Fall/Spring Research Log

Martin Moore
moore.3807@osu.edu
Department of Mechanical and Aerospace Engineering
The Ohio State University, Columbus, OH, 43210 USA
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1. Introduction

Throughout the fall and spring semesters, I continued to work on the linear and circular magnetic gears. I continued to collect data from the linear gear through DataPhysics, and I was tasked with designing and building a demonstration setup for the circular magnetic gear.

2. Linear Magnetic Gear

Data Collection and Analysis of the Linear Gear

Tangential data collection from the linear gear was still needed after the completion of the summer term. Modulated and source-only flux measurements were taken through the use of a quattro, from DataPhysics, to add to and compare with the radial data taken in the summer term. A schematic of the data collection setup of the unmodulated tangential flux can be seen in Figure 2, and the modulated tangential data collection setup for unmodulated tangential flux is shown in Figure 4. The setups of the unmodulated and modulated radial setups are also shown in Figures 1 and 3, respectively. The setup of a modulated tangential trial is depicted in Figure 5.

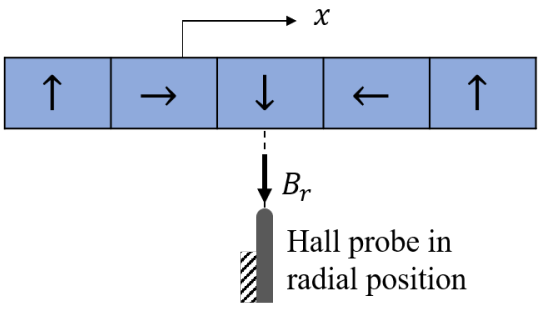

Figure 1: The unmodulated radial setup with probe orientation shown.

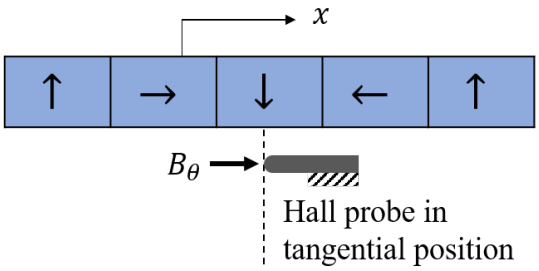

Figure 2: The unmodulated tangential setup with probe orientation shown.

The unmodulated data, as seen in the graph of Figure 6, shows what was expected; the tangential data plots to be a sine wave and the radial data plots to be a cosine wave. This makes sense since when the radial readings are at a maximum, the tangential readings of flux density are zero, and vice versa. It can be imagined by thinking about the components of each flux field. As Figure 1 shows, the Hall probe at its zero position is only receiving flux in the vertical component direction, meaning the hall probe in Figure 2 is also receiving flux data only in the vertical direction, giving a reading of 0 T in the horizontal direction, which is what the tangential hall probe is reading.

For the modulated data, 25 individual tests were carried out at discrete positions along one full period of the flux modulator in order to record the flux measurements along the entire section. For each radial test, the probe was positioned along the inner wall, at different β positions, where the outer rotor would normally be. Once the

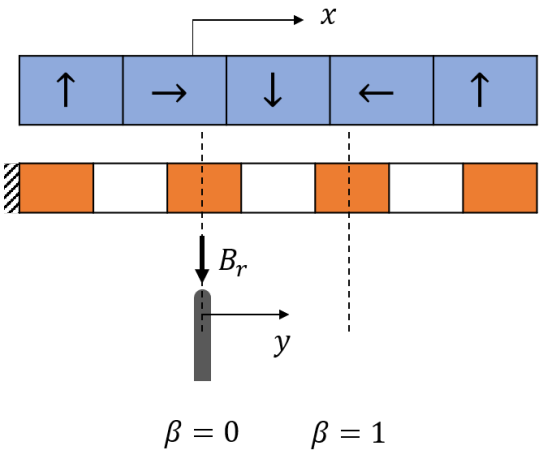

Figure 3: Radial modulated setup with magnetic orientation shown. Steel modulator pieces shown in orange and air gaps in white.

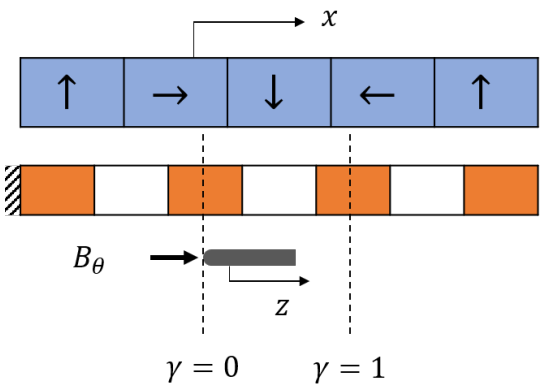

Figure 4: Tangential modulated setup with magnetic orientation shown. Steel modulator pieces shown in orange and air gaps in white.

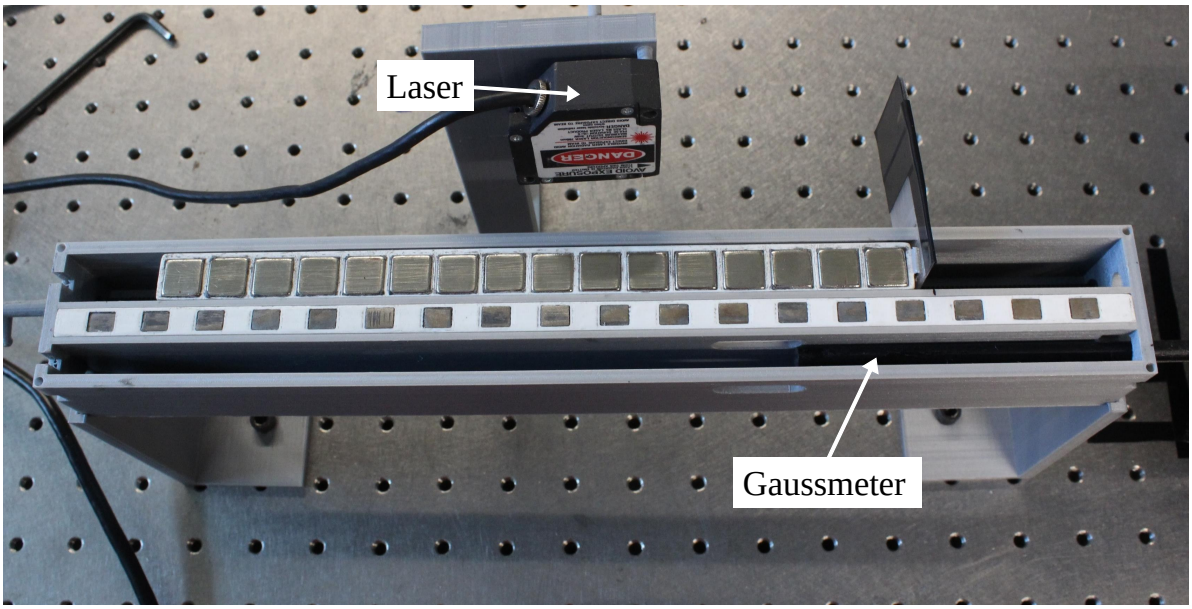

Figure 5: Tangential data collection setup.

probe was in place, the inner rotor was translated along positive x direction, and the distance and flux density were recorded. The same data was collected for the tangential modulated configuration as well, where γ is the variable quantifying discrete positions of the probe in the tangential setup.

With the flux density and distance vs. time data collected, flux density was plotted against distance for all 25 sets of data individually. This was done for both the radial

and tangential data to present the variation of flux relative to the steel modulator pieces, or the modulation effect.

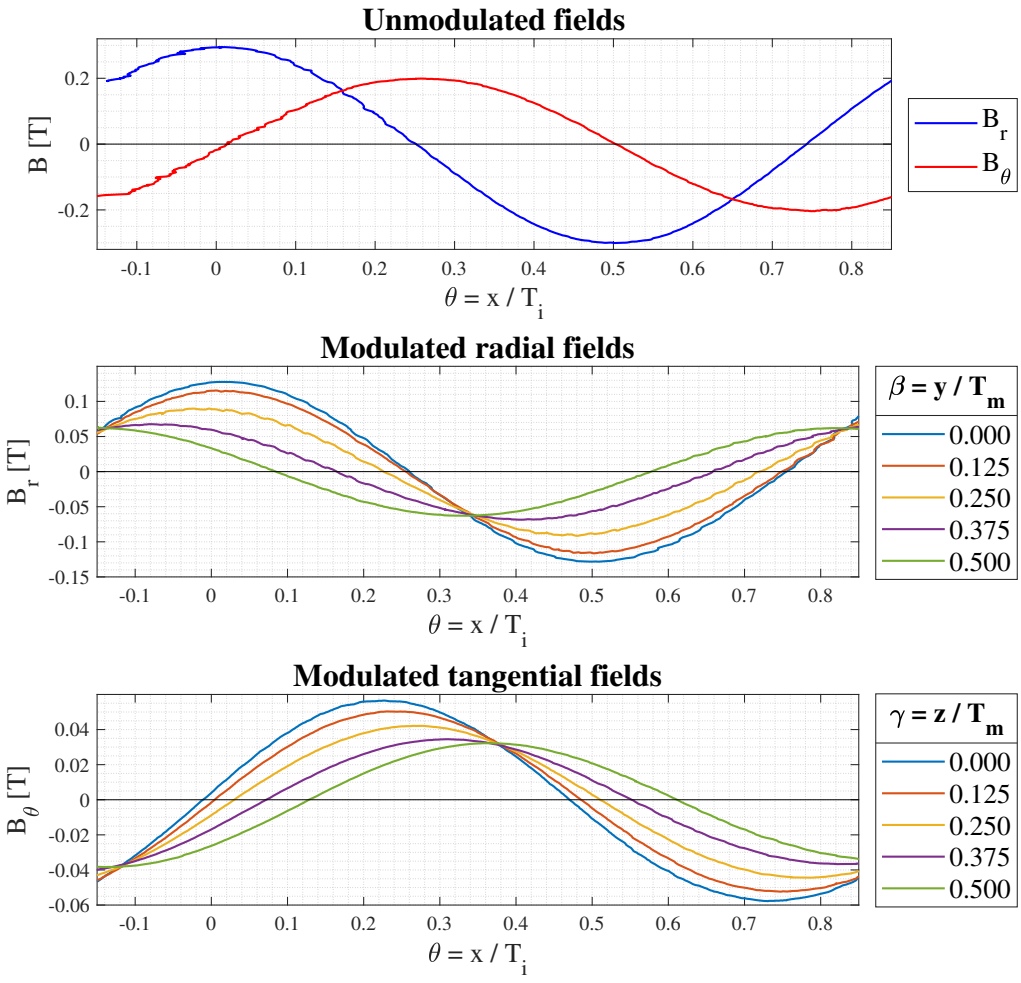

Figure 6: Radial and tangential data comparison. T_m is the period of the modulator. T_i is the period of the inner rotor.

With the collected data, the FE simulation results run by Ismail can be verified and further simulations can be modeled.

Along with the inner rotor, the outer rotor was analyzed and the necessary data was collected as seen in Figure 7. With the addition of this data to the inner rotor data, the complete set of data for this linear magnetic gear is known.

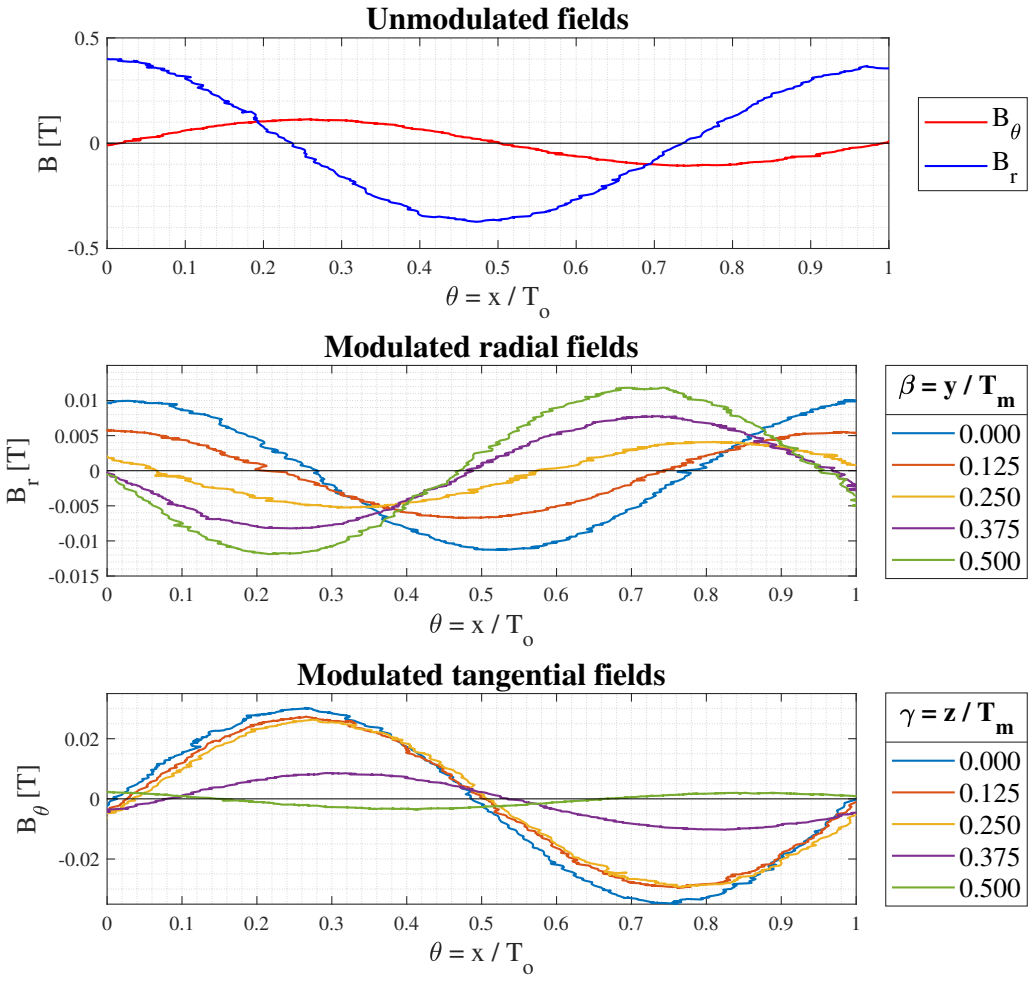

Figure 7: Radial and tangential data comparison. T_m is the period of the modulator. T_o is the period of the outer rotor.

With the complete linear set of data collected, it can be compared to the corresponding model results. Six plots can be constructed to compare the data: IR unmodulated, IR modulated radial and tangential, OR unmodulated, and OR modulated radial and tangential.

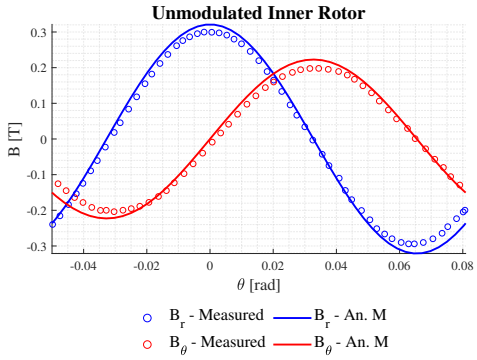

Figure 8: Unmodulated model results compared to collected data.

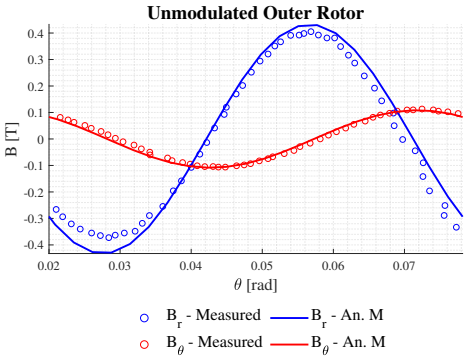

Figure 9: Unmodulated model results compared to collected data.

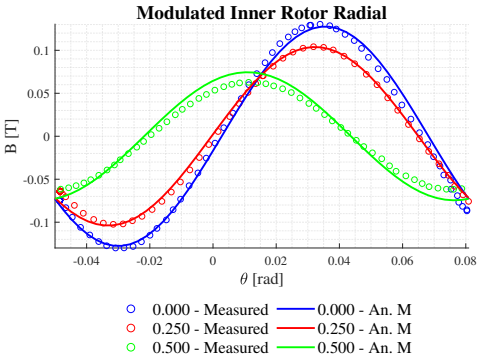

Figure 10: Modulated model results compared to collected data.

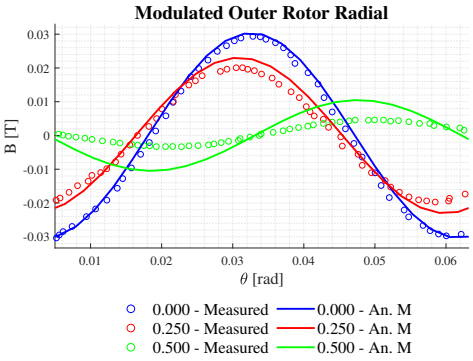

Figure 11: Modulated model results compared to collected data.

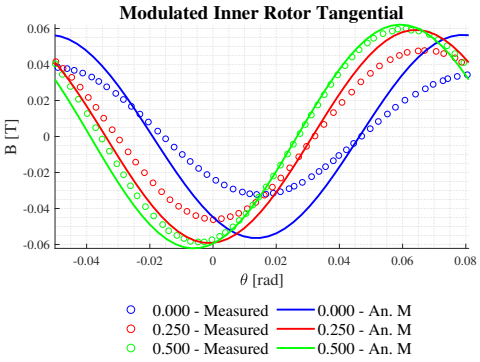

Figure 12: Modulated model results compared to collected data.

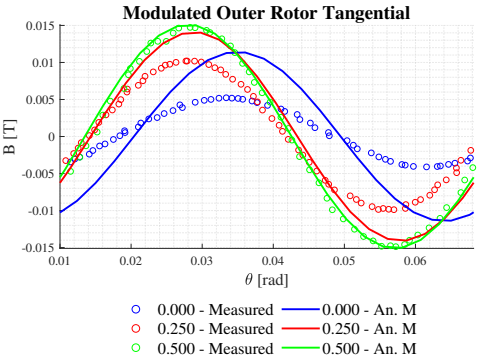

Figure 13: Modulated model results compared to collected data.

3. Circular Magnetic Gear

With the completed circular magnetic gear, a demonstration setup was constructed to show its low frequency dynamic operation. The setup not only represents the magnetic

gear as a transmission element, it also serves as a demonstrator to highlight its smooth and quiet operation.

Construction of the Demonstration

The base of the setup was machined from an aluminum slab; it was cleaned and cut to size in the machine shop. Holes were cut to size so that the magnetic gear could be positioned inset into the slab, and a custom 3D part was printed in order to support the magnetic gear so the base of the gear would not spin when an input torque was applied to the input shaft of the gear. Holes were drilled for the sleeve bearings as well as the motor mount.

After the construction of the base, the motor was wired into an H-bridge which was controlled through an Arduino. The H-bridge enabled the motor to be driven both in the forward and reverse directions, as controlled through the Arduino. The schematic for the complete demo can be seen in Figure 14. When relays 1 and 4 are activated, the motor runs forward; when relays 2 and 3 are activated, the motor runs in reverse. The H-bridge and Arduino were placed in a wiring box with a power-supply. The wiring box was rigged with a button allowing for the control of the demo. The complete demonstration can be seen in Figure (need to add figure still).

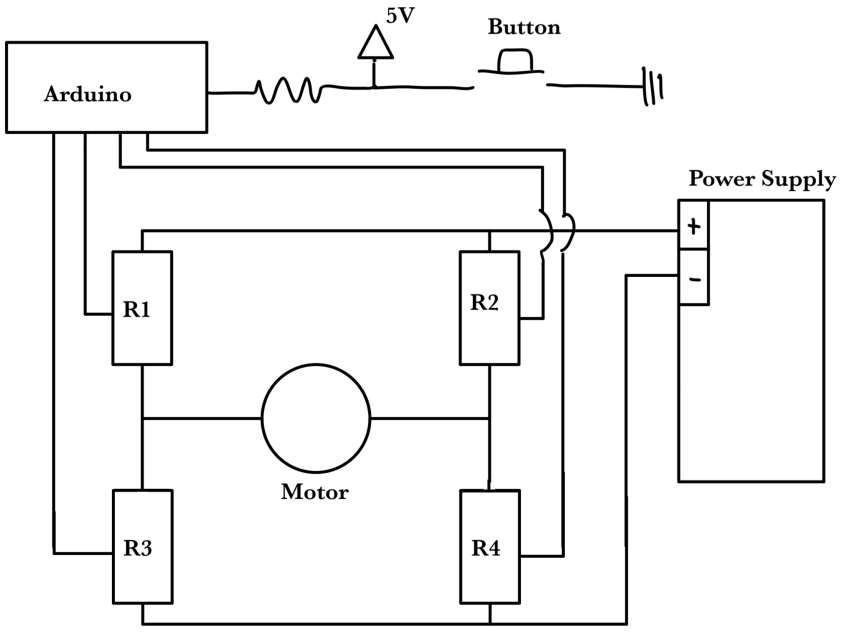

Figure 14: Wiring schematic for demonstration.

4. Reading Log

5. Miscellaneous

6. To Do

- Finish circular demo. - waiting on parts (just the weight)
- Read up on magnetic equations and their relation to the magnetic gear project as to be able to incorporate them into the paper.
- Understand MATLAB code Ismail sent.

Appendix A - Linear Model

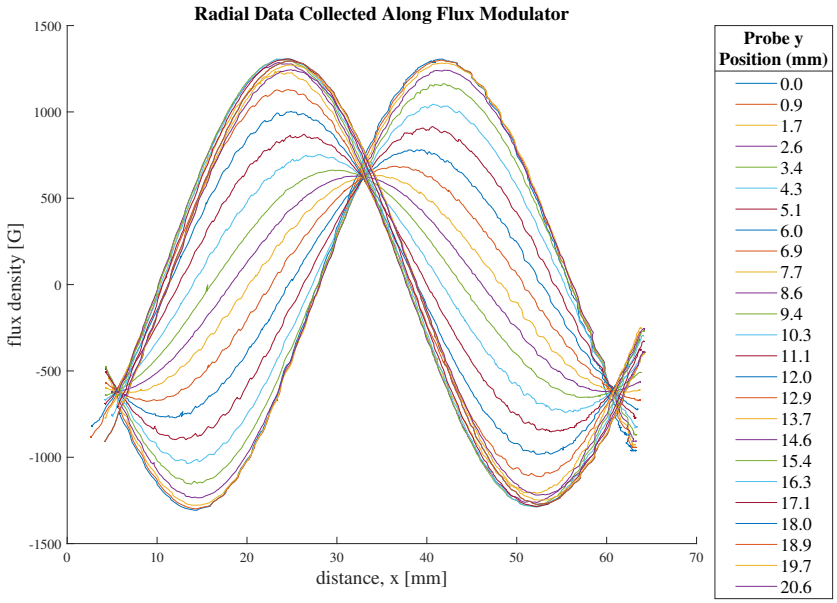

Figure A1: Raw modulated field data collected from the radial setup. Trend as Gaussmeter moves along y axis can be seen.

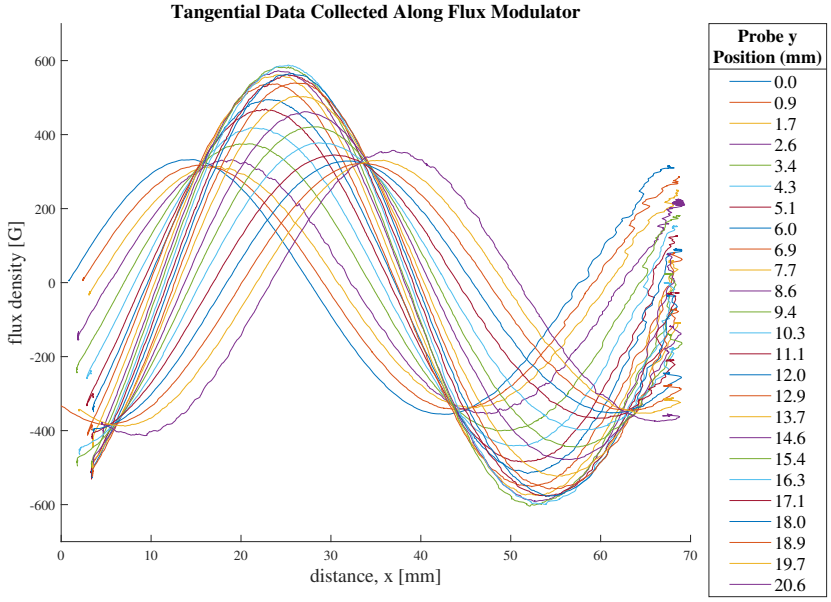

Figure A2: Raw modulated field data collected from the tangential setup. Trend as Gaussmeter moves along z axis can be seen.

Appendix B - Linear Error Analysis

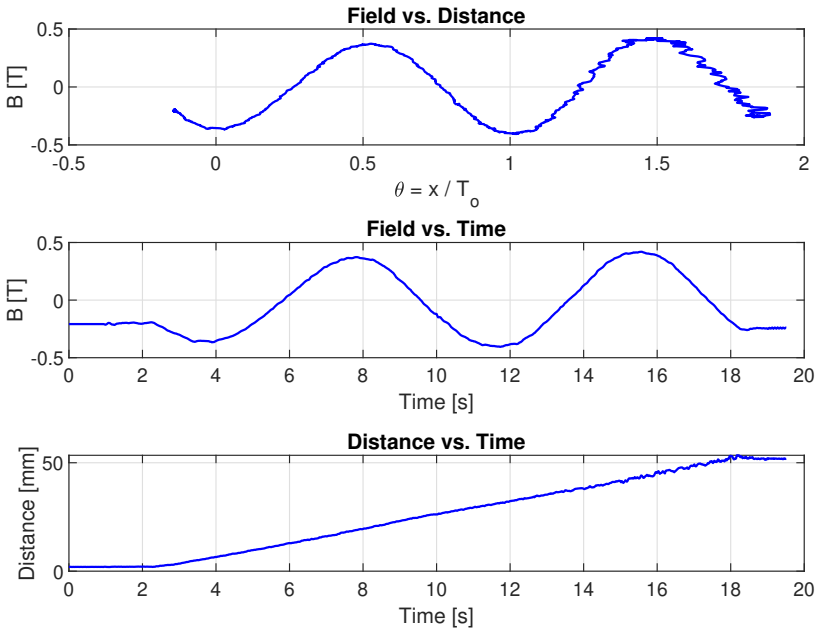

Figure B1: Field and distance readings are plotted independent of each other within their own graphs to show where error comes from. The majority of the error is introduced with the distance readings, from 14-18 seconds.

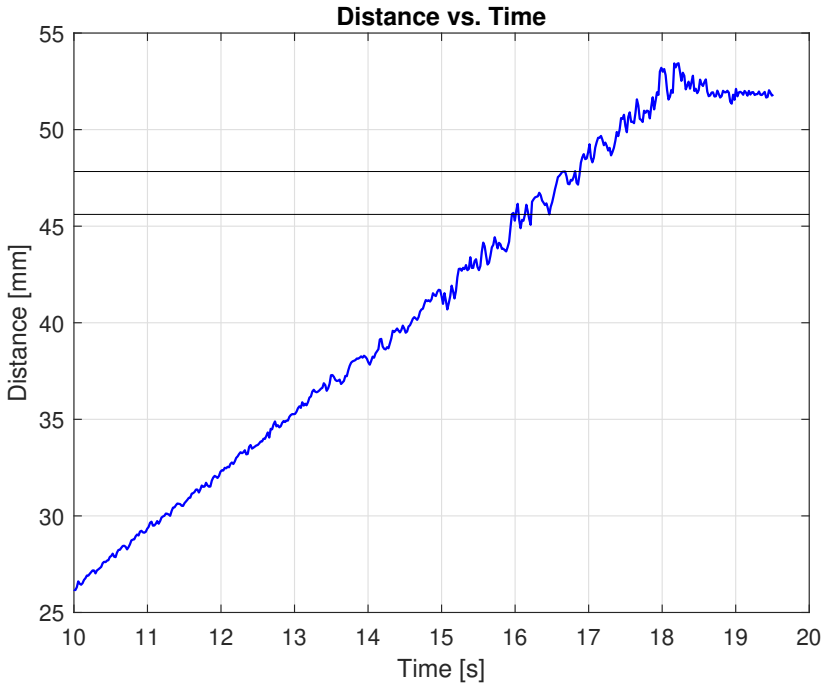

Figure B2: the distance was moved consistently with time, as the flags distance from laser increased, the fluctuations between minimum and maximum readings while changing distance increased. The two black lines are just over 2mm apart.

Appendix C - Circular Model

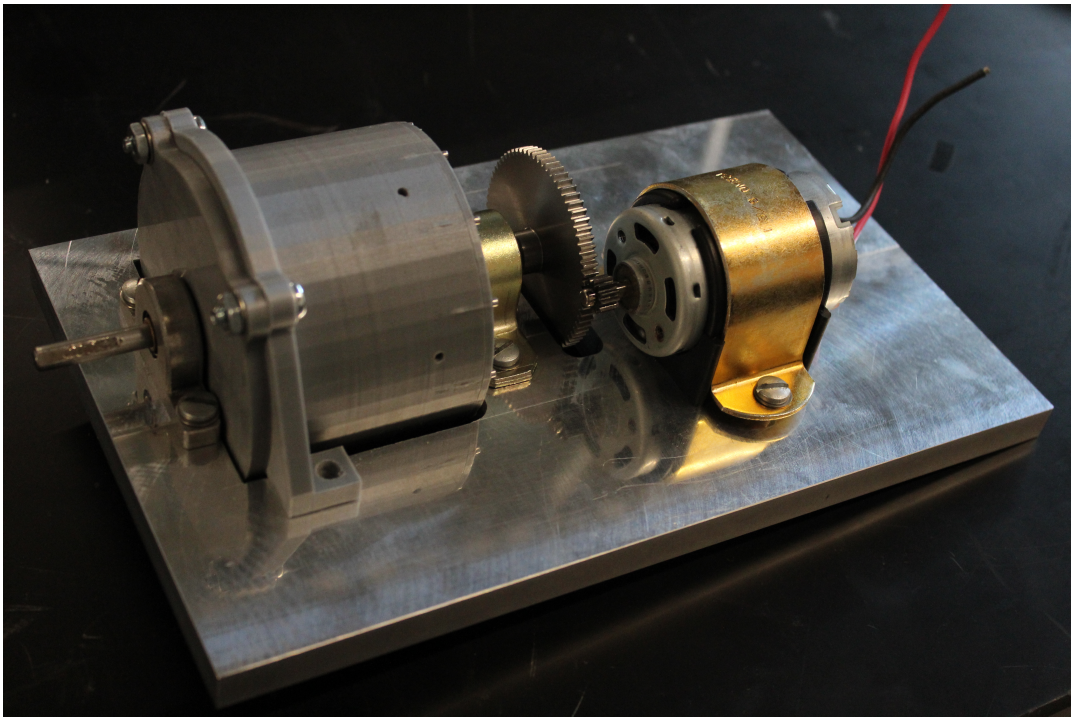

Figure B3: Demonstration setup as seen prior to wiring.

References