Wire Coiler Improvement

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Introduction

The purpose of this project was to redesign an existing part ("finger") on a wire coiler to keep it from putting small damage marks on the wire. Defects made to copper wire that is drawn down into coiler baskets for the production of magnet wire can cause quality problems for the wire throughout the manufacturing process. Our goal was to design a part that will prevent this from happening, fabricate the new part, test the new designed part on the coiler and document the improvements to the quality of the wire. After several months of designing and testing our new finger design the team successfully completed the goal of the project.

Overview

Since the approval of the project, the team has been working on how to approach and solve the problem regarding the magnet wire coiling machine. After determining the exact cause of the problem, the team began to think of a permanent solution that was effective and simple, yet cost efficient. Initial sketches were drawn, which led to full CAD drawings and part fabrication once the team had come to a consensus. Progress report 1 shows step-by-step progress made through February 20th.

After the submission of the first progress report, the team set to install the redesigned machine components and begin the first testing procedure. As it turns out, an issue arose during initial testing. After installing the part into the machine, it didn't take long for the operator, who was running the machine, to notice that something was wrong. When the operator started up the machine, he heard an unusual "thump..thump..thump..." and shut down the machine and contacted the team. After talking with the operator and inspecting the part it was clear that the back side of the finger mount was being scraped by a radial arm in the machine that wraps wire around the coiler plate. Progress report 2 detailed the progress made through March 20th.

Following the second progress report the team redesigned the part following the mishap in the previous testing. The part has been refabricated and was tested for clearance on the machine. During the redesign the original part was modified and ran on the coiler for several weeks and no evidence of wire hitting the part was found.

Exploring the Problem

As stated in the official proposal for the project, the coiled copper wire has a tendency to spring outward once release from the coiling machine. In turn, this causes the wire to make momentary contact with the base of each of the 15 fingers mounted to the machine. The fingers help to keep the coiled wire's shape by pressing the wire against the rotating portion of the coiling mechanism and consist of two flat, rectangular plates of steel. The front plate is the plate that makes contact with the wire and is made from a polished chrome steel. The back plate is mounted behind the chrome plate, which provides extra support and is made of plain carbon steel. The impacts made by the wire to each of the 15 finger bases results in minor defects of the wire's surface; an issue that can affect the quality of the final product. Though it was known that contact with the base was being made, it was not known where the exact point of contact was. In order to better understand the problem, a simple solution was proposed.

It was decided that the base of the finger mount would be painted yellow, which was done for two purposes. The first purpose was to provide a temporary fix to the problem while the team worked on a permanent solution. The paint provided a softer impact surface, which helps to reduce the damage done to the wire when exiting the coiling machine. The second purpose was to provide an accurate visual representation of the impacts occurring during operation. Since the paint eventually wears off over time due to the repetitive impacts, the bare metal underneath appears exactly where the impacts are located. Shown on the next two pages is a detailed assembly drawing that depicts the stationary portion of the coiling mechanism, two pictures that provide a close-up view of a finger and its base, and a picture that shows the impact locations on the base of one of the finger mounts.

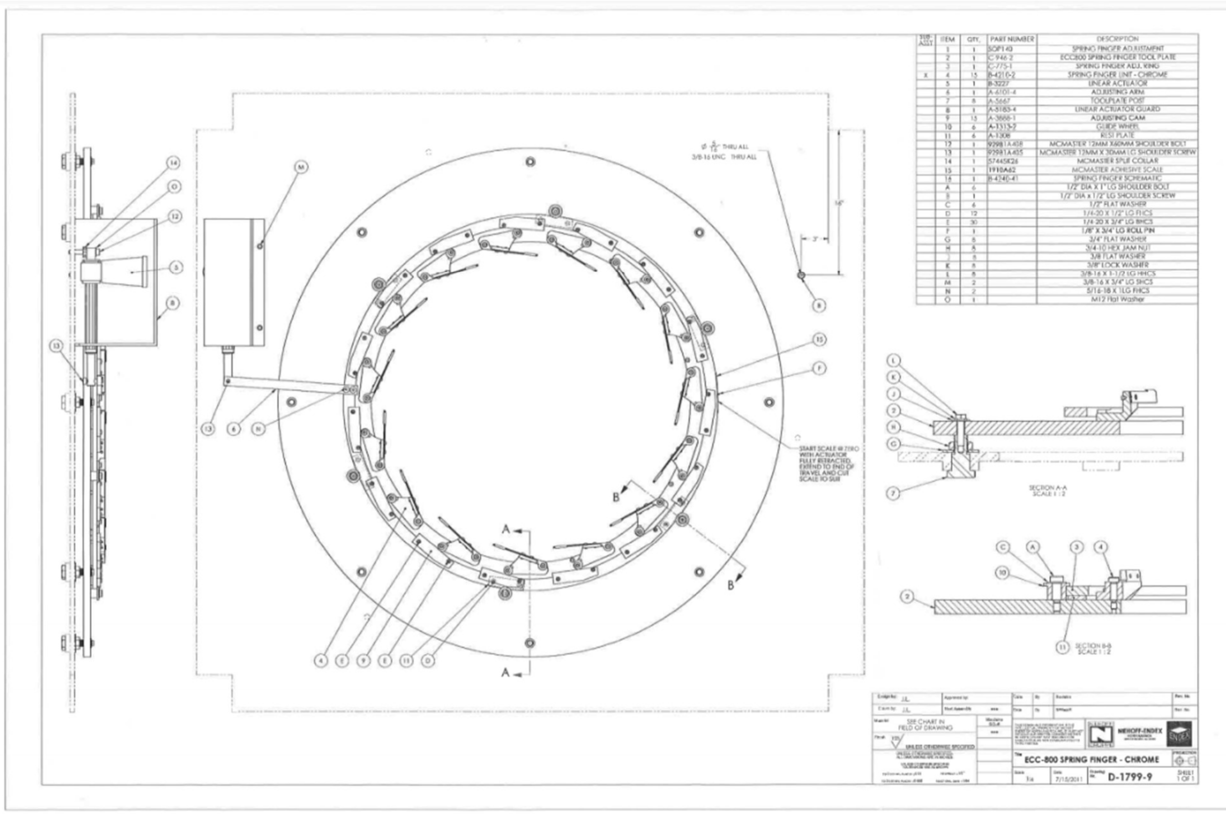


Figure 1. A detailed assembly drawing of the stationary portion of the coiling mechanism. Depicted are the location and orientation of each of the 15 fingers mounted to the stator.

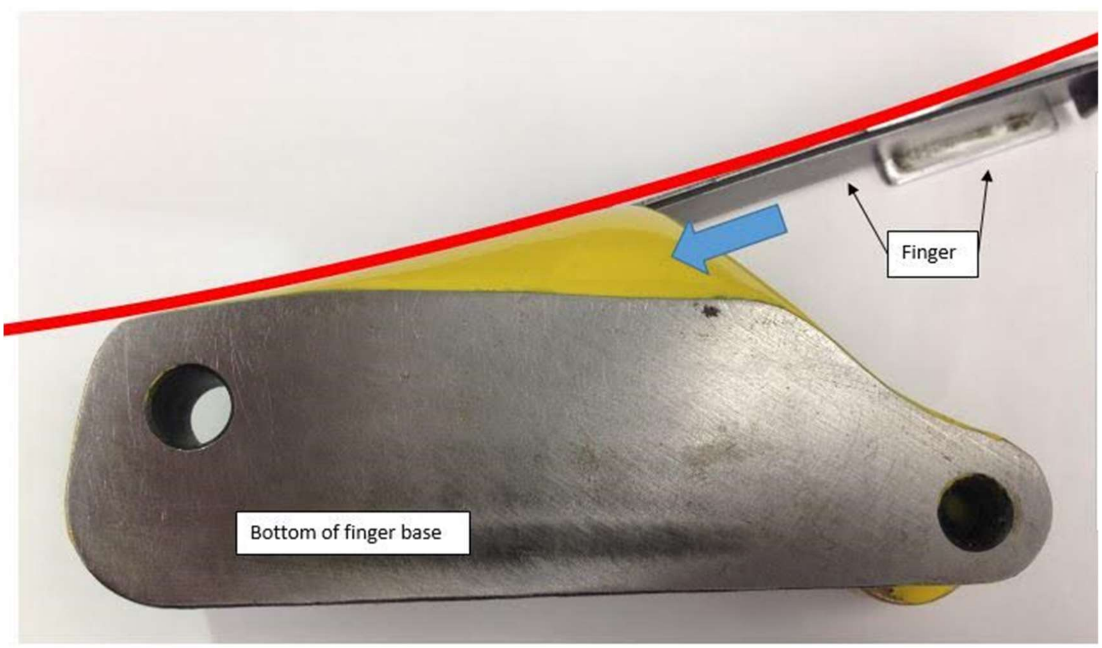


Figure 2. A close-up view of an individual finger and finger base with the yellow paint added.

Figure 3. A close-up view of an installed finger and finger base from the underside of the machine.

Figure 4. An image showing the exact contact location between the coiled wire and the finger base.

Determining a Solution

After determining the location of the impacts made between the wire and finger base, the team set out to come up with solutions that would resolve this problem. The initial suggestion was to replace the face of the base on the existing part with another material that would take the blow of the wire, as it hit the part, without damaging the wire. The materials considered to make up the insert were ceramic, plastic and rubber, with ceramic being the most compelling because of its ability to be ultra-durable and smooth and the fact that the light force of the wire hitting ceramic would not be enough to damage the ceramic itself. Ultimately though, the team decided to redesign the base of the finger by recessing the portion of the base of the finger that faced inward to the machine completely in order to provide complete clearance between the base and the wire exiting the coiling mechanism, with the hope that doing so would eliminate the chance of impact. The second solution was to be redesign the supporting back-plate of the finger. Extending the width of this plate would result in a greater guiding assistance of the exiting wire to the bin below the machine. The team believed that the combination of these two modifications would prove to resolve the problem.

Finger Force Testing

In order to redesign the finger base without making other significant changes, the team knew that the current force load applied to the finger needed to remain the same value. To determine this value, a load simulation was set up. First, a finger was removed from a machine and separated from its base. Then, a flat piece of steel stock was used as a mount for the finger. After drilling two holes in the steel stock and bolting the finger to it, it was mounted in a vice. Then, a hole was drilled in the approximate load point on the finger. Finally, a force gauge was hooked to the hole in the finger and attached to a come-along tool at the other end of the gauge.

Once the simulation was set up, the come-along tool was cranked until the deflection of the finger approximately matched the deflection of the finger when mounted in the coiling machine. To be as accurate as possible, free-length and deflected finger measurements were taken prior to the simulation and served as a targeted measurement when mounted in the simulation. The load applied to the finger was determined to be about 47 lbs. The following pictures depict the setup and testing of the simulation rig.

Figure 5. Shown here is an image of a finger that is mounted in the machine. The length from the tip of the finger to the back of the mounting block is approx. 5-5/32 inches.

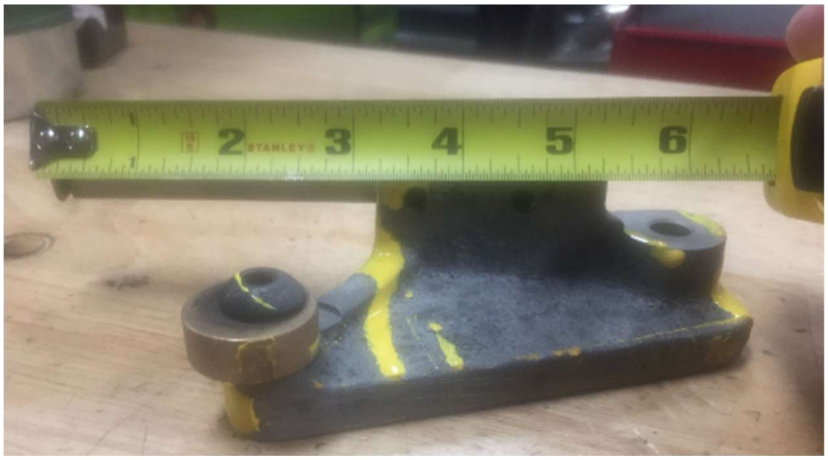


Figure 6. An image of a finger and finger base removed from the machine with no load. Dimension is measured to be approx. 5-10/32 inches.

Figure 7. An image showing the finger with a hole drilled at the approximate point of contact (3/4 of an inch) and mounted to the flat steel stock.

Figure 8. An image showing the entire simulation setup.

Figure 9. An image showing the change in dimension when loaded versus unloaded, matching the dimensions when the finger is installed in the machine.

Figure 10. A close-up view of the force gauge. Reading is approx. 47 lbs.

Note: After completing the finger force testing, coming up with the design of our part and consulting with Dr. Dupen it was determined that the force of the finger calculations were not critical to the outcome of the project's effectiveness. The amount of material left in the final design of the base to support the finger would ultimately provide adequate and comparable force to the wire in comparison to the part that we were redesigning.

Proposed Base and Back-plate Redesign

As previously stated, the team planned on redesigning the finger base and finger back-plate, which are intended to resolved the issue of the minor defects made to the copper wire from impacting the base of the finger. Both components were manufactured by Adaptek Systems. Below are the team's initial proposed redesign drawings for both the finger base and finger back-plate.

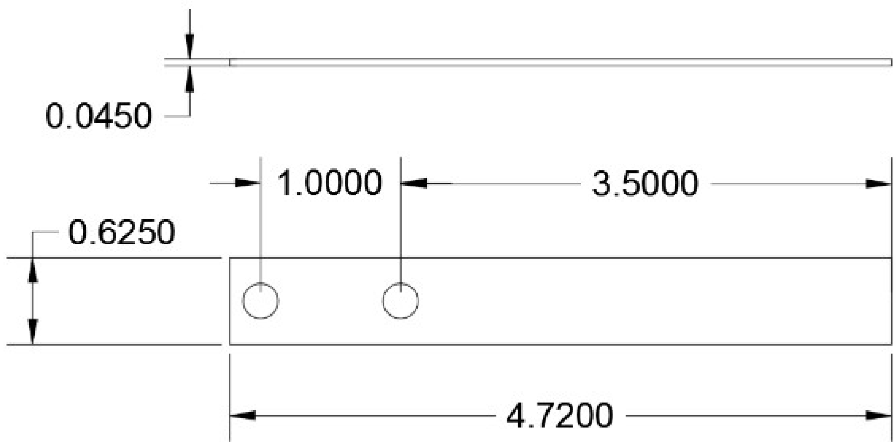


Figure 11. Current back-plate design

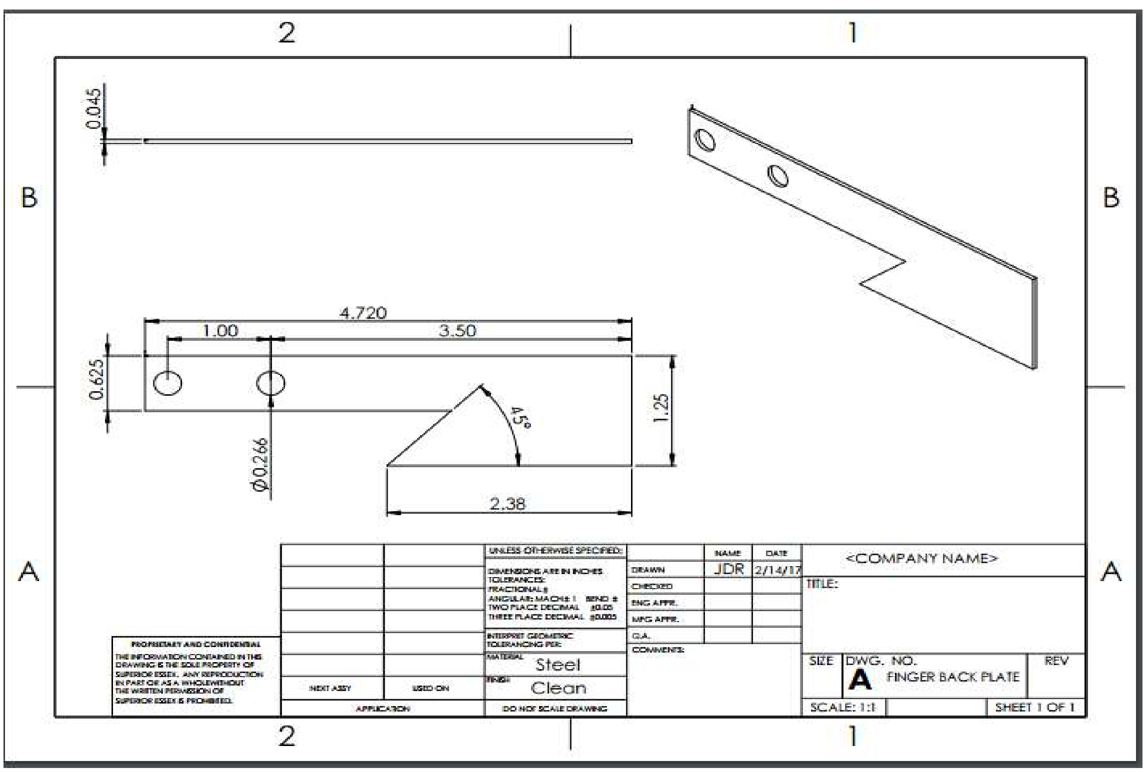


Figure 12. Proposed back-plate redesign. Note the extended width to provide guidance of the wire to the bin below the machine. The portion of the plate with the 45-degree cut will be bent back slightly (into the paper) to smoothly guide the oncoming wire to the main portion of the plate.

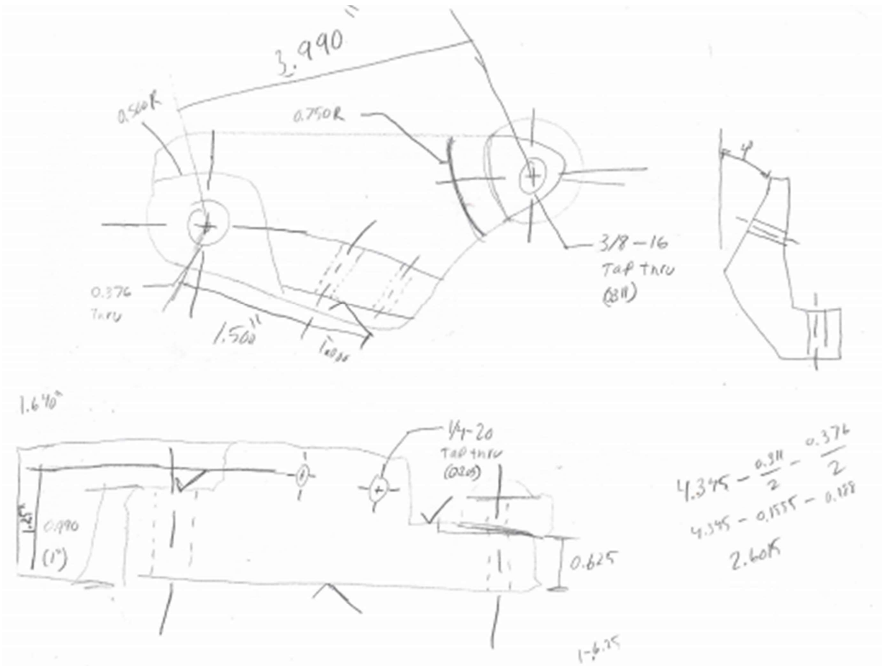


Figure 13. A rough hand-drawn sketch of the initial proposed finger base.

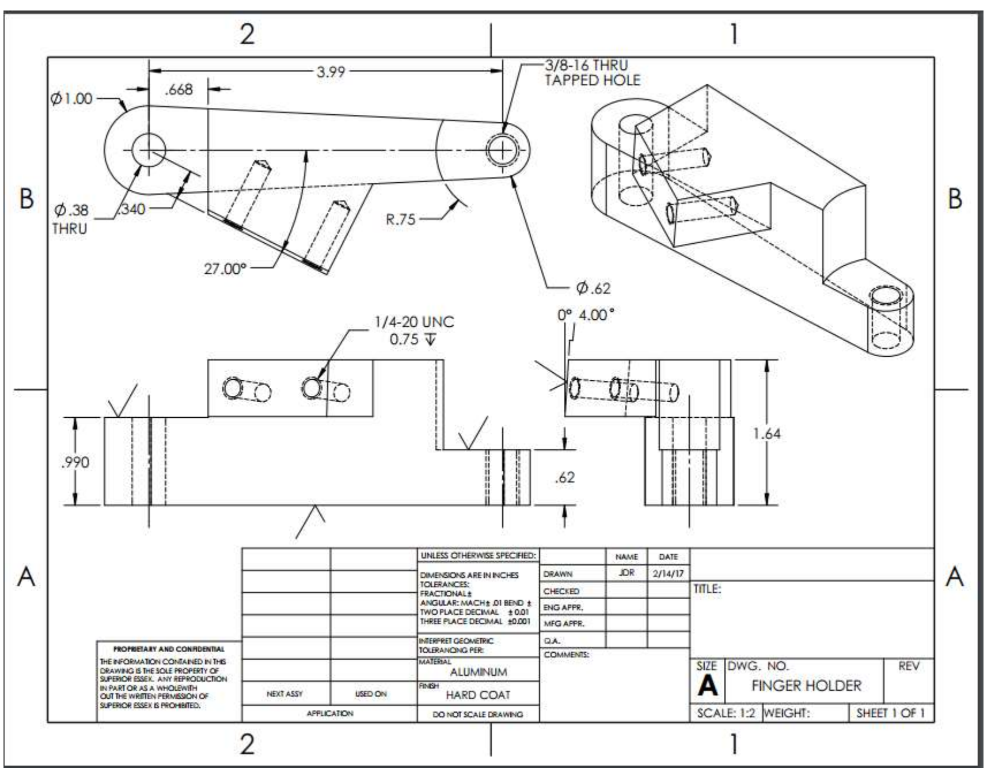


Figure 14. A completed CAD drawing of the initial proposed finger base. Note the removal of the lower portion of the original base, which was painted yellow. This undercut provides additional clearance between the wire and the base.

Component Installation

After the first progress report, the redesigned finger base and back-plate had finished fabrication. After receiving the new parts, they were installed into one of the coiling machines for test fitting. Installation proved to be successful and caused no immediate issues. Below are a few pictures of a coiling machine with the new components installed.

Figure 15. An overall view of the new finger base and back-plate installed.

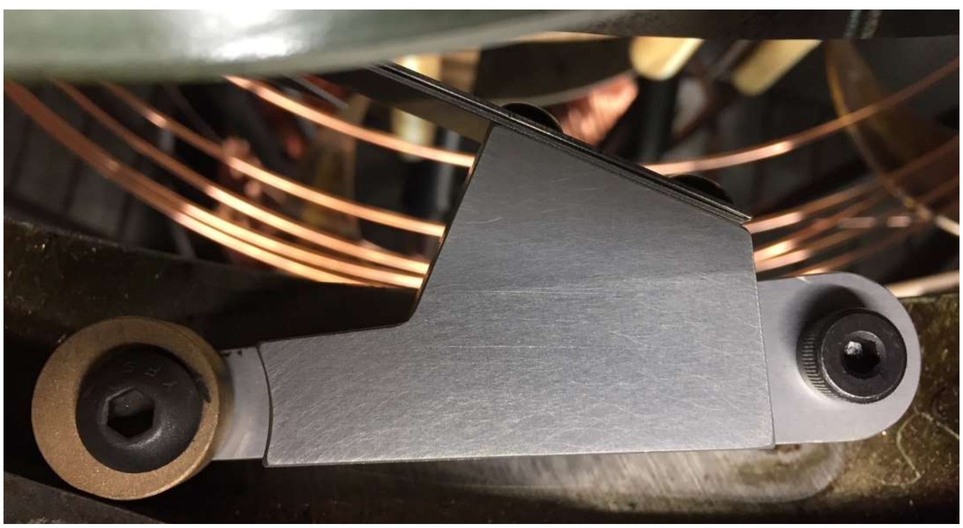


Figure 16. A top view of the finger base installed in the machine.

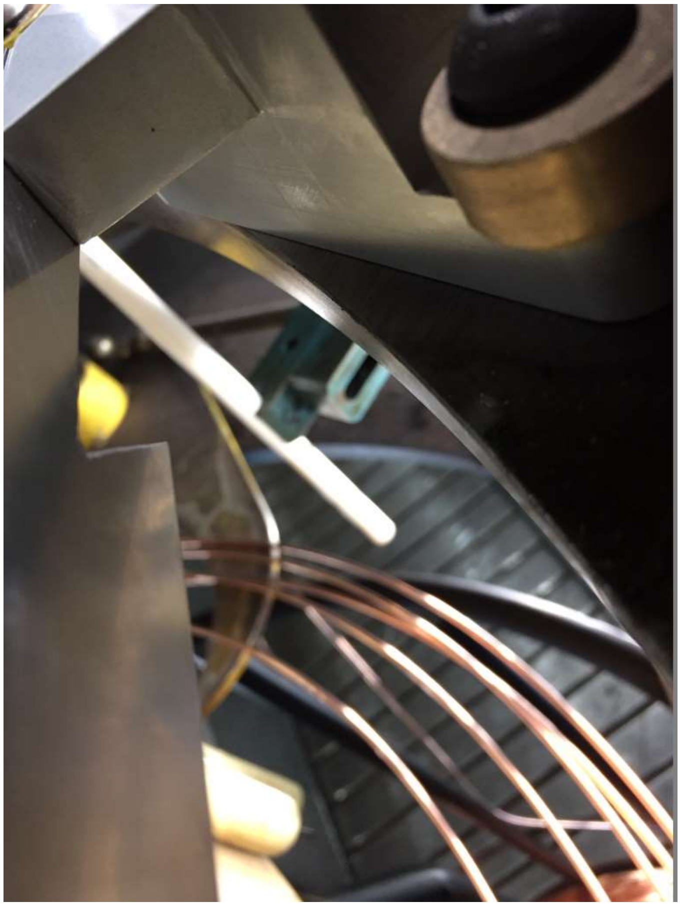


Figure 17. A close-up view of the underside of the new finger base showing the additional clearance provided by the undercut.

First Testing Procedure

After the test fitting of the new components, the first testing procedure began. Right away, unfortunately, there was a problem. After the machine was started, the operator heard thumping noises coming from the machine. The machine was then inspected after being shut down to search for the source of the noise.

It was determined that part of the radial arm for the coiling mechanism was making contact with the top rear portion of the new finger base. Each pass of the radial arm scraped the new finger base, creating the repetitive thumping sound that the operator heard. To provide a temporary fix, the damaged surface of the finger base was sanded down in order for the radial arm to clear it when operating. The following pictures were taken after the discovering the damage done to the finger base.

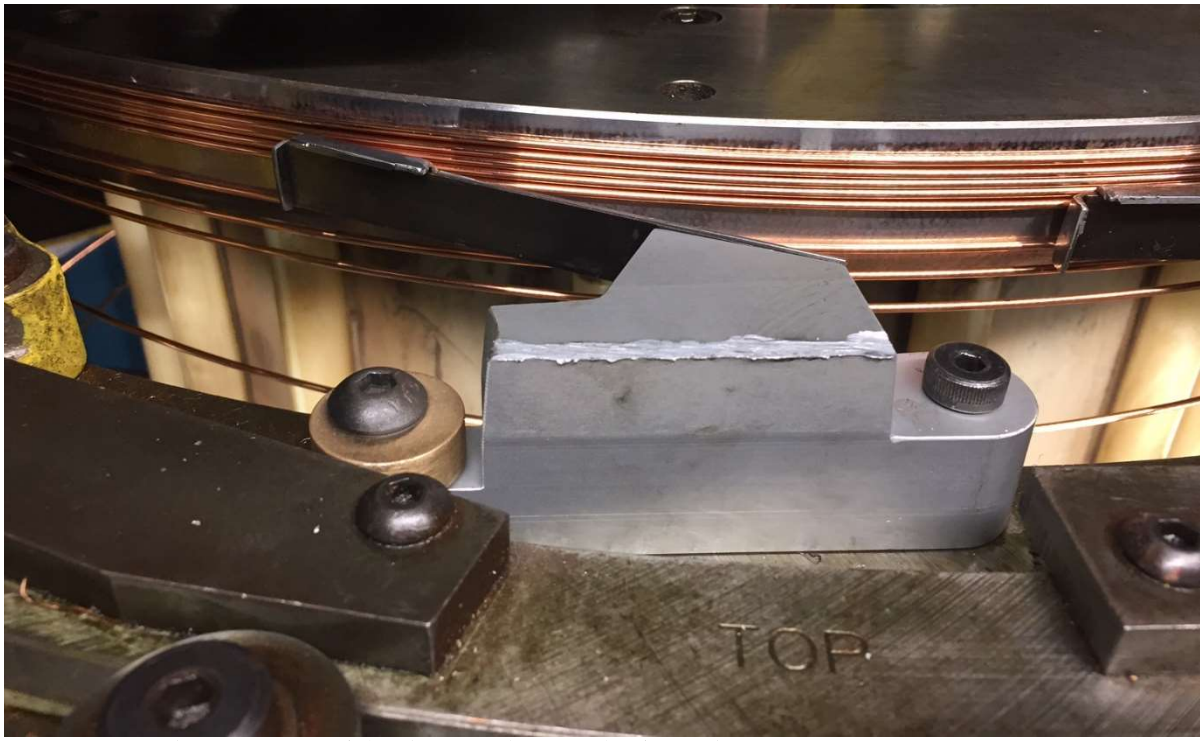


Figure 18. A close-up view of the damage done to the finger base.

Figure 19. An image of the radial arm. The portion below the small white pulley is the cause of the damage to the finger base.

Follow up after Initial Testing

Following the issues of the first testing procedure, it is clear why the original finger bases were designed in such manner. The team made a small design change to the finger base to prevent the issue from occurring again. It was decided that the easiest change to make is to include a cut out of material to the top rear portion of the finger base.

Two slow motion videos were taken; one of the original finger in production, showing the wire hitting and scraping across the side of the finger base and the other showing a side by side comparison of the old finger design and the new design which shows the wire hitting and scraping across the side of the old finger design base and not coming in contact with anything at the drop with the new finger base design. These videos are included in the power point presentation.

Along with the slow-motion film, the team sprayed the finger base and mounting ledge with layout fluid. The purpose of this was to provide additional confirmation of any improvements made by the new designs. The layout fluid acted like the yellow paint used initially in the project. If the copper wire was still making contact with the machine, bare spots in the layout fluid would have confirmed that.

The layout fluid was applied on Thursday March, 23rd and installed into the coiler. The base plate that the finger sits on was also painted to see if the wire would hit that area now that we've removed the area of the finger that the wire was previously hitting. On March the 31st, the finger was removed from the coiler and both the part and the base plate were inspected for damage. No wire damage was observed on either part.

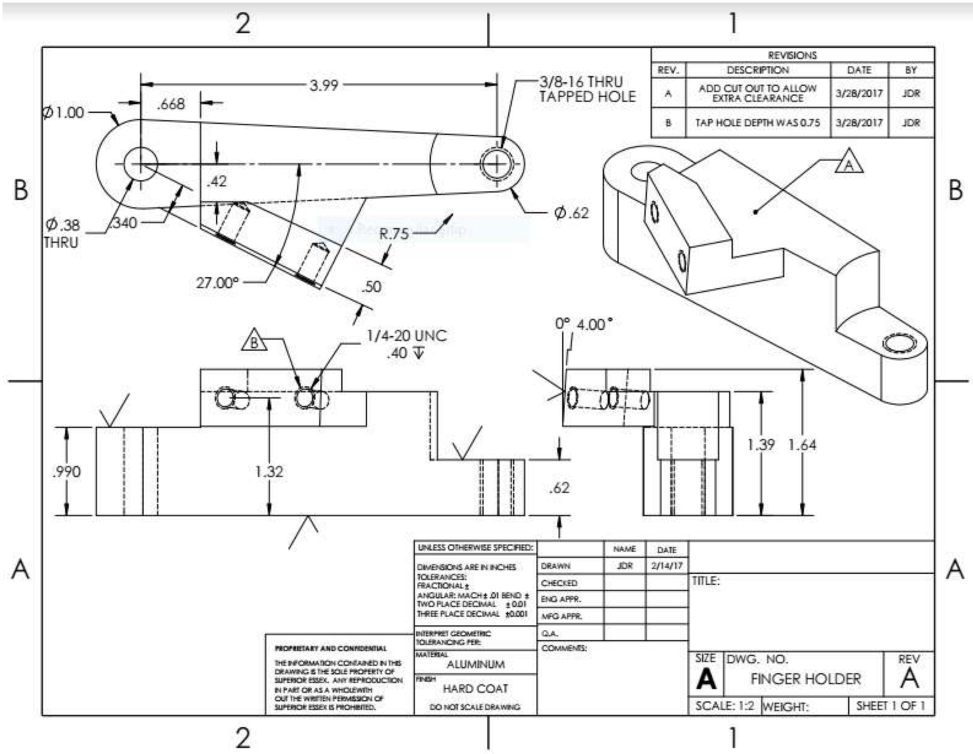


Figure 20. A completed CAD drawing of the improved finger base. Note the removal of the back of the base where contact was previously being made by the radial arm.

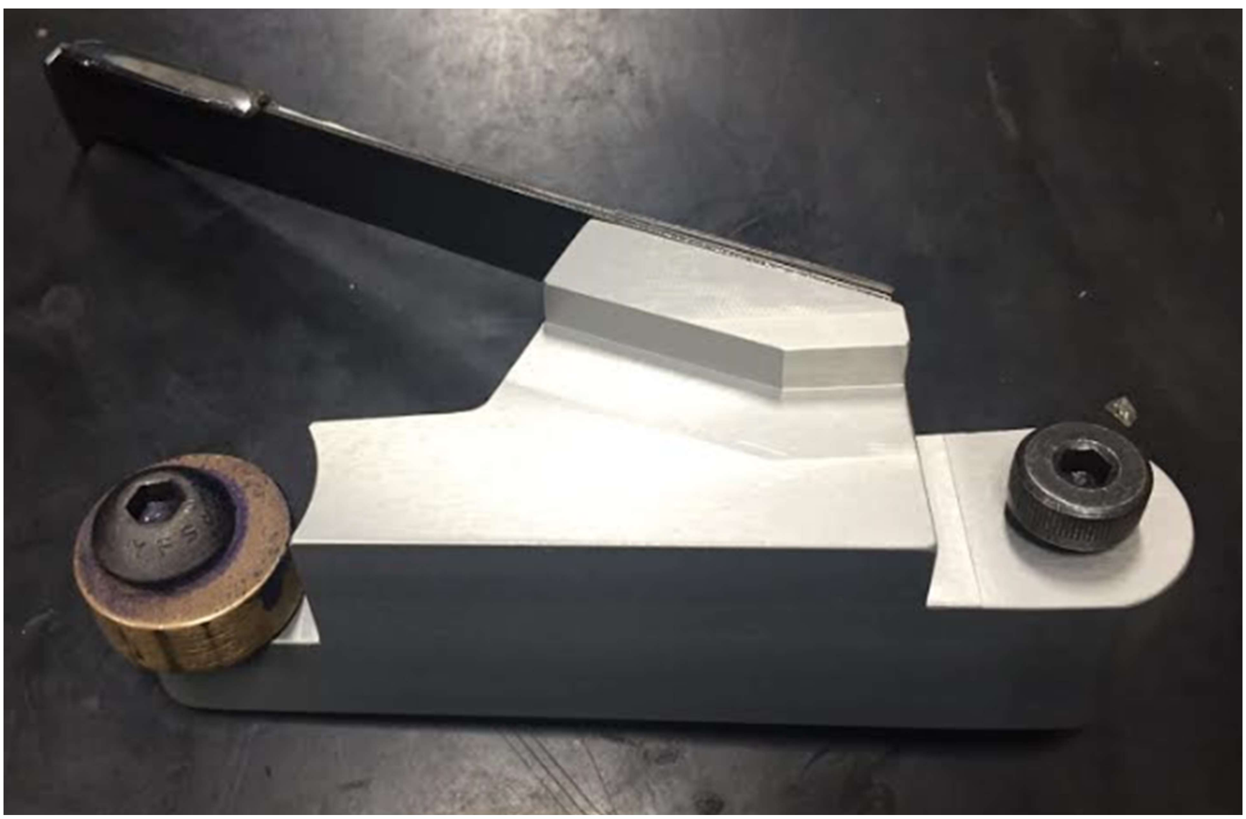


Figure 21. An overall view of the improved finger base.

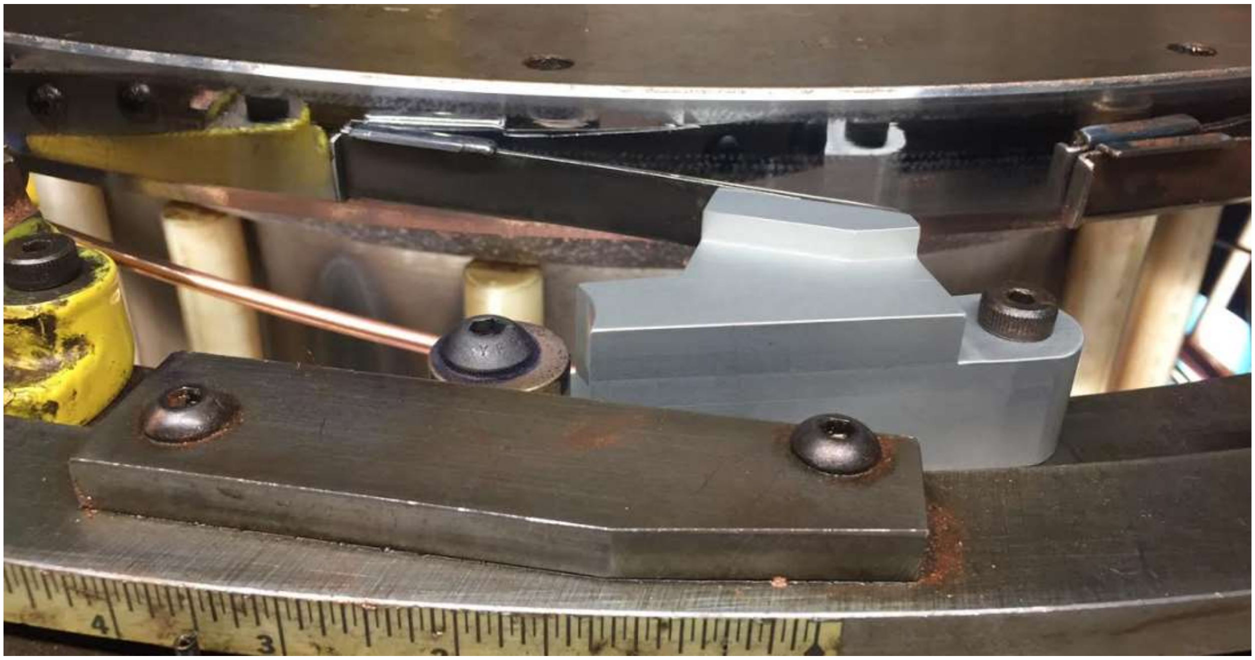


Figure 22. An overall view of the improved finger base and back-plate installed.

Figure 23. A view of the improved finger with a coat of layout fluid on the day it was installed to be tested in the coiler.

Figure 24. A view of the improved finger with no damage to the coat of layout fluid on the day it was removed from the coiler.

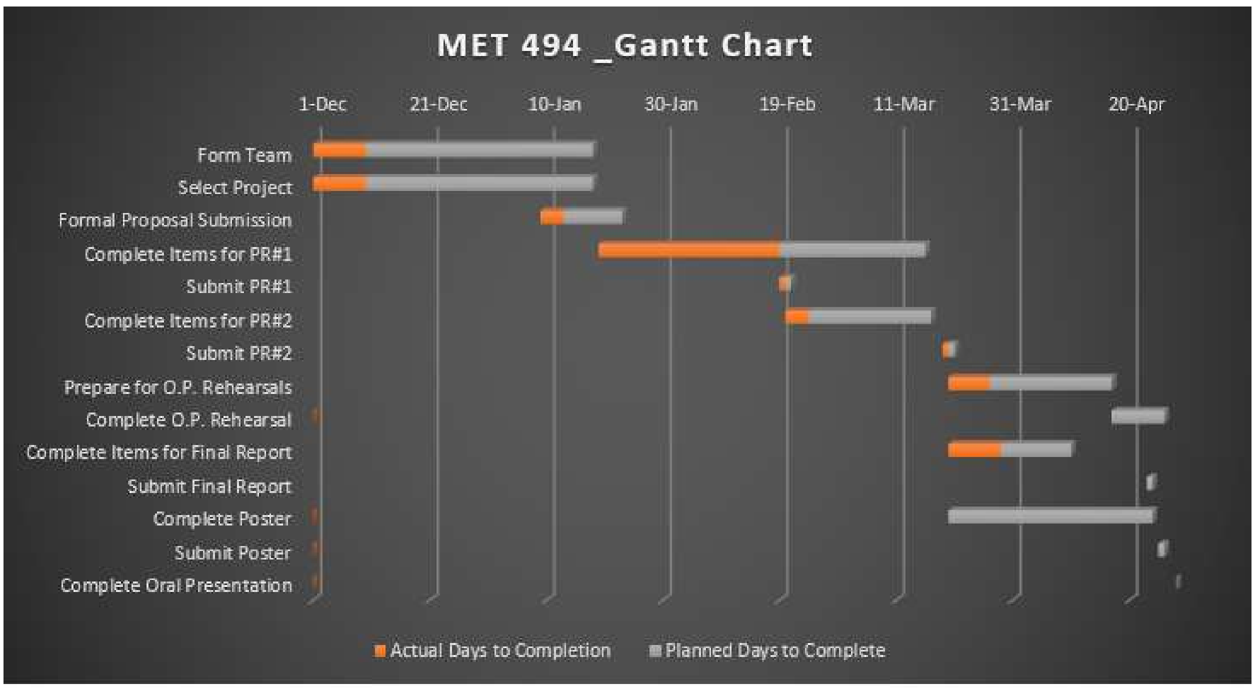
Costs

A prototype part and a final part was made during the duration of the project. Adaptek Systems fabricated these parts at no cost using stock material and fabricating the part a fill in work during a time when fabrication was slow. The parts where sent out to coating with batches of other parts to prevent extra cost. Both parts took six hours of programing and machining to produce. For an estimated part cost, Adaptek typically charges $65.00/hour for machining, the minimum charge for hard coating is $85.00, and the material cost $20.00/pc. The estimated cost of the final prototype part is $495.00. When the final parts are produced the per part cost will be less because the program will only have to be created once and all the parts can be sent to coating at one for a single batch charge. Mass producing the part after the initial setup is 1.5 hours per part at $65.00/hour, $15.00/pc. and $85.00 to hard-coat the entire batch. Since the coiler needs 15 new fingers, the total cost would be $1772.50 or $118.17/pc. The part was designed to use the existing hardware so there will be no additional cost in changing over from the existing part.

Conclusion

After months of designing, testing, re-designing and retesting the group was able to succesfully design a finger that can operate efficiently without damaging the product (magnet wire). This improvement will reduce the amount of returns from the customer and increase the quality of the wire by preventing the possible problems accosiated, down the road in production, from these small inperfections that are caused from the wire hitting and scraping the old finger design. The group learned how to efficiently work together as a team by combining schedules, troubleshooting issues and come up with and design a part that is a significant improvement over the old design.

Gantt chart



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