MONTANA STATE UNIVERSITY

Department of Mechanical and Industrial Engineering

ETME 499R Capstone: Mechanical Engineering Design II

TECHNICAL ADDENDUM

Battlebot Team 3

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Prepared to Partially Fulfill the Requirements for EMEC 499R

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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 3.075” by 3.601” | Mill | 20 minutes |
| 1 | Cut 3/8" steel to 2.7" x 2.7" triangle with .75" radii at edges | Bandsaw | 15 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