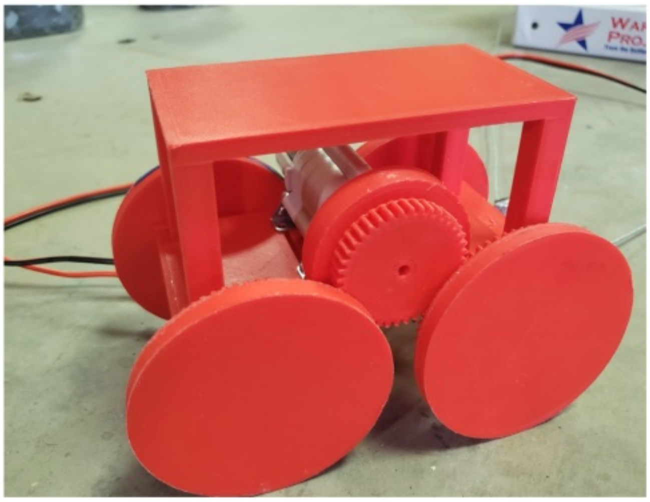
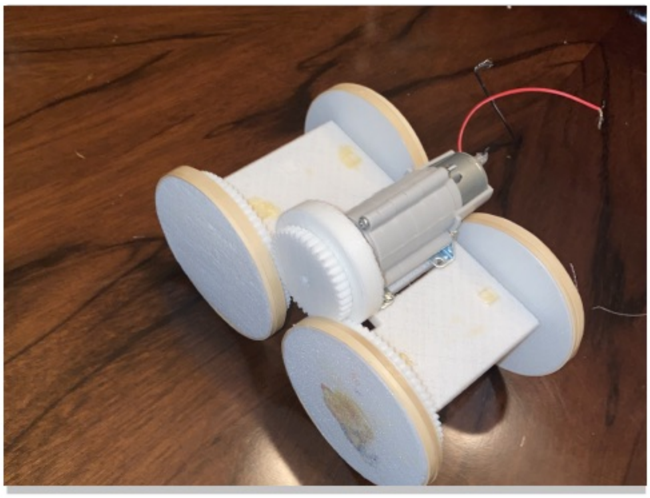
Project 4 | Furiosa vs. The War Boys

Team R2A+

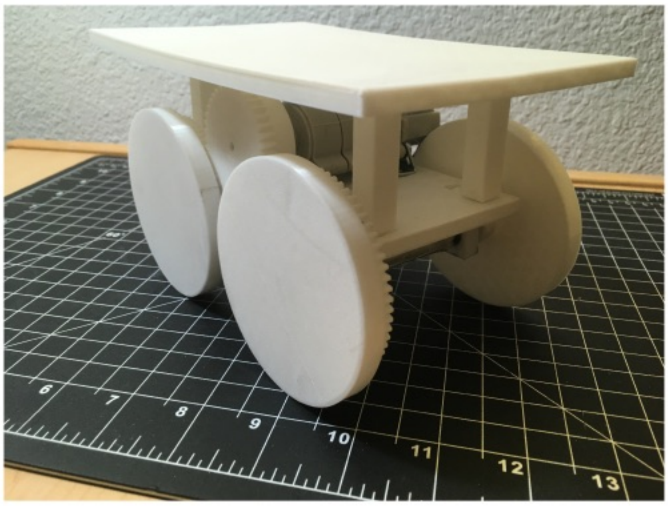
Ramgopal - Greene - Brantley

Photos

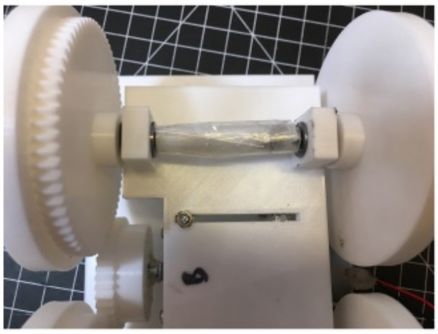




Coco Ramgopall



Alan Brantley



Axle broke during construction; the tests where all performed under the repair condition seen above. Super glue and tape for the win!

Description and Reasoning

Overall Design

We present a four wheel drive system driven by a center mounted motor and drive wheel. The gear system is arranged so that the drive gear powers the wheels on either side, each of which double as driven gears.

Chassis and Drive System

We decided on a 4 wheel drive system to mitigate slipping due to inconsistencies in the surface of the floor. The 4 wheel drive system helps maintain traction when one or more wheels slip due to floor conditions or is raised above the surface of the floor while towing the load.

Gears

The gear arrangement was selected as a response to our desired 4WD system. The idea was to simultaneously drive to wheel-gears with a single gear and transmit the torque to the other two wheels using a rigid axle assembly. The gear ratio of 700:1 was a compromise between max power output calculations and geometric constraints inherent to our design. Our motor utilizes all four planetary stages for an output ratio of 400:1, while our external gear system uses a 1.75:1 ratio.

Axles

The rigid axle assemblies consist of two wheels (one of which is a driven gear), two dowels, two chassis supports, and two bearings per support for a total of four bearings per axle. The dowels are press-fit and glued into their respective wheels and connected through a central axle. The axle assembly was designed to reduce friction as much as possible, with bearings added to provide "frictionless" rotation. In addition to the press-fit design, we applied glue to prevent slippage between the steel dowels and PLA plastic.

Chassis Supports

The supports are modular in design and consist of PLA housing and two bearings. The supports were designed to reduce the bending of the dowel and forces on the bearings. With this design, the forces applied to the bearings are half the forces applied to the wheel. The supports were designed to press-fit into the chassis to facilitate an easier assembly process.

Conclusion

Overall, our robots underperformed our expectations for a variety of factors. Two of us performed under emergency repair conditions. Future iterations would seek to construct a more rigid axle and add a more creative design to incorporate a higher gear ratio.

Estimates and Measurements

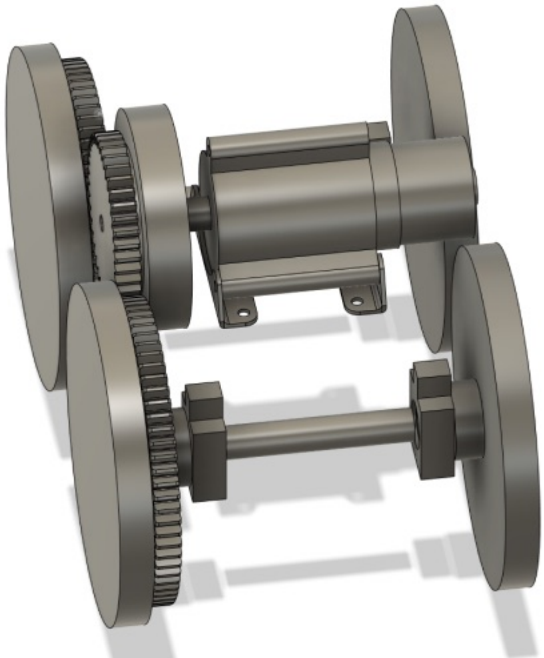
	Coco	Logan	Alan
Current (A)	2.1 A	1.24 A	1.43 A
Pull time (s)	78 s	50 s	108 s
Max Payload (kg)	0 kg	5.98 kg	2.023 kg
Applied Voltage (V)	3.5 V	3.4 V	4.4 V

Motor-to-robot speed ratio:
700:1

Transmission

Description and Reasoning

The motor operating point was chosen with respect to thermal considerations. The team calculated the maximum current for a given starting temperature and estimated operating time that the motor could operate safely. From the maximum current and motor constant, the motor torque was calculated. Subtracting motor friction from the motor torque resulted in the torque at the motor shaft. The shaft torque enabled the team to calculate the necessary motor speed to provide the max power from the motor power curve. Plugging in the resistance, max current, motor speed, and motor constant provided the voltage that needed to be applied. Using the max power— calculated from the motor operating point— and an overestimated system efficiency, a max force could be determined given the distance needed to travel and the time constraint. An overestimated system efficiency was used to make sure that the calculated max force was not less than was actually achievable. The max force provided a torque out at the wheel for a given wheel radius. Dividing by the motor shaft torque resulted in the optimal gear ratio to accomplish the task.



Power Flow

$$P_{elec} = V * I$$

$$P_{in} = P_{elec} * \eta_{motor} * \eta_{gear}^4$$

$$P_{out} = \frac{F * d}{t}$$

$$P_{out} = \frac{0.3 * 5.98 * 9.81 * 1}{50} = .352\ W$$

$$\eta_{printgears} = \frac{P_{out}}{P_{in}}$$

$$\eta_{printgears} = \frac{.352}{.399} = .88$$

$$\eta_{system} = \eta_{motor} * \eta_{gear}^4 * \eta_{printgears}$$

$$\eta_{system} = .53 * .65^4 * .88 = .083$$

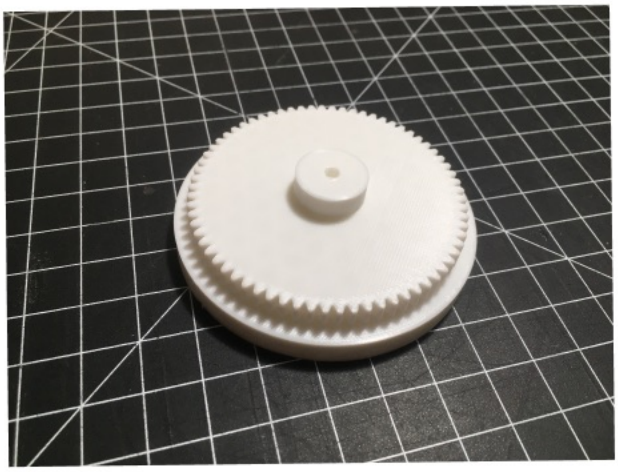
The majority of the power was lost in the motor and the planetary gear stages. In this assembly, more than 90% of the power into the motor was lost to friction in the DC motor and the planetary gears which were dissipated as thermal energy. From the motor and the planetary gears, the efficiency in the print gears, axle assembly, and wheels were high. The printed gears, axle assembly, and wheels retained 88% of the energy that was received. Again, the power loss was due to friction in the gears, axles, and wheels. The overall system efficiency was 8.3%.

Wheel and Gear

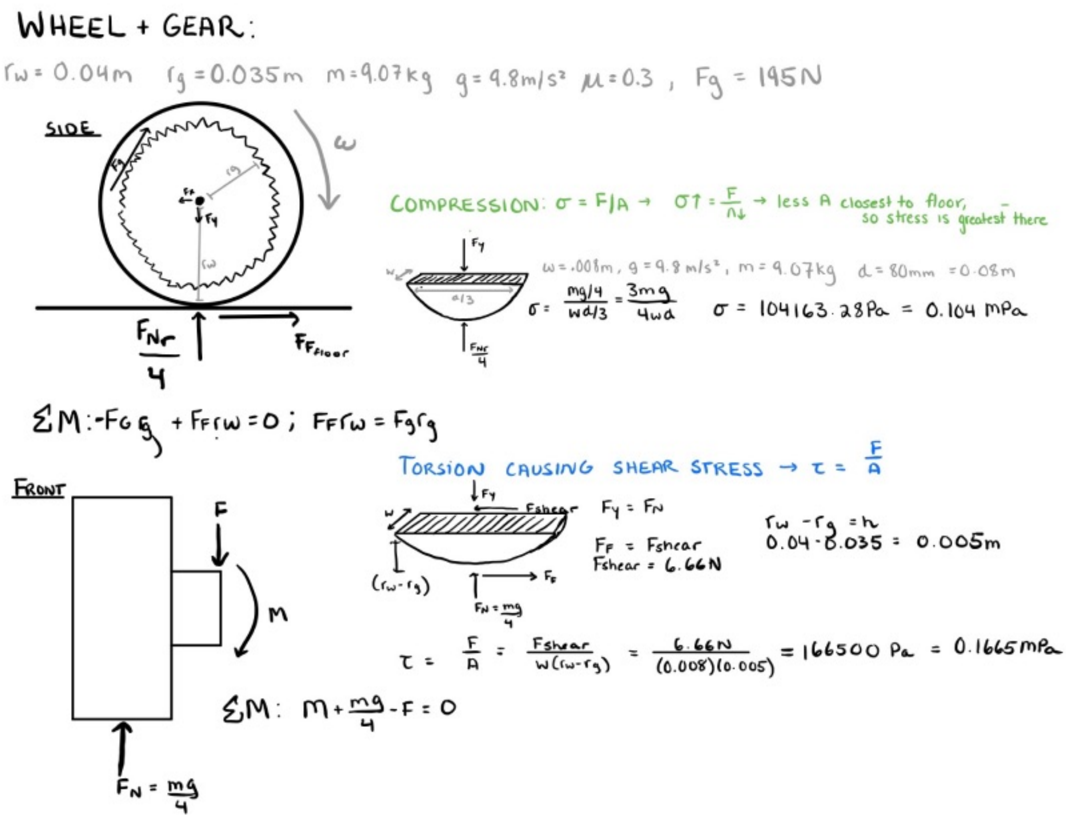
Description and Reasoning

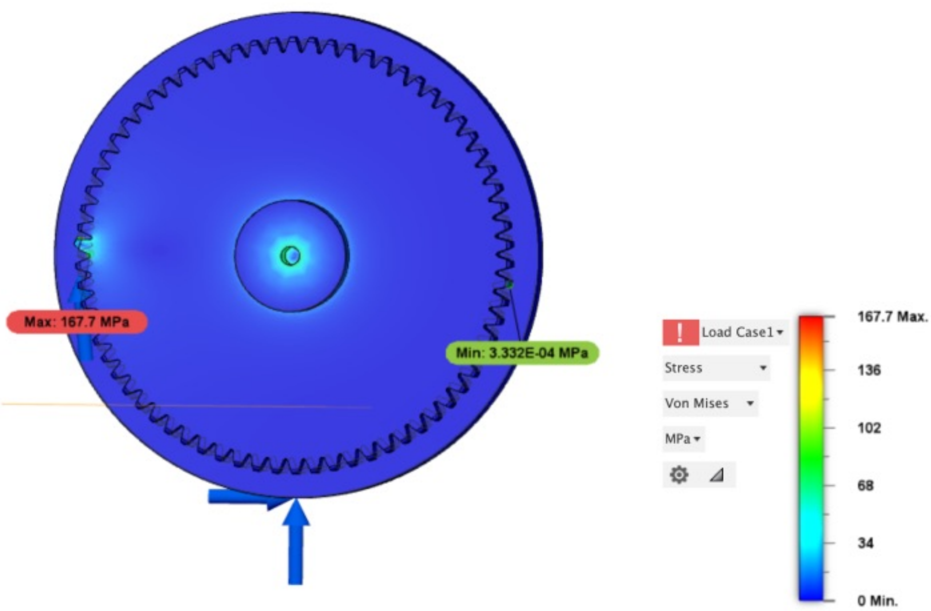
Coco Ramgopal

The driven gears on one side of the robot double as wheels. This was done to avoid shear stress that would have occurred had the gear been rigidly attached using adhesive. We decided to drive the wheel directly to minimize the number of interfaces from the motor to the ground.



Wheel and Gear

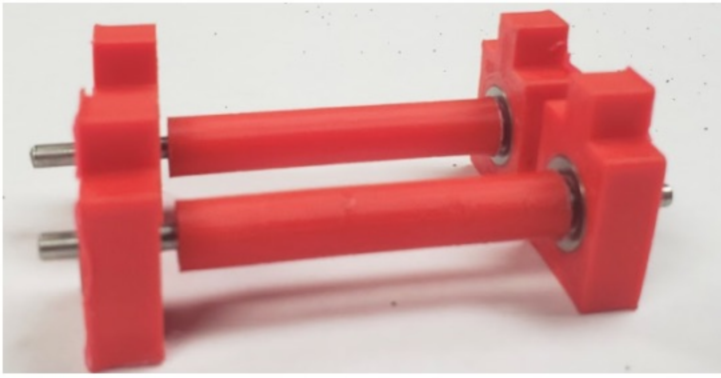


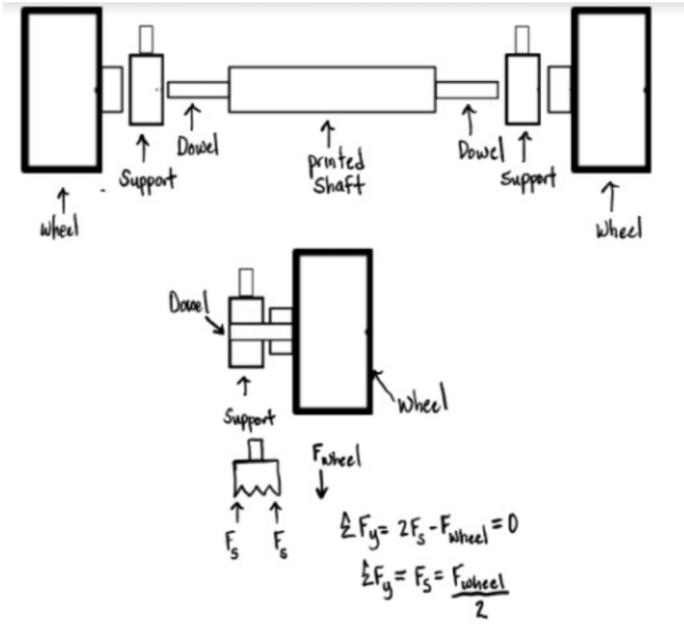


Rigid Axle

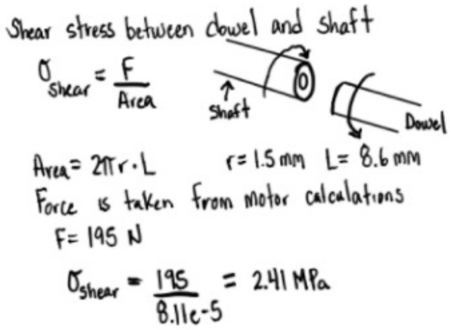
Description and Reasoning

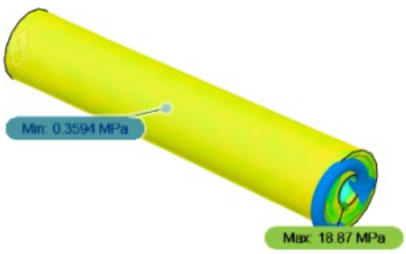
Logan Greene

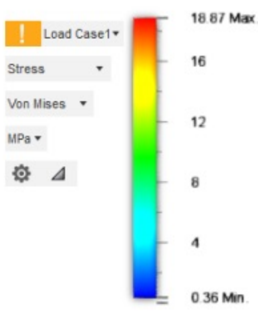




The configuration of the axle assembly was chosen because of concerns that the axle would shear from the wheel if it was printed as one piece. The optimal orientation of the print would align the layers to the axis that the moment in the shaft is generated about. The layers are the weakest area of the part and would be the first place that would fail once significant torque was applied to the wheel. The adhesive was thought to provide sufficient bonding strength of the dowel and the printed parts. The shear strength of the adhesive is typically a couple of MPa compared to the largely unknown shear strength of the part due to variations in print quality. Also, providing bearings in the chassis supports provides less friction than a plastic shaft rotating in plastic supports. The chassis support and the wheel configuration reduce the chance for the shaft to bend. The minimal gap between the wheel and the support produces a negligible moment in the support housing.



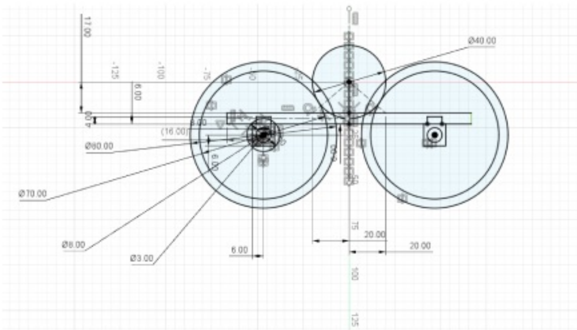




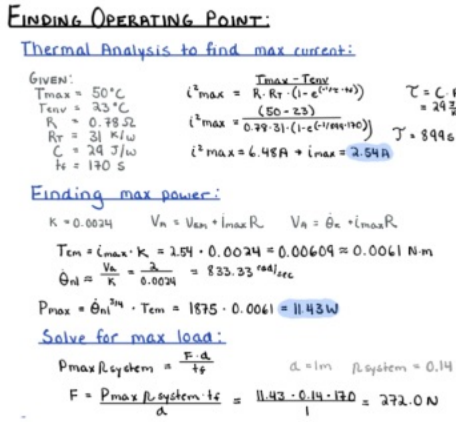
Gear Configuration and Chassis

Description and Reasoning

Alan Brantley



Given our decision to implement a 4WD, we ultimately decided on a symmetric gear system with the drive gear situated in the middle of the two driven gears. Our goal was to pull as high a load as possible in 270 seconds. We calculated the maximum power output of 11.43 W and, given an estimate of 0.14 system efficiency, we arrived at a target goal of 272N. Based on these values and an estimated wheel radius of 30mm, we calculated that a gear ratio of ~1300:1 would result in maximum power transmission. However, we were geometrically constrained by the physical size of the motor and the fact that the wheels must be larger than the driven gears. The largest gearbox to robot ratio we could achieve without the wheels interfering with each other or with the motor was 1.75:1, resulting in a final gear ratio of 700:1.



The overall chassis geometry is dependent on the gear configuration and the length of the four-stage motor. The thickness of the chassis was derived to accommodate the length of the set screws, while the length is proportional to the distance between the front and rear wheels. The screw slots are wider than the screws to accommodate variations between team member motors. We chose slots rather than screw holes to allow for fine-tuning of the motor's position relative to the driven gears.