge | Mill (M6x.5 Tap) | 5 minutes |
| 6 | Tap M6x.5" thread on center line .5" from opposite edge | Mill (M6x.5 Tap) | 5 minutes |
|  | \*On 2" Wide Face |  |  |
| 7 | Drill .5" hole 3.179" from first referenced edge (for axle) | Mill (.5" bit) | 5 minutes |
| 8 | Drill .5" hole 6.321" from first .5" axle hole | Mill (.5" bit) | 5 minutes |
| 9 | Moving farther from the originally referenced edge, Tap M6x.5 thread .625" above and .875" from center of previous axle hole | Mill (M6x.5 Tap) | 5 minutes |
| 10 | On same horizontal line, (but on other side of .5" hole) tap M6x.5 thread 2.5" away from first tapped hole | Mill (M6x.5 Tap) | 5 minutes |
| 11 | Vertical (across 2" width) tap M6x.5" thread 1.25" below previous | Mill (M6x.5 Tap) | 5 minutes |
| 12 | On same line (horizontal), tap M6x.5 2.5" from previous and below/on same vertical line of first tap | Mill (M6x.5 Tap) | 5 minutes |

Section B-6: Frame Front (FR3)

|  |  |  |  |
| --- | --- | --- | --- |
| FR3 (2x) | Process | Tool | Time |
| 1 | Cut aluminum rectangular tube to a length of 2" | Bandsaw | 5 minutes |
| 2 | Tap M6x.5" thread .5" from horizontal edge and .25" from vertical edge | Mill (M6x.5 Tap) | 5 minutes |
| 3 | Tap M6x.5" thread 1" below previous | Mill (M6x.5 Tap) | 5 minutes |

Section B-7: Frame Short Roller Arm (FR4)

|  |  |  |  |
| --- | --- | --- | --- |
| FR4 | Process | Tool | Time |
| 1 | Cut aluminum rectangular tube to a length of 3.75" | Bandsaw | 5 minutes |
| 2 | Tap M6x.5" thread .5" from horizontal edge and .5" from vertical edge on 1" face | Mill (M6x.5 Tap) | 5 minutes |
| 3 | On same side hole was tapped (but on 2" face) cut slot for RM1 (Roller/bearing bracket) | Mill | 5 minutes |

Section B-8: Frame Roller Space (FR5)

|  |  |  |  |
| --- | --- | --- | --- |
| FR5 | Process | Tool | Time |
| 2 | Cut aluminum rectangular tube to a length of 7" | Bandsaw | 5 minutes |
| 3 | On centerline, Tap M6x.5" thread 3.5" from horizontal edge | Mill (M6x.5 Tap) | 5 minutes |

Section B-9: Frame Long Roller Arm (FR6)

|  |  |  |  |
| --- | --- | --- | --- |
| FR6 | Process | Tool | Time |
| 1 | Cut aluminum rectangular tube to a length of 5.5" | Bandsaw | 5 minutes |
| 2 | On 1" face, Tap M6x.5" thread.5" from horizontal and vertical edge | Mill (M6x.5 Tap) | 5 minutes |
| 3 | On one side of 23" face, cut 1.22" x 4" window | Mill | 5 minutes |
| 4 | On other side of 2" face, (and on centerline) cut slot for roller/bearing | Mill | 5 minutes |
| 5 | On same side of 2" face, drill the 4 M6 clearance holes for motor mount | Mill (3.4 mm bit) | 15 minutes |
| 6 | In center of 4 clearance holes, drill .2756" hole for motor | Mill (7 mm drill bit) | 5 minutes |

Section B-10: Roller Mount (RM1)

|  |  |  |  |
| --- | --- | --- | --- |
| RM1 | Process | Tool | Time |
| 1 | Cut Aluminum block down to 2"x 1.27" (.25" thick) wall with bottom 1.625" x 2" (.125" thick) protrusion | Mill | 25 minutes |
| 2 | Drill 2 M6 clearance holes as called out In RM1 drawing | Mill | 10 minutes |
| 3 | Use CNC mill to cut out .125" thick, .6" wide, tab with .425" radius | CNC mill | 15 minutes |
| 4 | Use 11/16" drill bit to drill hole in center of protruding tab | Mill | 5 minutes |

Section B-11: Roller Hub (RH1)

|  |  |  |  |
| --- | --- | --- | --- |
| RH1 (2x) | Process | Tool | Time |
| 1 | Cut 3/8" steel to 2.7" x 2.7" triangle with .75" radii at edges | Bandsaw | 30 minutes |
| 2 | Drill 4 .5" clearance holes for roller bars/axle | Mill (.5" bit) | 20 minutes |

Section B-12: Axle Front (AF1)

|  |  |  |  |
| --- | --- | --- | --- |
| AF1 (2x) | Process | Tool | Time |
| 1 | Cut .75" stock 1020 steel rod to 3.67" length | Bandsaw | 5 minutes |
| 2 | Turn rod down to .5" with the exception of .6" diameter (.2" long) end | Lathe | 15 minutes |
| 3 | Cut .25" long set screw slot starting .44" from .6" diameter end | Mill | 5 minutes |

Section B-13: Axle Rear (AR1)

|  |  |  |  |
| --- | --- | --- | --- |
| AR1 (2x) | Process | Tool | Time |
| 1 | Cut steel rod to 4" length | Bandsaw | 5 minutes |
| 2 | Turn rod down to .5" | Lathe | 15 minutes |
| 3 | Turn one end down to .25" diameter for .437" | Lathe | 5 minutes |
| 4 | Cut set screw slot in .25" diameter | Mill | 10 minutes |

Section B-14: .5” Bore Pulley (P1)

|  |  |  |  |
| --- | --- | --- | --- |
| P1 (4x) | Process | Tool | Time |
| 1 | Bore out (from bought pulley) .25" hole to .5" | Mill (.5" bit) | 5 minutes |

Section B-15: Gear Box

|  |  |  |  |
| --- | --- | --- | --- |
| GB1 (2x) | Process | Tool | Time |
| 1 | Mill aluminum down to 2"x1.1"x3" block | Mill | 15 minutes |
| 2 | Cut 2x1.5 (.85" deep) window | Mill | 10 minutes |
| 3 | Drill outer 4 M6 clearance holes for mounting to frame | Mill (M6x.5 Tap) | 10 minutes |
| 4 | Drill inner 4 M6 clearance holes for motor mount | Mill (M6x.5 Tap) | 10 minutes |
| 5 | Drill .5" diameter axle hole | Mill (.5") | 5 minutes |
| 6 | Drill 23/32" hole for motor mount |  | 5 minutes |

Section B-16: Roller Bar (RB1)

|  |  |  |  |
| --- | --- | --- | --- |
| RB1 (3x) | Process | Tool | Time |
| 1 | Cut steel rod to 6.5" length | Bandsaw | 5 minutes |
| 2 | Turn rod down to .498" | Lathe | 5 minutes |

Section B-17: Roller Axle (RA1)

|  |  |  |  |
| --- | --- | --- | --- |
| RA1 | Process | Tool | Time |
| 1 | Cut steel rod to 8.7" length | Bandsaw | 5 minutes |
| 2 | Turn down to .5" diameter | Lathe | 10 minutes |
| 3 | Turn one end down to .25" diameter for 1.1" | Lathe | 10 minutes |
| 4 | Turn other end down to .25" diameter for 1.1" | Lathe | 10 minutes |

Section B-18: Tube Cap (TC1)

|  |  |  |  |
| --- | --- | --- | --- |
| TC1 | Process | Tool | Time |
| 1 | 3d Print tube cap | 3d Printer | 1 hour |

Section B-19: Motor Mount (MM1)

|  |  |  |  |
| --- | --- | --- | --- |
| MM1 | Process | Tool | Time |
| 1 | Cut 1"x1" aluminum square | Mill/Bandsaw | 10 minutes |
| 2 | Drill 18 mm motor hole in center | Mill/18mm bit | 5 minutes |
| 3 | Drill 4 M6 Clearance holes for motor to mount | Mill | 15 minutes |

Section B-20: Frame Assembly

|  |  |  |  |
| --- | --- | --- | --- |
| Frame Assembly | Process | Tool | Time |
| 1 | Weld one of side frame pieces to frame back piece | SMAW | 20 minutes |
| 2 | Weld second side frame to frame back | SMAW | 20 minutes |
| 3 | Weld other end of frame side piece to FR3 | SMAW | 20 minutes |
| 4 | Weld other end of FR3 to FR4 | SMAW | 20 minutes |
| 5 | Weld FR4 to FR5 | SMAW | 20 minutes |
| 6 | Weld other end of FR5 to second FR6 | SMAW | 20 minutes |
| 7 | Weld FR6 to second FR3 | SMAW | 20 minutes |
| 8 | Weld FR3 to frame side (FR2) | SMAW | 20 minutes |

Section B-21: Wheel/Axle Assembly:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Process | Tool | Time |
| 1 | Place 4 bored out pulleys (P1) inside FR2 (Frame side) windows with belts around both pairs |  | 5 minutes |
| 2 | Insert AR1 into FR2 axle hole/bearing/pulley and tighten pulley set screw |  | 5 minutes |
| 3 | Place gear on ¼” part of axle and tighten set screw | Screwdriver/ Drill | 5 minutes |
| 4 | Mount motor to gear boxes and tighten set screw of pinion gear onto motor shaft | Screwdriver/ Drill | 5 minutes |
| 5 | Mount gear box to frame and make sure gear teeth mesh | Screwdriver/ Drill | 5 minutes |
| 6 | Bolt both bearings on FR2 | Screwdriver/ Drill | 5 minutes |
| 7 | Press fit both wheel hubs into wheel bores | Press | 10 minutes |
| 8 | Insert AR1 into FR2 axle hole/bearing/pulley |  | 5 minutes |
| 9 | Insert all press fit hubs into wheel bores |  | 5 minutes |
| 10 | Tighten wheel hub clamp onto axle | Screwdriver/ Drill | 5 minutes |
| 11 | Repeat step 10 - 18 for other side | Screwdriver/ Drill | 15 minutes |
| 12 | Insert AF1 into frame pulley and bearing from inside of frame so that .6" diameter head stops at frame |  | 5 minutes |
| 13 | Tighten pulley set screw | Screwdriver/Drill | 5 minutes |
| 14 | Clamp wheel hubs onto end of axle | Screwdriver/Drill | 5 minutes |
| 15 | Repeat steps 20-22 for other side | Screwdriver/Drill | 10 minutes |

Section B-22: Roller Assembly

|  |  |  |  |
| --- | --- | --- | --- |
|  | Process | Tool | Time |
| 1 | Press fit flanged bearings into RM1 (2x) | Press | 5 minutes |
| 2 | Place roller bars and roller axle into roller hub (RH1) |  | 5 minutes |
| 3 | Weld Roller hub in place | SMAW | 30 minutes |
| 4 | Place second roller hub in place at other end of roller |  | 5 minutes |
| 5 | Weld second roller hub in place | SMAW | 30 minutes |
| 6 | Slide bearings with roller mount (RM1) onto both 1/4" ends of roller axle |  | 5 minutes |
| 7 | Slide 1/4" 24 tooth pulley onto end of roller axle and tighten set screw | Screwdriver | 5 minutes |
| 8 | Place 6 mm pulley inside FR6 (long roller arm) with bet around it |  |  |
| 9 | Secure motor mount to FR6 | Screwdriver/Drill | 5 minutes |
| 10 | Secure motor to motor mount through pulley bore | Screwdriver/Drill | 5 minutes |
| 11 | Tighten set screw from pulley to motor | Screwdriver/Drill | <5 minutes |
| 12 | Slide roller/brackets into place at front of bot, slip belt over pulley, and screw brackets into frame | Screwdriver/Drill | 10 minutes |
| 13 | Press tube caps into place |  | 5 minutes |

Section B-23: Finishing up/Making Repairs

|  |  |  |  |
| --- | --- | --- | --- |
|  | Process | Tool | Time |
| 1 | Bolt AP1 (with electronic panel) into frame | Screwdriver/ Drill | 5 minutes |
| 2 | Mount battery (with velcro) to FR1 |  |  |
| 3 | Wire motors to raspberry pi/motor control panel |  | 5 minutes |
| 4 | Wire battery to control panel/motors |  | 5 minutes |
| 5 | Bolt in AP2 to frame | Screwdriver/drill | 5 minutes |
| 6 | Test bot |  |  |

The major change in the design and manufacturing from capstone I to capstone II was the armor plate. Previously the armor plate was designed with 3/16” Aluminum plate, and then changed to 1/2" plywood. This change is mainly due to weight restriction on the Battlebot. After the change, the bot’s weight was reduced by nearly 6 lbs. and ultimately the cost also got reduced. After testing the 1/2” thick plywood, the team is satisfied that the plywood will serve it purpose as an armor plate during the combat.

Testing

Revised Drawing Package