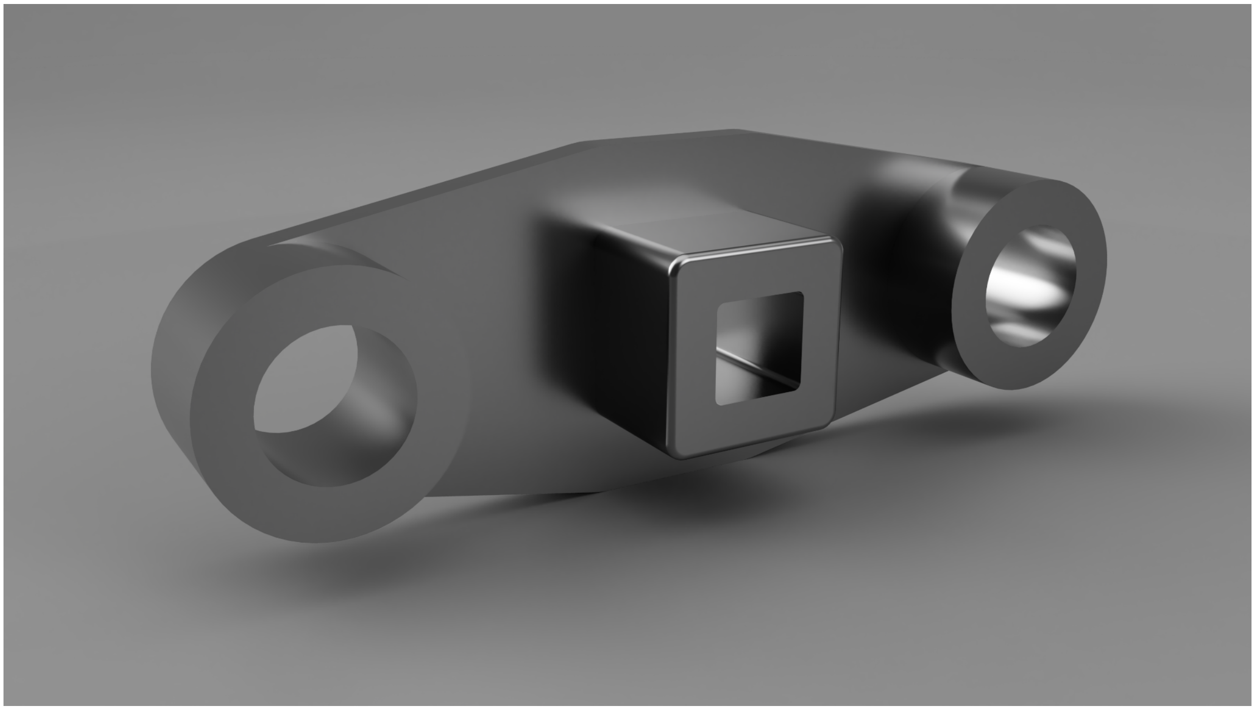

Reinforced Gear Insert

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Introduction

During the 2021-2022 season of VEX Robotics, our team has experienced many challenges with building our robot. One of the largest problems we experienced was parts breaking. In the towers we built to lift the mobile goals, the shafts were twisted and bent out of shape (see Image 5). This was due to compound gearing in the system applying too much torque onto the shaft. However, this was not the only issue we faced with gears. We encountered an issue with a gear stripping internally, rather than from its teeth (see Image 6). This was caused by the gear being locked in place while rotational force was still being applied to the shaft, turning the gear insert and twisting the inside of the gear's shaft hole. Using gears with the normal shaft hole or using high strength shafts are possible solutions, but we did not have the sufficient materials available. Our problems with gears had limited, feasible solutions, so a new one was necessary.

Product Description

For this season's "Make It Real" CAD Engineering Challenge, the Reinforced Gear Insert was designed. It is an improved version of the high strength gear insert, as it integrates the shaft bar lock's screw hole mechanism and applies it to gears. The original design of the gear insert is minimalistic, only connecting to the shaft hole and not extending past the dimensions of the gear. However, when greater forces are applied to this insert, it can fail. This new design is made to use the adjacent screw holes to disperse the force being applied to the center.

There are variations of the Reinforced Gear Insert for different situations. There is a design for the 30-tooth gear, 60- or 84-tooth gear, and two 60- or 84-tooth gears attached together (see Images 1, 2, 3). The dimensions of the 30-tooth gear are slightly different, with the screw holes extending to the width of the gear, while the larger gears' internal screw holes are thinner. When compound gearing or strengthening a gear, two gears are placed adjacent to each other on the same shaft. The double gear insert variation is designed to attach both together, causing them to move in unison.

Design Process

Before the Reinforced Gear Inserts could be designed, the original high strength gear insert needed to be analyzed. From observing the features of the CAD file, it was observed that when two inserts are attached to a gear, there is a small gap between them. This was incorporated into the Reinforced Gear Insert, as it was possibly for preventing air pockets from being created when inserting them.

These models were created in Autodesk Fusion 360, on version 2.0.11894. A CAD file of the 30- and 60-tooth gear were used when designing the different versions, allowing for an exact reference when designing. By creating a sketch, a tentative design was drawn to scale and then extruded to the correct sizes. All of the designs besides the version made for the 30-tooth gear do not extend past the dimensions of the gear. Extensions to the screw holes were made to create a direct connection between the insert and the screw holes of the 60- and 84-tooth gears. The version made for the 60- and 84-tooth gears was mirrored and the shaft hole inserts were increased in length so only one insert was needed to connect the two gears.

Data Analysis

Autodesk Fusion 360's Finite Element Analysis (FEA) program was used to collect data for this project, using mainly the "Static Stress" simulation. In this simulation, a "Remote Moment" force was applied to the center of the gear inserts of varying magnitudes (2.1 N m, 6.3 N m, 14.7 N m, 102.9 N m). Each magnitude was chosen as it represents different possible gear ratios. (2.1 N m represents a direct output (1:1) from a V5 smart motor with a red gear cartridge.) The outer faces of the sides of the gear were fixed points, as the simulation is predicting how the gear and the insert could handle varying forcing being applied while the outside of the gear is locked in place. The gear was set to a material of “plastic”, and the gears and screws were set to a material of “steel”.

The data from the simulations that was focused on for this project was the strain and total displacement of the gear and shaft. At 102.9 N m, the original design performed the worst, with a max displacement of 3.123mm and a max strain of 1.358. The Reinforced Gear Insert for 30-tooth gears performed the best, with a max displacement of 0.0522mm and a max strain of 0.03041 (see Table 1). The visual simulations also show that the Reinforced Gear Inserts performed better than the original, as the force is distributed over a larger portion of the gear (see Image 4).

Conclusion

Based on the data from the FEA software simulations, all of the Reinforced Gear Inserts performed better than the original. The reinforced designs are significantly larger and require two screw holes, but that is a minute cost for preventing the gears from stripping. There is still room for improvement as these are three separate designs. With more time and research, a singular design could be created to satisfy all of the different gears and their requirements.

Within the timespan of this project, my understanding of CAD has improved, as I have learned how to use the FEA and rendering softwares. I was also able to learn about the data from the simulations and what they mean, including stress, strain, and displacement. Having this knowledge now, I will be able to use the Engineering Design Process much more efficiently, by thinking with the method of CAD. Instead of thinking of the 3D solution, starting off a 2D sketch and extruding it into a 3D object will allow me to think outside of the box.

Appendix A

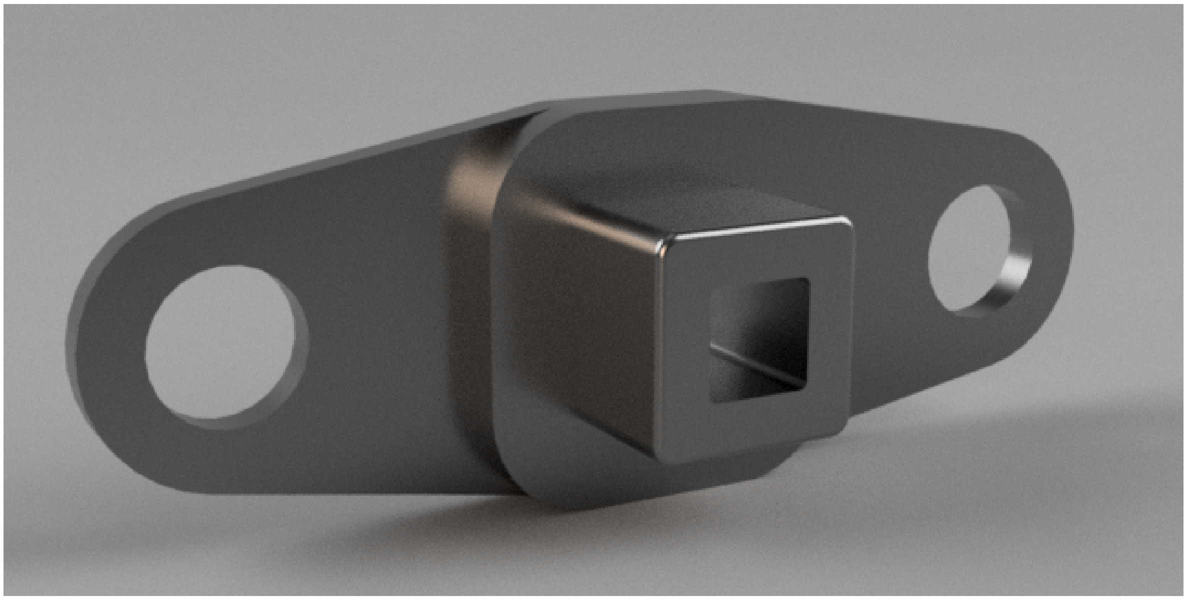
Table 1:

Original Design			
Torque Forces (Nm)	Max Von Mises (MPa)	Strain	Displacement (mm)
2.1	274.4	0.02772	0.06374
6.3	823.1	0.08315	0.1912
14.7	1920	0.194	0.4462
102.9	13443	1.358	3.123
Reinforced Gear Insert (for 30-tooth gear)			
Torque Forces (Nm)	Max Von Mises (MPa)	Strain	Displacement (mm)
2.1	94.01	0.0006206	0.001065
6.3	282	0.001862	0.003196
14.7	658.1	0.004344	0.007458
102.9	4607	0.03041	0.0522
Reinforced Gear Insert (for 60- and 84-tooth gears)			
Torque Forces (Nm)	Max Von Mises (MPa)	Strain	Displacement (mm)
2.1	100.7	0.01748	0.03757
6.3	302	0.05244	0.1127
14.7	704.8	0.1224	0.263
102.9	4933	0.8566	1.841
Double-sided Reinforced Gear Insert			
Torque Forces (Nm)	Max Von Mises (MPa)	Strain	Displacement (mm)
2.1	111.3	0.01338	0.02108
6.3	334	0.04015	0.06324
14.7	779.4	0.09368	0.1476
102.9	5456	0.6557	1.033

Data table of Static Stress simulations from Autodesk Fusion 360 FEA program.

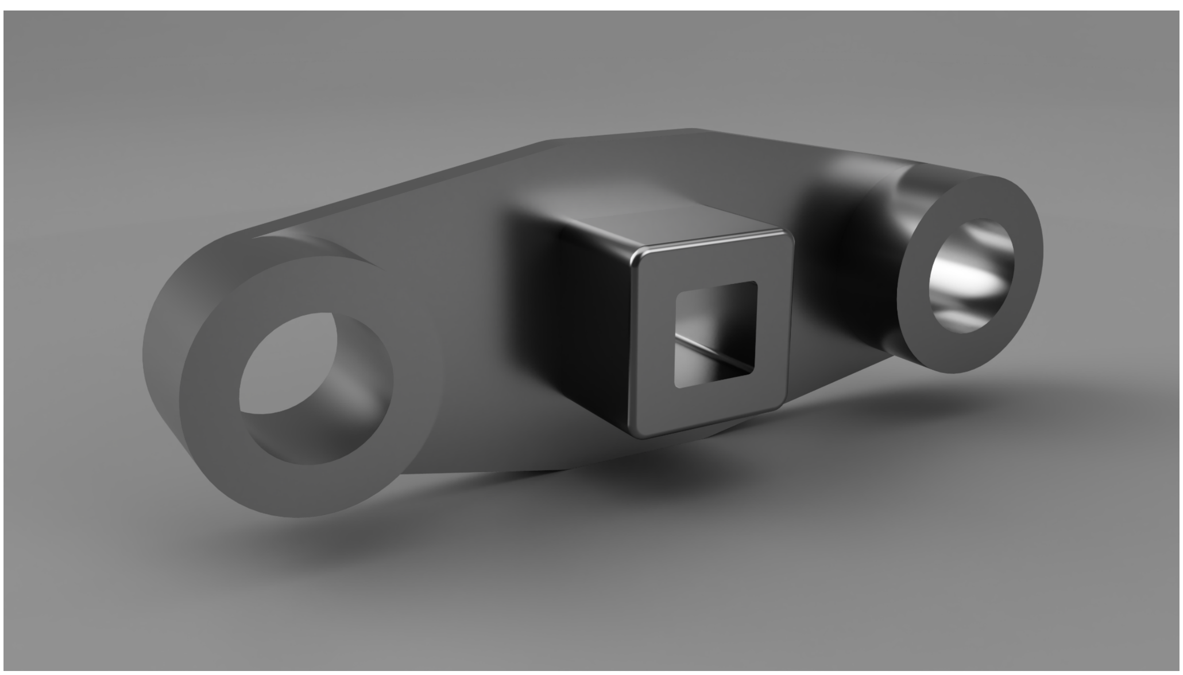
Appendix B

Image 1:



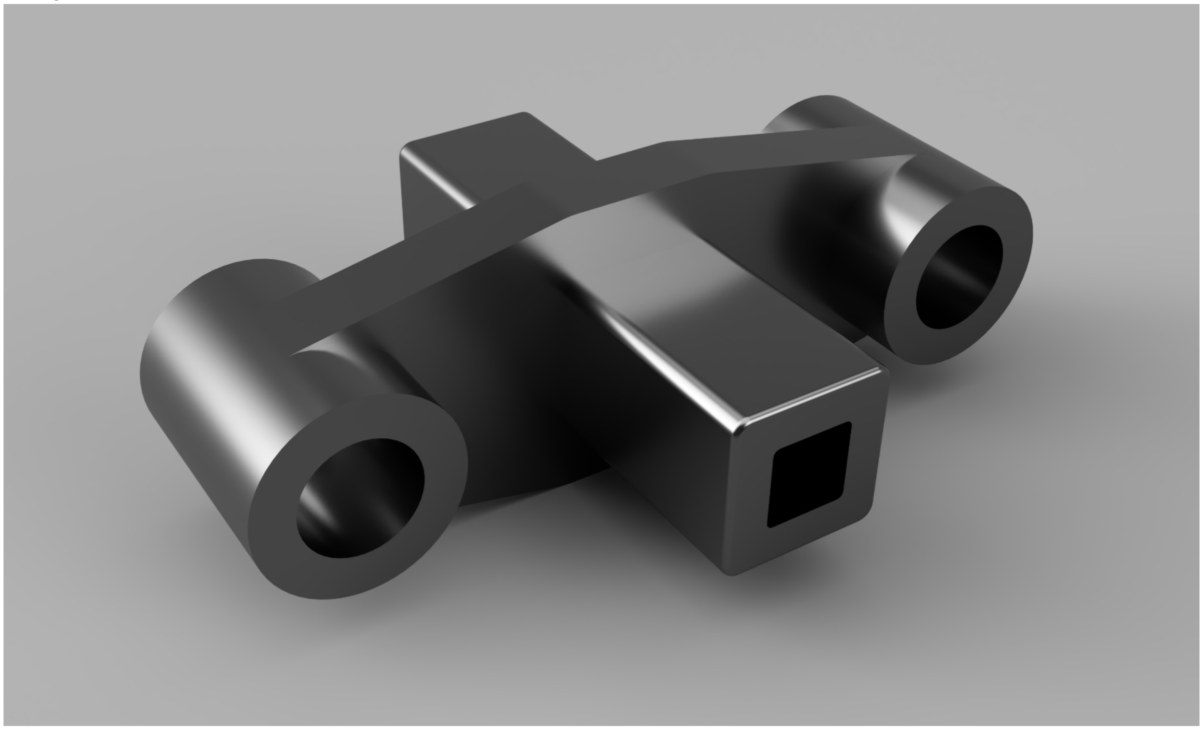
Rendered image of the Reinforced Gear Insert (for 30-tooth gear). Rendered in Fusion 360 v2.0.11894.

Image 2:



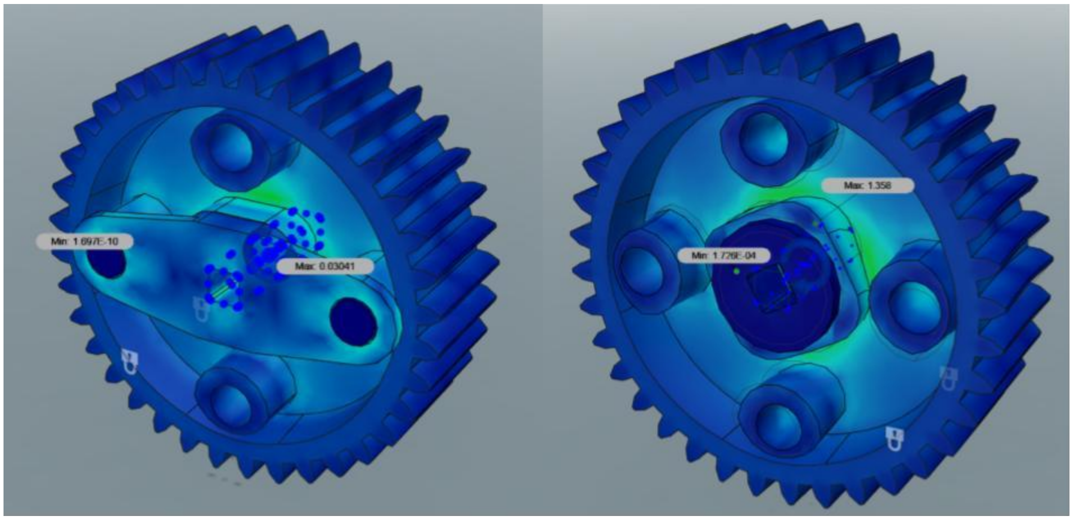
Rendered image of the Reinforced Gear Insert (for 60- and 84-tooth gears). Rendered in Fusion 360 v2.0.11894.

Image 3:



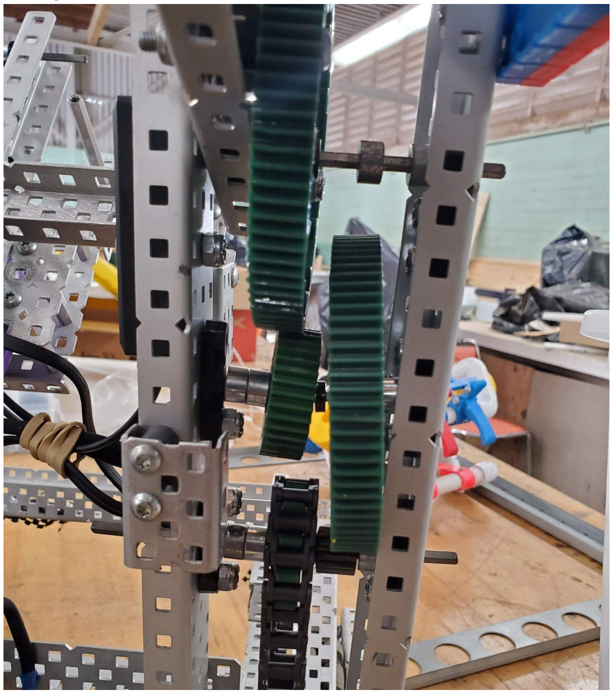
Rendered image of the Double-sided Reinforced Gear Insert (for 60- and 84-tooth gears). Rendered in Fusion 360 v2.0.11894.

Image 4:



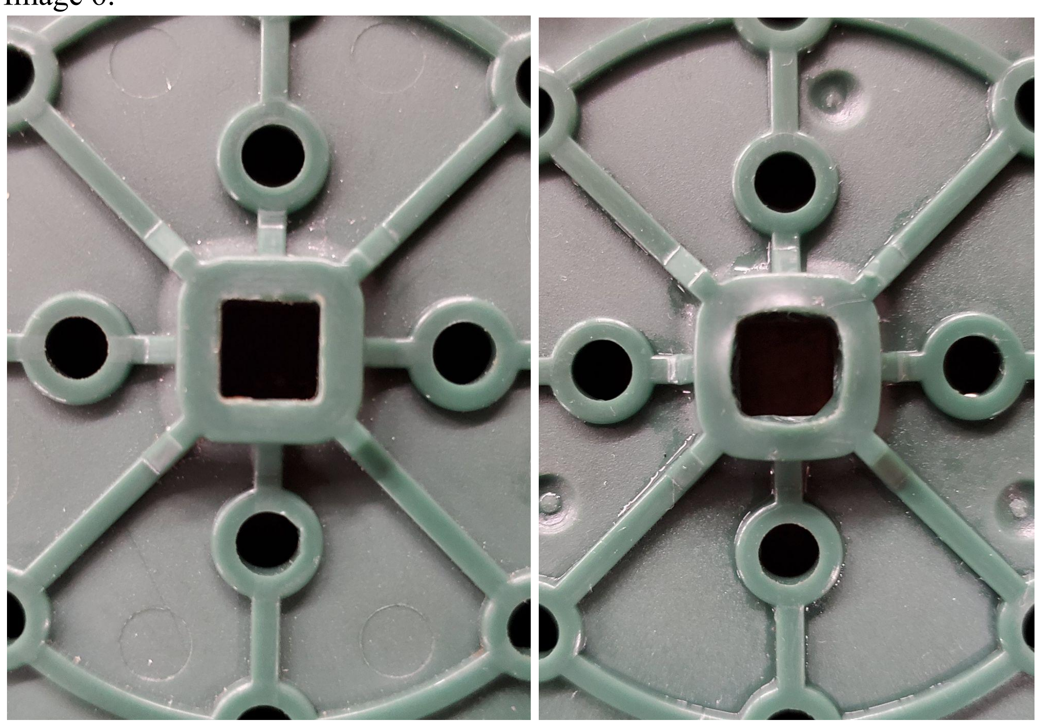
Side-by-side visual comparison of the strain simulations between the Reinforced Gear Insert for 30-tooth gear (Left) and the original gear insert (Right). (Load case of 102.9 N m) Simulation generated in Fusion 360 FEA software v2.0.11894.

Image 5:



Picture of one of the robot's towers. The shaft in the center is twisted and bent from the torque of the compound gearing system.

Image 6:



Side-by-side comparison of a normal 84-tooth gear's shaft hole (Left) and a stripped normal 84-tooth gear's shaft hole (Right).