The Davenport Electric Railway: A look at Motor Mechanics in an Alternative Motor Design with Scarce Documentation

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Introduction

The Electric Railway designed and manufactured by Thomas Davenport was an engineering revelation for its time. Davenport was one of the first people to test out the usage of electric motors to create motion when provided with an electric charge. Davenport was inspired by Michael Faraday who widely publicized the concept of electromagnetism. Without Davenport's plentiful experimentation with electromagnetism and creating running electric motors, motor technology would probably be far behind where it is today.

History of the Electric Railway

In the 1830's, inventor Thomas Davenport began experimenting with producing running electric motors. The concept of electricity and using current to power a circuit was fairly new at the time. Davenport in 1834 produced a running electric motor using permanent magnets and a fairly simple armature design.[1] Power was generated by the magnetic flux of the permanent magnets causing the closed armature circuit to spin and drive an output shaft. William Hopkins heavily revised a recreation project of Davenport's 1834 motor example for the Interactive Qualifying Project. There will be more discussion on Will's work later on.

After Davenport developed his first motor, he went on to design and build more kinds of motors. In 1837, Davenport developed the Electric Railway. The railway was an external motor attached to a central rotational axis, around which the railway car would spin around. The counterbalance of the railway car was the three lead cup-style batteries used to power the railway. Davenport's railway design was larger than the 1834 example in terms of taking up space and the motor mechanism was of a different design. Davenport used a shunt-style motor with one fixed armature and one rotating armature to generate the magnetic flux needed to spin the output shaft when a current was passed through. The motor was documented to have been owned by Mrs. Willard's Female Seminary in Troy, NY, hinting that the railway may have existed before its documented creation date of 1837. Notable engineering author Franklin L. Pope wrote about Davenport's motors in depth and published it in his series of papers on electrical engineering known as *The Electrical Engineer: A Weekly Review of Theoretical and Applied Electricity*. Volume 11 contains information on Davenport's work developing electric motors under the title of "The Inventors of the Electric Motor With Special Reference to the Work of Thomas Davenport."

Beyond Volume 11 of *The Electrical Engineer* which I have been unable to find anywhere, there is very little information documented on the electric railway elsewhere. If I were to guess, most of the records of this motor either do not exist or have been lost over time as the world has become more digital.

Design

General Design:

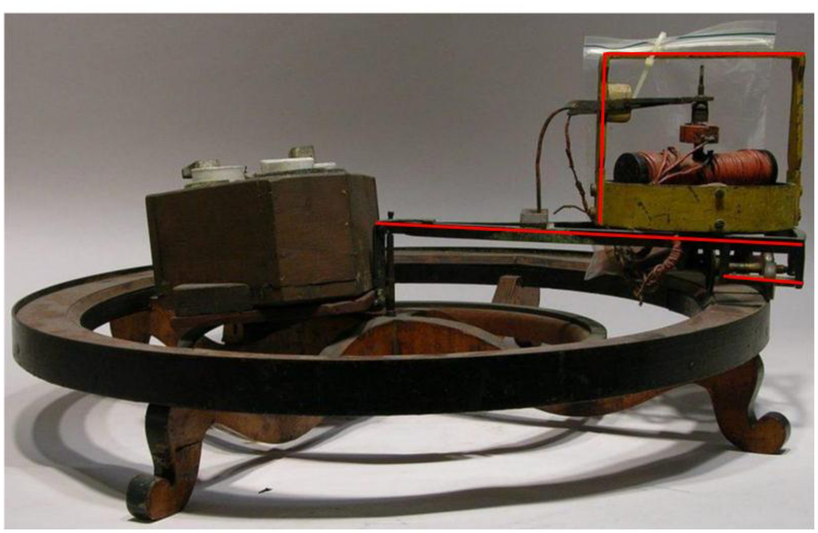
The Davenport Electric Railway is a unique design of electric motor compared to other designs produced by Davenport in that era. What separates this design out from a typical motor is the rotating assembly of this motor is placed outside the axis of rotation of the assembly. The rotating assembly of the motor is placed on a rail with the driveshaft of the motor being attached to a bevel gear that turns the drive wheel, moving the armature around the track. Another key element that separates this design of motor from others is there is one fixed armature and one rotating armature. The fixed armature and rotating armature work together to produce opposing magnetic fields and flux regions to spin the motor when electricity is passed through the circuit. On the original motor, three mercury cups were used as battery cells. The goal of this project was to recreate the motor using manufacturing techniques that Davenport used himself back in the 1830's, and the batteries are one of the areas that would be very difficult to recreate accurately today. The wood for the frame of the motor was most likely made out of oak or a similar hardwood. To preserve the historical accuracy of my model, I went with oak for the legs, frame, and outer circles.

Design Updates:

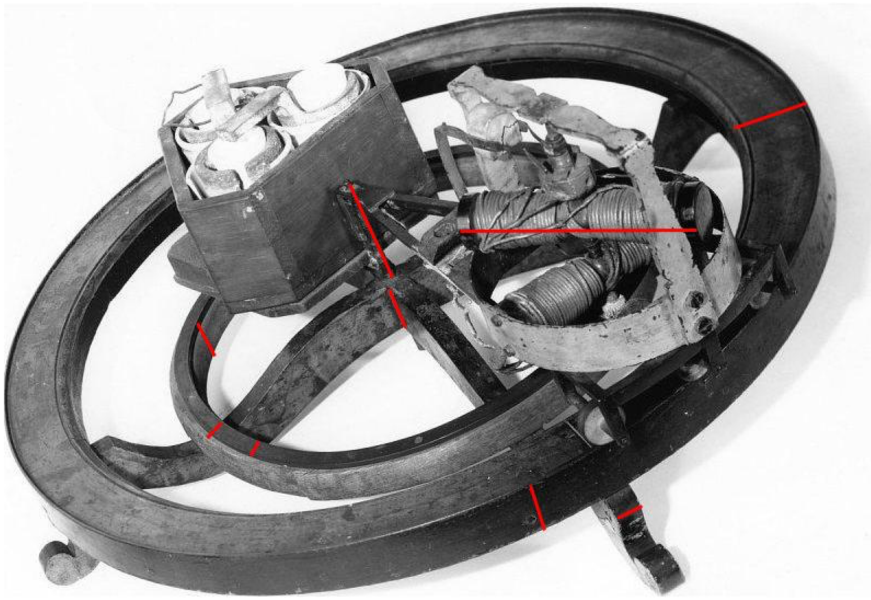
My design is a little bit altered from the original, most specifically in areas where getting historically accurate materials was very difficult. One of the most notable changes from the original design to my design are the armature cores. A low-carbon steel was used, much like what was used on the original model. However, the armature diameters are reduced on my model. The original design had low-carbon steel cores that were ¾" in diameter, whereas the cores I have are 5/8" in diameter as that was the most easily accessible low-carbon steel rod on the market and that was the largest diameter on the market that was not unreasonable looking from a cost perspective. Like I mentioned in the previous section, the mercury cup batteries would be incredibly difficult to recreate in today's world. I have rather stuck to using modern day battery cells and digital power supplies for testing the motor itself when that stage is eventually reached.

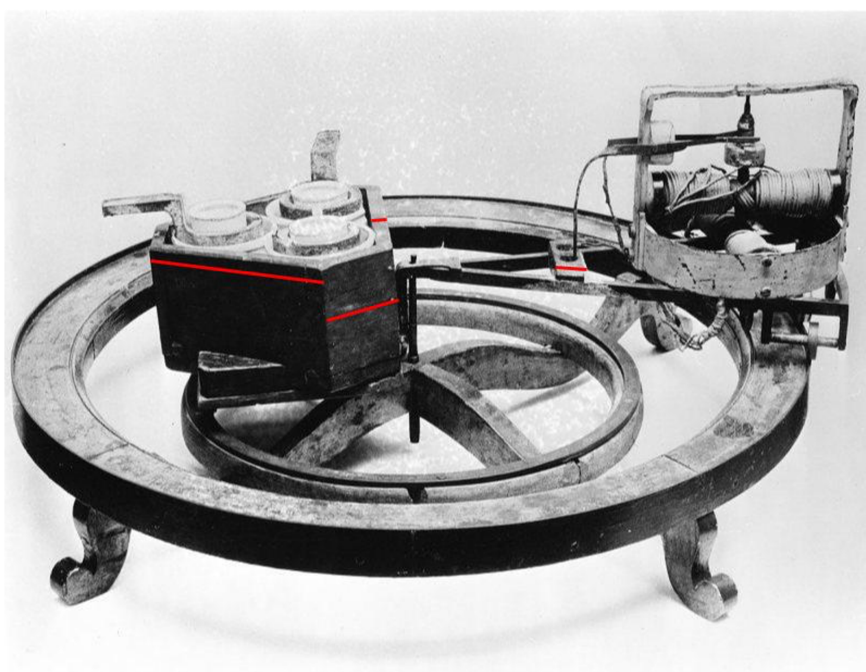
Measurements:

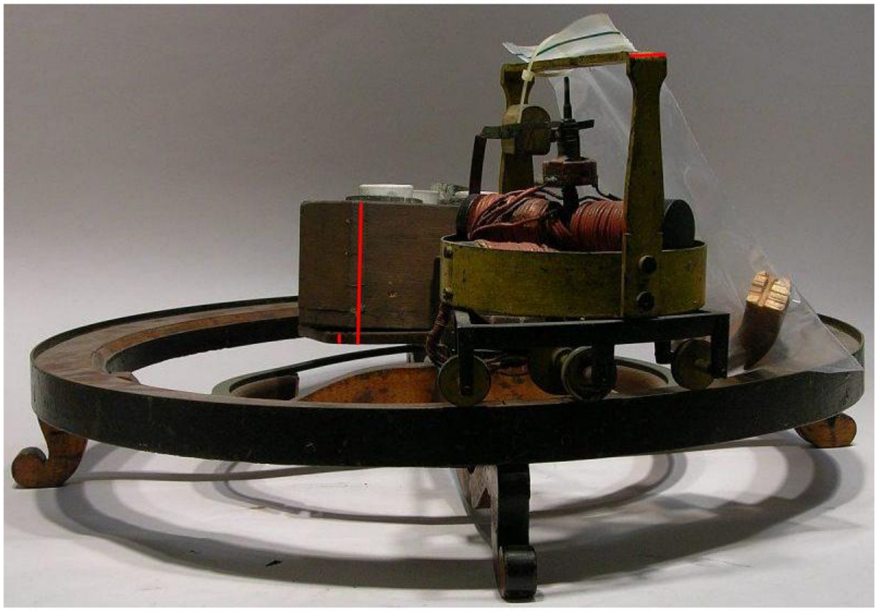
The measurements on their own from doing many hours of research came back with very limited results. So, I got in touch with the Smithsonian to get someone to measure the original model for me. I'd like to send out a special thank you to Hal Wallace, curator of electricity collections at the Smithsonian, for making this happen. Without his help, I would have been without much to go on except for some pictures from the internet and a lot of guessing. Pictured below are images of the model with red lines overlayed on them to represent measurements I needed to recreate this motor. I interviewed Hal and was shown the motor live on a zoom call. Hal took the measurements I marked on these pictures live for me:



On the next two pages are 3 more images marked up with red lines like the ones shown above.



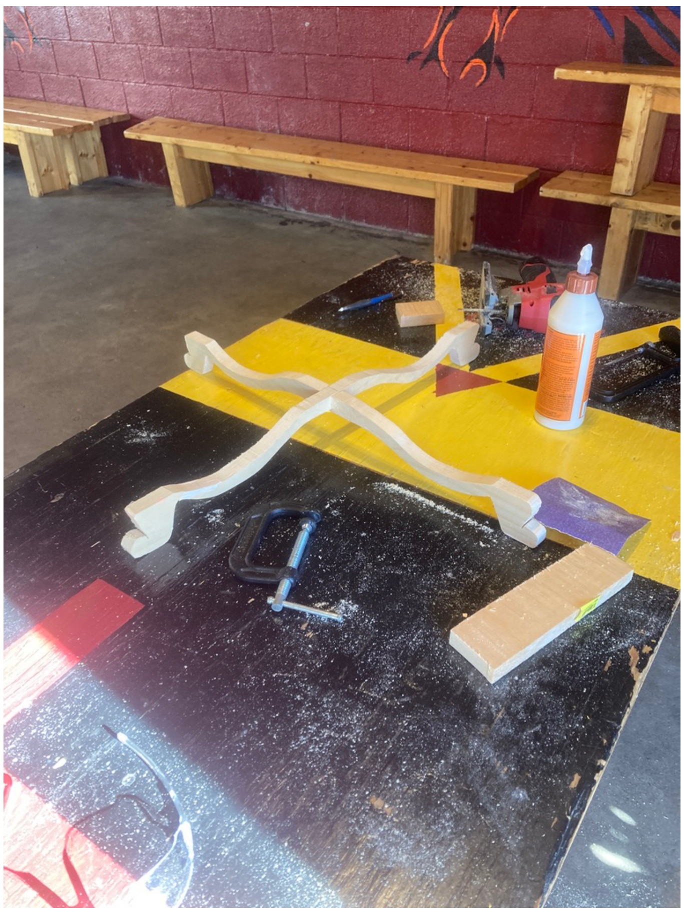




These images depict only a small portion of one of the greatest challenges I faced this entire project, that being getting information about the railway. At this point, I have spent days trying to find any useful information or documents with any sort of information about the motor. Without the help of Hal, I would have only had the pictures on the Smithsonian's website, and a couple drawings of the motor from other scarce sources online. The information provided on Davenport's patents from previous similar projects did have some valuable information, but the patent information of the dimensions differ slightly from what was measured by Hal.

Manufacturing Process

The beginning of reproducing the motor began by looking at what materials Davenport would have used in the 1830's. The materials that were used through a majority of the model are steel, copper armature wire (20 gauge), and wood. Choosing which wood to use was very tricky. I began using pine to make a very rough model of the legs for the railway. The pine was very easy to work with, but it is not a very strong wood for this.



The solution to this was to use oak. A saber saw was used to cut hard oak into the shape of legs. The circular wood sections of track are going to be produced in a similar fashion. The metal frame is made out of 16 gauge mild steel sheet metal, with the intention being to tack weld the pieces together. The parts are pictured on the next page.

I have no access to materials for brazing which was inferred to be the method Davenport used to bind the metal structures on the original model.

The armature consists of two cores: one is to be fixed to the metal cage that is supposed to surround it via the use of two screws on each side via threaded holes at the top and at the bottom edge of that core, and the second core is fixed to the output shaft of the motor. The armature wire used is 20 gauge enamel-coated copper wire as that will generate better magnetic fields for the electric motor since it can be wound around the cores tighter than 16 gauge armature wire. The armature is pictured on the next page.

A spring system was used for connecting the rotating armature core to the rest of the circuit. I struggled to come up with a working concept for this element of the circuit as I could not find any great materials to use that would not wear down easily while maintaining a level of historic accuracy. If I had time to produce a fully functioning circuit, I would have chosen to connect 3 D-cell batteries in parallel. The rails on the outer edge of the bigger circle are to be made of metal bandstrapping. I was unable to find any information on what material was used for the rails, so I felt it appropriate to use the bandstrapping as a reasonable alternative. What is unfinished on the motor is the metal frame around the armature needs to be bent to shape and constructed, armature needs to be threaded and screwed into the cage surrounding it, the output shaft needs to be trimmed down to a shorter length, the sheet metal work needs to be heavily reworked, and a bunch of the wood needs to be cut into shape and assembled.

Project Challenges & Failures

As I mentioned in the previous section, there were mechanical elements of the motor design that I struggled to produce due to sheer complexity and lack of accurate materials. The biggest setback for me through this whole project was not having set myself goals to make reasonable progress every week. I went into this project with a cloudy idea of a plan, and that resulted in progress being rather lackluster. Additionally, I massively struggled with my mental health this entire school year and have been trying my best to fight it and improve. Towards the end of D23, I was involved in a big car accident which resulted in physical injuries as well as shock and other side effects of trauma from the collision. The most prominent injury is to my left wrist, which has made doing hands-on work extremely difficult. I do not feel safe using dangerous tools since I do not have full strength in both of my wrists to help control the tools adequately. The other biggest challenge was finding information on the motor. I have spent days looking for the source I mentioned earlier in the paper written by Franklin L. Pope. The closest I could find by Pope was Volumes 10 and 12 of *The Electrical Engineer* on Google Books. I could not find any references to a Volume 11 on any database except for an old library catalogue from the University of Sydney in 1892. Beyond that, I could not track down the document at all.

Project Successes

So, besides the failures and hardships this project had along the way, there was good about it too. The project allowed me to take a deeper look into the history of a device that our society takes completely for granted now. Motors are a very clever feat of engineering on their own, but looking deep into the historical design of motors was fascinating. I was rather surprised to learn that besides the 1834 motor example and the electric railway, Davenport created many different versions of motors, unfortunately with far less documentation than the electric railway. This project also taught me the importance of trying to maintain historical accuracy. It gave me a completely new kind of challenge to work with which pulled me out of my comfort zone to say the least.

Conclusion

Overall, I learned a lot about electric motors while attempting to recreate the electric railway. Will Hopkins did a ton of research into the fundamentals of magnetism for how his motor design worked, and that was a helpful guide for me.[2] However, life and personal failures have lead me to the end of this school year with no final project, just some parts. To the person who will be following in my footsteps: I highly advise you come up with specific goals in small time increments so that you will not get sidetracked on making progress. This project taught me the importance of structure, and had I been more structured during the process, I might have been more successful.

References

1. https://www.si.edu/object/nmah_705561
2. https://digital.wpi.edu/pdfviewer/gb19f901w