504 Engineering Robotic Arm

Documentation

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A picture containing LEGO, toy

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Chapter 1: Design Implementation

504 Engineering’s stepper motor-based manipulator provides agile and precise movement across the ROV’s z axis. It utilizes a NEMA 17, provided by Doehler USA, which proved to be a challenge. This challenge was presented to us by North Paulding Robotics in order to achieve another first place victory in the MATE International Competition.

In December of 2021, they began the request with:

* 4-axes of movement
* At least two stepper motors in use (three if time allows)
* No servo motors in use.

They later changed the requirements, in March of 2022, to:

* 3-axes of movement
* Two stepper motors in use
* Ability to use one or two servo motors

A picture containing toy

Description automatically generated504 Engineering’s first design utilized four stepper motors to achieve the first set of requirements, however when inspected by North Paulding Robotics this design was determined to be an over improvement of the previous year’s design, in response a second set of requirements was given to us.

After a time period of two weeks a second design was presented, depicted in the image to the right. This design forgoes the second axis of tilt in favor of ease of use for the A picture containing LEGO, toy

Description automatically generatedpilots who will not achieve the nominal amount of piloting time of the final ROV. The total time of completion of this project was four and a half months.

Chapter 2: Gearboxes

Chart, bubble chart

Description automatically generated 504 Engineering’s manipulator contains a NEMA 17 stepper motor with a holding torque capacity of 0.43 Newton-meter. This holding torque capacity, during initial testing, was determined to be inadequate for North Paulding Robotics needs. Testing proved that the utilization of a speed reducer gearbox provided the needed results to prove useful. With the utilization of a v-belt system (gear ratio of 3:1) along with the dual speed reduction gearbox, which was a 25:1 gear ratio, the holding torque of the NEMA 17 was increased to 32.31 Newton-meters.

A picture containing graphical user interface

Description automatically generatedThis combination of the v-belt system (the silver portions of the picture below) and the speed reduction gearbox (red portions) allowed for a 75:1 gear reduction of the NEMA 17. While this improved the overall torque capacity of the motor, it lessened the speed of the overall tilt. However, after research into the team’s previous manipulator designs it was shown that the angular speed of the tilt body was only slightly slower than the servo-based design used previously. Further research into the newly designed manipulator showed that the overall lifting capacity of the newly designed tilt was 9.08 kilograms at the overall length of the manipulator.

As you can see to the right, at the distance of 0.3 meter, the newly designed manipulator achieves a lifting force of 120.02 Newtons and a weight capacity of 12.25 kilograms. Included in Graphical user interface, text

Description automatically generatedthe image is the calculations performed with the stepper motor without any gear reductions or v-belt systems, it can only achieve a lifting force of 1.6 Newtons and a weight capacity of 0.163 kilograms.

During the testing phases of the development of this gearbox reduction system, 504 Engineering testing various other options as well. Such as a cycloidal drive system, a harmonic drive system, stand-alone speed reduction gearboxes, and stand-alone v-belt systems. None of the listed options provided the nominal weight capacity required for the MATE International Competition as listed in their Product Demonstration Manual.

Chapter 3: Building Instructions

This chapter includes the building instructions in order to build 504 Engineering’s manipulator so that North Paulding Robotics can assemble and repair any part of manipulator. All the following parts are labelled with an alphabetical and numerical codex, which are put into Figure 1.1 for easy reading.

Instruction Steps:

1. A picture containing graphical user interface

   Description automatically generatedDiagram

   Description automatically generatedTake part one A0000 and six of A0001. Using a pair of needle nose pliers’, position one at the opening of each of the following positions marked by the arrows. After positioning the threaded inserts at their corresponding locations, use a hot soldering iron to push the threaded inserts into the holes until the top of the insert is just below the top of the hole. Make sure to insert them straight and precise due to the possibility of an error causing the entire part to be remade. When you are finished the assembly should look close to the image to the left. If it does not look the same, compare them and attempt to remedy the situation.
2. Graphical user interface, application

   Description automatically generatedNext take part A0002 as well as the rest of the assembly, position the part as seen as in the image. Then take four of the M3 screws included and screw part A0002 into position. When finished the assembly should look like the image to the right. If it does not, then compare and attempt to remedy the situation.
3. A picture containing electronics

   Description automatically generatedTake part A0003 and A0004, position part A0003 on to the output shaft of part A0004 like in the image to the right. After you have positioned it correctly, take a M2 hex key (inside your IFixit set) and tighten the black restraining screws on the side of part A0003.
4. Icon

   Description automatically generatedAfter completing the steps above, get part A0004 and position it as seen in the image to the right. After that is completed, gather four M2.5 screws from their designated location within the toolbox. On the inside of the assembly screw part A0003 into position tightly making sure not to thread the screw head as to not be able to A picture containing text, iPod

   Description automatically generatedremove them as you might have to do. Once completed your assembly should look like the one in the image to the right.
5. Chart

   Description automatically generated with medium confidenceA picture containing light

   Description automatically generatedNext take two A0006, and one of each A0005 and A0007, and one M3x30mm screw. Take part A0005 and the M3x30mm and screw it into position as seen in the image to the right. Make sure to line up the center of the part with A0003 on the NEMA 17 motor. After the part is screwed into position take parts A0006 and slide them onto part A0005 followed by part A0007 and make sure to screw them all into position as seen in the image to the right.
6. Take

|  |  |  |  |
| --- | --- | --- | --- |
| Part codex | Location in Parts Box | Description | Image |
| A0000 |  | The base of tilt system | Diagram, engineering drawing  Description automatically generated |
| A0001 |  | Threaded inserts | A picture containing kitchenware  Description automatically generated |
| A0002 |  | Black mount plate provided in the spare parts toolbox. | Diagram, engineering drawing  Description automatically generated |
| A0003 |  | GT2 20 Tooth Drive Pulley | Diagram  Description automatically generated |
| A0004 |  | NEMA 17  Part number: STP-MTR-17040W  Provided by: Doehler USA | A picture containing electronics, loudspeaker, projector  Description automatically generated |
| A0005 |  | Tension Bearing Holder Part 1 | A picture containing athletic game, sport  Description automatically generated |
| A0006 |  | Tension Bearing, 626-2RS | A picture containing shape  Description automatically generated |
| A0007 |  | Tension Bearing Holder Part 2 | Diagram, venn diagram  Description automatically generated |
|  |  |  |  |