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VEXU Competitive Robotics Team
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Design and Fabrication Process of Custom Indexer Wheel

I. Introduction

When presented with the new game each year, Team YNOT strives to tackle the tasks of the game in its entirety. Team YNOT sees this as an opportunity to use custom parts to efficiently utilize every aspect of our robot and unlock potential that VEX parts alone cannot reach. Custom parts allow us to achieve accurate spacing anywhere on our robot, allowing us to maximize our use of space and minimize wasted material. Through the creation of custom parts, we can integrate mechanisms into spaces that would otherwise be inaccessible. Additionally, because our use of materials becomes more efficient, we can reduce the overall weight of our robot which gives us an advantage during game play.

II. Need for Custom Parts

In previous seasons, Team YNOT has created rubber band rollers, also known as indexing wheels, using sprockets, standoffs, and rubber bands provided by VEX in order to manipulate game objects. In *Turning Point*, we used the rollers to intake the hard plastic yellow balls that were part of the challenge. The rubber bands allowed the perfect grip and tension to be compliant with the ball's shape while exerting enough force to bring the ball into the robot. **Figure 1** shows the rubber band roller we used in *Turning Point.*

Figure 1: *Indexing Wheel on the front of one of Team YNOT's robots from VEX Turning Point (2018-2019)*

Because this year's balls are much larger than those used in previous years (**Figure 2**), the sprockets provided by VEX were not large enough to create indexing wheels capable of efficiently intaking the elements. To achieve specific spacing, structural, and mounting requirements, design and production of custom indexing wheels was necessary as no existing VEX gears, wheels, or other available parts would allow us to meet our design goals.

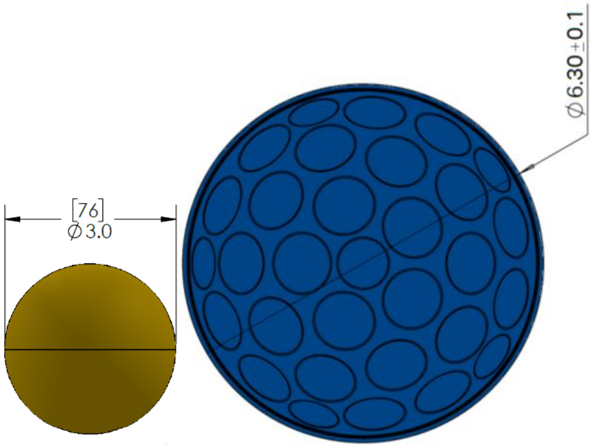

Figure 2*: Relative size of balls from Turning Point (left) and Change Up (right) (to scale)*

III. Goals and Design Process

The specific goal for this part was to create a space-efficient, fast indexer wheel to which we could securely attach and quickly replace rubber bands. Specifically, by maximizing the diameter of the wheel, we could: (1) achieve the greatest rotational speed, (2) consistently have a large surface area of rubber bands in contact with the ball, and (3) minimize the need for additional wheels. We also needed to be able to attach a motor to the indexer (directly or indirectly) with flat or square high strength shaft insert bearings. To save even more space, all screws and inserts needed to be countersunk so that the roller could be as wide as possible without having any interferences.

The first step to designing this part was for the team to talk about potential ways to achieve our goal. Because we ruled out Vex gears and other stock parts quickly as the diameters would not allow us to minimize the number of wheels needed and use our space efficiently, we had to produce a custom solution. Initial thoughts were to design a scaled-up gear with individual teeth to hold each rubber band. This would allow us to quickly change rubber bands and maximize the diameter of the roller, but we worried this would not secure the rubber bands enough to prevent them from becoming detached. We theorized that a wheel with holes for zip ties would allow us to reach each of our design goals (**Figure 3)**. The next step was to draw out our plan on whiteboards and on paper so we could all agree upon the design and avoid confusion later in the fabrication process. Keeping our goals and constraints in mind, we used CAD software including Autodesk Inventor and Fusion 360 to design the wheel (**Figures 4.1 and 4.2**), find interference issues with other parts on the robot, and export the design to STL, which is the necessary format for 3D printing. This was one of the first parts we designed for our robots, and this is reflected in the structure of our robots being centered around our wide rollers.

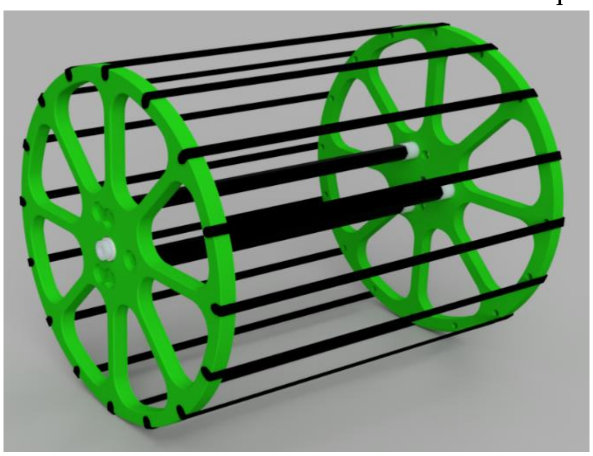

Figure 3 (above)*: CAD Render of Indexer Assembly*

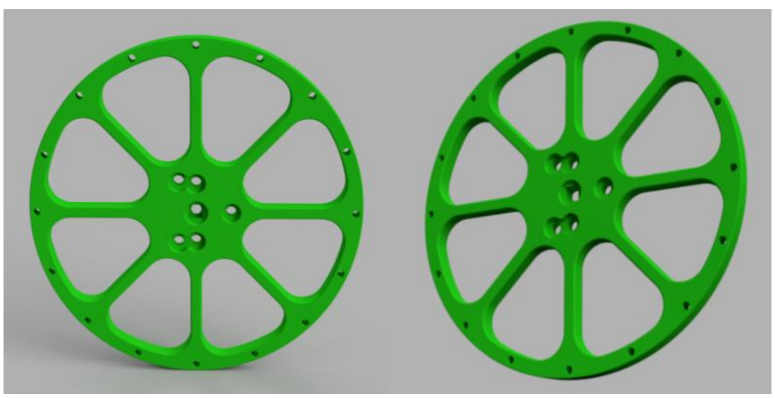

Figure 4.1 and 4.2: *CAD Renders of Individual Indexer Wheels*

IV. Production and Testing

After finishing the initial design, we printed several test wheels and added them to our early season robot. Our observations from the performance of the rollers were beyond what we had hoped for as the uptake system using our new wheels was quick, simple, not prone to jamming, and easy to integrate (**Figure 5**).

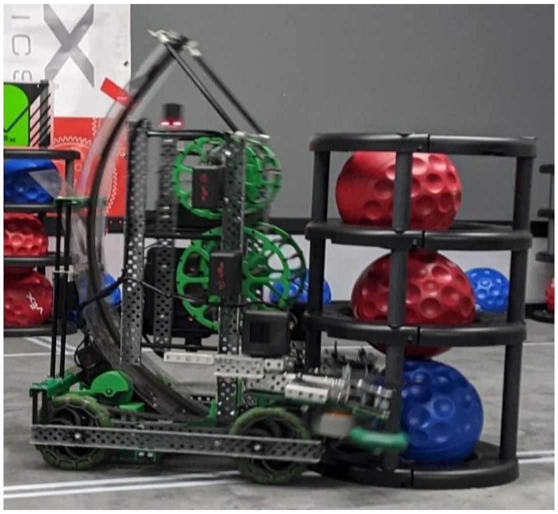

Figure 5*: Indexer Wheels in Action on our early season robot*

Only small adjustments were made to the overall design in the CAD once we settled on our final design. The most notable adjustment was adjusting the diameter of the wheel to allow for enough space for the zip ties and rubber bands to not contact anything. Our initial printed wheels had the issue of each of the holes for zip-tying rubber bands down being too small for our zip ties to fit though and the countersunk holes for each screw were too small for the screw heads, so we had to enlarge each of those holes to allow for the proper fit. We also scaled down this design to a smaller outer wheel diameter so that we could have a second roller that could be rotated separately to hold or shoot the ball out regardless of if the larger wheel was spinning. On the smaller design, we added small hooks to allow for additional locking options that may be needed in the future.

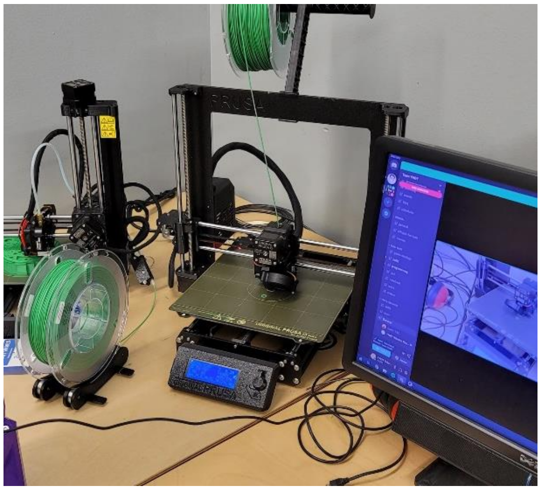

Figure 6*: Start of Indexer Wheel 3D Print*

We decided that 3D printing would be the most effective and economical method to fabricate this component since it would experience loads that would not justify the need for a part machined out of aluminum or another material. Our decision to 3D print allowed us to produce the part and scaled variations quickly and cheaply, which were influential in our decision to use this part and its derivatives on our early season robot and both our 15 and 24-inch robots. Machining this part would have required significantly more time, human input, and money.

We selected Polymaker PolyMax PLA for this part (and all our printed parts) because of its easy-to-print nature, impact resistance, and other mechanical properties compared to other common materials like ABS and regular PLA. To maximize strength in our parts we use these printer settings for our Prusa Printers (**Figure 7**).

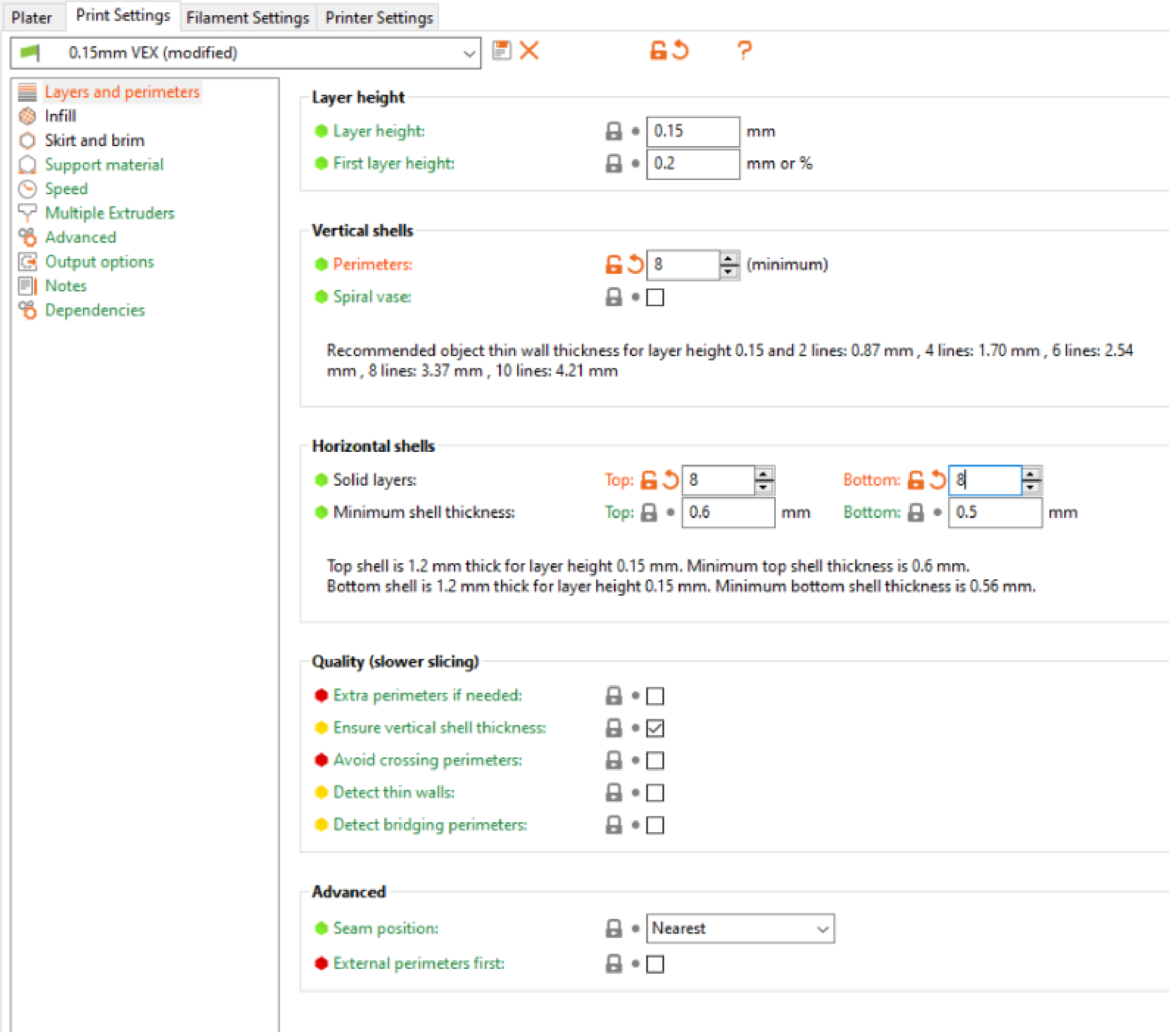

Figure 7: *Screenshot of Printer Settings used for our prints*

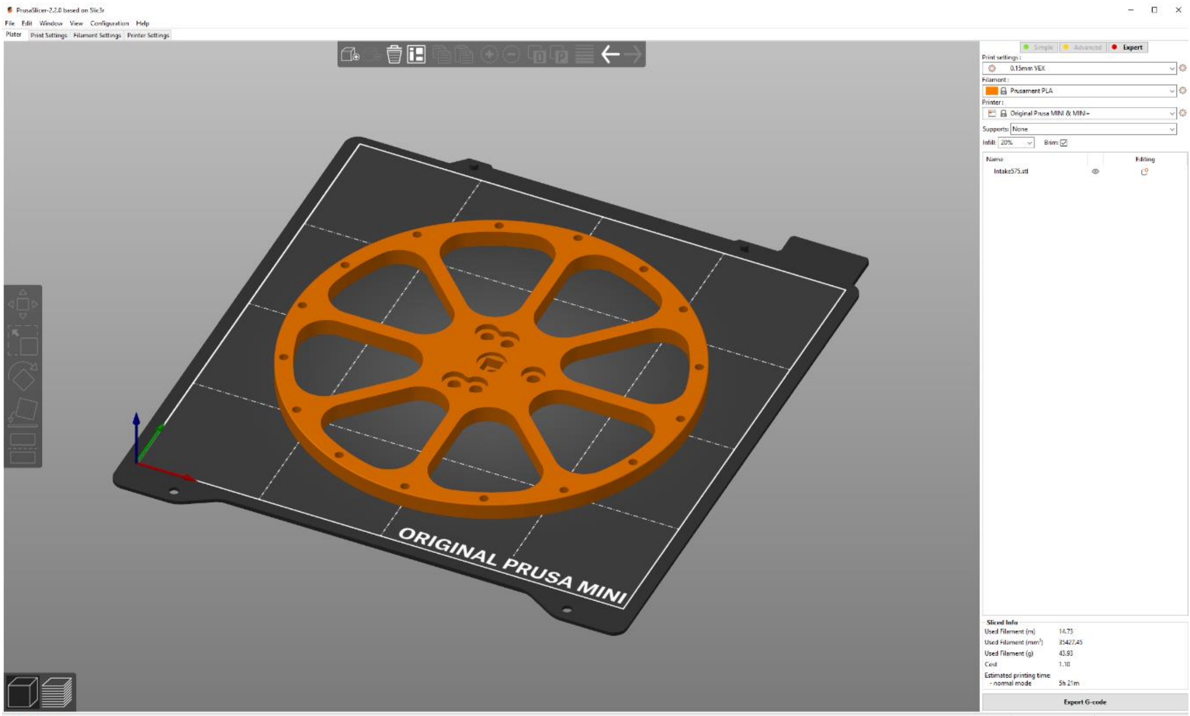

***Figure 8.1**: Slicing of Wheel in PrusaSlicer*

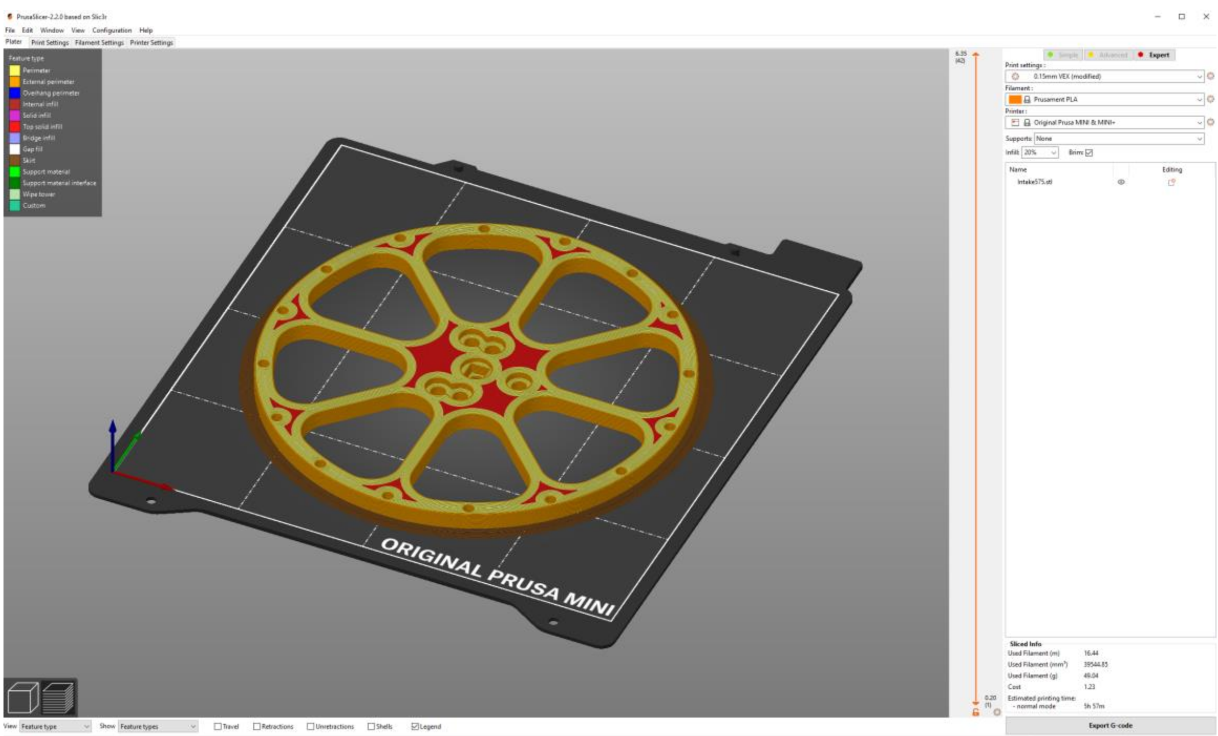

***Figure 8.2**: Slicing of Wheel in PrusaSlicer*

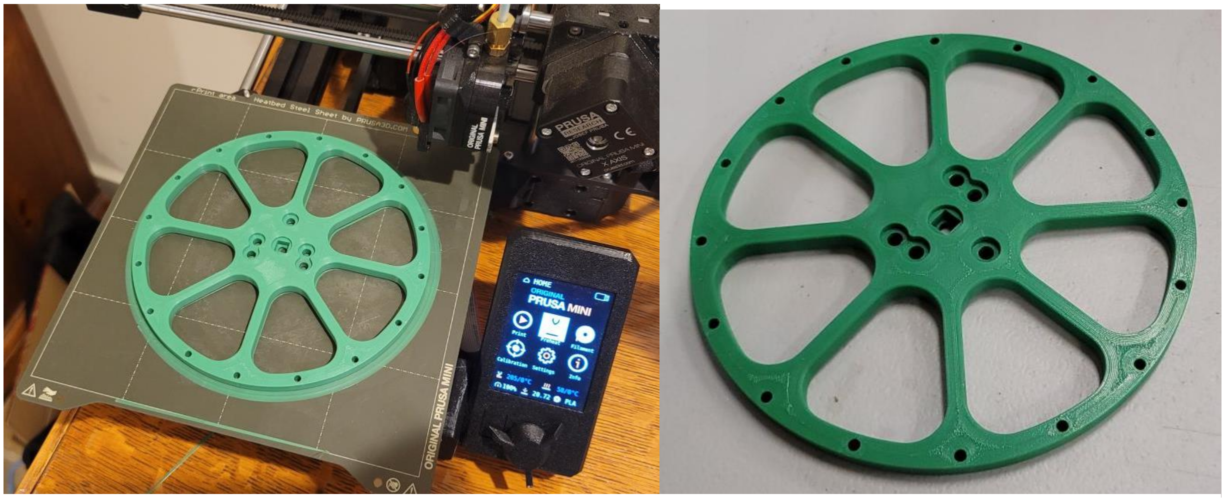

Figure 9.1 and 9.2*: Wheel before and after removed from printer*

Figure 10.1, 10.2, 10.3*: Assembly of Indexer Roller*

V. Final Design

Our final design **(See Figure 11.1 and 11.2)** consists of a wheel with a 5.75-inch diameter and 16 individual mounting holes for zip ties evenly spaced along the outside of the wheel. These allow us to minimize maintenance times when replacing damaged or broken bands because we do not need to remove the whole roller just to replace one band. Instead we just cut and replace two zip ties and one rubber band. We also included three holes in the middle segment of the wheel to mount standoffs in a triangular pattern to achieve different widths of the roller. Finally, the 3 holes in line with each other will allow us to mount a flat bearing should the need arise, and the central hole has a countersink to allow for a square bearing insert to be added for direct drive. Each mounting hole is countersunk to allow for mounting screws to be flush with the outer surface, this minimizes rubbing and allows for the maximum width roller which increases stability and grip on the balls because there will be more tension in the rubber bands.

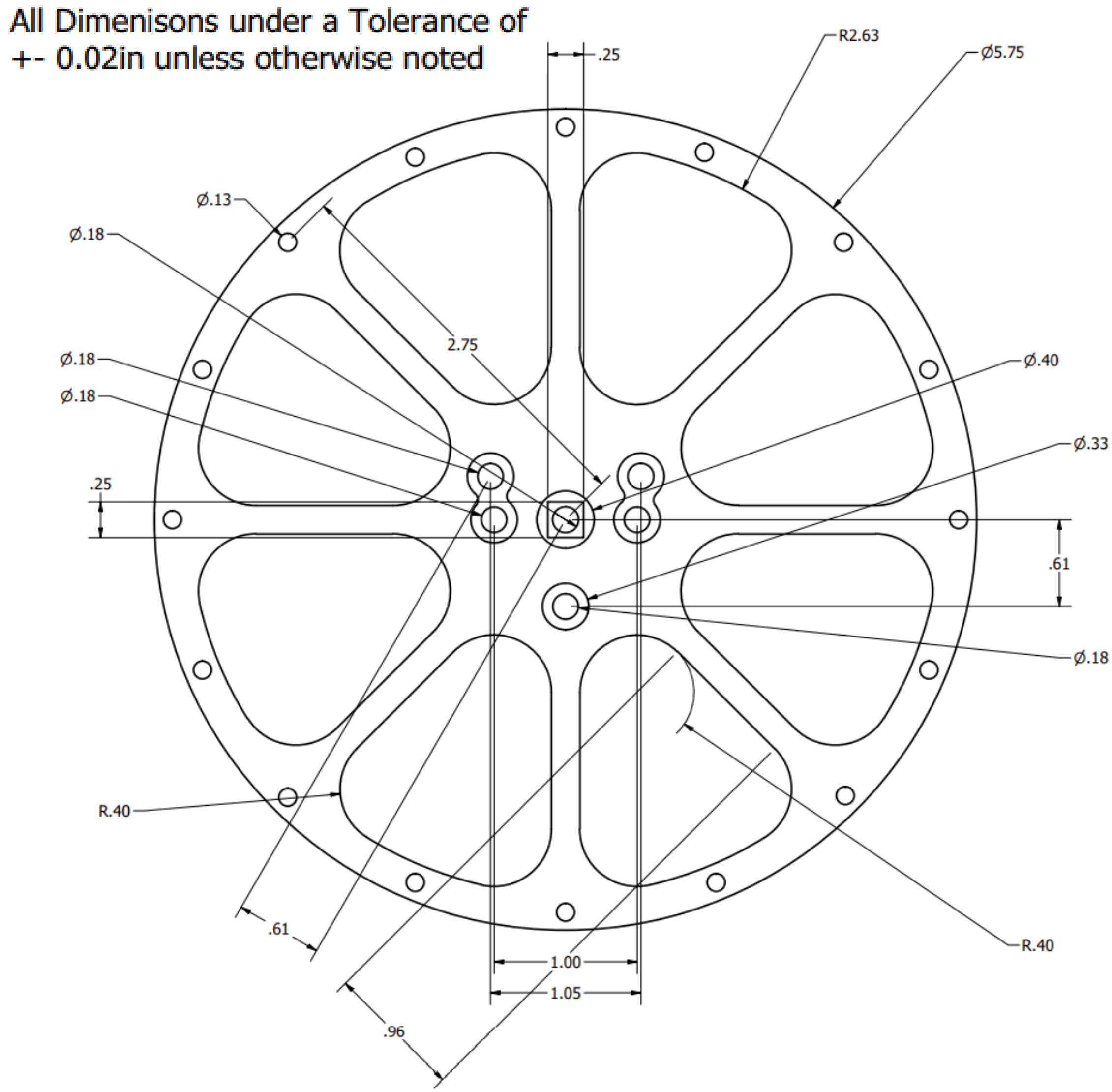

Figure 11.1: *Wheel Engineering Drawing (Front)*

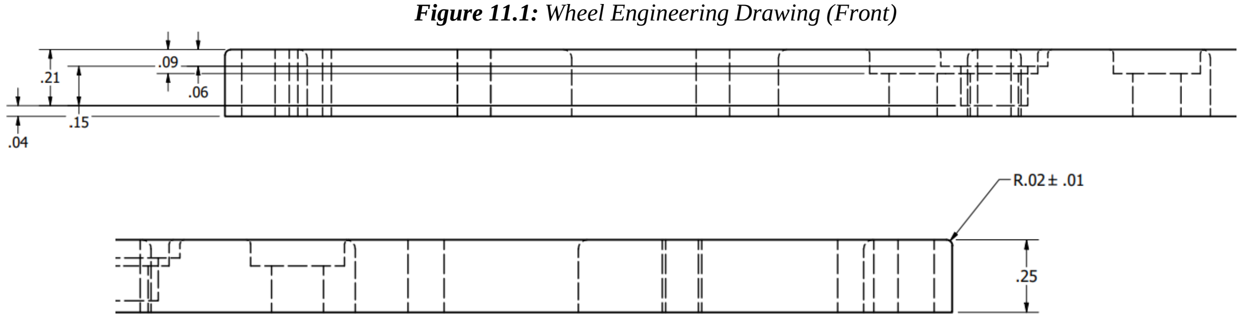

Figure 11.2: *Wheel Engineering Drawing (Side)*

VI. Future Iterations

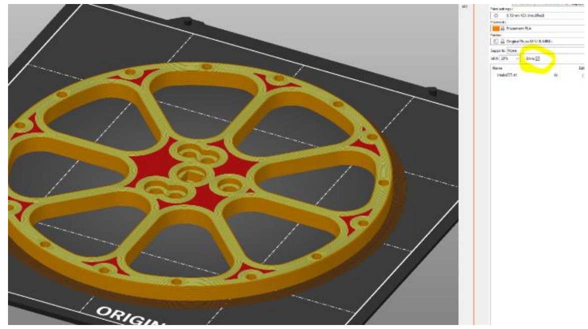

Figure 12: *Screenshot of brim around wheel in PrusaSlicer*

For future iterations, we recommend using plenty of glue on the build surface of your 3d printer and adding a brim (**Figure 12**) to make sure the wheel does not peel up from the print bed as there is such a small surface area contacting the printer. Furthermore, when selecting print settings, we used 6 perimeters, top, and bottom layers to maximize strength, especially in the spokes of the wheel. Additionally, we had eight spokes supporting the outer radius of the wheel; however, five or six spokes may work just as well and decrease the weight of the part if this is necessary. We also might add extra mounting holes so we can sprocket or gear drive the wheel directly, depending on each bot's set up this might not be necessary, however.

VII. Component Performance

This part drastically improved the performance of our robot. There have been no issues with gripping the balls and effectively transferring energy to them when shooting. We have seen a noticeable difference in the speed of cycling balls though our robot compared to other robots with similar indexing methods. We also are incredibly happy with the easy-to-swap nature of the rubber bands and we can change broken or worn bands in less than a minute; we hope this will prove useful in competition when there is little time between matches.

Figure 13.1, 13.2, 13.3*: Indexer Wheel and Smaller Variation mounted to our 15-inch Robot*