Magnetic Attachment for Drones

Magnetic Microsystems & Microrobotics lab

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Executive Summary: The Army Research Lab (ARL) has been working on wireless charging methods for drones and needs a way to easily attach and detach their drones from the charging point without taking too much power and space on the drone. Electropermanent magnets can be turned on and off but do not require constant power in the on stage which would be too strenuous on the drone. The ARL tasked UCI with developing a way to magnetically connect the drone to the charge surface quickly and have found EPMs to be the most viable option for this. Working with Professor Camilo Velez, we designed and fabricated a design of electro-permanent magnets (EPMs) within a metal casing that will allow for quick attachments and releases from the charge points. This prototype can produce a 60N normal holding force.

Future Improvements:

- Optimize simulations immediately using acquired magnets and base plates
- Use simulations to find ideal NdFeB and AlNiCo to fit into original EPM design that can be printed later
- Machined uni-body base plate to eliminate air gaps and other imperfections that affect magnetic field

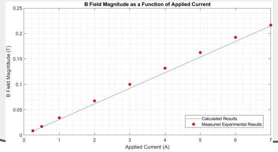
References and acknowledgements:

Sponsor: Professor Camilo Velez
Advisor: Professor Mark Walter-role
Advisor: Professor Hassaan
Advisor: Professor David Copp

Engineering Analysis:

Coil Calculator:

- Comparing projected B-field values to tested values produced by commercial coils confirmed the accuracy of MATLAB code used to calculate the coil parameters (Figure 1)



- The coil calculator lets us test different currents to know what the theoretical B-field produced should be at the axial center of the coil. This value compared to the theoretical value needed gives the current needed (Figure 2)

Inner Radius (m)	Layer Numbers	Applied Current (A)	Outer Radius (m)	Number of Turns	Coil Hmax	Coil Bmax (T)	Temp Change (K)
0.0047625	20	5	0.0103	457.56	144,130	0.1811	0.0024
0.0047625	20	4	0.0103	457.56	115,300	0.1449	0.0015
0.0047625	20	3	0.0103	457.56	86,479	0.1087	0.00087145
0.00635	15	7	0.0105	343.17	135,280	0.1700	0.0047
0.00635	15	6	0.0105	343.17	115,950	0.1457	0.0035
0.00635	15	5	0.0105	343.17	96,627	0.1214	0.0024
0.0047625	20	15	0.0103	457.56	432,390	0.5434	0.0218
0.0047625	20	12.5	0.0103	457.56	360,330	0.4528	0.0151
0.0047625	20	10	0.0103	457.56	288,260	0.3622	0.0097
0.00635	15	20	0.0105	343.17	386,510	0.4857	0.0387
0.00635	15	17.5	0.0105	343.17	338,190	0.425	0.0297
0.00635	15	15	0.0105	343.17	289,880	0.3643	0.0218

- With the current found previously we can compare that value to the max current our circuit and wire can handle.
- This comparison gives us an idea if the entire assembly will function with each component
- This entire engineering analysis can be done repeatedly to find the optimized relationship between current needed, B-field generated, coil size, and how they all integrate into the final design

Final Design:

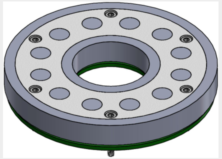
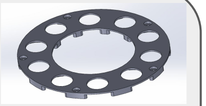
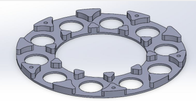


Figure 3: The final CAD model has an array of magnets with coils wound around and an acrylic or 3D printed part casing the EPM. countersunk screws will hold the whole assembly together and keep flush

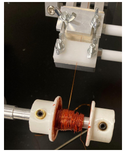




Figures 4-6 [From top, left then right]: Base plate without magnets or coils. Acrylic piece how it will sit and flipped to show screw holes and full design

Hardware Performance

Figure 7 (Below): Power supply below is main source of power to our trial coils to measure magnetic field generated and to flip magnetic direction

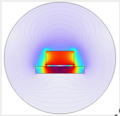


Figures 8-9 (Above): The coil winding machine is challenging to perfect and the uniformity of the coil greatly affects performance, better free standing coils are made used than the one shown.

Design Process and Key Design Features:

Simulations:

- Optimize magnet and steel plate dimensions
- Implement design choices into magnet choice and base plate array
- **Figure 10:** Simulation of magnetic forces between a NdFeB magnet and a steel plate.



Magnets:

- Choosing magnets that will exert a sufficient force individually
- Finding magnets that fit within our casing
- Measuring the necessary B value needed to flip the magnetic direction

Coil Limitations:

- Coil **(Fig 11 on right)** has a max current that can be pulsed through it for 10 µs and as DC power
- Coil and wire have a resistance and will negatively impact the overall circuity if connected in series and parallel improperly

Steel Base Plate:

- Coil needs to increase in size to produce a larger B-field for lower current
- This increases the base plate outer radius and needs to be re-machined to fit
- Current design needs optimal 3D printed magnets to function