Cal Poly Hyperloop Magnetic Levitation Analysis using EMWorks Simulation Software (EMS)

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February 3rd, 2020

Introduction:

Cal Poly Hyperloop is a club dedicated to the research and development of high-speed transportation technology. SpaceX hosts an annual competition in which college teams from around the world showcase their unique hyperloop pods. Cal Poly Hyperloop intends to compete in the next competition with our newly developed magnetic levitation system. Our goal is to be the first team to successfully race a pod running with magnetic levitation.

To date, we have successfully hovered a 6061-T6 aluminum plate by spinning a wheel embedded with neodymium magnets in a Halbach array with a synchronous DC motor. Next, we hope to maximize the weight which the levitation thrust supports.

Throughout this paper, we briefly discuss the theory, design process, and initial testing of our arrangement and how the EMWorks simulation software helped us prove that our model would work.

Background:
Our magnetic levitation system consists of a circular array of permanent magnets that rotate at high speed and induce eddy currents in a non-magnetic and conductive subtract. The produced magnetic field is used to repel our pod off the ground. The magnets are arranged in a continuous Halbach array, which is a special orientation that amplifies the magnetic field on one side of the array. This is achieved by placing the magnets in a specific orientation so the magnetic field lines are non-uniformly distributed, and just so happens that the strength of the magnetic field on one side of the Halbach array. This helps generate a larger magnetic flux going into the conductive subtrack because the magnetic field is concentrated toward the ground. This phenomenon is depicted in Figure 1 below.

After the magnets are in orientation, they are spun above the subtrack. The rotating array of magnets induces a continuous change in magnetic flux through the subtract. This change in flux creates a potential difference and induces a current in the subtract which opposes the change in magnetic flux. These currents, otherwise known as "eddy currents", circulate in the subtract and create a secondary magnetic field that repels the permanent magnet. The repulsive force between these two magnetic fields provides the lift force to produce levitation.

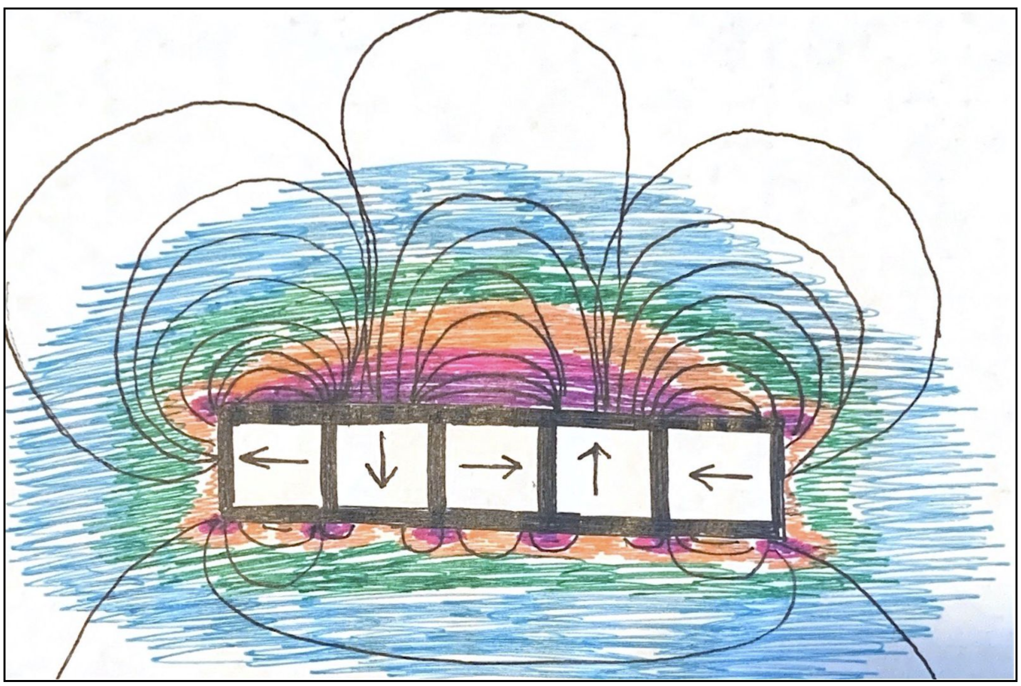

Figure 1: A depiction of the magnetic field lines from a Halbach array. In this picture, the ground is taken to be above the picture.

Our model:

In our SolidWorks model, we created a design that allows for magnets to be placed securely into 'pockets' while the wheel is spinning (Figure 2). This wheel was machined by a student in our campus machine shop using a CNC machine (Figure 3). The wheel was balanced at a local engine balancing company to ensure safety during testing. Afterward, the magnets were glued into the pockets and then covered with a plastic lid (to prevent any debris from scratching the magnets and to prevent an escaping magnet). The magnets are 1" cube N52 Neodymium magnets, which have a strength of about 150 lbs. Cal Poly Hyperloop utilized EMWorks software to simulate this model and act as proof that the theory behind the magnetic fields and eddy currents holds true Figure 2 contains an image of our CAD model, and figure 3 contains a picture of the machined fixture.

Figure 2: The CAD model of the magnetic levitation wheel.

Figure 3: The machined wheel with installed magnets.

Analysis:

Our simulation consisted of several steps. First, the magnets must have specific directions applied to them to show the direction of the magnetic field. This required setting local coordinate systems on each magnet and then assigning a magnetic direction. Then, material was defined for each part of the system, including Aluminum 6061 for the subtrack and wheel, and Neodymium N52 for the magnets. After that, a Motion Study was created in SolidWorks that allowed the wheel to spin about its central axis over the subtrack. The subtrack was modified to allow current to flow through it using the conductive material selection within EMWorks simulation tool EMS.

After running the simulation, we were able to view the eddy currents that were being formed within the conductive subtrack. This proved that permanent magnets' magnetic fields form circular eddy currents, as shown in Figure 4 below.

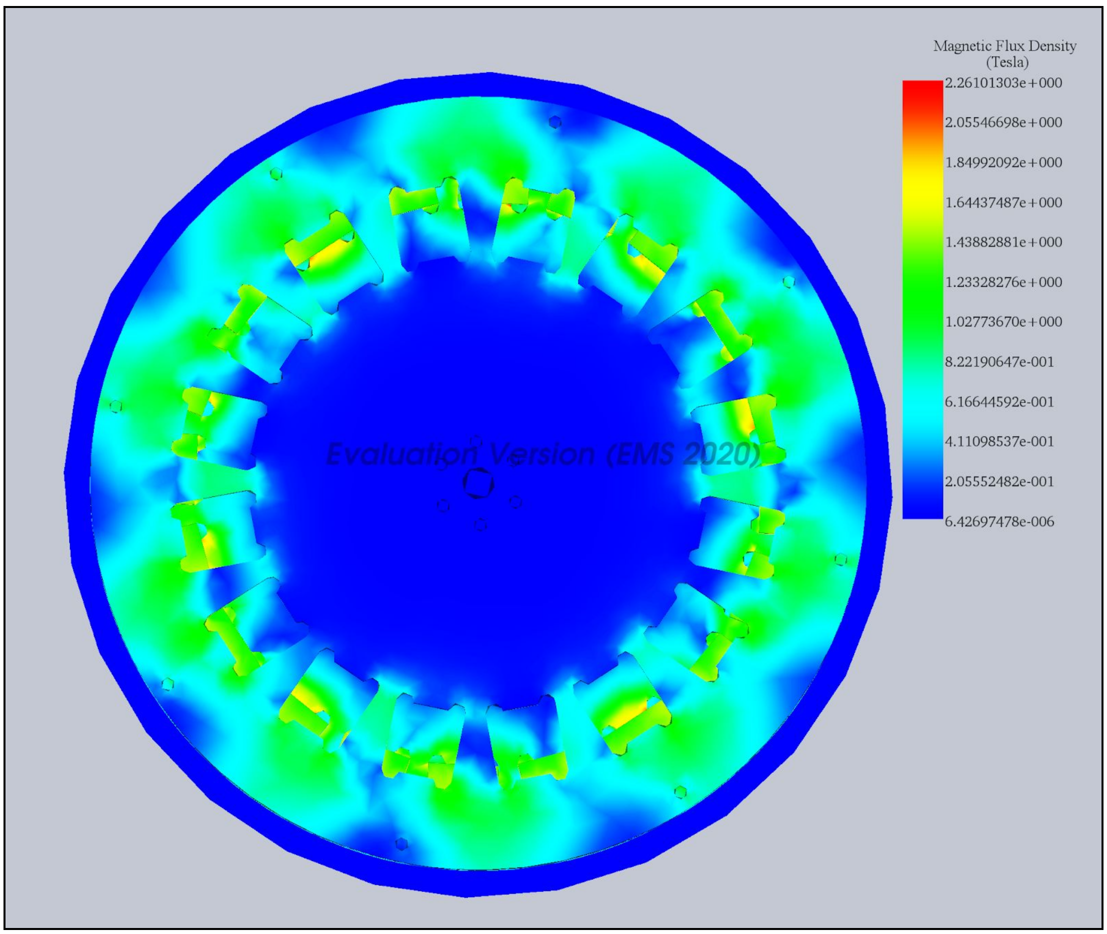

Figure 4: The green circles represent the eddy currents that are formed when the wheel spins over the subtrack.

Furthermore, as seen in Figure 5, we were able to view the effect of the Halbach array because the magnetic field lines were amplified on one side and reduced on the other. We could see the density of the magnetic flux and current, which is helpful in understanding where the powerful eddy currents are being formed.

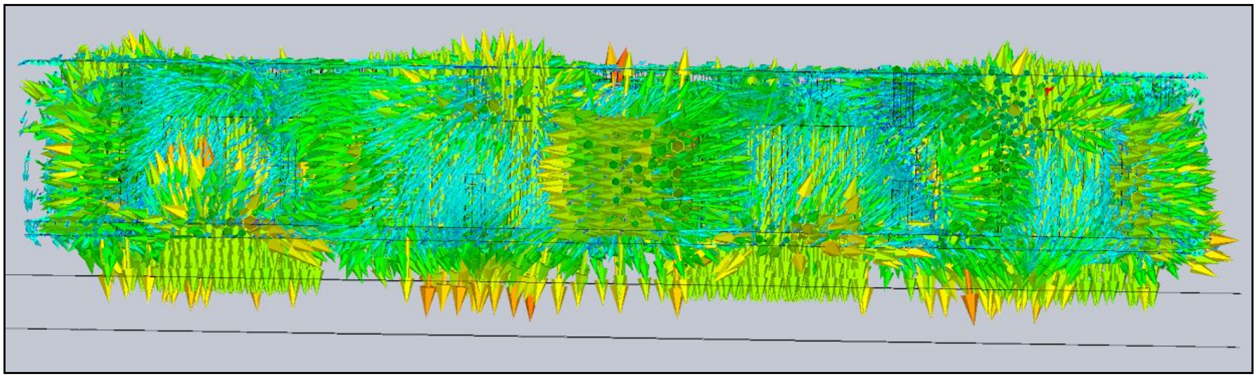

Figure 5: Side view of the wheel containing the magnet array; the magnetic field lines are amplified on the bottom side of the wheel.

Conclusion:

The simulation helped prove the theory behind magnetic levitation by providing important data that reinforced theoretical models. With the knowledge gained from the simulation, Cal Poly Hyperloop can use these concepts of induced eddy currents to further optimize their magnetic levitation mechanisms with the end goal of supporting a pod as it travels down Space X's vacuum tube.