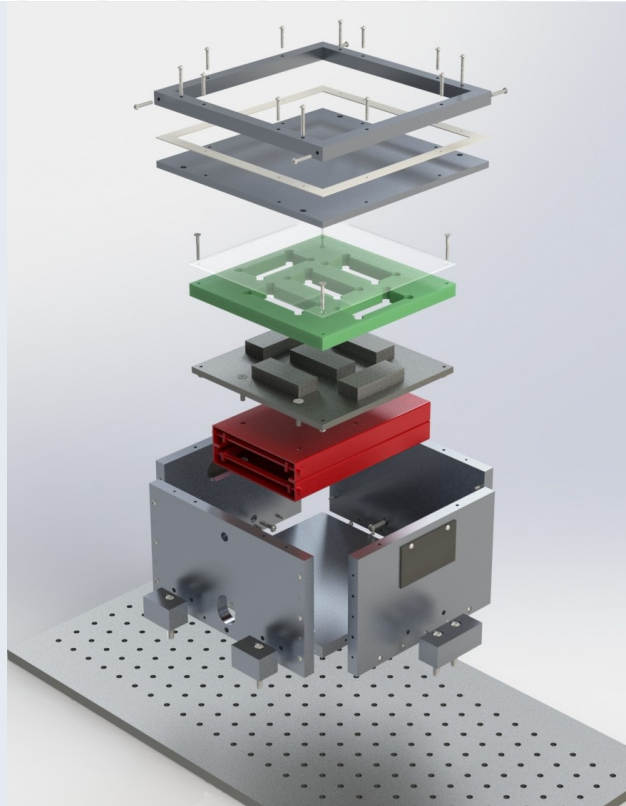# Team 16: Accu-Precision
CNC Workholding Fixture with Smart Fluids

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Accu-Precision

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Accu-Precision

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In manufacturing, many of the parts can be thin-walled and have non-standard, complex shapes, making them difficult to physically hold down during machining.

- A thin-walled part consists of many different shapes and sizes that have very small wall thicknesses, making them more prone to bending and shifting during the machining operation if not constrained properly.

- The current method of machining any thin-walled component consists of designing and machining specialized fixtures to hold these parts in place and account for ~80% of the total cost of machining.

Since it is critical to hold every part to very tight tolerances while machining, thin-walled parts can require special and complicated **plugs and fixtures** to withstand the forces and stresses applied during machining.

- A fixture or plug is a device to hold a part down while machining which requires both time and money before actual milling can begin.

- With a ferrofluid-based fixture, we save machinists about 8x the time in machining thin-walled parts and can save the machinist up to 3x in cost as compared to the current method of manufacturing new fixtures and plugs.

Thin-walled part gripped by its fixture

The goal of our system is to provide the following:

- Minimize set-up time

- Reduce material costs and labor costs associated with set-up

- Increase small batch production efficiency

- Reduce material waste

Project Background

Ferrofluid

"Smart fluids" are fluids whose properties (such as stiffness) can be changed by applying a magnetic field. One such type of "smart fluid" is **ferrofluid**, a mixture of magnetically attracted metal particles suspended in a carrier fluid. We utilized the same iron-based ferrofluid mixture as the previous year's team due to promising results from their work; the composition of the ferrofluid has a volume ratio of 3:2:0.176 of iron filings: silicon oil: grease. Our project incorporates the ferrofluid by utilizing it as a method of gripping the part when it comes into contact with the magnetic field produced by the Halbach array.
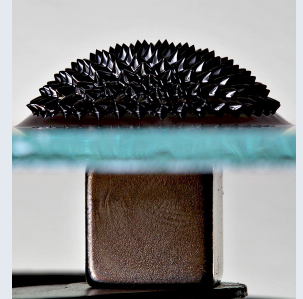

Continuation From the Previous Design Team

A smart fluid mixture of an iron-based ferrofluid and the use of permanent magnets had been specified to move forward as the primary method of fixture following the research of the previous year's team. Additionally, the previous team included a removable basin that we ended up utilizing and refining in our design.
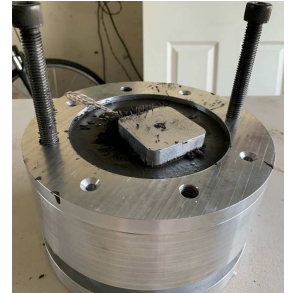
Magnets and the Halbach Magnetic Array

Moving forward with the previous year's design, we used single permanent magnets to engage the ferrofluid. One key change, however, is that we arranged them in a Halbach array for increased performance in both magnetic field strength and field coverage. A Halbach array is an arrangement of identical simple permanent magnets oriented in a way that increases the magnetic flux of magnets in one direction - creating a homogeneous magnetic field.
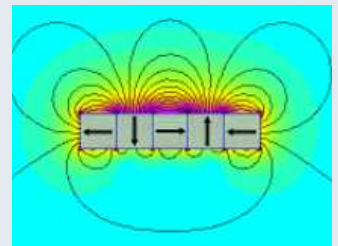

Halbach Orientation

Magnetic Field Engagement Mechanism

We came up with various methods to accomplish engagement of the magnetic array such as magnetic shielding and rotating or sliding the array. However, we noticed that maintaining a static basin while moving the array away will result in the safest and easiest option. This is what led our team to decide on using a motorcycle jack to mechanically move the array.

Specifications

We have been given a standard thin-walled aluminum test part by Accu-Precision as a means of evaluation. This part measures 12" x 8", with wall height of 3/4" and a wall thickness of 1/8". The following deflection specifications are held relative to this test part within the fixture basin.
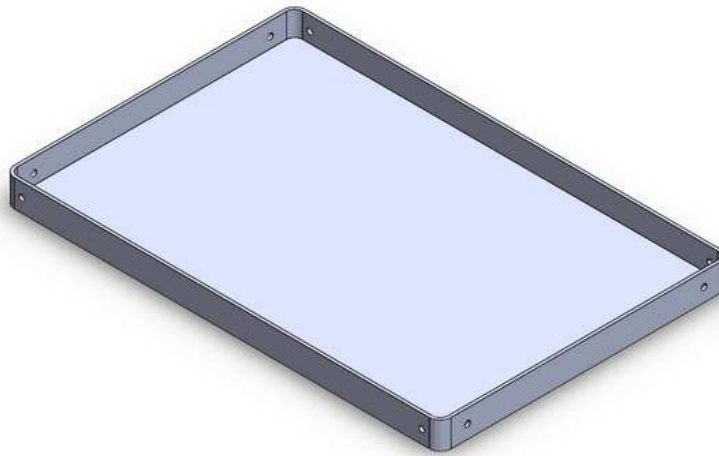

- The fixture shall limit deflection on our given standardized test part to ±0.01" under standard machine operation.
- The fixture shall fit within a 20"x20"x50" total volume space (based on the space constrained by a VF-4 Haas CNC mill table), and shall be able to be set up in under 30 minutes.
- The fixture usage shall be cheaper than current fixture manufacturing methods used in industry and the fluid should be reusable for a minimum of a 10 part batch.
- The magnetic array must also not interfere with other electronics or affect the safety during operation for any machinists.

Design Overview

The fixture attaches to the CNC table, where the ferrofluid is then poured into the basin. The to-be-machined part is placed in the fluid.
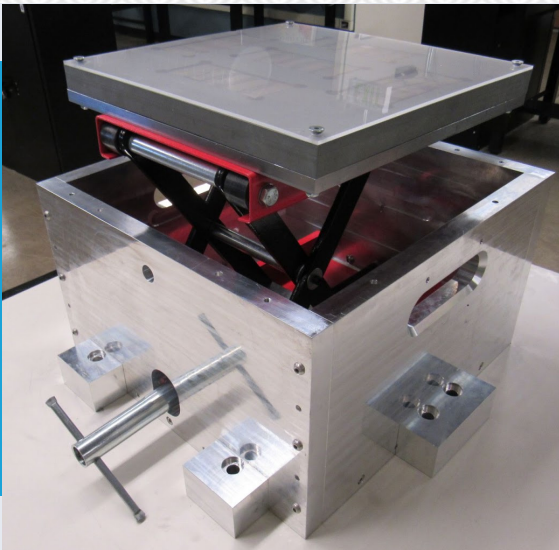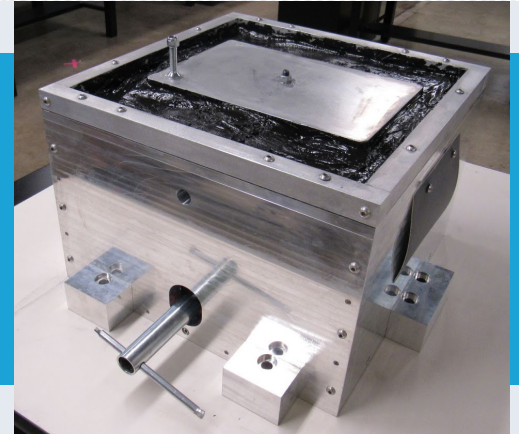
The magnetic array which interacts with the ferrofluid is raised and lowered with ease using a socket wrench. This engages the raising mechanism which moves the magnetic array to and from the basin. A viewing hole is added to the front to ensure proper engagement with the basin.

The ferrofluid hardens when interacting with the magnetic field from the array. The ferrofluid secures the part in place, which then allows for it to be machined on a CNC mill.

Holding Parts and Limiting Deflection

- Our design has the ability to fix almost any shaped part (depending on overall size dimensions). This modularity is unprecedented in the industry and, once fully developed, could replace many current methods of fixing parts to a machine.
- We have the ability to manufacture parts while maintaining the industry tolerance standard of ten thousandths of an inch (0.010").
- No metal fixtures required, resulting in more flexible cutting patterns and less interference with the actual fixture.

Usability on a CNC Mill

- Our design fits on VF-4 CNC mills and can easily be adapted to be able to fit on most standard milling tables.
- Slots are incorporated into the design to allow a lift to raise the box onto the milling table.
- Total box weight of ~170 pounds means the assembly is able to be moved via 2 people or with a mechanical lift.

# Cost Effectiveness and Safety Concerns

- Current operation uses a lot of cutaway aluminum that our team has eliminated entirely.
- We have successfully reduced the setup time by an estimated 800% and our cost per 10 part batch by roughly 350%.
- The ferrofluid is nonflammable.
- Electronics will not be affected by the magnetic field when the array is fully engaged.

Design Sub-Assemblies

Box Sub-Assembly

In order to minimize deflection of the part, a sturdy fixture to contain the magnetic array and raising mechanism is required. Parts to be machined will be deflected through the force of the bit, and the vibration caused by the bit. Our box is made using 1 inch thick 6061 aluminum. Along with the tight tolerance on the box, the deflection in the box is negligible.
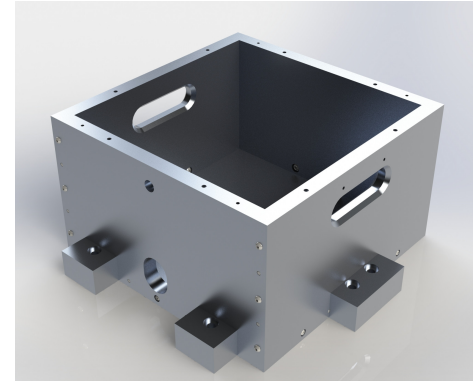

Basin Sub-Assembly

The basin is designed to withstand the force of the mill bit machining the part and the force caused by the pull of the fluid onto the magnets. Along with the extra support due to the engaged magnetic array, this deflection in the basin is negligible. In order to add and remove fluid into the basin, the basin is fully removable as one whole piece from the fixture assembly. The design of the basin is modular. The basin is able to be deconstructed just by leaving the floor of the basin attached to the fixture. This allows for the floor to be machined flat before use in case of damage to the floor of the basin.
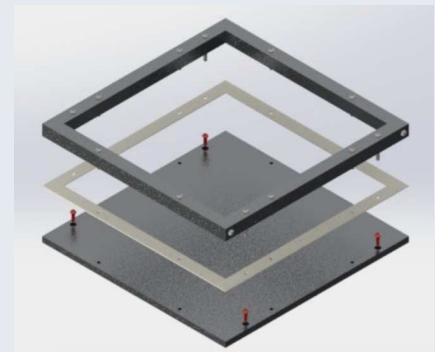

Magnetic Array Sub-Assembly

The Halbach arrays in this assembly are composed of N52 Neodymium magnets and were arranged to maximize the area of coverage and magnetic flux. This arrangement produces a strong magnetic field to provide proper engagement with the ferrofluid while being able to safely disengage within the height constraint of the box. The multiple arrays are encased in a PVC mold with an acrylic cover to ensure that the magnets do not shift from their specific orientation.
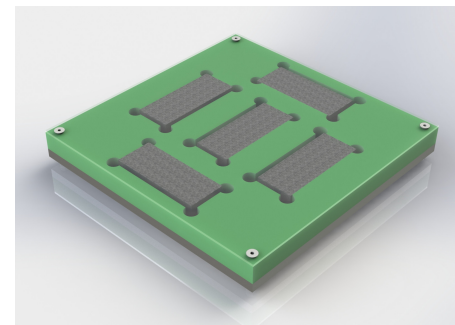
Testing and Analysis
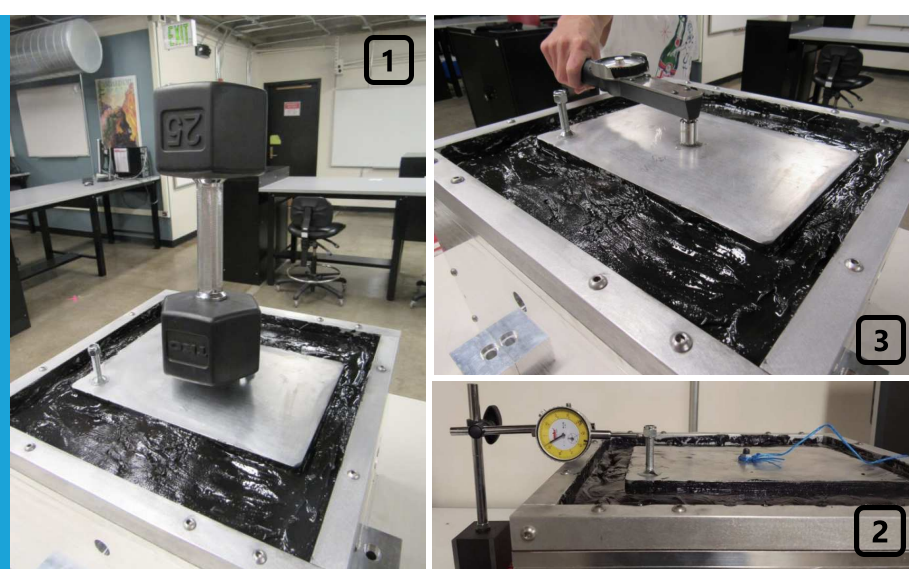
1 Vertical Deflection Test with Dial Indicator
- At 1.25" from the center, our part deflects .009"

2 Horizontal Deflection Test with Dial Indicator
- 12" edge, the part deflects .010" at average of 7.08 lbs
- 8" edge, the part deflects .010" at average of 5.07 lbs

3 Torque Test with Torque Wrench
- The part deflects .010" with an average of 7 lbf-ft

1 2 The CNC drill bit oscillates at **60 Hz**; to ensure that our assembly does not deflect due to vibration, we performed both vibration simulation analysis and testing to determine what frequencies the box vibrates at. Using Solidworks simulation, the first resonant frequency was found to be **718 Hz**. Using an accelerometer, the acoustic frequency was found to be **362 Hz**. This gives us a range of frequency that we expect the box to vibrate at; since the range far exceeds the drill frequency, we can safely ignore vibration as a source of deflection.

3 Simulation analysis of the magnetic field of our array using EMS in Solidworks. This allows us to observe the heat-map footprint of the field density and also quantify the expected field strength at the surface of the array (with a maximum of 4.018 Tesla).

Min : 2.573e-003
37e-001 , -2.54e-005 , -5.97e-002)
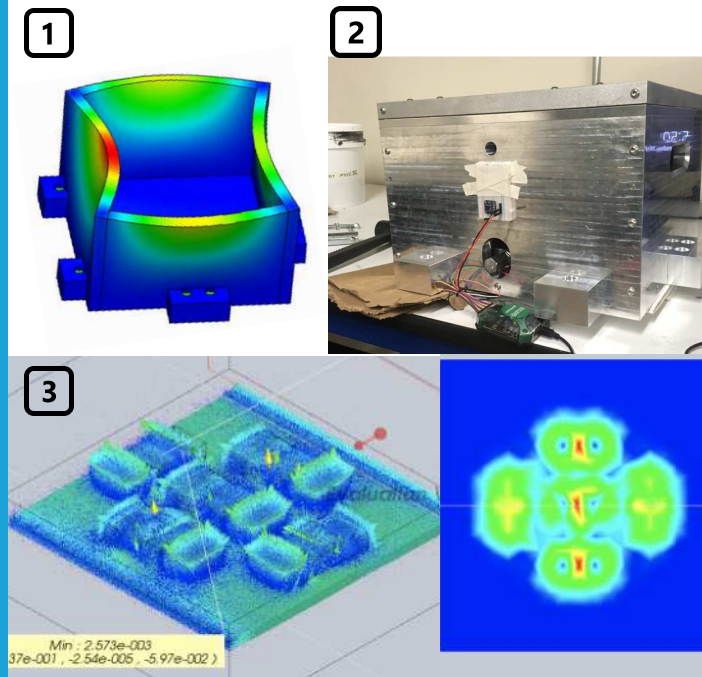
SUMMARY

In conclusion, we created an adaptable, user-friendly device capable of holding down a part during the process of CNC milling. This device has the capability to save money every time it is used while maintaining a safe working environment. While this design can maintain tolerances of under 10 thousandths of an inch, it does not hold this for the largest of applied forces in the current design iteration. There are multiple ways that our design could be improved to provide more gripping strength including **decreasing the distance** between the basin floor and magnetic array, implementing a **custom raising mechanism**, and changing the **ferrofluid composition**. With further research and development, this design could revolutionize the manufacturing industry by eliminating the need for machined fixtures.

MEET THE TEAM

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Acknowledgements

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