Fused Deposition Modeling Single-piece Mechanisms

Michael Luchini
ME557
12/17/19

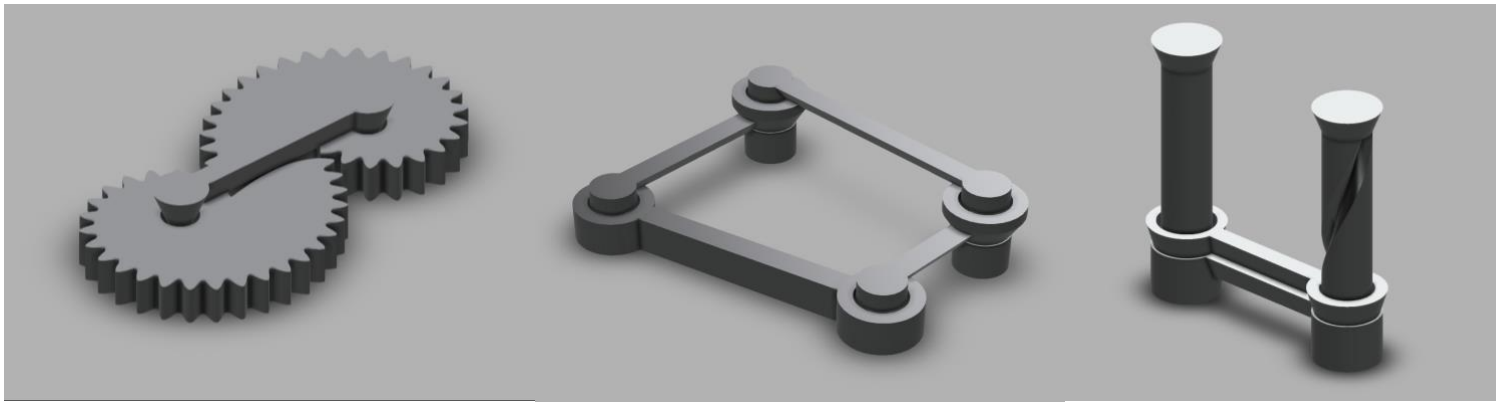
Introduction

In this project, I designed and FDM printed several unique mechanisms which can be printed in one piece. The goal of this project was to design functioning joints, beams, and threaded rods that can be substituted into almost any mechanism to allow it to be printed as a single part.

This project was inspired by a YouTube channel called Maker's Muse. The channel features videos about a variety of 3D printing experiments. I was particularly inspired by the creator's fascinating attempts to FDM 3D print moving parts, as well as unique mechanisms such as "nautilus" gears.

Design

Three parts were designed: a pair of linked nautilus gears, a simple four-bar mechanism, and a threaded rod with a free moving bar.



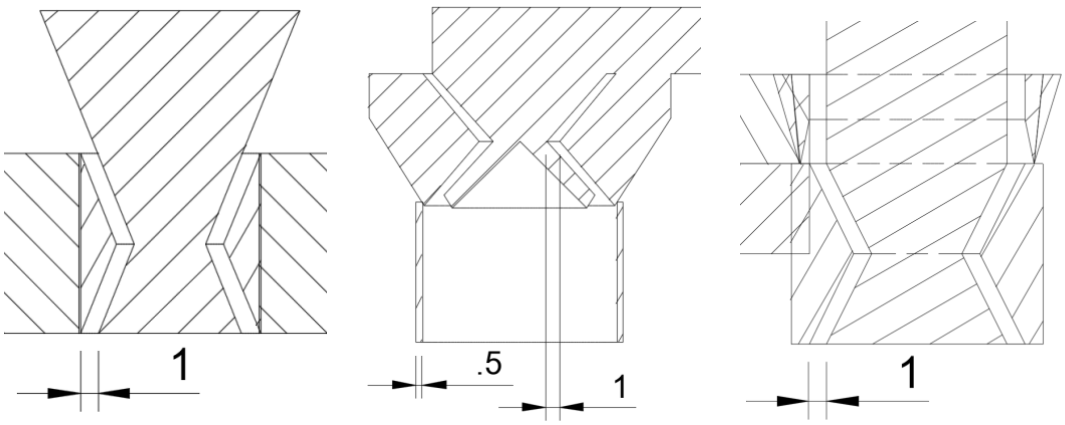
Fusion360 Models: Nautilus gears, four-bar mechanism, threaded rod and bar

When designing each part, I found that no overhang angles could exceed 40$_o$ from the vertical without affecting print quality.

All of the single-axis rotational joints, such as the joints in the four-bar mechanism, were designed to interlock using a single closed thread. This joint's cross section resembles an hourglass.

All of the raised bars were designed to have a maximum overhang angle of 40$_o$ from the vertical with an inverted triangular cross section. This design allows the bars to printed over large gaps using a few tree supports.

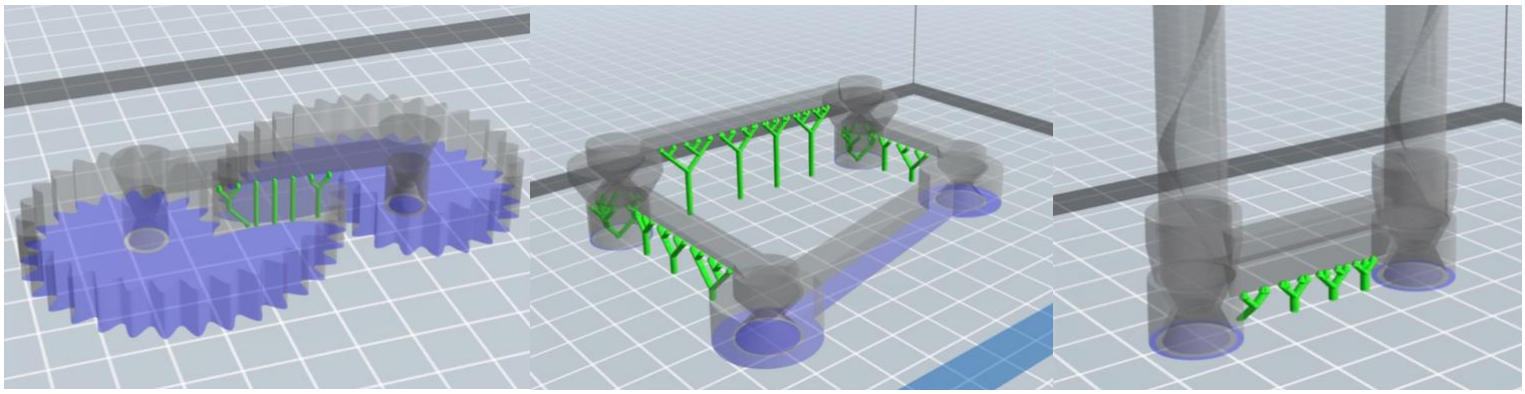
The threaded rod was designed in a similar manor as the previously mentioned joints. It is a single inset thread coiled one full rotation from the base to the top of the rod. The collar has a corresponding thread.



Cross section drawings: Nautilus gear joint, four-bar raised joint, threaded rod dual-joint
Dimensions: mm

Print Orientation and Supports

All of these parts were designed to require very few supports. All bars which extend over free space were supported using 1.5 mm tree supports.



Generated supports for all parts

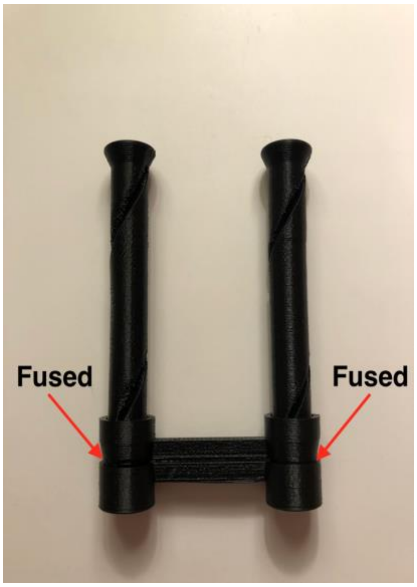
The only other supports needed were designed into the CAD model for the four-bar mechanism. These supports are hollow cylinders with a wall thickness of 0.5 mm, which provide a platform to begin printing the raised joints on the four-bar mechanism.

Challenges

Over the course of this experiment, there were numerous challenges. Nearly ten prints failed due to various reasons, and each design required at least 3 iterations. The main problems faced were fragile joints, overhang print failures, and fused parts.

Fractured joint in nautilus gear

Failed four-bar raised joint



Fused threaded-rod and bar

The first successful iteration of the nautilus gears proved to be very fragile due to a very small minimum diameter in the inner joint as well as the 15% hexagonal fill pattern. After increasing the minimum joint diameter as well as the fill percentage, this problem was resolved.

The main area where overhang failure occurred was in the upper joints of the four-bar mechanism. In early iterations, no custom CAD supports were used, and tree supports were unable to adequately support the inner or outer part of the joints. This problem was solved when custom CAD supports were added.

Joints became fused during the first iteration of the nautilus gears as well as the threaded rod. This problem was easily fixed by increasing the gap tolerances to 1 mm.

Conclusion

The goal of this project was to demonstrate the feasibility of printing moveable mechanisms as a single part. After working through numerous challenges, three single-part mechanisms were successfully designed and FDM 3D printed. The design techniques used to create these mechanisms can be applied to a variety of applications, and greatly broadens the scope of what can be FDM printed in a single job.

Links:

Working Printed Mechanisms:

Nautilus gears

Video: https://youtu.be/QI_B3uY6h7g

Fusion360 Model: https://a360.co/35aGuar

Four-bar mechanism

Video: https://youtu.be/Fdfse7mU4ro

Fusion360 Model: https://a360.co/2PuTlgW

Threaded-rod and bar

Video: https://youtu.be/lbRjM9Xu3UM

Fusion360 Model: https://a360.co/2Pmo8wu

Maker's Muse YouTube Channel: https://www.youtube.com/user/TheMakersMuse