Cycloidal Disk Motor Cartridge

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About us:

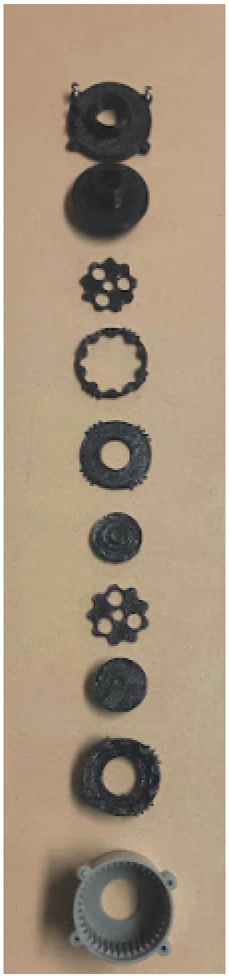
I am Micah, a Junior at Harrisburg High School in South Dakota and this is my seventh year in robotics. Ian Brueggeman, also a Junior at HHS, has been involved in robotics for four years. We both compete on team 7686B under the Tiger robotics organization.

Why we created the part:

Torque gear ratios are very important for most types of lifts in VEX. This is simply because it requires a lot of torque to raise a mobile goal or a mechanism in the air. We wanted to create a part that would improve something that had to do with our robot this season, but would also be applicable in future seasons, as well as integrate with current vex parts. We picked a cycloidal drive because it is a compact way to achieve high torque. For high torque gear ratios, our new part allows for a significantly more compact and simple installation.

The Part:

We have created an 81:1 motor cartridge that converts the output of the motor to approximately 14.8 rpm. This compared to a 36:1 cartridge (which is really just 12:1 because some of that gearing happens within the motor) has roughly seven times the torque; the same amount achieved with a 12 tooth gear driving an 84 tooth gear. It uses two stacked cycloidal disks that each have a 9:1 gear ratio to create a compound gear ratio.



The Image to the shows the ten parts of the cycloidal gearbox.

← Cartridge cap

← Output Rollers/Shaft Insert

← Upper Disk

← Upper Ring Pins

← Separator

← Output Roller/Input Cam

← Lower Disk

← Input Cam

← Lower Ring Pins

← Cartridge Housing

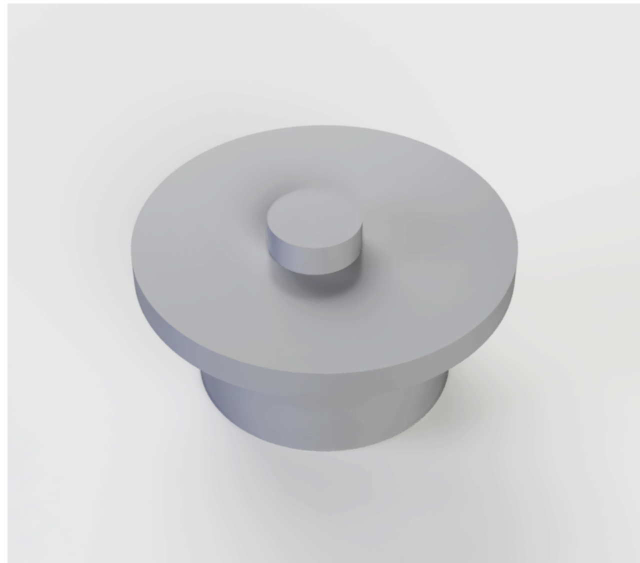
Because a cycloidal disc is not a very common mechanism, I will explain how it works. The Wikipedia article on [Cycloidal Drives] has more information and a great animation. A cycloidal disk performs offset rotations driven by a cam. It spins inside a base with ring pins. There is one more ring pin tooth than on the disk. The cam makes the disk slowly rotate around the ring pins. Then, there are pegs that go into the holes in the disk. This receives an output as the disk spins. Its gear reduction is exactly n number of teeth on the cycloid to one (n:1), which in our case is 9:1. Our entire design fits into a standard size motor cartridge and can be installed in a motor.

Above is the assembly next to the cartridge housing, inside the housing and fitted in a motor, and enclosed inside a motor.

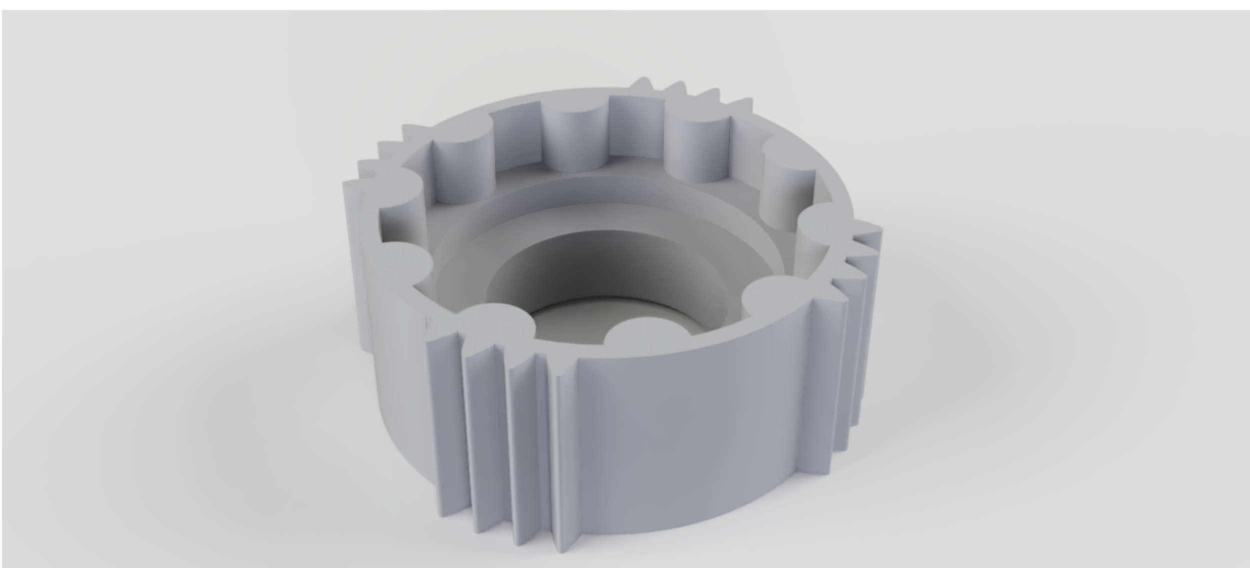
3D Modeling:

For this project, Fusion 360 was our chosen Autodesk Software. It was on version 2.0.11894.

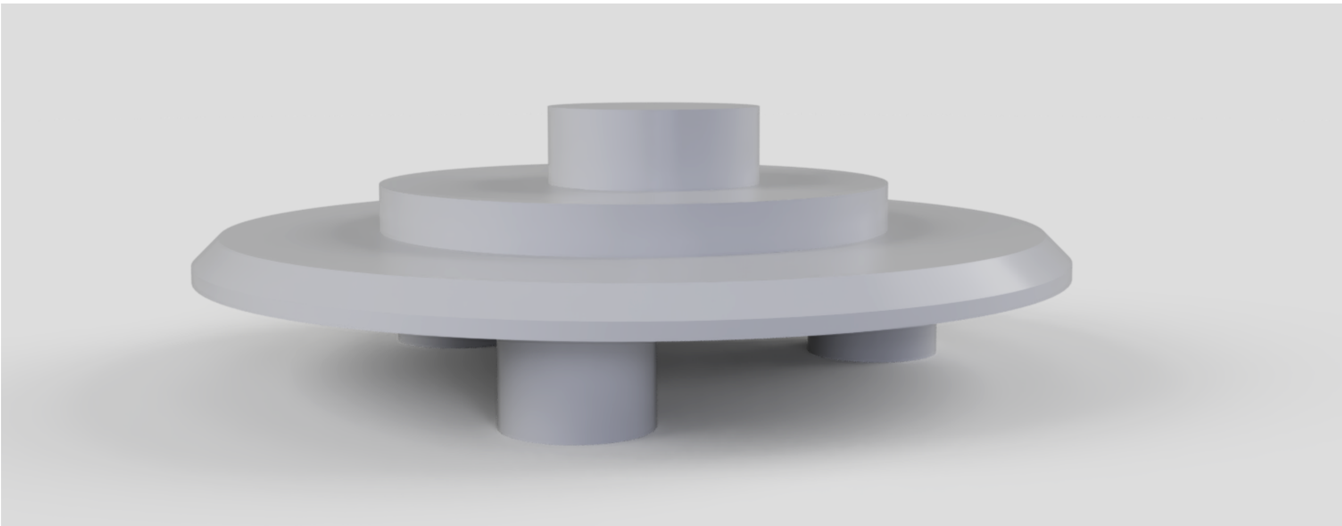
I started by calculating the ideal gear ratio for the cycloidal drive. I ended up with two 9:1 gear ratios from the 1200 rpm motor output. This would mean I had to have ten outer teeth and nine inner teeth for my cycloid. The way a cycloid rotates is with an input cam, as shown here:



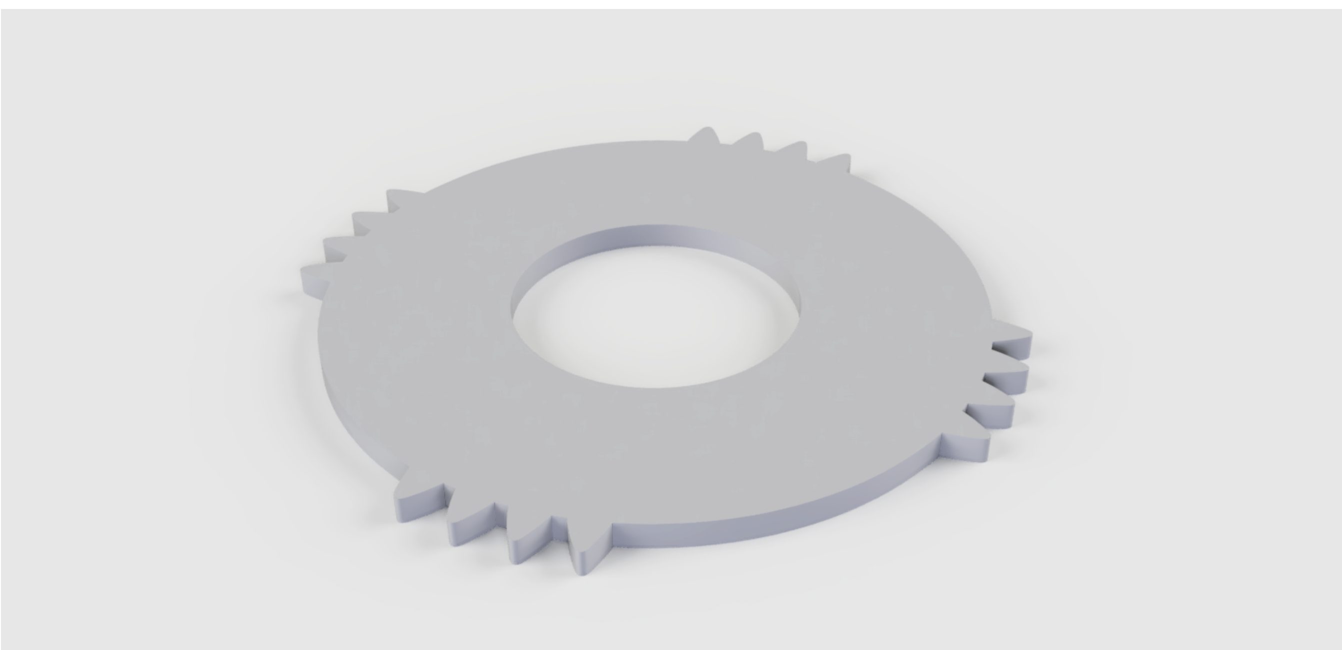
It has one off-center peg to rotate the cycloid in the body. The body slots into the existing cartridge through the use of gear teeth in four spots:



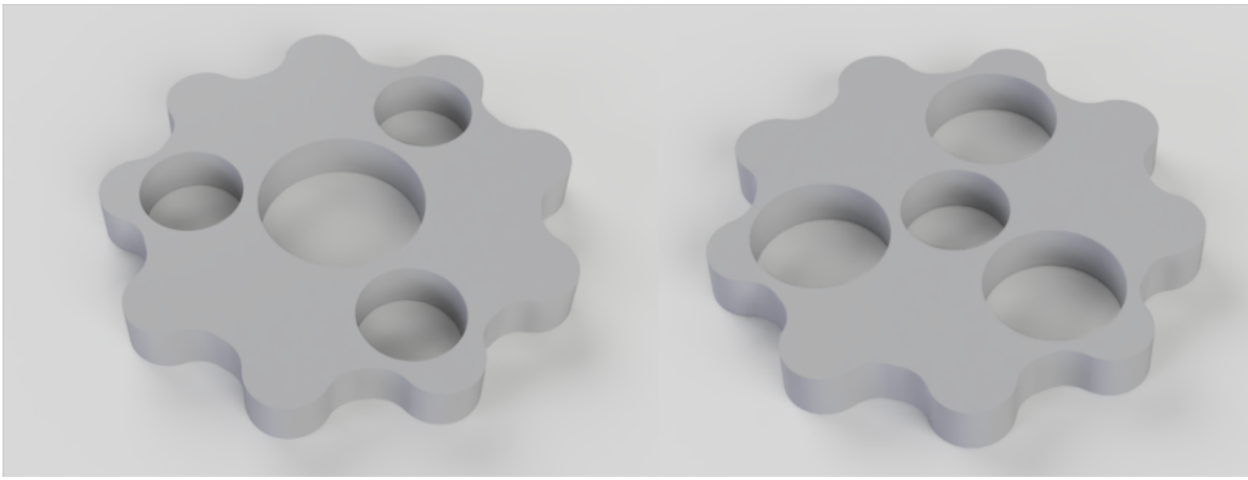
The output of the first cycloid goes into the power transferer, which connects it to the next input cam:



The transfer is kept stable by the separator:



The most important part of this mechanism is the cycloid itself. I went through several iterations, as shown here:



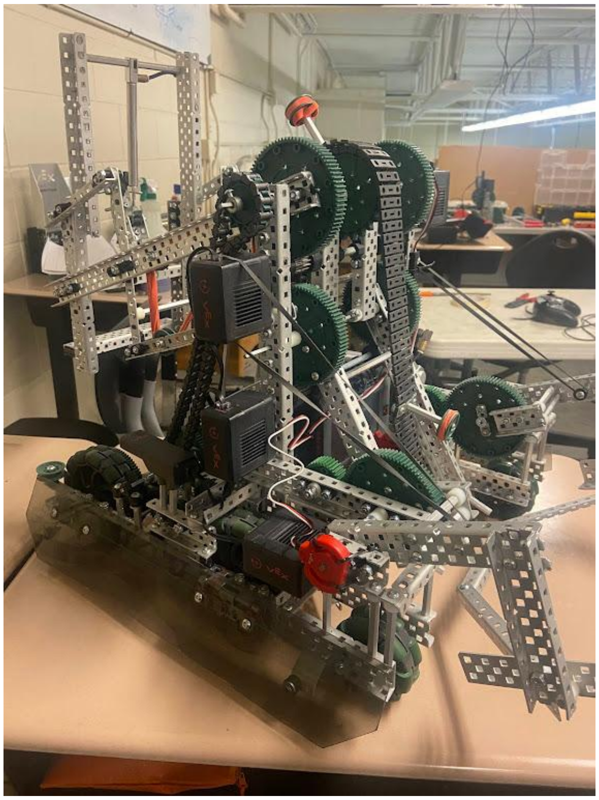
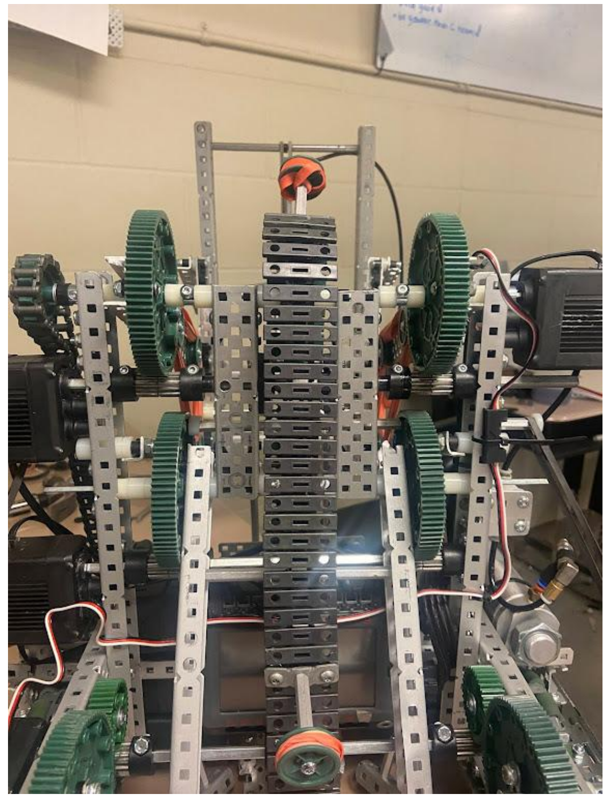
Old version of cycloid New cycloid

I decided to prioritize the outer holes rather than the inner one in the later designs. This is due to how the cycloid's motion is translated into linear rotation. Mathematically, the output rollers have to be half the diameter of the outer holes, this meant that if I kept the original design, the rollers would be too brittle to handle a heavy load.

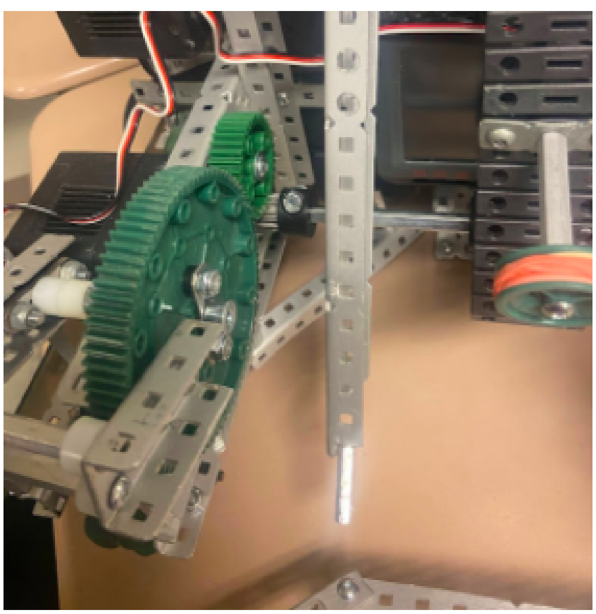
Because of the limitations in strength and precision of 3D printing, it is likely that this design would not be able to run a lift with weight applied, unless it was created out of precision machined metal, like standard motor cartridges. We also have to do a little bit more testing with input cam parts to figure out the optimal offset for the durability of the mechanism.

Applications on our robot:

Our robot has three separate instances of a 7:1 gear ratio. All of which could be made much more compact by the application of our part.

Above is a picture of our whole robot on the left for reference. We have three lifts: A pivot lift in the front, an auxiliary mobile goal lift behind the pivot lift, and a 6-bar on the back, also to pick up mobile goals. The right shows the three 7:1 gear ratios, all driven by 100 rpm motors.

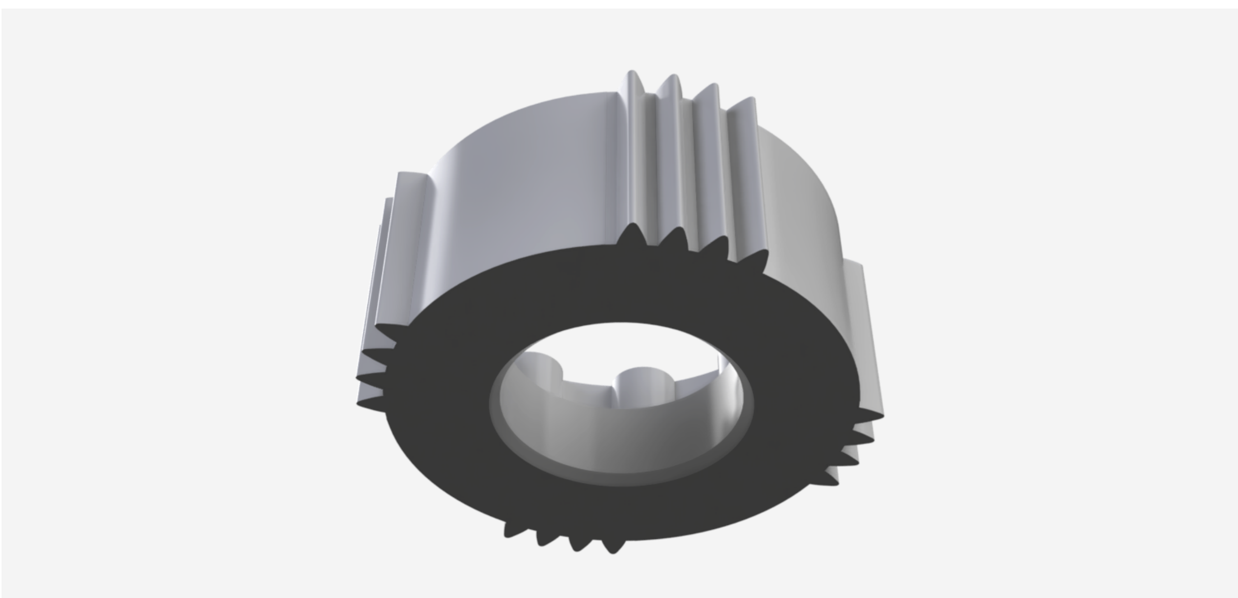


A closer view of the pivot lift gearing.

The 6-bar and auxiliary lift could easily be directly powered by a motor through the use of our cycloidal disk motor cartridge. This would save space and add stability. It would also eliminate the need for the floating stabilizers, which are the c-channels between the big gears that are only attached to the axles. All they do is stabilize the gears for both of the lifts. This would further save space and make it much easier to optimize our ring conveyor system and open up more options for ring loading mechanisms.

What We Learned:

(Ian) This project bettered my understanding of all the aspects of CAD. Before this project, I had little understanding of how to animate a design to represent assembly. This knowledge will be beneficial to me in the future when I am trying to explain my designs. One feature that I hadn't used before this project was the offset feature, which allowed me to map edges of surfaces easier. The circular pattern feature was very helpful in designing the cycloidal disk, as well. I also used chamfered edges to help to reduce the elephant's foot. As shown on the bottom of the lower ring pin body:



(Micah) I developed ways to convey ideas of the design process using adequate vocabulary. Despite the fact that our design is not simple, it makes things much easier for the part's end user.