2/28/2019

Drivetrain Technical Report

2019

Frog Force 503

Contents

Drivetrain Architecture

In regards to the design of the drivetrain this year, we decided against doing a PUGH matrix. This is because we looked back at our previous years' gearbox and determined that there would not be any new factors that would change the previous Pugh Matrix. Therefore, we continued with the Tank Drive Architecture.

Table 1: Drivetrain Pugh Matrix

	Weight	Tank	Swerve	Holonomic	Tankonomic	OmniTank	H-Tank
Speed	6	6	5	1	4	5	4
Scrub	4	2	6	6	6	4	6
Agility	6	2	6	6	6	4	6
Weight	2	6	3	5	2	4	1
Space	3	5	6	3	2	4	1
Defense	3	6	4	1	4	5	4
Programmability	2	6	1	3	3	5	3
Time	2	6	1	2	2	5	3
Maintenance	2	6	5	3	2	4	1
Totals :		**137**	**140**	**104**	**120**	**133**	**115**

Figure 1: Drivetrain CAD

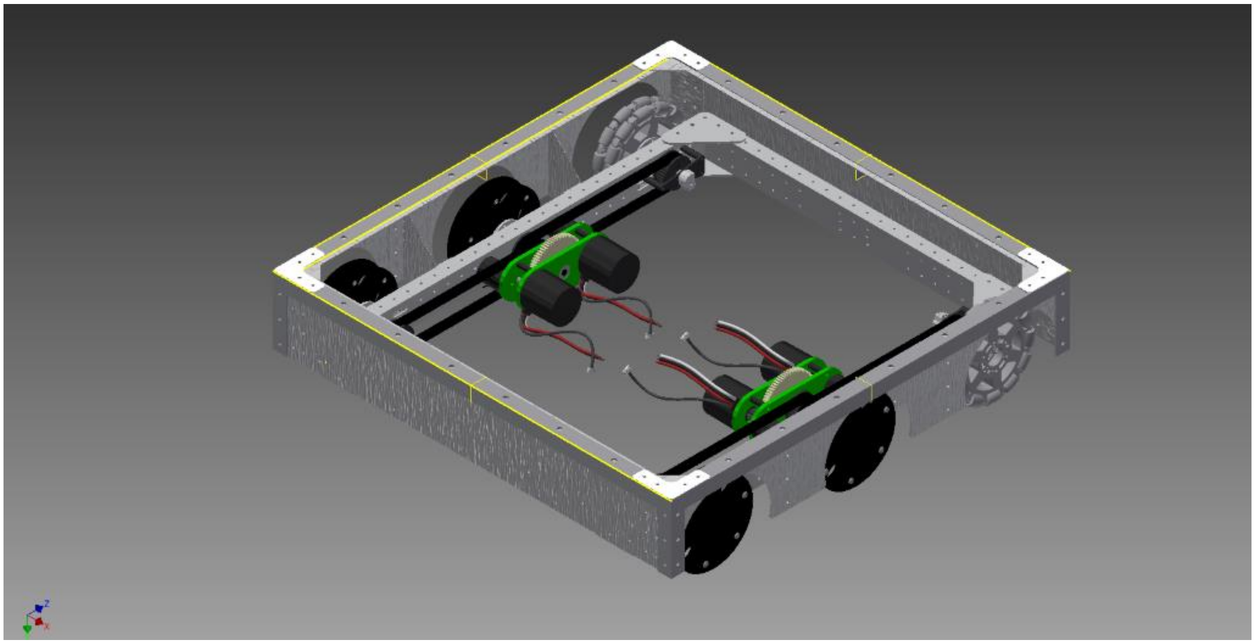
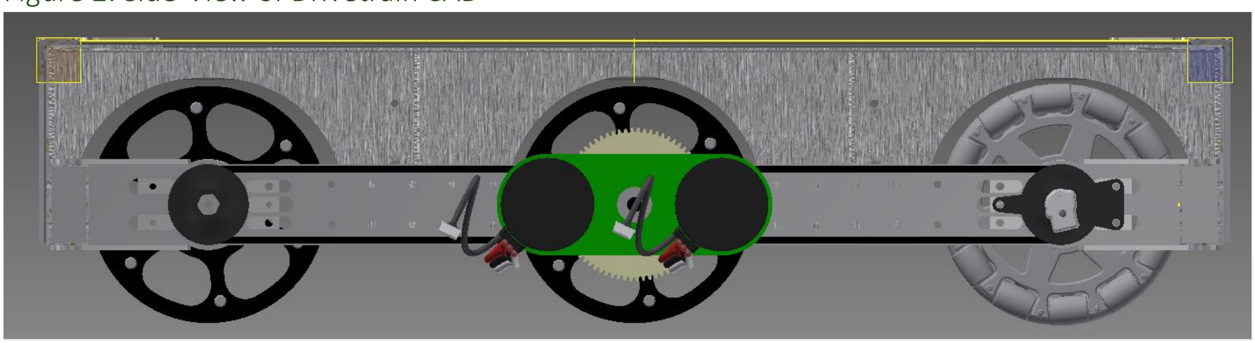


Figure 2: Side-View of Drivetrain CAD



Gearbox and Ratios

Gearbox Requirements:

- Simple - after last year's complex and difficult to maintain gearbox we decided to go with a simple custom gearbox that would be as easily serviceable as possible
- Provide the quickest cycle time across the field accounting for acceleration
- Light weight
- Space saving

Gearbox Design

- Complexity reduction and increased serviceability were obtained by a one stage reduction gearbox rather than the two stages we have done in the past
- In order to calculate the quickest cycle time, we utilized the Aren Hill Drivetrain Simulator Sprint Distance Calculator to derive a target speed for our gearbox given motor data for the motors we chose to use
    - The Aren Hill Simulator gave us a speed of around 16 feet per second with the REV NEO Motors
    - We then used the JVN Mechanical Design Calculator to obtain a 7.4:1 Gear Ratio. For this year's robot that meant a 74 Tooth Vex Robotics Spur Gear with 10 Tooth Vex Robotics Pinions.
- As a space saving measure we chose to do a Low Profile "Flat" Gearbox in which all the rotational axes lie on the same plane, therefore reducing gearbox height at the expense of width.
    - As our plates were naturally small due to the Flat style of the gearbox we were also able to meet our low weight goal
- A departure from last year is that we used new REV NEO Motors. These motors are lighter, faster, and more efficient than the CIMs we have used in the past
- An issue we ran into during testing is that the motor pinions were able to slide down the shaft and interfere with the nut that mounted the gearbox to the chassis. In order to alleviate this problem, we machined and inserted custom spacers onto the motor shafts that prevented pinion slippage.

Figure 3: Gearbox CAD

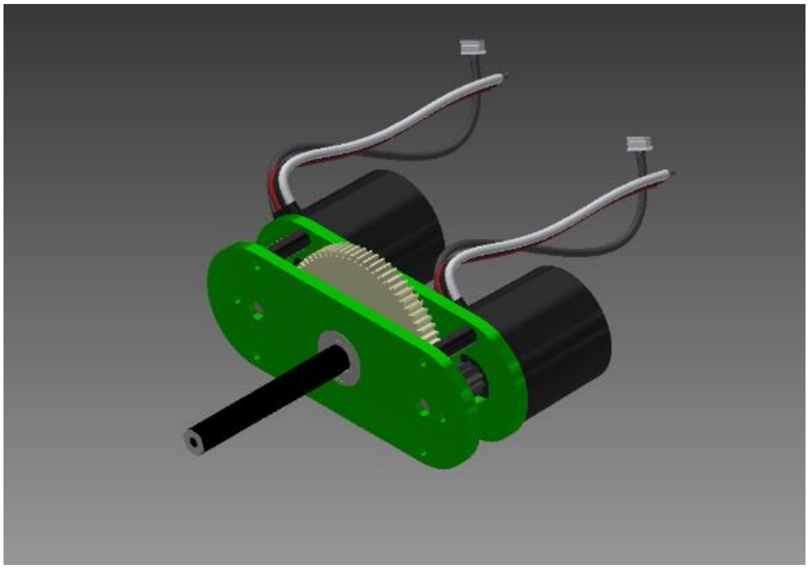


Table 2: Gearbox Specifications

1-Speed Drivetrain

	Free Speed (RPM)	Stall Torque (N*m)	Stall Current (Amp)	Free Current (Amp)	Speed Loss Constant	Drivetrain Efficiency
REV NEO	5676	2.6	105	1.8	81%	90%

# Gearboxes in Drivetrain	# Motors per Gearbox		Total Weight (lbs)	Weight on Driven Wheels	Wheel Dia. (in)	Wheel Coeff
2	2		125	100%	6	1.1

Driving Gear	Driven Gear		Drivetrain Free-Speed	Drivetrain Adjusted Speed	"Pushing" Current Draw per Motor
10	74		20.08 ft/s	16.27 ft/s	71.24 Amps
1	1		7.40 : 1	<-- Overall Gear Ratio	
1	1				
1	1				

Power Transmission

Belts and Pulley

- Instead of doing chain and sprocket as in the past we chose to do a belt and pulley system using 15mm HTD 5mm Pitch Belts and Pulleys
- Advantages Over Chain:
  - **Low Maintenanc**e – with our new tensioning system we should never have to replace the belts and belts do not require lubrication. Because we are running with a 3x safety factor in our belts there is no danger of belt breakage unlike chain in which MasterLinks are prone to flying apart during competition.
  - **Higher Efficiency** – due to less backlash in the system, more of the power from our gearboxes is transmitted to our wheels rather than being lost.
  - **Quieter** – Who doesn't like a quieter drivetrain?
  - **Lighter** – Saving weight is always one of our goals and this was a step in the right direction
- Disadvantages Compared to Chain:
  - **Lower Load Capacity -** A loop of chain without MasterLinks can transmit significantly more power than belts of the same size. However, due to our team's history with using MasterLinks we have found that this "Effective Load Rating" is significantly lower.
    - **Fix:** We also combatted this problem by using larger pulleys and wider belts to compensate for the lower load. As another step in our design process we utilized the "Gates Light Power and Precision Design Manual" to confirm that the belts would be able to handle the loads that we were putting through them
  - **Strange Center to Center Distances -** With #25 chain calculating center to center distances is relatively simple (until the chain wears in and effectively becomes longer). With the 5mm pitch architecture the numbers were not friendly to work with.
    - **Fix:** Once again we utilized the "Gates Light Power and Precision Design Manual" to calculate our center to center distance and implemented a tensioning system to account for any manufacturing errors.
- We utilized custom 3D printed Onyx Pulleys on our drive shafts rather than COTS Pulleys. The benefits are:
  - Lighter Weight
  - Better Packaging
  - Cheaper than most COTS alternatives.
- During testing we realized that the rounded ThunderHex Shafts were boring out a hole in our pulleys resulting in slippage. With metal sprockets like we have used in the past this has not been a problem but with the 3D printed pulleys it created a significant issue
  - Our already installed tensioners contained round ThunderHex bearings which would not support standard ½" Hex Shaft
  - **Fix:** We created a hybrid Hex/ThunderHex shaft that would satisfy our requirements. This way we were compatible with our tensioners and the increased surface area on the Hex side prevented the Hex Bore in the pulleys from rounding out

Figure 4: 30 T 30 mm Wide HTD Custom Pulley

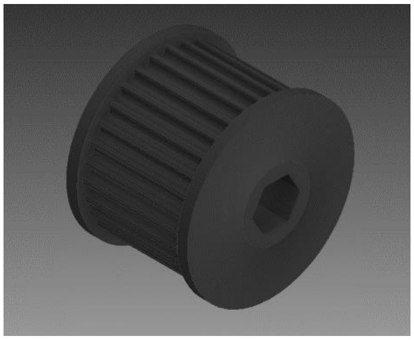


Figure 5: 30 T 15 mm Wide HTD Custom Pulley

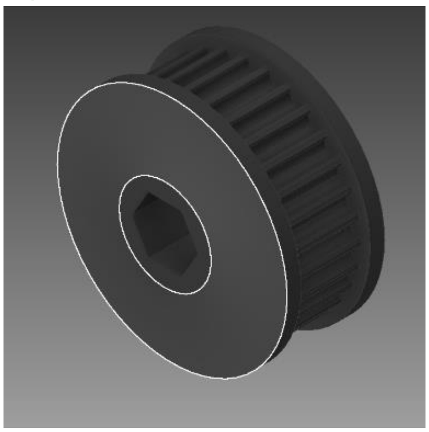
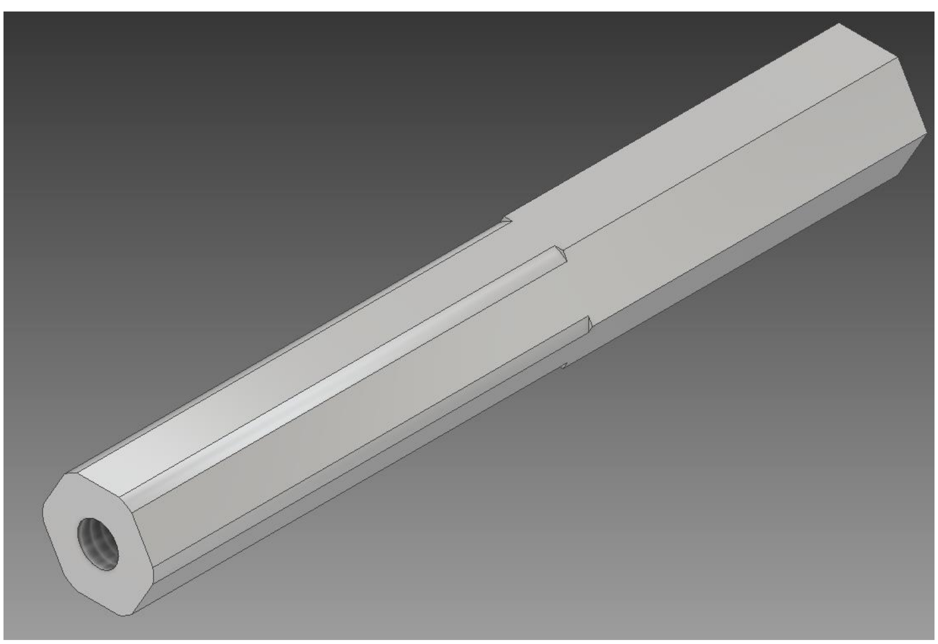


Figure 6: ThunderHex-Hex Hybrid Shaft



Tensioning System

Tensioning System Requirements:

- In the past we have attempted tensioners for chain that include bent Lexan plates and Delrin rollers that both push on chain to reduce slack. Both of these proved very inefficient and we realized it was time for a more industrial solution.
    - With chain some amount of slack is still usable but with belts any amount of slack could result in serious slippage or damage to the belt
- With our belt system this year it was important that we could make very minute adjustments to the tension.

Tensioning System Design

- In the end we ended up with four custom machined sets that had the following features:
    - Floating Blocks
        - Floated within chassis rail
        - Pockets for ThunderHex Bearings to allow for live axle power transmission
        - Grooves in the top and bottom to allow clearance for bolts and rivets that stick into the chassis rail
        - A tapped end of the block allowed for a bolt to be partially threaded into the block
    - Header Block
        - Bolted to chassis rail
        - A large clearance hole for the bolt
- The system works by threading a bolt through the header block into the floating block. The header block provides a bearing surface for the bolt to act against and therefore when the bolt is turned clockwise it pulls the floating block closer.
- An additional feature that we decided to add is the option to loosen the belts for ease of serviceability. This is done by rotating the bolt counter-clockwise and then pushing the Allen wrench into the chassis.
- As a result of our tensioning system the frame now needed slots for the drivetrain instead of the regular bearing holes that we have done in the past.
- Since the fit of the tensioner blocks is imperative, they were precisely machined by our sponsor Denso. In order to ensure proper fit and alignment it was important that we remove all burs and debris trapped inside the chassis rail.
- Another aspect we had to keep in mind was that the encoder system would have to be mounted to the floating block in order for it to measure an accurate wheel speed. We overcame this obstacle by making three tapped 10-32 holes in the block to which the encoder assembly mounts.

Figure 7: Floating Tensioner Block

Figure 8: Tensioner Header Block

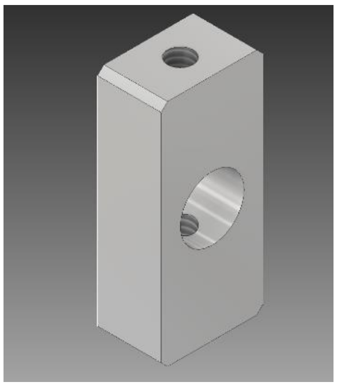


Figure 9: Slots in Chassis Rail

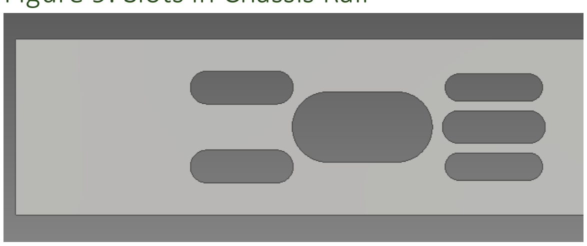
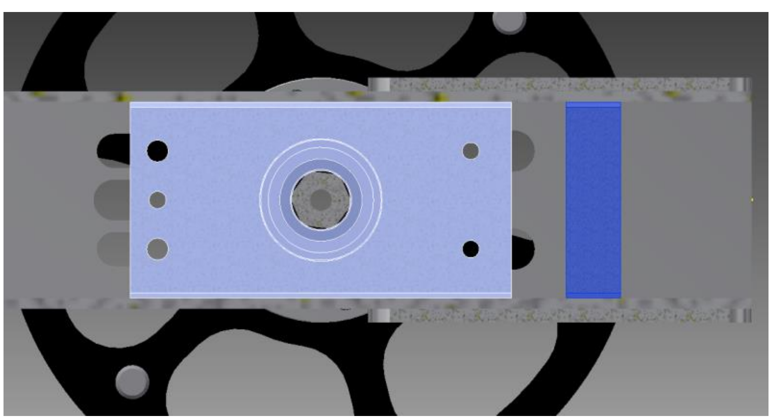


Figure 10: Assembled View (Side View)
(Highlighted blue parts are the tensioner bocks)



Encoders and Encoder Mounting

Encoder and Encoder Mount Requirements

- Provide accurate wheel speed and position data
- Low maintenance
- Easy serviceability
- Encoder Mount must mount to Tensioner Floating Block

Encoder Mount and Encoder Design

- We decided to continue to use the CTR SRX Mag Encoder that we have used the past two years as they have been very accurate and relatively low maintenance.
    - On occasion the encoders are prone to “going orange” or being out of the desired range of the magnet for optimal performance and this requires minor adjustment. This is done by either sanding the mount or adding shims to obtain the correct offset.
- In order to account for as much backlash as possible we decided to mount the encoders on a drive axle rather than the gearbox shaft.
- A key challenge to the encoder mount was leaving enough clearance for the belts and pulleys while also having it compact enough to fit on the tensioner block
    - Due to the strange geometry needed, we once again utilized 3D printing to make the encoder mount
- As using a bolt on both sides to secure this axle was not an option, we decided to use a spring retention clip – we’ve had success with these in the past

Figure 11: Encoder Mount with Encoder

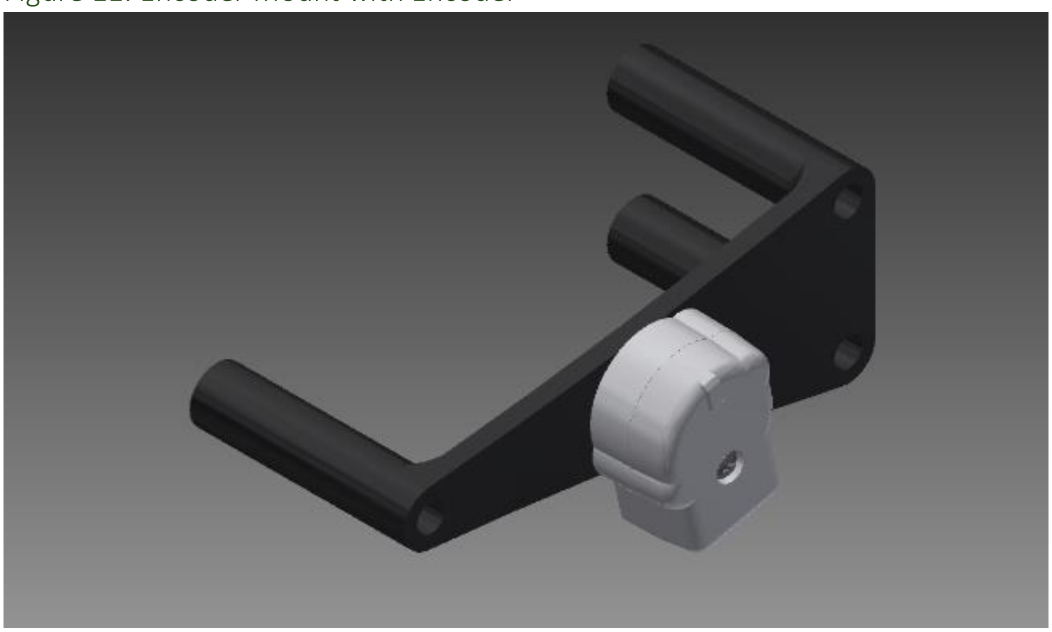


Figure 12: Encoder Mount Mounted

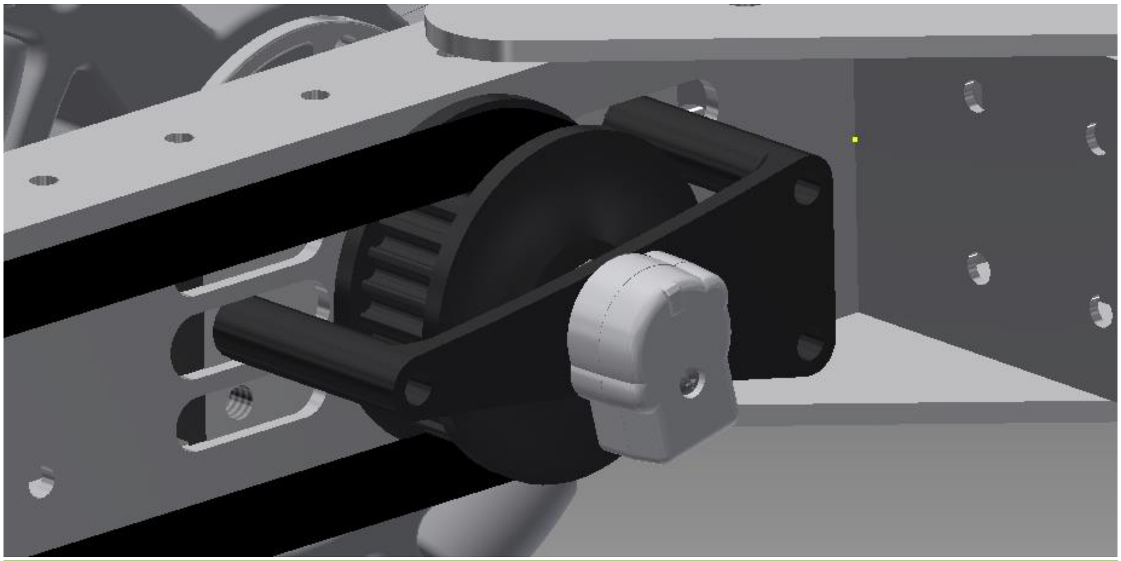
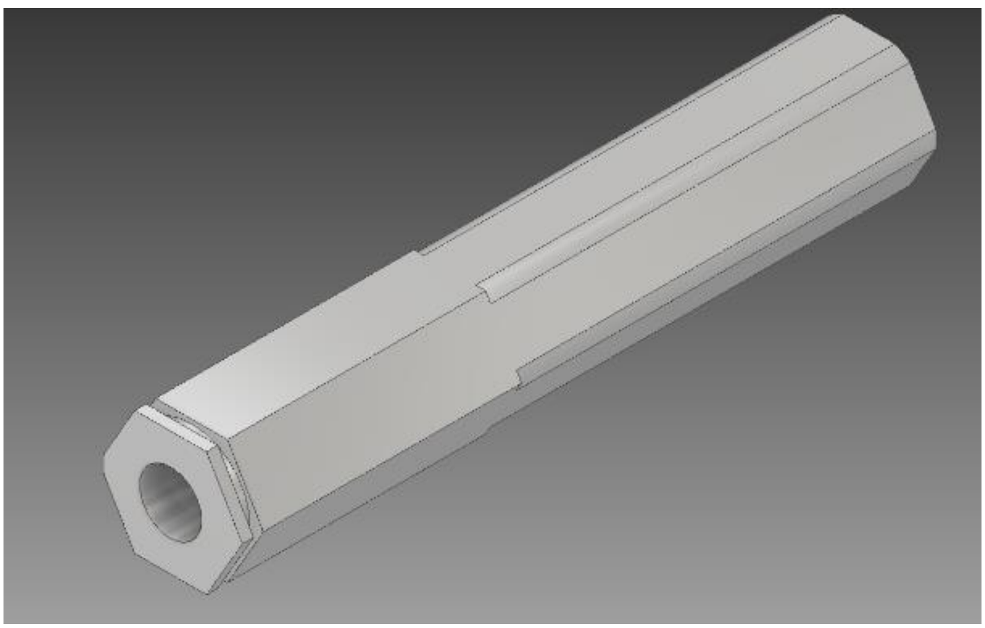


Figure 13: Encoder Axle



Wheel Selection and Configuration

Overall Wheel Requirements

- Provide good traction for efficient power delivery to the ground
- Provide low scrub when turning for reduced energy lost during turning
- Clear the edge of HAB Level 1 without interference

Initial Wheel Selection

- Six (6) inch diameter wheels to clear the edge of HAB Level 1
- Two (2) AndyMark Blue Nitrile Plaction Wheels in the center of the drivetrain (one per side)
    - We've had success with these wheels in the past as they provide excellent traction against FRC Regulation carpet.
    - Unlike in past year's where we have used different types of adhesives to secure the tread to the wheel, this year we decided to use rivets which proved to be more reliable and low maintenance.
- Four (4) VexRobotics Omni Wheels on the corners of the drivetrain (two per side)
    - Again, experience with these wheels played a crucial role in our selection of them
    - Very low scrub wheels when placed at the edge of the drivetrain, great for turning the robot

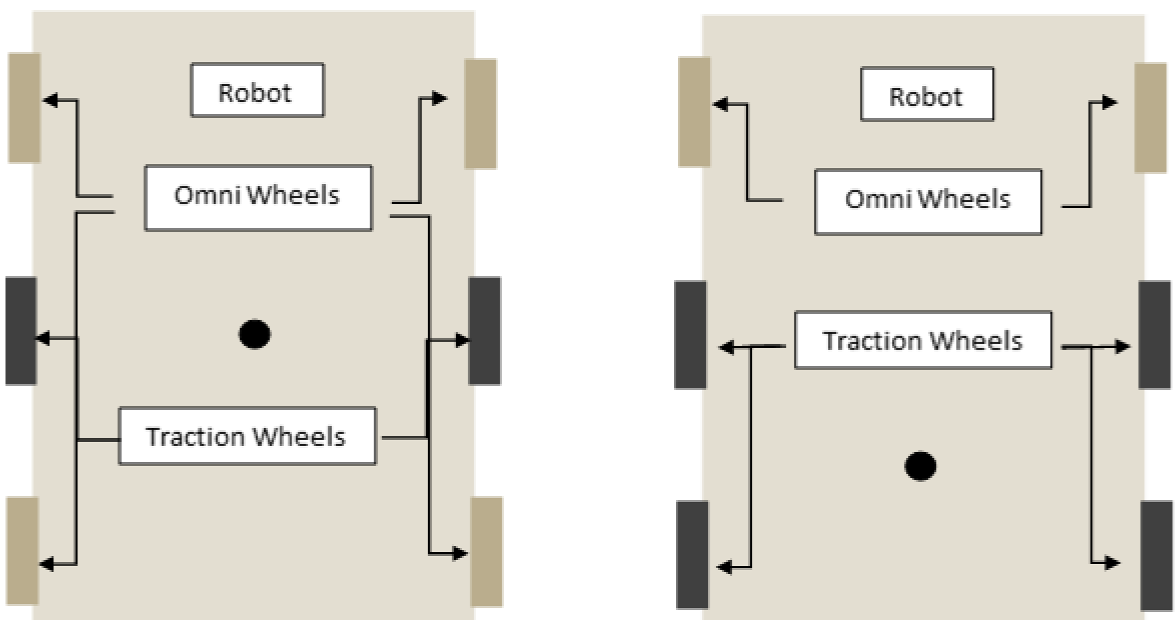
Final Wheel Selection

- When programming received the robot, they found that it was very difficult to control - the robot wanted to turn very very easily due to its extremely low scrub (it's not like we designed it that way or anything, hmmmm)
- We ended up replacing two of the Omni Wheels on the end with two more of the AndyMark Plaction Wheels. This raised the scrub of the robot and made it much more controllable both in teleoperated and more consistent during autonomous programming.

Figure 14: Omni Wheel

Figure 15: AndyMark Plaction Wheel

Figure 16: Initial and Final Wheel Configuration



WITH THIS FINAL CHANGE, OUR DRIVETRAIN IS FINALLY READY TO PLUNGE INTO DEEP SPACE!