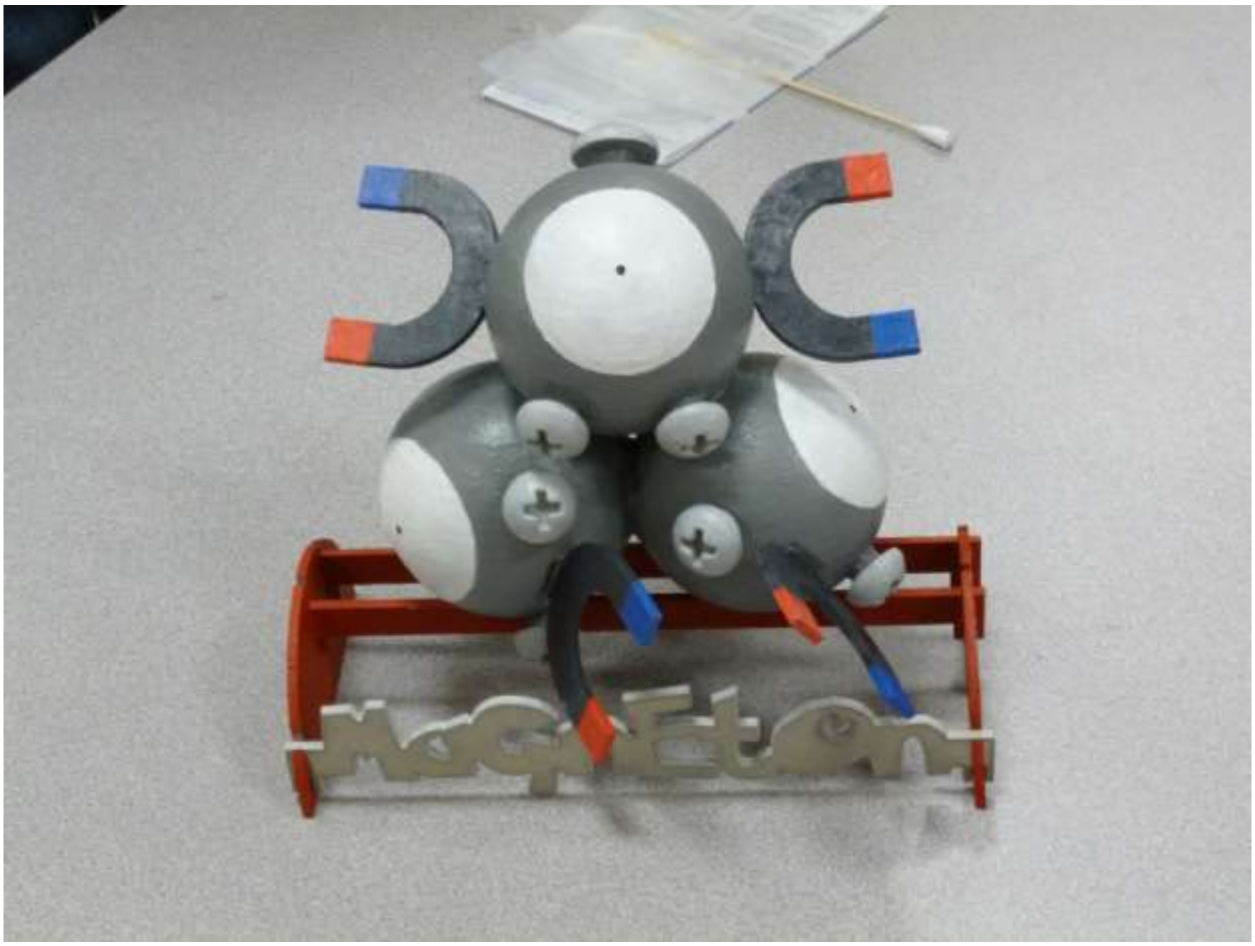
Team Magneton



Team Members:

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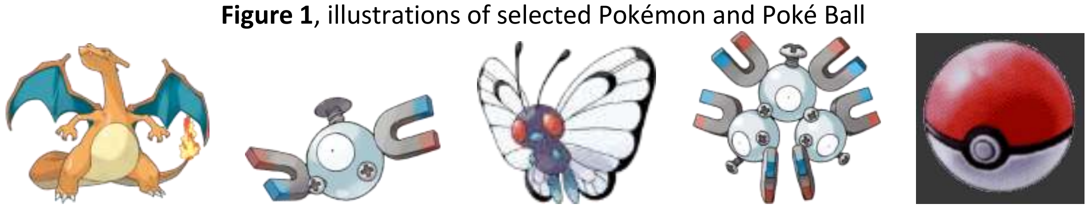
Introduction

This project emulated a real-life engineering situation in that we had to work together as a team to accomplish the common goal of designing and manufacturing a product within the given constraints. The machines we were allowed to use were limited to a 3D Printer, an abrasive waterjet cutter, an EDM, and a CNC Mill. We were only allotted one 12 x 12 x 1/8 inch aluminum plate and a material volume limit of 4 x 4 x 4 inches for the 3D Printer; any other materials would have to be purchased from outside sources. We were required to design and manufacture one part using the 3D Printer and one or more parts using the waterjet cutter. The 3D Printed part had to mate to the waterjet cutter part(s). We also had to utilize the EDM by applying the stamp to one of our waterjet cutter components. In addition, we had to design a theoretical object related to our project that would be fabricated using the CNC Mill.

Motivation/Background

Keeping the design constraints in mind, our team quickly came to the consensus that we did not want to overcomplicate our design by including moving components. We also wanted to avoid having to purchase outside parts. However, we still wanted to make our project complex and original. During the brainstorming process, we offered many different ideas along with a general idea of how these designs would be accomplished. After much discussion, we realized that we all liked Pokémon or at least were familiar with the franchise. We almost immediately decided to manufacture a Pokémon; the problem, then, became deciding which one to fabricate. Although we would have liked to recreate a badass Pokémon like Charizard, we quickly realized that the allotted materials and equipment would have made creating a faithful replica impossible. We also wanted to maximize our usage of the given materials, so we actively avoided having our project be primarily 3D Printer based with little use of the waterjet cutter. Keeping this in mind, we narrowed down our choices to Pokémon with simpler designs such as Magnemite, Butterfree, and Magneton (see **Figure 1**).

Figure 1, illustrations of selected Pokémon and Poké Ball



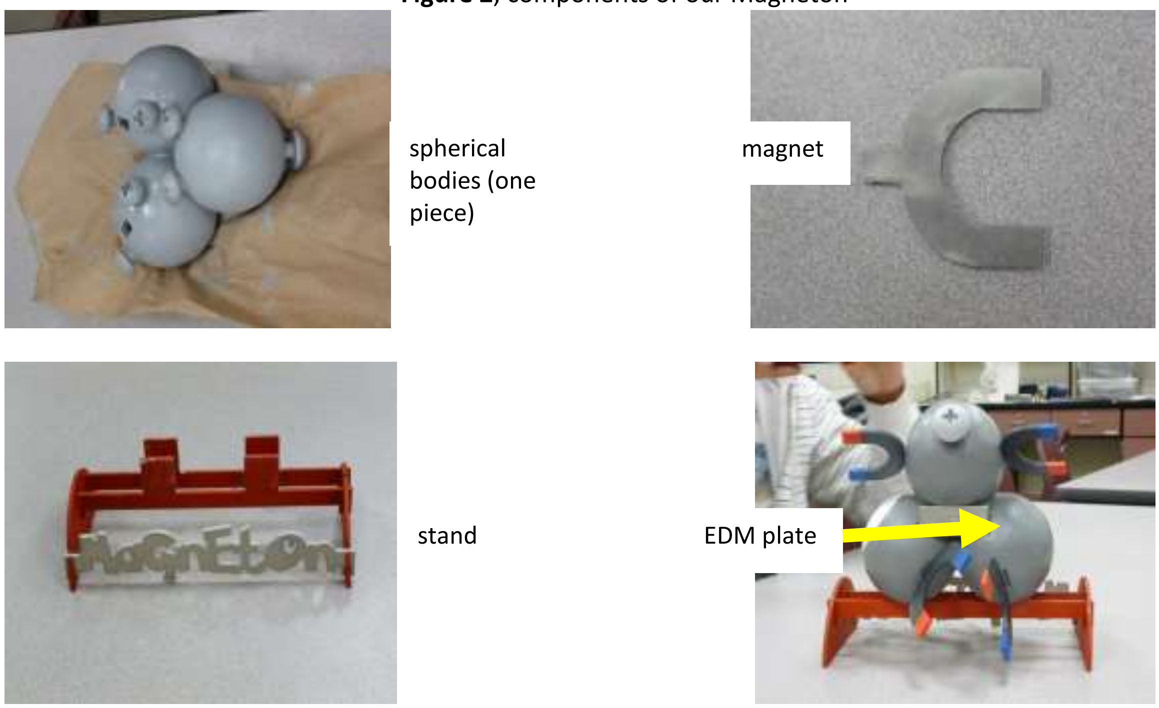
Charizard[1] Magnemite[2] Butterfree[3] Magneton Poké Ball[5]

Our first idea was to create a Magnemite resting inside a propped open Poké Ball (see **Figure 1**), but this would have required us to fabricate multiple 3D-Printed parts. Since the design requirements stipulate that we can manufacture only one part by the 3D Printer, we began devising a different method for holding our Pokémon. This Poké Ball served as the precursor to our final design for the stand. Since we could not manufacture this Poké Ball, we decided to tackle a more ambitious design by choosing Magneton. At first, we were unsure whether the three spherical bodies of Magneton could be fabricated as one piece by the 3D Printer. However, once we obtained the TAs' assurances that our design could be accomplished, we immediately decided to manufacture a Magneton. We also took into account its associations with electricity and steel, which make sense in an engineering class.

Designs and Processes

We divided our Magneton model into four different components: the spherical bodies with attached screws, the magnets, the stand, and the EDM plate (see **Figure 2**). The spherical bodies were fabricated using the 3D Printer, and we used the waterjet cutter to cut out the magnets, the components for the stand, and the aluminum plate upon which we applied the UCLA stamp using the EDM.

Figure 2, components of our Magneton



3D Printer

CAD Design

Our principal concern for the spherical bodies was whether or not the 3D Printer was capable of producing our CAD design, which was comprised essentially of three spheres melded together as one piece (including the screws). We wanted our Pokémon to be a reasonable size to hold in our hand, so right off the bat, we were debating how big we wanted our 3D-Printed component to be. We decided it should probably range from 4 inches to maybe 6 inches wide, but to save up on powder making such a large piece, we had to make sure we designed the component to be hollow.

We made our CAD model using Solidworks to make sure everything would assemble without complications first. In our design of the Pokémon, each sphere was made to be 3 inches in diameter, intersecting each other by a circular area. In actuality, Magneton is made up of three spheres that intersect by a single point, but that was impossible for us to make using the Printer. After each sphere was made, several work planes had to be created in order to make each screw that was sticking out of the Pokémon and each slot that was cutting through the spheres at the sides and bottom. There are a total of seven screws, so each needed a geometric work plane of its own. After the planes were created, each angled and distanced to a particular sphere, circles were extruded, domes were made, and a plus sign (+) was cut out of each dome to form each screw. More work planes were also created to form the slots needed for our Magneton, five more, to be precise, bringing up the total of extra work planes to 12. For each sphere, we designed two holes for magnets to be inserted into. We included indents in the back to place our EDM plate within. In addition, we designed holes on the bottom of the Magneton so that we could insert our model on the stand (see **Figure 3**). Once the TAs approved our CAD design, we began the process of fabricating the spherical bodies using the 3D Printer.

Figure 3, CAD drawing and real life model of 3D-Printed component

Fabrication

At this point, we were ready to produce our part. We successfully fabricated the spherical bodies without any major complications. We began to prepare to apply hardener to our part to give it more structural integrity. However, before we could start this, we found a large amount of loose powders inside the bodies fell through the holes (the part made by the 3D Printer was hollow on the inside). Since we did not want these spare particles to interfere with the hardening process, we attempted to remove as much loose powder as possible by blowing it out. We were careful to do so without damaging the part itself, which was still tender at this point. Once we had removed most of the loose powder from the insides, we started applying hardener to the outside surface of the part. This process took a long time and was a messy ordeal, but we managed to spread an even coat of hardener on the outside surface for the most part (see **Figure 4**). We attempted to spread some hardener to the insides of the part, but there really was not much we could do since these areas are hard to reach. Once the hardener dried, the spherical bodies were ready to be painted.

Figure 4, 3D-Printed component with hardener applied

Waterjet Cutter

Objective

Our initial plan was to use the abrasive waterjet cutter solely to create the magnets that would attach to the Magneton's body. This meant that we would have to cut six magnets from the aluminum sheet. In addition, the plate upon which the EDM stamp would be applied would be cut from the aluminum sheet as well. However, the team believed that this would result in a large amount of left over aluminum. Since we wanted to use as much of the given material as possible, the team decided to construct a stand for Magneton to sit upon with the extra aluminum.

2D CAD

We used Solidworks to create the 2D CAD models of the magnets and the stand. With the exception of the nameplate "Magneton," they were designed using the simple line and arc tools. The dimensions were arbitrary since we just wanted them to be proportional to the Magneton's body.

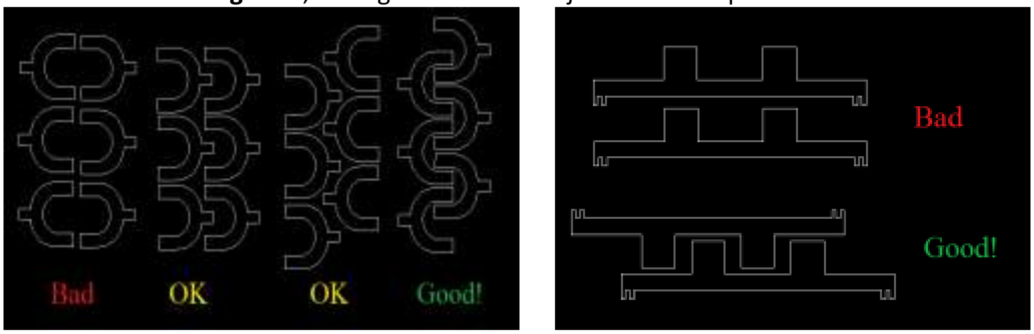
In order to create the nameplate, a free font, which was modeled after the actual lettering used in the Pokémon logo, was downloaded and installed onto a computer. Then, the "Text" tool was used to type out "Magneton." Then, right clicking on the text gave an option which, when chosen, converted the text into lines and arc as if they were made by those basic tools. After each of these sketches was made, they were saved as .dxf files (see **Figure 5**).

Figure 5, CAD drawings of stand components and EDM plate

From top to bottom then left to right:
nameplate, horizontal section of stand, magnet, vertical section of stand, and EDM plate

As mentioned before, the dimensions of the parts were arbitrary, but the constraint was that they had to be able to fit onto the 12 x 12 inch aluminum sheet. Thus, we had to find an efficient orientation to fit six magnets, two vertical stands, two horizontal stands, a nameplate, and an EDM plate. Our solution involved arranging the magnets and the horizontal nameplates. The other parts did not have much of a more efficient arrangement other than placing them as close to each other so we this. However, when placing the parts so close, we had to make sure that each part was at least 2 mm away from other parts or the edge due to the cutter's stream width. After placing all of the CAD parts onto a 12 x 12 inch CAD square, we saw that we had extra space, which we could utilize if any of the parts did not come out well (see **Figure 6**).

Figure 6, arrangement of waterjet cutter components



Different formations the team looked at to achieve efficient orientation on the aluminum sheet.

Fabrication

After loading the file onto OMAX Layout, we followed the proper steps, including determining the quality, leads, removing duplicate points/lines, etc. However, one addition we made was to add tabs on each part so that they would not fall through the grating once they were cut. We then loaded the files onto OMAX Make. Here, we made sure that the cuts were going to be on the correct side of the lines. It must be noted that almost all of the parts had an outside cut. The only parts that had an inside cut were the holes in the "a" and "o" in the nameplate. After setting a correct home (not too close to the edge of the aluminum), making sure the aluminum was properly clamped, and testing the waterjet cutter, we were able to cut our parts. However because we were making multiple copies of some parts, we cut only one of each to ensure they would cut well. After doing so, we reset our home to the proper place and cut the rest of the pieces. After cutting, we got rid of the tabs by using pliers to take most of the tab off and then sanding off the rest. We also sanded the corners and edges a little to make sure they were not sharp (see **Figure 7**).

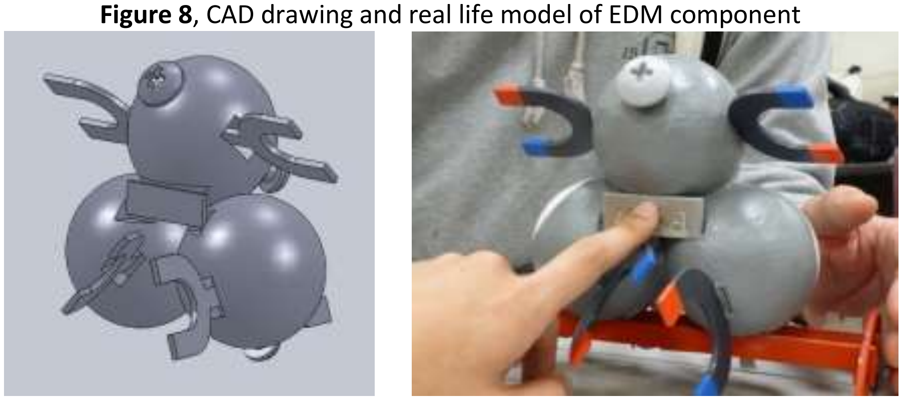
Figure 7, fabricated waterjet cutter parts

magnet | nameplate | horizontal stand | vertical stand

EDM

Finding an area on Magneton's spherical bodies to apply a flat stamp on proved to be a challenge. Since we had to apply this stamp on an aluminum plate cut out by the waterjet cutter, we had to devise a method for placing this plate onto our project. It was obvious that we would not be able to attach it to the spherical bodies unless we created inserts for the plate to fit within. With this in mind, we designed indents into the back of the spherical bodies for a rectangular plate of aluminum to fit inside. Another one of our ideas involved placing the stamp on one of the Poké Ball components of the stand. This would have been easier, but we had already fabricated the spherical bodies at this point. Not only would this have wasted the potential of the inserts on the Magneton's back, but this would have constituted a change in project design from the progress report, which would have cost us some points. We decided to stick to the original plan and used the EDM to apply the UCLA stamp on the aluminum plate. All we had to do then was glue this aluminum plate within the confines of the indents (see **Figure 8**).

Figure 8, CAD drawing and real life model of EDM component



Painting/Assembly

Primer

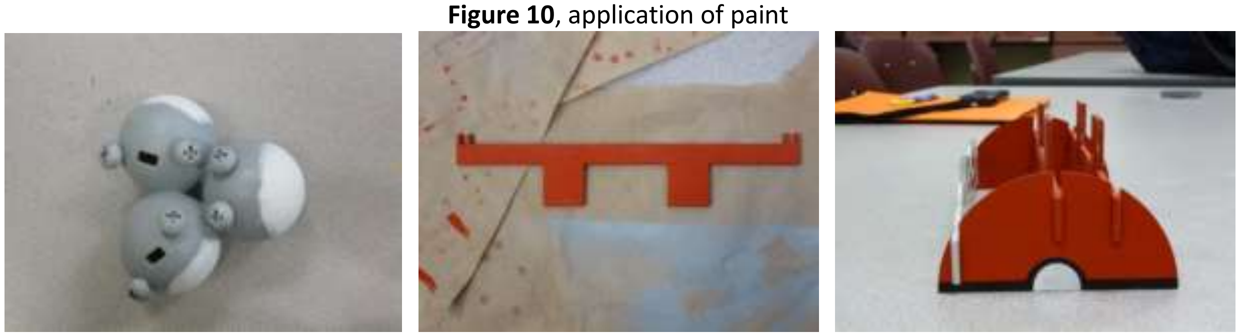
In order to create a faithful replica of Magneton, we had to paint our model to match the color scheme of the original design. Adhering to our high standards for quality, we decided to paint our model properly by first applying primer to all the parts which were to be painted: the spherical bodies, the magnets, and all the stand components except for the nameplate (see **Figure 9**).

Figure 9, application of primer

Paint

Next, we added coats of paint in layers. The colors we chose for the Magneton itself were pretty accurate. First, we painted the whole 3D-Printed component grey. Then, mixing grey with white, we created another shade to paint the screws. In order to paint the Magneton's eyes, we made a stencil of a circle out of paper. The purpose of the stencil wasn't to make perfect eyes; its purpose was just to make sure that all of the eyes were relatively the same size. After painting over the stencil with white, we had to apply more white and grey paint to make the edges of the eyes sharper. We completed the eyeballs by dotting the pupils using a black sharpie. The magnets that we inserted into Magneton were painted a darker grey, again, different from the color of the screws and of the Pokémon's main body. Everything except for the tips of these magnets was then covered with masking tape, and the tips were then painted with either blue or red paint. We painted the vertical stand components after the top half of a Poké Ball, the horizontal components completely red, and left the nameplate as it was so that it would stand out (see **Figure 10**).

Figure 10, application of paint



Assembly

Once the paint on all these parts dried, we proceeded to assemble the project together. One flaw we noticed with our components was that the slots in which we were to insert our magnets were too wide, so to fix this problem, we covered the tip that was to go inside the Magneton with multiple layers of tape. We squeezed each magnet into the slot, and then we painted over the tape to cover it up and make the Magneton presentable. After the Pokémon was all assembled, we had to remove the masking tape that was covering each magnet (tape was still covering the whole magnet except for the painted red or blue tips). Assembling the stand proceeded smoothly since all the stand components fit within one another easily. Finally, we inserted the Magneton onto the stand via the holes on the bottom (see **Figure 11**). Mission accomplished!

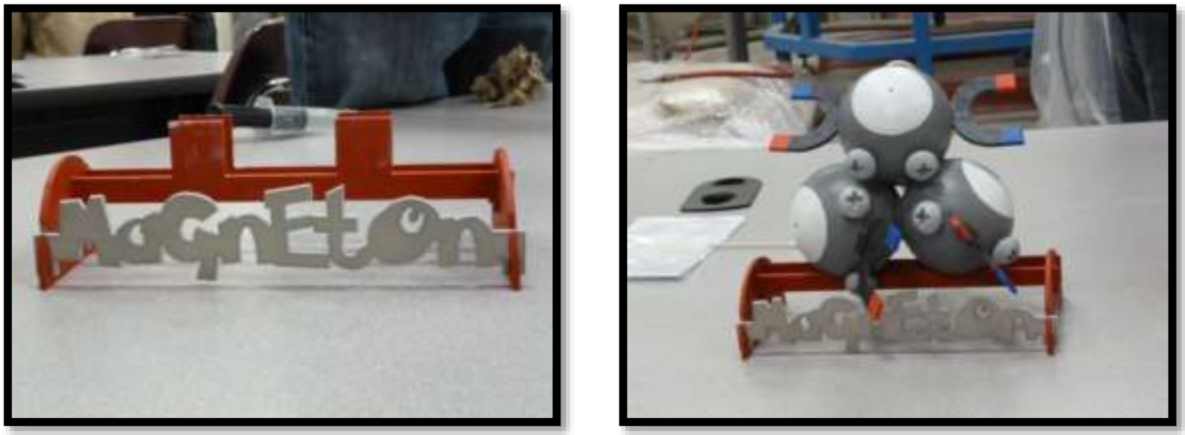
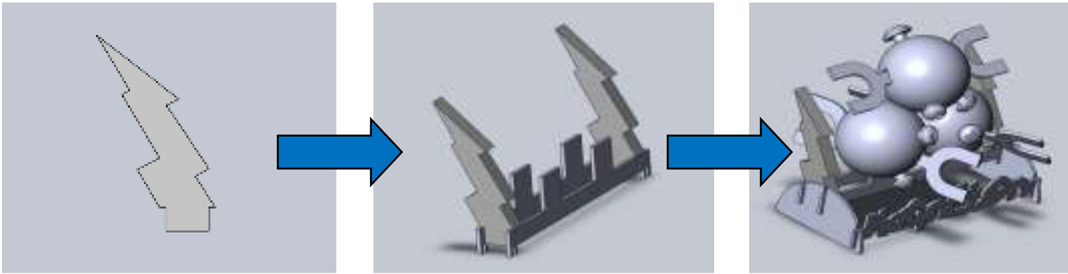


Figure 11 Assembly

Process Flow for Hypothetical CNC Mill Part

Figure 12, hypothetical CNC Mill part integration

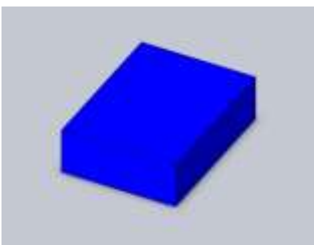


CAD Drawing

Glue to stand

Final Assembly

For our hypothetical CNC Mill part, we decided to fabricate lightning bolts, which would fit into the assembly (see **Figure 12**). The following process flow depicts the fabrication of these lightning bolts.

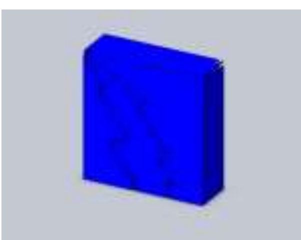


We are provided with one 3 x 4 x 1 inch wax block.

Upload CAD drawing to CNC Mill.
Set the CAM parameters:

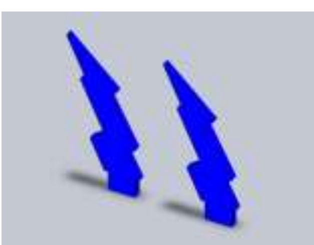
- tool: 1/16 inch end mill
- depth of cut: ¼ inch
- rotational speed: 5000 rpm
- feed: 30 inches/minute
- pocket or contour: contour

Zero the x, y, and z dimensions.



Etch ¼ inch thick lightning bolt onto 3 x 4 plane. Perform the etch again on the other side.

Cut parallel to the 3 x 4 plane ¼ inches off along each side with a band saw. This results in two 3 x 4 x ¼ inch blocks with lightning bolt etchings.



We can then push out the lightning bolt shapes out of each block to obtain our lightning bolts.

Production Summary

Week 1 (9/26-10/2)

- Brainstorm ideas for project

Week 2 (10/3-10/9)
- Narrow down project topics to Pokémon
- Unanimously decide on Magneton
- Plan out design of Magneton

Week 3 (10/10-10/16)
- Topic Report
- Preliminary CAD drawings

Week 4 (10/17-10/23)
- Finalize CAD drawings
- Fabricate spherical bodies using 3D Printer

Week 5 (10/24-10/30)
- Apply hardener to spherical bodies
- Cut out one magnet and a few stand components using waterjet cutter

Week 6 (10/31-11/6)
- Progress Report
- Apply primer to spherical bodies, magnet, and stand components
- Begin painting spherical bodies, magnet, and stand components
- Cut out the rest of the magnets and stand components using waterjet cutter
- Apply primer to the rest of the parts to be painted
- Finish painting spherical bodies and magnet
- Cut out slab of aluminum for EDM stamp
- Resize dimensions of aluminum plate
- Cut out resized aluminum plate
- Finish painting/assembly

Week 7 (11/7-11/13)
- Use EDM to apply stamp to aluminum plate
- Glue stamped slab to indents in the back of Magneton
- Submit finished project

Week 8 (11/14-11/20)

Week 9 (11/21-11/27)
- Design hypothetical CNC Mill part
- Final Presentation Powerpoint
- Final Presentation

Week 10 (11/28-12/4)
- Final Report

Lessons Learned

CAD Drawings

- When we made the CAD drawings, we designed the magnet slots inside each sphere of the 3D-Printed component to be a little too large because we incorrectly assumed that the hardener would be able to fill the gap when applied. However, there was still a great deal of left over space even after applying the hardener. We should have assumed the hardener to be approximately 2 mm thick at most and adjusted the slots accordingly. This setback was easily solved by applying multiple layers of tape over the parts that stuck out of the magnets and filling in these holes. Once we applied the paint, it became difficult to detect the problem.

3D Printer

- We encountered a few problems due to the hollow design of our 3D-Printed component. It was difficult to apply hardener to the inside of the part. As a result, a great deal of powder fell out through the holes on the bottom of the part. The loose powder did not compromise our project, but we learned that hollow designs pose some troubles.
- We also learned the importance of applying hardener to the surface evenly. Had we taken our time and applied the hardener evenly rather than letting large droplets slide across the surface, the surface would have been smoother. This did not significantly affect the aesthetic quality of our 3D-Printed part since we had planned to apply primer over it anyways.
- One minor problem we encountered was due to the swelling of the 3D-Printed part. This caused the indents on the back of the Magneton to grow, making it too large for the aluminum slab we designed to rest within it. This was easily solved by measuring the new dimensions of the indents and cutting out a new aluminum slag according to these measurements.

Waterjet Cutter

- We were somewhat close to running out of space on the aluminum sheet. We should have reduced amount of aluminum used by shrinking the design size. In this way, we would not have had to worry about running out of material if we suffered a serious complication. Luckily, no such mistake was made so we were not in any danger of running out of aluminum.

Painting/Assembly

- As in the case of the hardener, we learned the importance of applying the primer evenly. Applying too thick of a coat lengthened the time it took for the primer to dry. Extra time spent waiting for the primer to dry was essentially time we could have spent doing more painting. Also, we should have rested the parts on wax paper to avoid accidentally imprinting any designs on the surface of the parts. By the time we realized this, several of our parts had been resting on coarse paper with a bumpy surface, which caused these parts to be rougher than we had anticipated. However, this did not prove to be a huge problem since we had already decided to paint over the primer anyways.

Other

- We could have finished even sooner if we had done the waterjet cutting at the same time as the 3D Printing. Had we done this as well as several other time saving techniques, we could have potentially been the first team to finish their project. Regardless, we still finished our project pretty quickly.

Conclusion

Overall, our project went by pretty smoothly. Once we had decided upon our topic, we worked swiftly to finish our project as quickly as possible by dividing up the work amongst one another. We did not encounter any large errors that completely compromised our project. The errors we did encounter were relatively mild, but it was from these small errors that we learned more about the material and equipments' deviations from an ideal situation. We worked together and found creative solutions to successfully overcome these problems. In the end, we managed to successfully produce a high quality Magneton replica with an original twist.

The team and Magneton
Top row, left to right: Patrat, Austin, Pikachu, Eugene, Douglas
Bottom row, left to right: Joyce, Seung Ho, Wilson

References

1 http://www.serebii.net/pokedex-bw/006.shtml
2 http://www.serebii.net/pokedex-bw/081.shtml
3 http://www.serebii.net/pokedex-bw/012.shtml
4 http://www.serebii.net/pokedex-bw/082.shtml
5 http://www.serebii.net/pokemon_advance/pokeballs.shtml