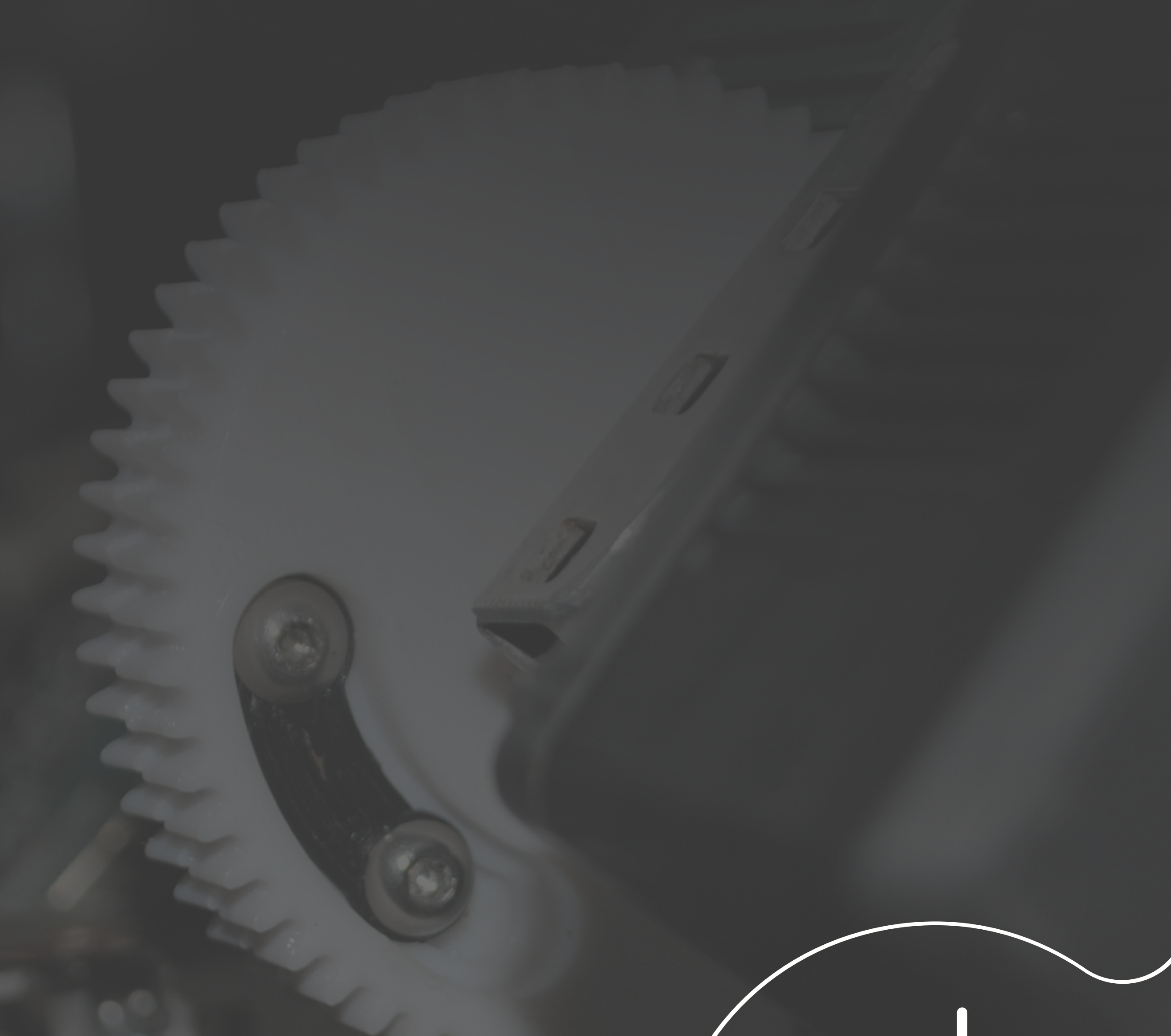
Anti-backlash Gear

Final Report

2022 "Make It Real" CAD Engineering Challenge
Sponsored by Autodesk



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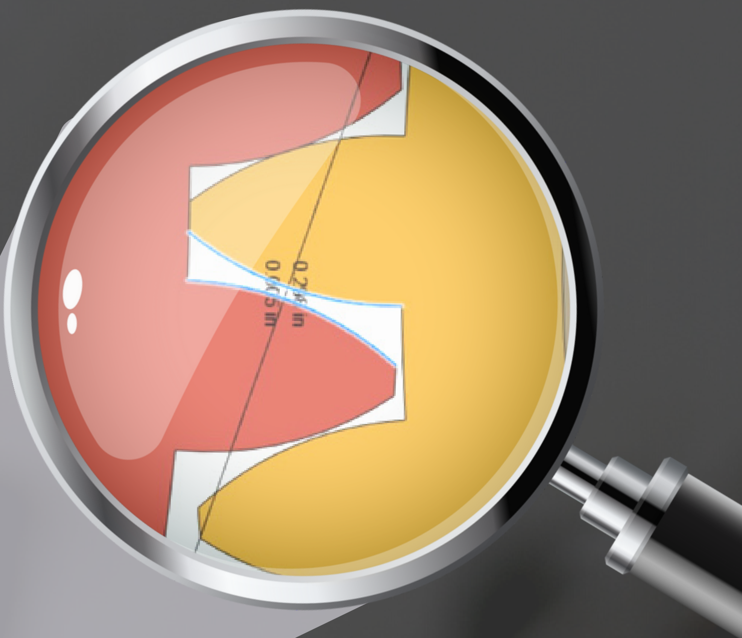
Introduction

Insights into our development scope

In VEX Robotics Competitions, externally geared mechanisms requiring precise movements are a universal necessity seen in nearly all robots. Getting accurate rotational data from these is one of the keys to effective autonomous programming. However, spur gears include a clearance between the mated gear teeth which is a necessary feature that allows proper movement of the meshing gears. This play between the gear teeth can affect the recorded position of the driven gear, especially after changes in direction.

In our VEX-U robots, we have encountered compounding errors in our positioning code caused by gear backlash. As a response, we have developed a solution in the form of a compounded two-gear assembly that mechanically compensates for this backlash.



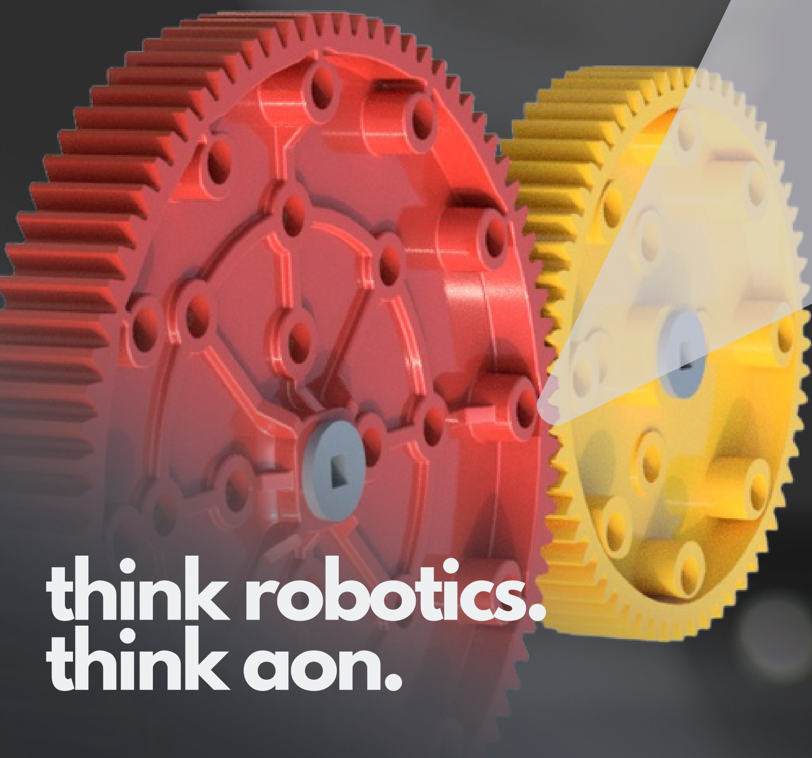


Figure 1: The backlash between VEX Gears is 0.0054" inches; as such, before the driving gear (red) engages the driven gear (yellow), it will have travelled this distance. This causes a discrepancy between the output distance to travel and the actual distance travelled.

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Specifications & Platform Integration

Technical description & use-cases

This 60-tooth gear assembly was designed to be a drop-in replacement for a standard VEX High Strength Gear. The assembly consists of three main 3D printed parts: the fixed half, the free half, and the tension spring. The fixed gear mounts to a shaft using a VEX shaft insert, and the whole assembly is held together using VEX-standard 0.375in #8-32 machine screws.

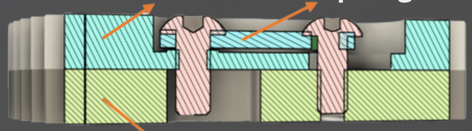

Figure 2: Anti-Backlash Gear Assembly Cross-Section

The fixed half is mated to the shaft while the free half is not. The TPU tension spring pulls both halves together and ensures there is always contact between the teeth of the anti-backlash gear and the gear it is meshing with **(Figure 2** & **3)**. #8-32 screws self-tap into the PETG gears to hold the whole assembly together. Both screws tap on one half-gear each and extend into a slotted section on the other half gear, to allow for the rotational movement of the anti-backlash mechanism.

Figure 3A-C: As the system turns, the spring pulls the halves together to compensate for the backlash movement

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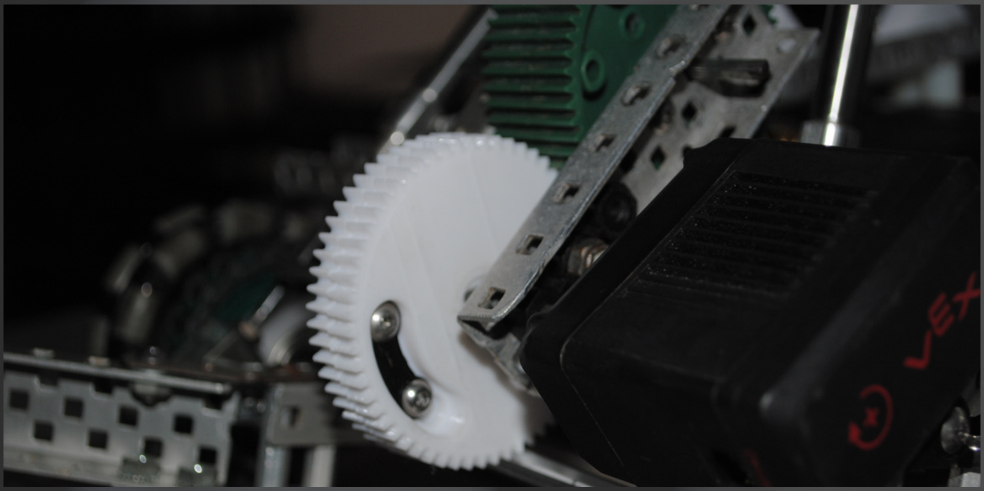
Specifications & Platform Integration

Technical description & use-cases

Although the backlash itself is a relatively small quantity (0.0054in for VEX gears), its effect can be very noticeable following multiple direction changes. In general, our anti-backlash gear enhances movement precision on mechanism that produce a limited angular or linear translation. By constraining our design to hold an identical footprint as a VEX High-Strength Gear, any mechanism already using a high-strength gear such as like bar lifts, claws, a rack and pinion, or even drivetrains would benefit from the precision the anti-backlash gear provides during autonomous movement when positioning to score. These characteristics make this a highly economical way to vastly improve robot performance whilst also enabling development lead-time savings, particularly for programmers by minimizing the need for in-code corrections as a cause of these types of mechanically unavoidable inaccuracies.



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Design Process & Tools

Applied PMTs (Process-Method-Tools)

Autodesk Fusion 360

As a platform, we opted to employ Autodesk Fusion 360 Student for the development of this component in order to maximize in-team collaboration and inputs - this decision was further validated by the seamless integration Autodesk Fusion 360 provided with our Agile methodologies and platform. We began by importing the official model for the VEX High Strength Gear and Shaft Insert to project upon an initial sketch to guarantee that our new model preserves the exact same dimensions. Within the sketch, we traced five (5) equally spaced radial guidelines. At ¾ of each line, we established the center points for the tapping holes for both screws and the slots, which were used both for the negative space in the extrusion and for the 3D printed spring.

The space for the spring was an important constraint, which led us to design our own TPU spring instead of using a coil spring for our device. We also wanted the part to be a single extruded profile, to ensure ease of manufacturing when 3D printing of the part, as flexible TPU filaments can be difficult to work with on certain hardware.

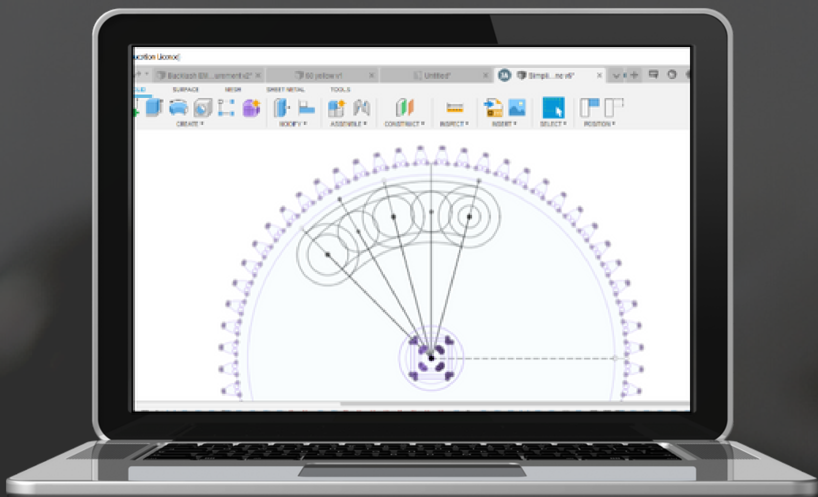

Figure 4: Preliminary sketch used to create all three (3) components

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Design Process & Tools

Applied PMTs (Process-Method-Tools)

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We realized we could achieve different spring constants by changing the profile of the spring. Therefore, multiple test designs were drawn for varying levels of elasticity and later evaluated, resulting in the design shown in yellow in figure 5.

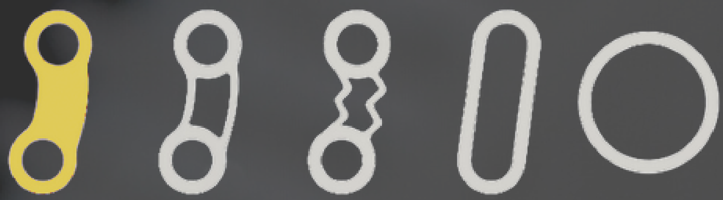

Figure 5: All considered spring profiles

With the initial sketch, both halves were extruded 0.25in in opposite directions as separate bodies to create the main components in the assembly. Further extrusion operations were done to create the final features drawn in the initial sketch.

Once all 3D components were modelled, we created the assembly which included each half gear, the spring, the shaft insert and both screws. We then manufactured each part using a FFF (Fused Filament Fabrication) 3D printer and tested for functionality and tolerance.

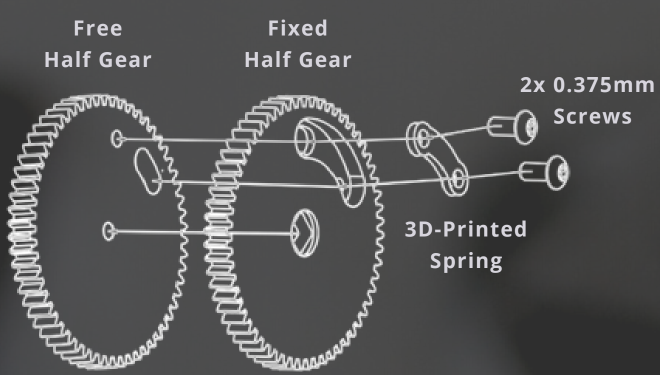

Figure 6: Anti-backlash Gear Assembly

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Conclusion

Process-driven gains: their impact and their value

Through the challenge of developing our anti-backlash gear, we learned the design freedom and opportunities CAD provides for rapid prototyping and robotics. In like manner and as we progressed with Fusion 360, we got acquainted with better parametric design practices, especially when creating sketches. CAD is at the core of modern engineering, and for this reason we will continue to use it in our robotics team to prepare our team members to excel in their future engineering careers. We have made CAD an integral part of our design process when creating our competition robots, since we assemble each robot within Fusion 360 to verify everything fits correctly before building our designs in real life, saving us both time and materials thereby ensuring that all our deliverables remain on-scope, on-budget and on-schedule.

Acknowledgements

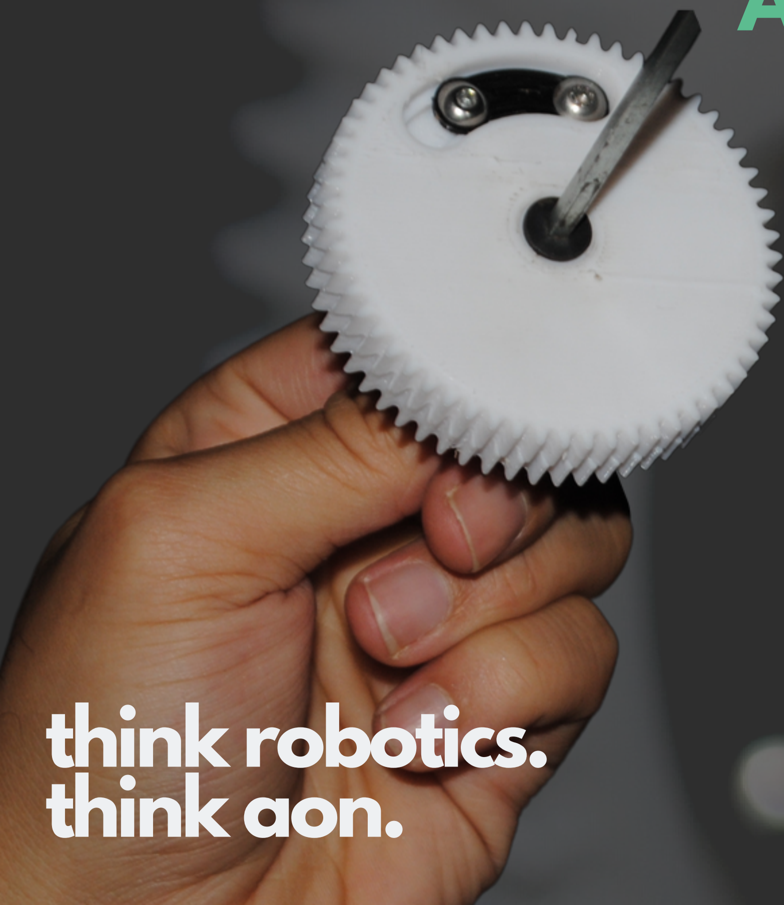
Stakeholders critical to our team's success

gm

Chevron

INME

uprm



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