The Flux Capacitor: Machining Using Ferrofluid Fixtures

Introduction:

When milling thin walled parts, it is time consuming to create fixtures and plugs needed to secure parts creating a large cost for small lot sizes. Using our innovative work holding technology, the Flux Capacitor, we have significantly reduced the setup effort for securing parts. To set up and secure, the part is placed inside the Flux Capacitor and surrounded by a magnetic ferrofluid (MRF). Ferrofluid is a mixture of iron filings suspended in oil, the fluid behaves like a viscous liquid with no magnetic field present and like a solid in the presence of a strong magnetic field. The part, surrounded by MRF, is brought near a powerful magnet that actuates the fluid and locks the part into place.

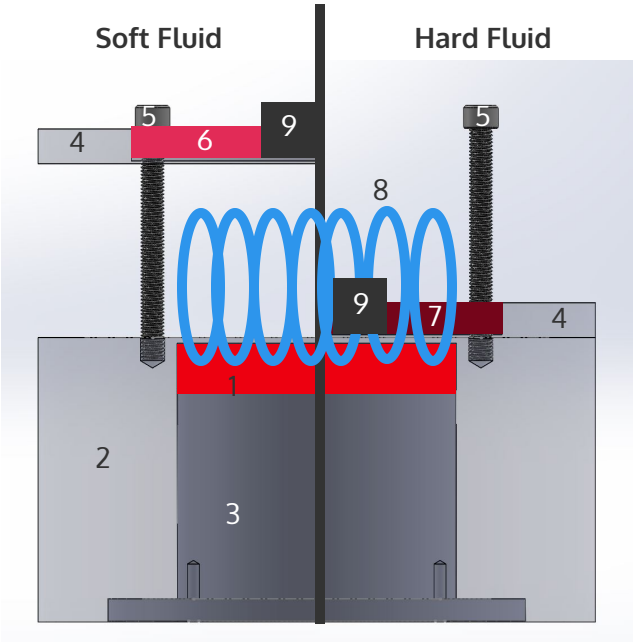
Background:

The original goal of this project originally was to develop an innovative way, utilizing ferrofluid, to support thin walled parts in a mill. As the team pushed forward with the project, the ferrofluid proved to have strong potential in purely holding parts so they pursued with that goal.

When machining thin walled parts in small quantities, most of the time to make the parts is commonly taken up by designing a fixture to hold the parts. With our use of ferrofluid to hold parts, the setup and fixture time has the potential to be cut by more than 4 times. This will reduce both cost and lead time, which will help speed up new product development, where small lots are used. The Flux Capacitor is an important project because it has the potential to significantly increase the efficiency of machining thin walled parts, typically found in aerospace machining applications, allowing for machine shops to have faster turnarounds, take in more work, and allowing companies to shorten their project schedule.

Challenge:

The first challenge was to develop a suitable ferrofluid mixture that would support parts in the presence of a magnetic flux and confirm what flux was required. Once that was taken care of, the team had to determine a suitable magnet system to harden the ferrofluid effectively. The team learned through research and testing that permanent magnets were the best course of action. Permanent magnets are the only ones that will permeate a field 0.75 inches away from the surface of the magnet. The team initially pursued the goal of using an electromagnet because of the off-on capability allowing for easy placement and removal of a part. The team found that the magnetic field does not permeate the necessary 0.75 inches. The next step was to try mechanically switchable magnets but the same issue was realized quite quickly. With permanent magnets being the course of action, a new challenge arose and that was finding an effective way to harden and soften the fluid.



1: Permanent Magnet
2: Magnet Housing
3: Plug to Hold Magnet at the Top of the Magnet Housing
4: Top Plate Containing Part and Ferrofluid
5: Bolts to Raise and Lower the Top Plate
6: Softened Ferrofluid
7: Hardened Ferrofluid
8: Magnetic Field Lines
9: Part to be Machined

Solution:

With the team facing the challenge of having to find a way to effectively actuate ferrofluid on a permanent magnet, the team set out and found a solution as pictured above. The team built a housing (2) that encased the permanent magnet (1) on the bottom and then it utilizes two bolts (5) to raise and lower the top plate (4) with ferrofluid contained on top. The plug (3) is necessary to prevent the magnet from sticking to the steel machining bed. When the top plate comes into contact with the housing, the fluid (6,7) is fully hardened and when it is 4 inches away from the magnet housing, the fluid is soft again. The bolts create an effective way to raise and lower the top plate enabling actuation of the fluid to allow easy mounting and removal of the machined part.

Results:

The team was able to make various design iterations and wound up with a prototype version used for testing and further development. The fluid was able to withstand a torque of 40 in-lbs and a lateral pull force of 14 lbs on a 2"x2"x0.75" part submerged in 0.75" of ferrofluid. The team has done testing with other sized parts as well and determined that the forces the ferrofluid can withstand scale up exponentially as part size increases. From these findings the team found that the teams flux capacitor has the potential to withstand 146 in-lbs on a 4 inch square part. Our results from our design and testing show a strong potential for being able to machine parts with ferrofluid as a fixture as the torque and pull forces that we are predicting are 5x higher than those imparted by a 1/4" end mill.

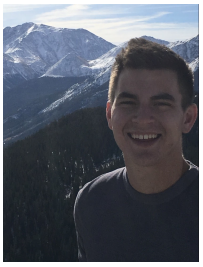
The Team:

Wyatt Cauble:

Wyatt is the manufacturing engineer. He has machining experience from previous internships that has made him vital in the design and manufacturing portion of the project. His knowledge of how milling machines operate and the nuances of part fixturing has helped him be helpful to his team and the outcome of the project.

Sunny Klein:

Sunny is the Systems and Test Engineer. His curiosity and attention to detail lead the team through the Research and Development and Testing phases of the project. His previous experiences helped shape the testing and validation of the performance of the system.



Joseph Knapp:

Joseph is the CAD Engineer. He has excelled in simulated modeling and prototyping having been the CAD lead on several other engineering projects throughout his college career. Having 500+ hours of CAD experience, he is able to help the team produce accurate, useful models to help drive the team forward to creating a working prototype.

Michael Lajevardi:

Michael is the financial manager for the team. His management of the budget and handling of procurement ensured that the team had the proper funds to finance the project and the correct materials to complete any necessary task.

Hunter Fuqua:

Hunter is the Logistics Manager for the design team. His management experience through his construction internship as well as his extensive communication skills made him the ideal candidate for this position. His leadership and flexibility to changing situations allowed for an exceptional team dynamic leading to the final product.

John Shanley:

John is the Project Manager for the design team. His management and leadership experience from his time in Air Force ROTC and junior hockey prepared him to easily step into the role of Project Manager. His leadership experience in dynamic situations taught him to successfully bring people from different backgrounds together to achieve a common goal and produce a quality final product.