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