Design and Construction of an Automated Solenoid Spooler

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Abstract

This project was conducted in support of one of the projects funded by the University Transportation Center for Railway Safety (UTCRS). The main goal was to design and fabricate an automated machine that can provide the research team with solenoids that are necessary for their Energy Harvesting project. The end result utilized various tools and methods, exemplifying the engineering design process.

Introduction

The UTRGV University Transportation Center for Railway Safety (UTCRS) uses sensors that detect "rolling element of tapered roller bearing component faults, through vibration diagnostic techniques"... "Proven to be among the most reliable analysis tools for deducing mechanical faults in the relatively low-speed pumps, compressors, turbines, motors, etc."(Hite III, 1993). A drawback of these sensors is that they are currently powered by batteries, which are often fragile and unreliable (frequently having to be replaced due to corrosion and short battery life). “Terfenol-D is a novel and sustainable solution for this problem due to its durable characteristics and strong magnetostriction." "The generated power is sufficient to run low-power bearing health monitoring systems" (Estrada, 2015). "Results obtained in a previously funded University Transportation Center for Railway Safety (UTCRS) project have shown that Terfenol-D has the capability to harvest significant amounts of energy (on the order of 100 mW/cm^3) under conditions typical of those found in railcar bearing adapters, and is also capable of acting as a real time load sensor." The team is attempting to harvest the kinetic energy of the train's vertical motion through a fixture designed using "multiple magnets ranging from 2450 Gauss to 6150 Gauss, a 300-turn solenoid using 26 AWG magnet wire, and a 19 mm (0.75 inch) long Terfenol-D rod with a 12.7 mm (0.5 inch) diameter" (Gonzalez, 2013). However, the solenoids used in the energy harvesting project are currently being hand wound. This method is inconsistent, usually creating crude coils and inaccurately counted turns. The machine created is a coil winding device that will serve to solve this issue, taking tension, timing, and geometric shape into account in order to produce compact and effective solenoids. This machine will greatly assist the energy harvesting project, reducing man hours spent creating the solenoids and accurately counting, and thus, building upon its efficiency and reliability. The solenoid machine will also cater to various needs of the energy harvesting team, allowing for greater or fewer turns depending on the task at hand. In essence, the machine will serve to expedite the energy harvesting processing, providing readily available solenoids for the team to use.

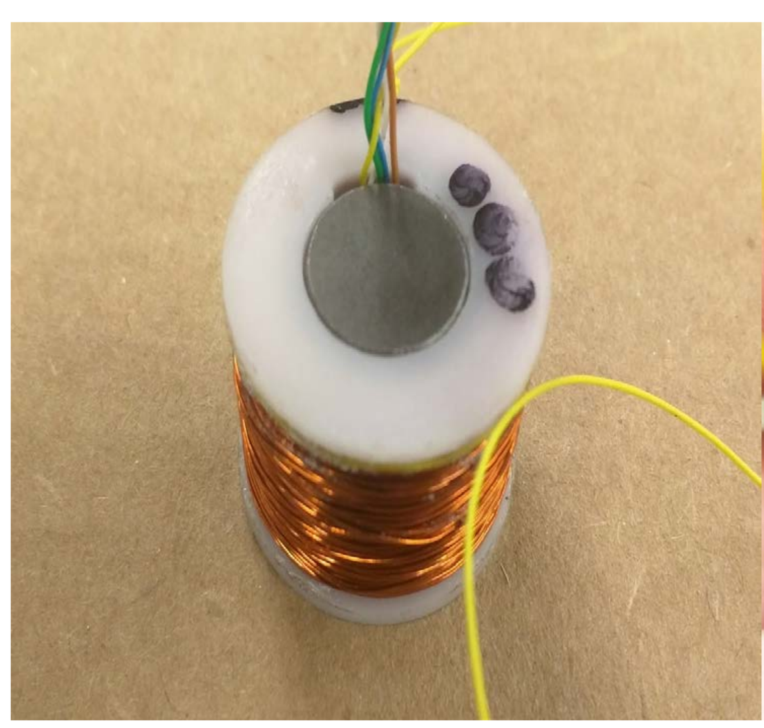

Figure 1: Strain Gauge Spool with 847 turns with 30 AWG wire. This spool was hand wound.

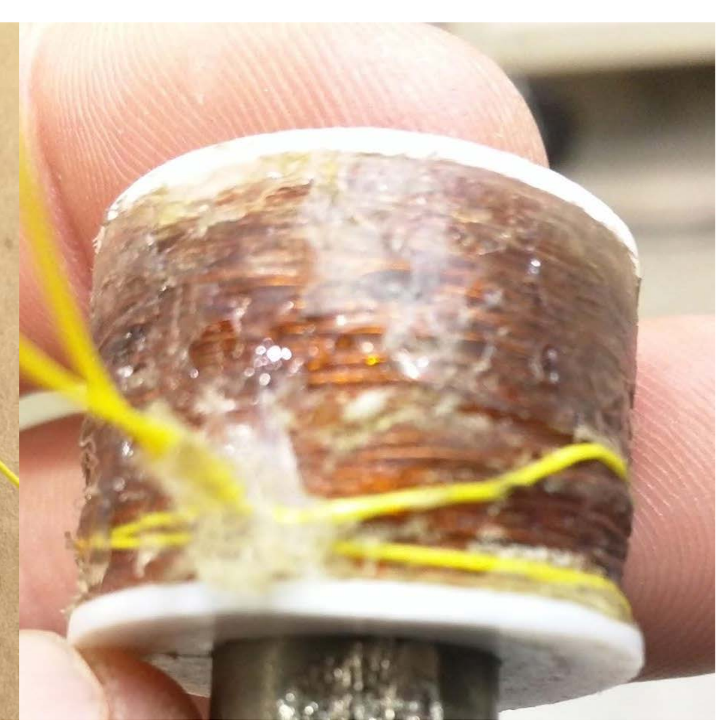

Figure 2: Yellow Spool with approximately 900 turns with 30 AWG wire. This spool was hand wound with a layer of hot glue to cover and protect the spool.

Methodology

The creation of the machine began with the brainstorming process. Initially, industrial solenoid winders were referenced as a basis of our design. However, many alterations were needed to suit the needs of the UTCRS team (such as making the machine compact and cost effective). Crude diagrams of potential machines were doodled depicting a spool spinning on a platform moving in horizontal back and forth motions. The design was then refined in a technical drawing which laid out the specifications and purpose of each part illustrated in Figure 3. After being approved by Dr. Constantine Tarawneh and other members of the UTCRS research team, the design was used to create a 3-D CAD model. Each component was modeled using life size dimensions and then assembled within the program SolidWorks illustrated in Figure 4. This assembly provided a guideline for the order in which the parts would come together and also provided a realistic render mock up of the finished product. After each tangible part was ordered and shipped, construction of the solenoid winder began. Larger custom parts were created with the tools in the Machine Shop, using schematics derived from the SolidWorks models seen in Figure 5. The MakerBot 3-D printer was also utilized to create smaller, more intricate parts. The frame was gradually assembled, with minor adjustments being made to compensate for variables such as gravity and friction.

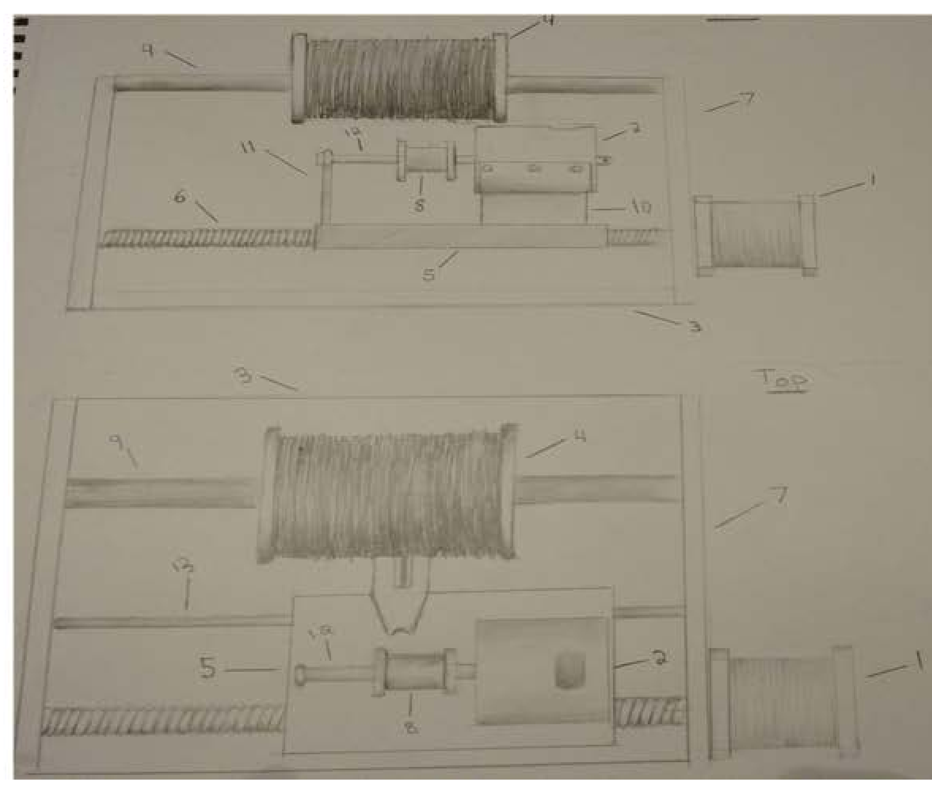

Figure 3: Hand drawn concept and design

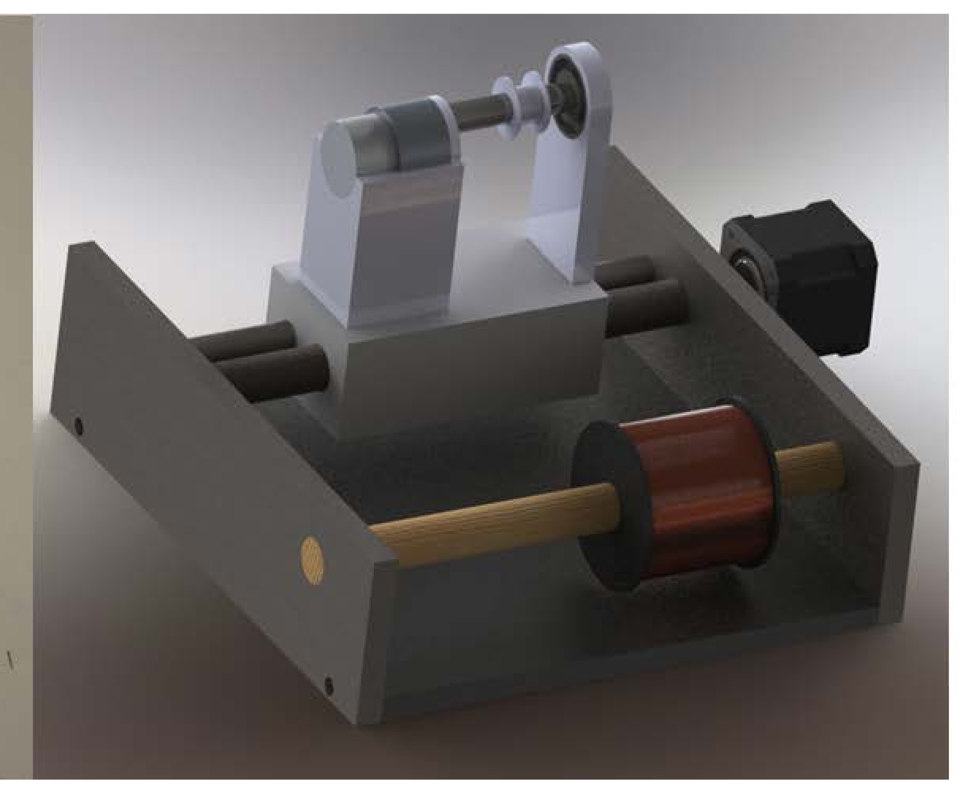

Figure 4: Solidworks CAD model to be fabricated

The introduction of the stepper motors that move the machine was controlled by lines of Arduino code that instructed both motors to run simultaneously while each completed different tasks. The Arduino code is listed in Figure 6. Several iterations of the code were written to complete the same task, with each iteration utilizing different methods of problem solving.

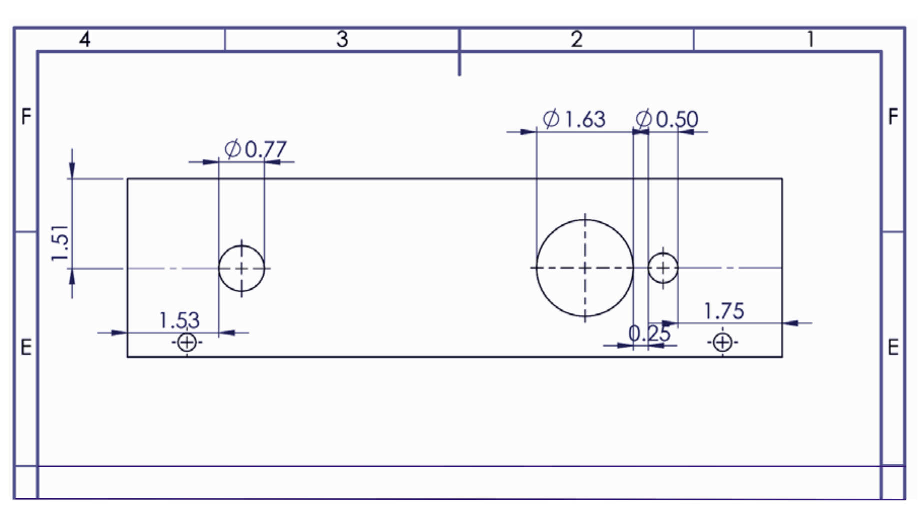

Figure 5: Schematics used while drilling holes with the mill.

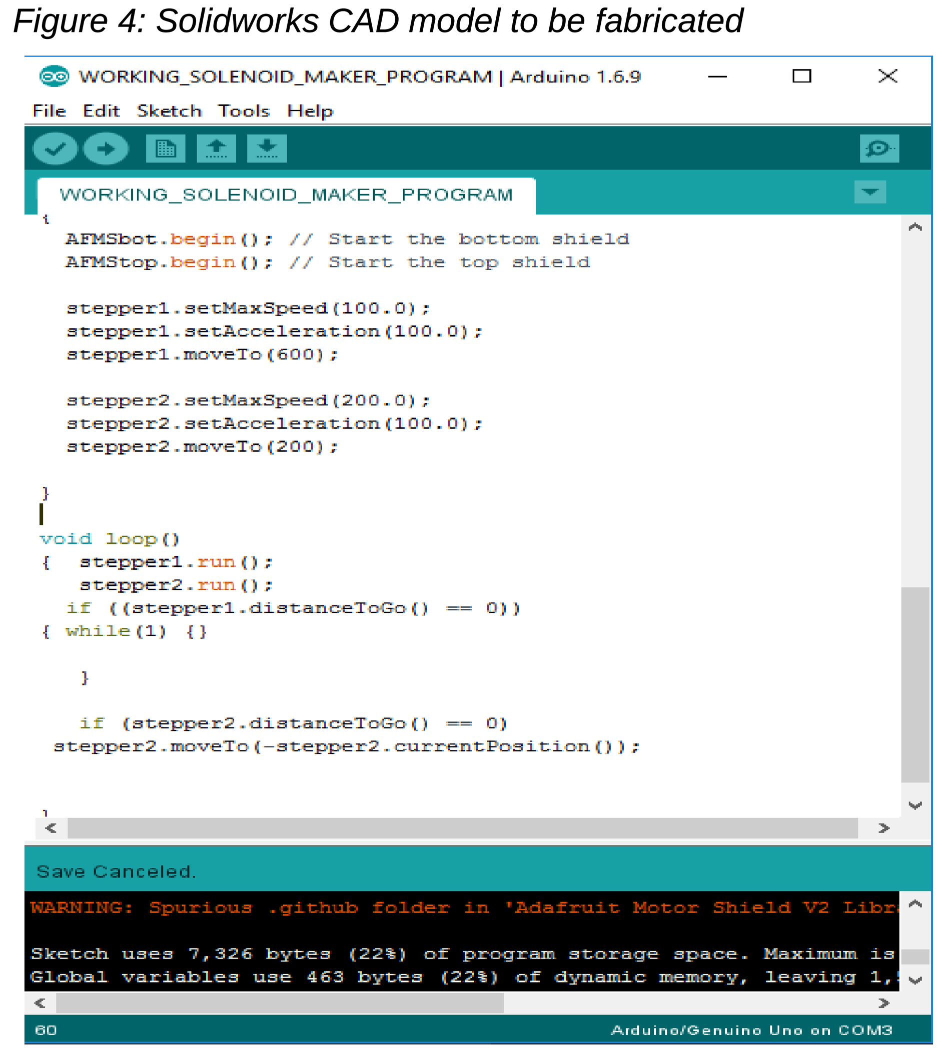

Figure 6: Lines of Arduino Code instruct one motor to loop back and forth horizontally, while the other motor spins at a constant speed for the desired number of turns.

After supplying the correct voltage and current to both stepper motors, the machine was running as anticipated, completing it's necessary functions as seen in Figure 7.

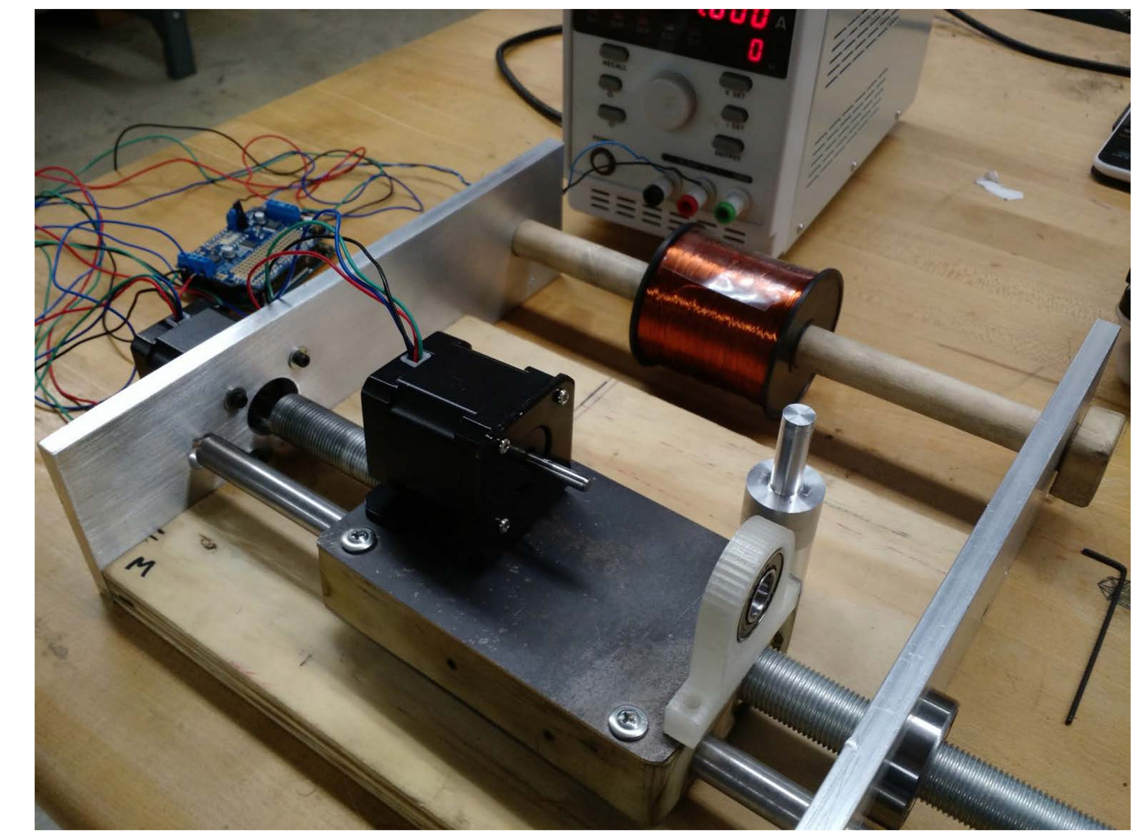

Figure 7: Final fabricated design concept of the solenoid spooler.

Discussion

This project provided an in depth look at the manufacturing engineering process. Though the project development experienced several challenges and difficulties along the way, a conceptualized design was successfully devised and fabricated into a tangible device that will serve the UTCRS team for the foreseeable future.

Future Research

Ideally, an LCD and switch would be implemented in the future to allow the user to easily modify the Arduino code and control the number of coils being wound. Support for three source spools of wire and three solenoid spools would also improve the efficacy of the device, allowing for three solenoids to be made simultaneously.

Acknowledgements

I would like to thank my mentors Jacob Bensen and Ryan Lechtenberg who donated a generous amount of time in assisting me in this project. They introduced me to a number of invaluable resources, tools, and machining skill-sets, and also taught me how to be patient, careful, and follow step by step instructions. Another special thanks to Dr. Constantine Tarawneh who offered this challenging project and supervised its progression. Also thanks to Ms. Melissa Pena and Leo Vasquez, who ensured that all required parts were purchased and delivered. Finally, I want to acknowledge the UTCRS and the USDOT for providing this research opportunity.

References

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