Fixing the Gap: A Novel Approach to Solve the Problem of the Gaps between Trains and the Platforms they Approach

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Executive Summary

This project was undertaken to eliminate the gap between train cars and the platforms that they pull into. People have been receiving injuries and in some extreme cases even death has occurred due to the large gaps. Using Creo Parametric, a design was created to cover the gap to reduce injury and aid handicapped people in boarding the train.

This design consists of a plate that emerges from the bottom of the door to cover the gap. This plate has a lip on it so that it can line up with the platform and form a rounded surface so that handicapped people can get on the train without any extra assistance. This system involves the use of four gears and three rollers in order to make the plate emerge from the bottom of the train.

As shown in figure 1, the gears and rollers are symmetrical except for the motor acting on gear 4. This motor provides the driving force in order to make the plate deploy. A motor was needed that could provide, at most, 25 ft-lb of torque to the drive shaft of gear 4. A 10 HP WEG motor that rotates at 1765 RMP was selected because it provides 29.76 ft-lb of torque and because it is programmable. The rollers function as extra supports for the plate and stop it from shifting and from detaching from the gears.

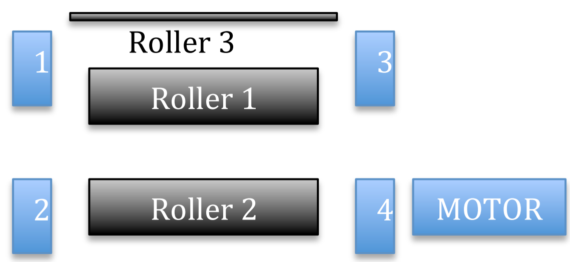


Figure 1: Top view of the roller and gear configuration

After the design was complete, analysis was run on all of the pins in the model to ensure that they would not fail under the maximum load. After the application of the loads and a dynamic analysis, the forces at each of the pins were resolved.

Part	Y Force (lbf)	X Force (lbf)
Gear 1	-1088.8	0
Gear 2	-1088.8	0
Gear 3	-1088.8	0
Gear 4	-1088.8	0
LG Roller 1	-15263.9	0
LG Roller 2	-15263.9	0
SM roller	-465.8	0

Table 1: Results of the dynamic analysis.

Using the values measured in table 1, finite element analyses were run on all of the pins. As shown, the forces on all of the gear pins and the roller pins were the same. Therefore, only one FEA was needed for gears 1-4 and for rollers 1 and 2. The results can be seen below. All parts did not fail and factors of safety are shown.

Part	MAX VON MISES (ksi)	YIELD STRENGTH (ksi)	FoS
GEAR PINS	17.04	64	3.7559
Small Roller Pin	37.77	64	1.6945
Large Roller Pin	51.2131	64	1.2497
Plate	3.313	36	10.8663

Table 2: Results of all FEA.

Introduction

The Long Island Railroad has received a lot of opposition due to large gaps in between trains and the platforms that the trains pull up to. These gaps do not only make it hard for handicapped people to board the train, it also can cause serious injuries or even death. In 2006 this opposition escalated when 18 year-old Natalie Smead fell in the 8-inch gap. As she began to cross the tracks to exit the platform, she was struck by a train moving in the opposite direction and killed. After her death, it was discovered that since 1995, the LIRR has logged over 900 commuter accidents caused or related to the large gap.

Figure 2: An example of an 8-inch LIRR gap

After this incident, the LIRR has made efforts to decrease the size of the gap and also implemented "Watch the Gap" signs along platforms and trains, which decreased gap related injuries. However, in 2014, there were still 34 gap related incidents that led to injuries, which proves that the gap is still an issue. At some stations there are still gaps of up to 10 inches, which is definitely large enough for someone to twist an ankle or possible fall in.

In addition to gap related injuries, the large gaps between trains and their platforms are also a large hazard to handicapped people. As of now, the method of assisting people in wheelchairs and other handicapped needs requires an attendant to walk through the train car with a ramp and place it over the gap. This process is inefficient and takes an unnecessary amount of time. The implementation of a system to eliminate the gap problem would not only improve the lives of handicapped commuters, it would also prevent injuries to other commuters.

Description of Final Design

In order to eliminate the gap between train cars and their platforms, a metal plate was designed to slide out from the bottom of the train car door. This plate consists of a hollowed out rectangle of A36 steel, which is .25 inches thick. At the end of the plate there is a T-cross-section that allows the lip to slide onto the plate. The lip is how the plate will dock to the platform. When the plate is deployed from the train, the lip will sit on the platform to provide support from the platform side of the plate. The lip is also rounded to allow wheels to roll onto the plate from the platform to accommodate handicapped people.

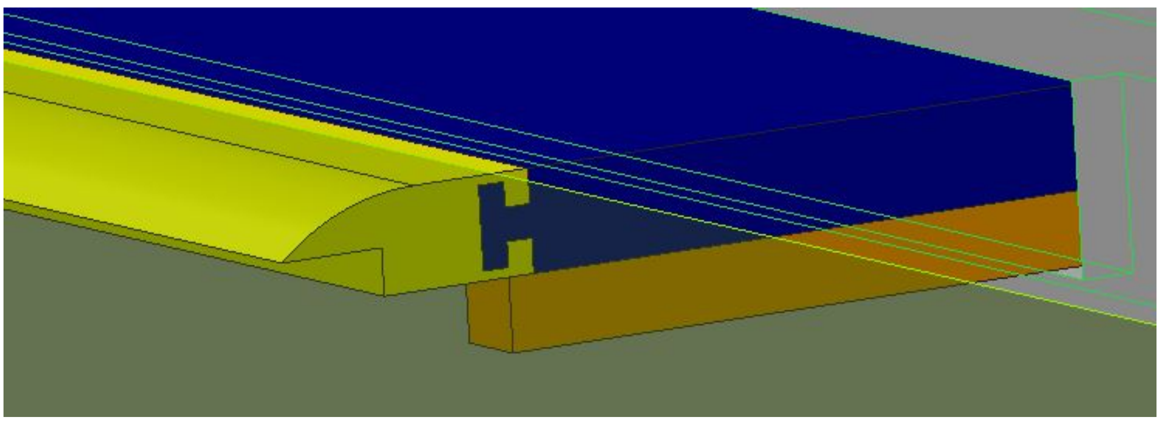
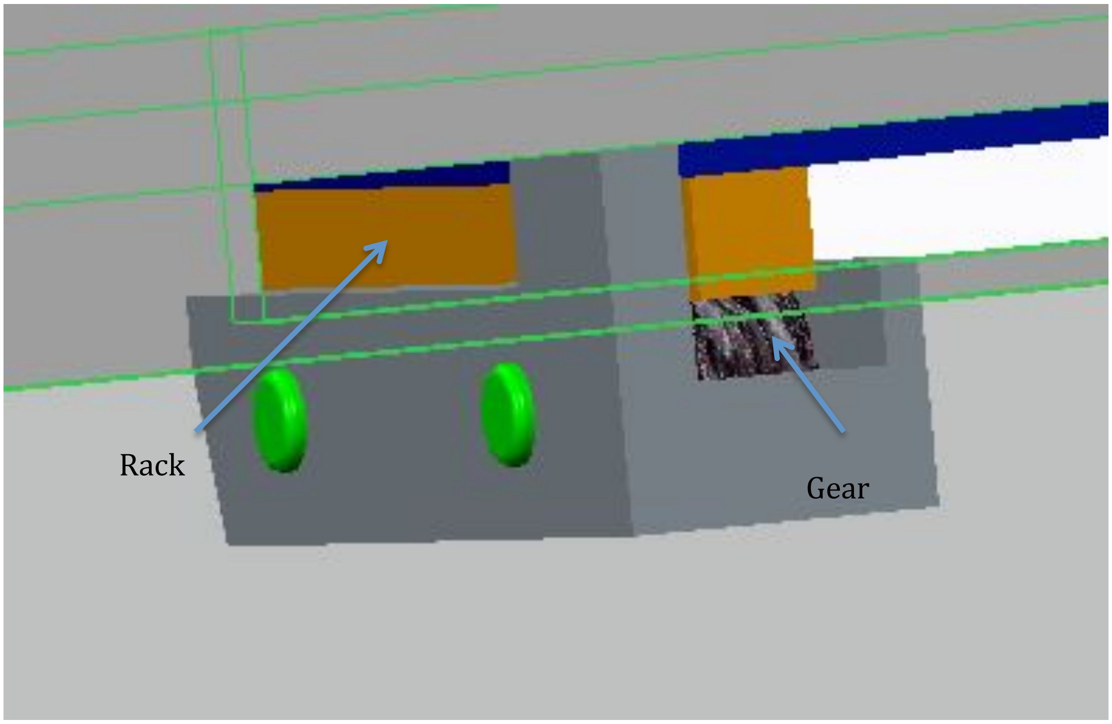


Figure 3: Lip attached to the plate

The next aspect of the design consists of four gears and two racks. The gears will interact with the racks in a “rack and pinion” configuration with a pitch of 8. These are standard parts and can be purchased from McMaster-Carr (part numbers found in Appendix C). The racks are both welded to the bottom of the plate .88 inches away from the sides. This allows the racks to line up perfectly with the gears. The gears are pinned to supports below the plate. Due to the fact that the gears and racks are standard parts, they were modeled to the specifications of the parts without the gear teeth. The gears are designed as two cylinders, while the racks are rectangular prisms two feet in length.



The gear supports are designed so that they are welded to the inside of the train car in three spots. They are designed to house the gears and provide support for the pins that act as the shafts of the gears. The gears sit in these supports at a height so that the gears can interact with the racks welded to the bottom of the plate. The gears are configured in a square; two on either side of the plate with the gear on the back left being the driving gear while the others are simply idlers. The motion of the plate is driven by a 10 hp, 1765 rotation per minute motor from Zoro, a motor distributor. This motor was selected because the plate, without any additional loads, weights about 200 lb. Multiplying this weight by the radius of the gear gives the required amount of torque for the gears to extend the plate. Then, using an equation that converts horsepower and RPM to torque, that motor was selected.

The final aspect of the design consists of three rollers, two of which are identical while the other is smaller and in a different position. The two larger rollers sit in an aluminum frame underneath the plate in the center, away from the racks and gears.

These rollers provide extra support to the plate when it is in the deployed position. The housing for these rollers is also welded to the inside of the train car under the floor.

The third roller is supported by two small supports that are welded to the bottom of the slit in the body of the train car. This roller is significantly smaller than the others and also provides support to the plate. The system of these three rollers prevents the plate from shifting when it is deployed and also keeps the back gear that has the motor attached to it locked with the rack.

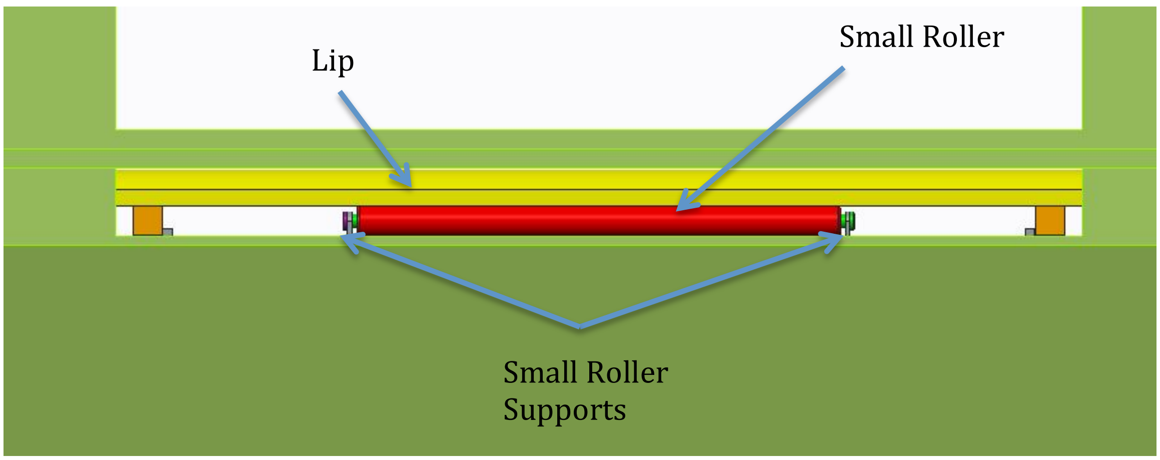


Figure 5: Front view of the small roller under the plate

All of the roller and gear connections need pins to keep them in place. Clearance fit and force fit equations were used to find the appropriate diameters for the pins and caps and can be found in Appendix D.

Analysis

The analysis of the design began with applying the maximum loads that the system would be subjected to. Two 300 lb forces were applied to the plate and static and dynamic analyses were performed to evaluate the forces at each pin. Measuring both the X and Y values of force for each pin yielded the following results:

Part	Y Force (lbf)	X Force (lbf)
Gear 1	-1088.8	0
Gear 2	-1088.8	0
Gear 3	-1088.8	0
Gear 4	-1088.8	0
LG Roller 1	-15263.9	0
LG Roller 2	-15263.9	0
SM roller	-465.8	0

Table 1: Results of static and dynamic analyses

The forces were the same for the static and dynamic analyses. Also, for all of the gear connections the forces were the same and the forces for both large rollers were the same. Since the X-components of all of the forces were zero, the forces were applied to the pins as only Y-components in the finite element analysis of the parts.

The first FEA that was performed was the FEA of pin 1. The pin was constrained as a simply supported beam and the force measured from the dynamic analysis was placed on the pin along a curve. The finite element analyses for the other pins were performed in a similar way. When FEA was run, the maximum von mises stress was found to be less than the yield strength of the 1030 Q&T steel (64 ksi) that the pins are made of.

FEA was also performed on the plate. The constraints were set at both ends of the plate. One constraint was on the T-cross-section while the other was 12 inches away constraining the rest of the plate. The load was distributed as 600 lbf across the whole unconstrained surface of the plate. When FEA was sun for this part, the maximum von mises stress was far below the yield strength of A36 steel (36 ksi). Another analysis was run in order to find the maximum deflection of the plate when the 600 lbf load is applied. This maximum deflection was found to be 6.19E-5 inches, which is barely noticeable.

Part	MAX VON MISES (ksi)	YIELD STRENGTH (ksi)	FoS
GEAR PINS	17.04	64	3.7559
Small Roller Pin	37.77	64	1.6945
Large Roller Pin	51.2131	64	1.2497
Plate	3.313	36	10.8663

Table 2: Summary of results of all FEA run with factors of safety included

Conclusion

When presented with the problem of larges gaps between train cars and their platforms, one solution stood out. The sliding plate covers the gap and also provides a platform for people with handicapped needs to board the train without any extra assistance. Using a system of gears and rollers the plate is deployed and retracted.

Although this design would cover most gaps, there are some disadvantages. For example, the lip is not guaranteed to line up with the edge of the platform perfectly for every station. Each station is slightly different and the heights of the platforms vary from station to station. This is a minor issue for the design because there is no way for the plate to adjust for different heights.

Each pin in the design was tested to make sure that it could withstand a very large load on the plate. After measuring the connection reactions at each pin, FEA was run on all of them. Each of the finite element analyses displayed a maximum von mises stress of less than the yield strength of the material that the pins were made of. Therefore, no parts would fail if this model were to be constructed.

Finite element analysis was also run on the plate to make sure there was an allowable amount of stress and to see how far the plate would deflect when subjected to the 600 lbf load. The maximum plate deflection was measured to be 6.19E-5 inches, which is very small and almost insignificant.

Ultimately, this design solved the problem of the gap in between train cars and their platforms. The parts do not fail when subjected to large loads and the plate does not deflect to any significant distance. It is safe to say that if this design were implemented, it would improve the lives of handicapped commuters and reduce commuter injury.

Appendix A: FEA Results

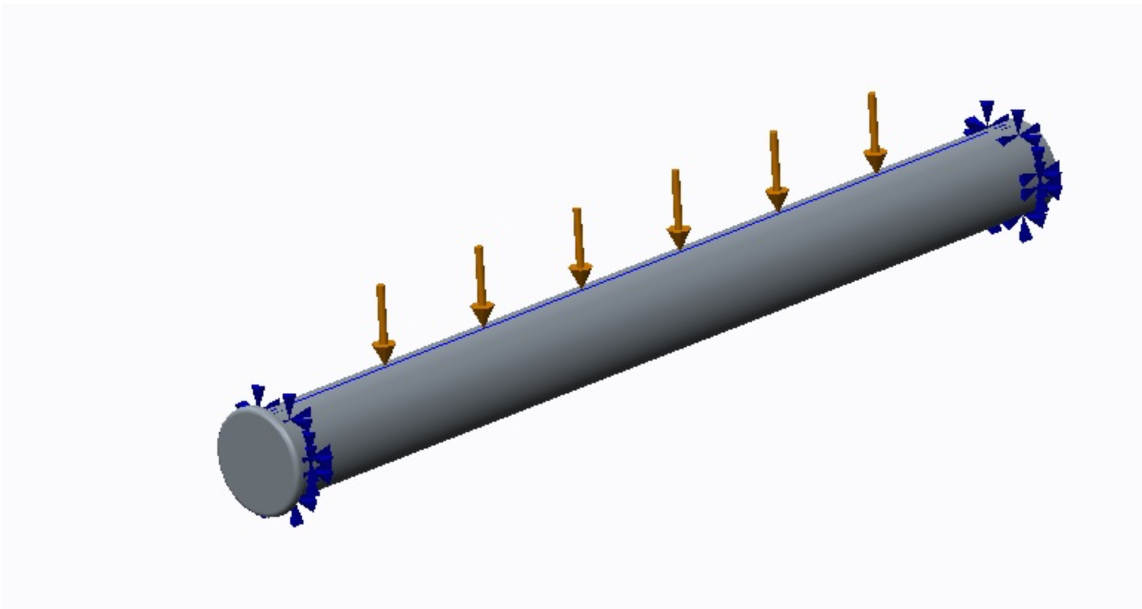


Figure 6: Pin 01 Constraints and Loads

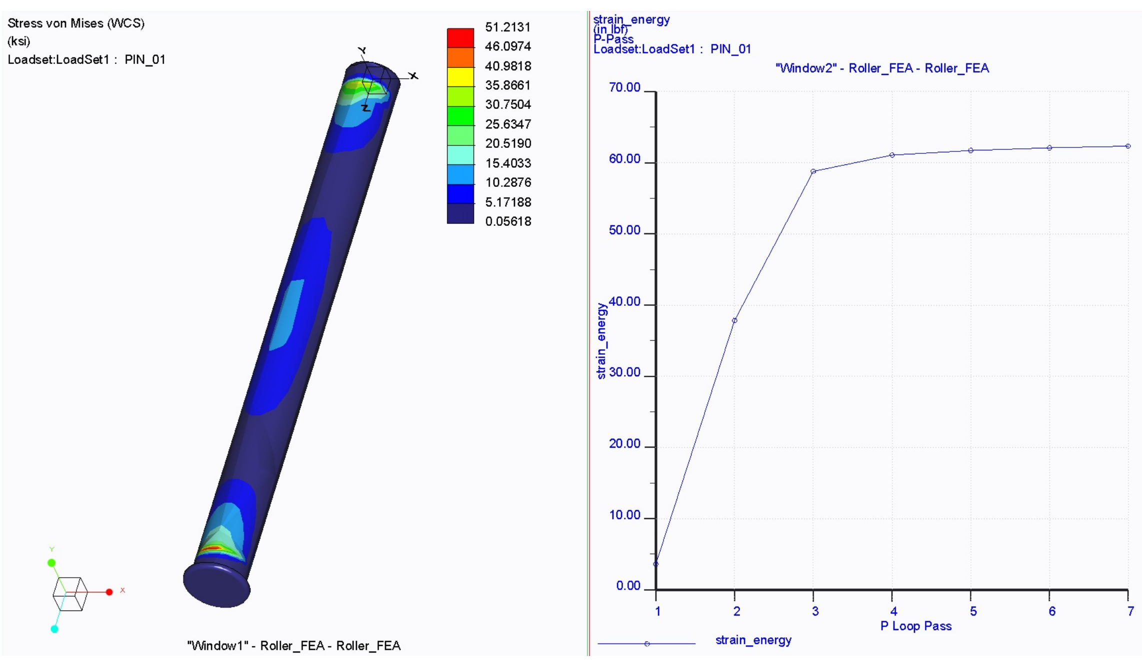


Figure 7: Pin 01 von Mises fringe plot and convergence plot

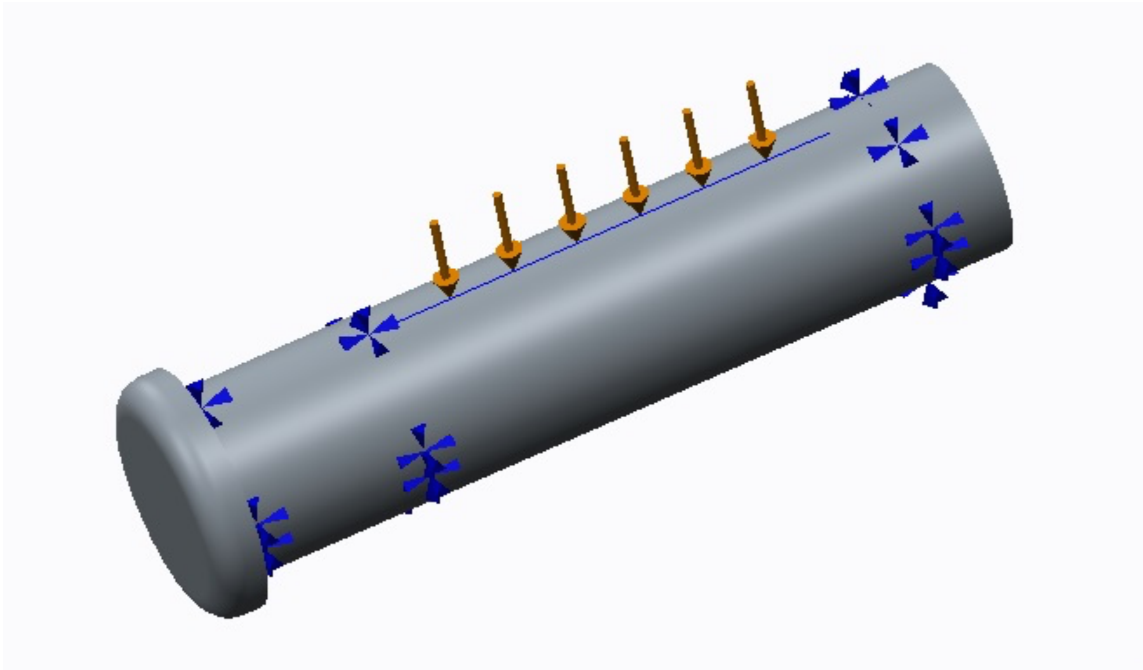


Figure 8: Pin 02 loads and constraints

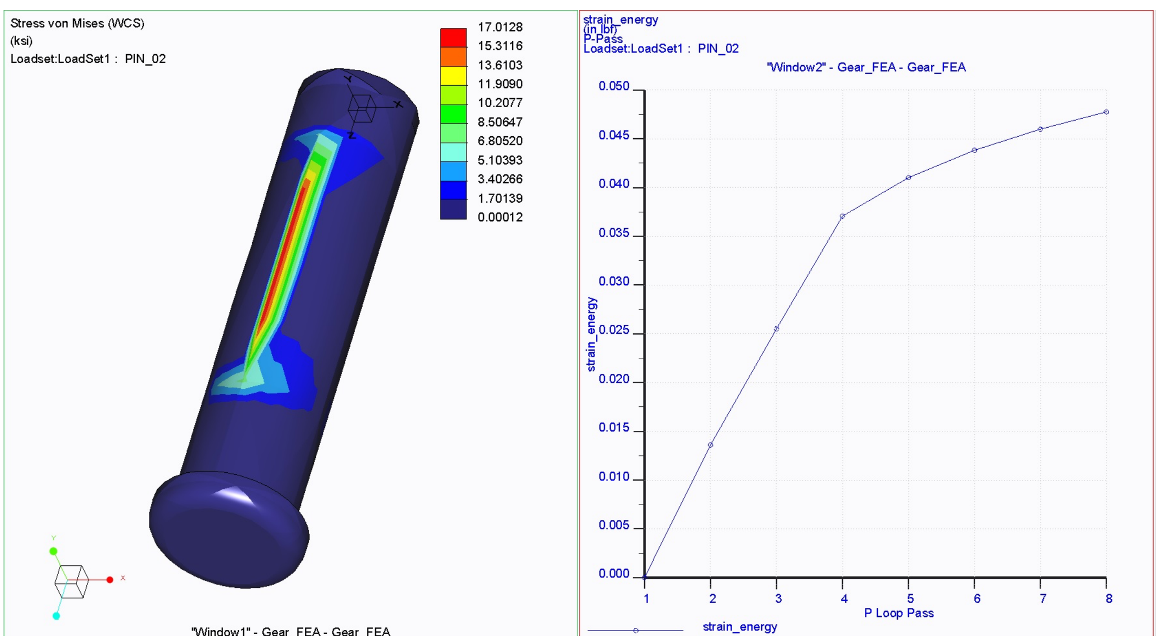


Figure 8: Pin 02 FEA results and convergence plots

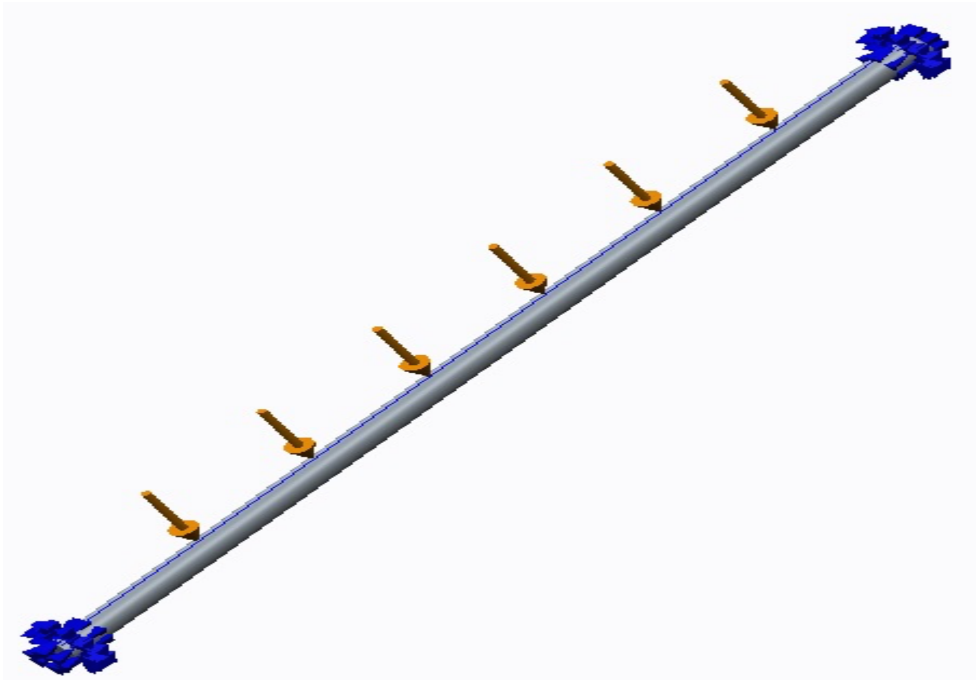


Figure 9: Pin 03 loads and constraints

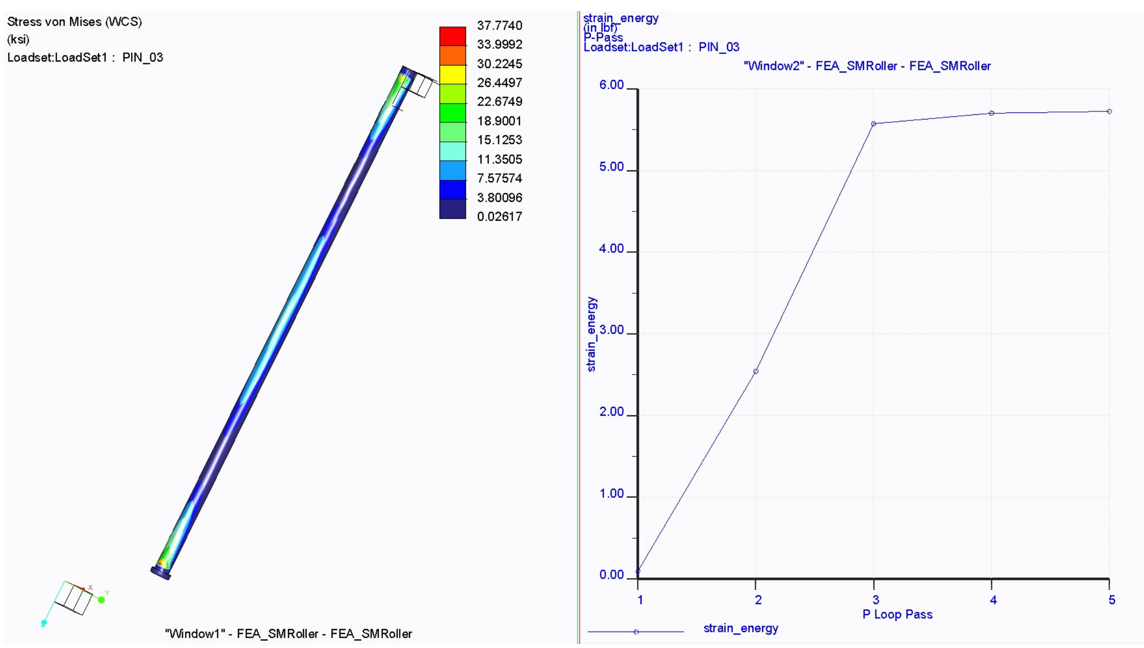


Figure 10: Pin 03FEA results and convergence plot

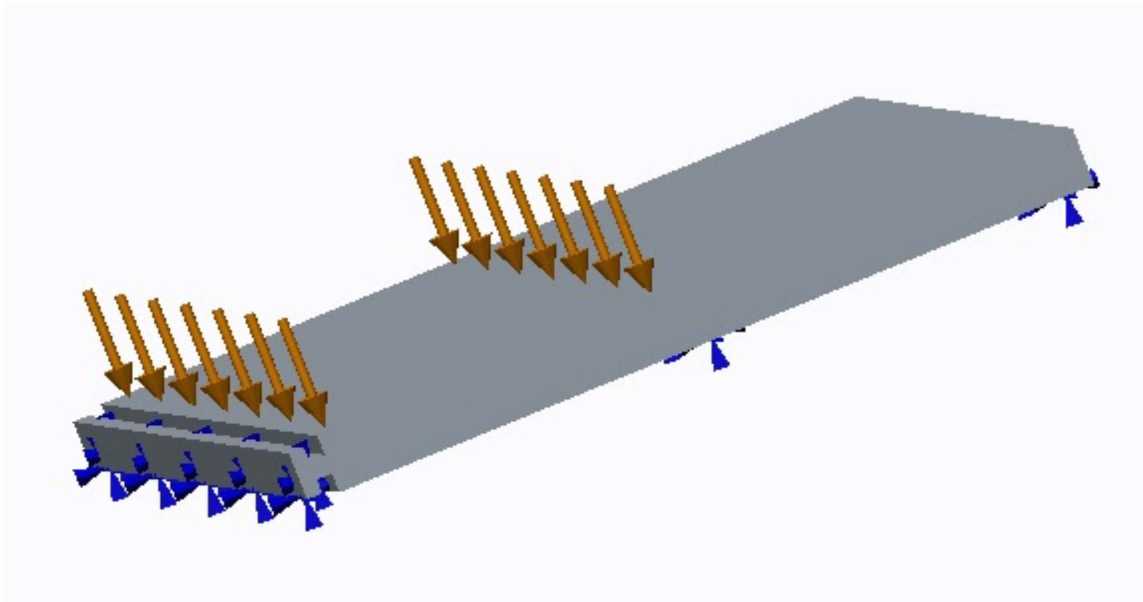


Figure 11: Plate loads and constraints

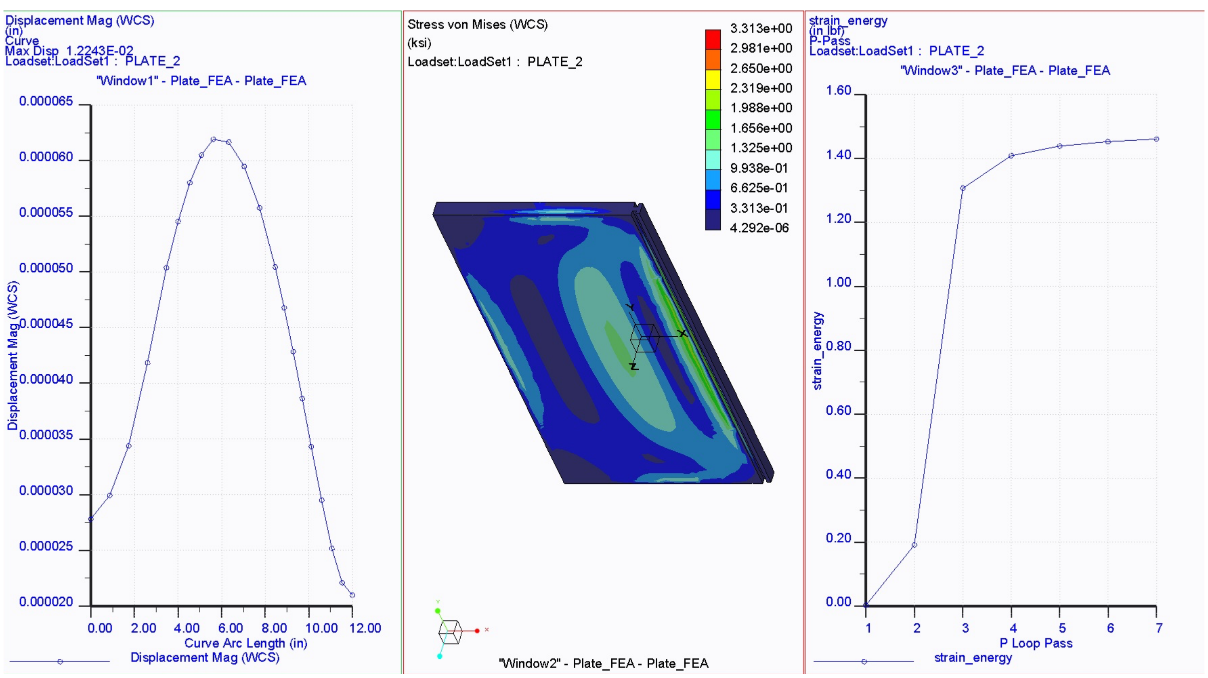


Figure 12: Plate FEA results, deflection analysis and convergence plot

Appendix C: Standard Parts

Part Name	Vendor	Part Number
20° Pressure Angle Spur Gears	McMaster Carr	5172T43
20° Pressure Angle Racks	McMaster Carr	5174T1
WEG Motor	Zoro	G2443865

Table 3: List of standard parts with part numbers and supplier

Appendix D: Hand calculations

Sliding fit Calculations:

Small Roller: H7/g6

D_{max} = 19.05 + .021 = 19.071mm = .7508in

D_{min} = 19.05mm = .75"

d_{max} = 19.05 − .007 = 19.043 = .7497"

d_{min} = 19.043 − .013 = 19.03 = .7492"

LG Roller: 2.5in = 63.5 =

D_{max} = 63.5 + .025 = 63.525 = 2.501

D_{min} = 63.5 = 2.5"

d_{max} = 63.5 − .009 = 63.491 mm = 2.499

63.49mm

d_{min} = 63.49 − .016 = 63.475mm = 2.499

Gears: 1" = 25.4mm

D_{max} = 25.4 + .021 = 25.421 = 1.001

D_{min} = 25.4 25.4 = 1

d_{max} = 25.4 − .007 = 25.393 = .999

d_{min} = 25.393 − .013 = 25.38 = .999

Figure 13: Hand calculations to determine sliding diameters for the pins and their supports

Force Fit Caps:

Small Roller:

$.75 = 19.043 = d_{max} = R + .041 \Rightarrow R = 19.002$

$D_{max} = 19.023 = .7489$

$D_{min} = 19.002 = .7481$

Large Roller:

$d_{max} = 63.491mm = R + .07 \Rightarrow R = 63.421mm$

$D_{max} = 63.421 + .016 = \cancel{63.446} = \cancel{2.497}''$ 63.437

$D_{min} = 63.421 = 2.4969''$

Gears: 25.393

$d_{max} = \cancel{.999} = R + .048 \Rightarrow R = 25.345$

$D_{max} = 25.345 + .013 = 25.358 = .999$

$D_{min} = 25.345 = .997$

Figure 14: Hand calculations for the force fit caps