Cooperloop Brakes

The brakes for hyperloop use an electromagnetic phenomenon known as eddy currents, which is electric currents induced over a given conductive, non-magnetic, material by changing magnetic fields. This concept allows us to produce a braking mechanism for the pod that employs an array of magnets over a conductive track, which consequently induces a braking force that causes the pod to decelerate.

Eddy Current Brakes (ECB)

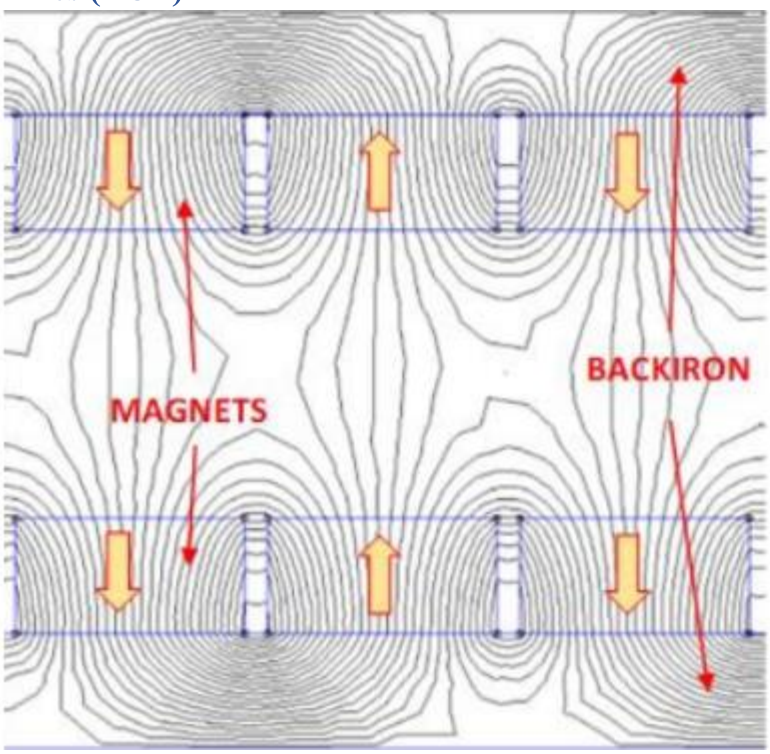


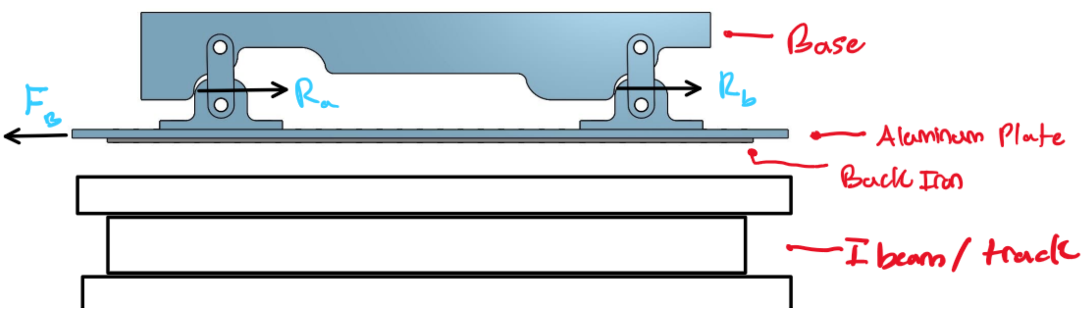
Figure 1: Example of Eddy Currents

Eddy currents arise when a changing magnetic field passes through a conductive object. These currents flow in closed loops within the conductive material and, according to Faraday's law, these currents create their own magnetic field which opposes the original magnetic field. The magnetic flux in a surface is defined by the amount of the magnetic field passing through that particular surface. Since eddy currents are generated from changing magnetic fields, they depend heavily on the amount and change in flux. Magnetic arrays are typically used instead of single magnets to maximize the change in magnetic flux and therefore the total drag force. These arrays alternate in polarity so that the magnetization of the array is a periodic function and can be easily modeled using harmonic analysis. Another common element in permanent magnet linear ECB designs is a back iron, or a slab of high-permeability soft magnetic material. This reduces the total reluctance, or resistance to magnetic flux, of any given flux path produced by the permanent magnet array. The Eddy Current Brakes (ECB) were designed using arrays of permanent magnets and soft iron materials to help channel flux. The diagram above shows the configuration of the magnets that produce the strongest flux between two channels of magnets.

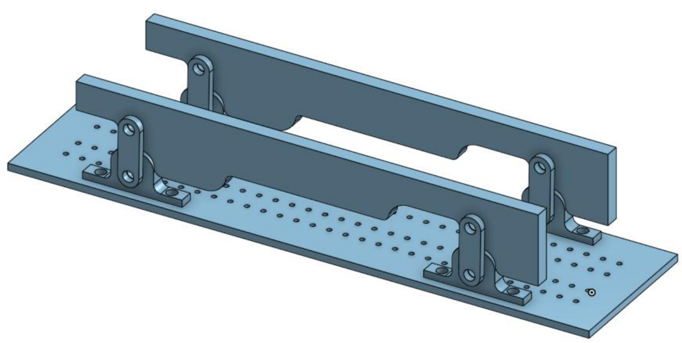
This is the exact orientation that we used to help simulate braking force in our current brake dynamometer.

Schematic and Design Overview

(a) Disengaged side view



(b) Engaged side view, Labeled



(c) Isometric view

Figure 2: Eddy Brakes Design

Figure 2 shows the current design for the Cooperloop eddy current brakes and demonstrates the chosen form of actuation. As shown, when the brakes are engaged *(Figure 2b),* the magnets, back iron, and aluminum plate actuate downwards over the track/I beam. This will then induce an eddy current force in the opposite direction of the pod's motion. The design is made to work with a piston that is attached to the base of the aluminum plate which holds the magnets. The magnet arrays are set in an alternating pattern to create the needed flux lines, as demonstrated in the following figure

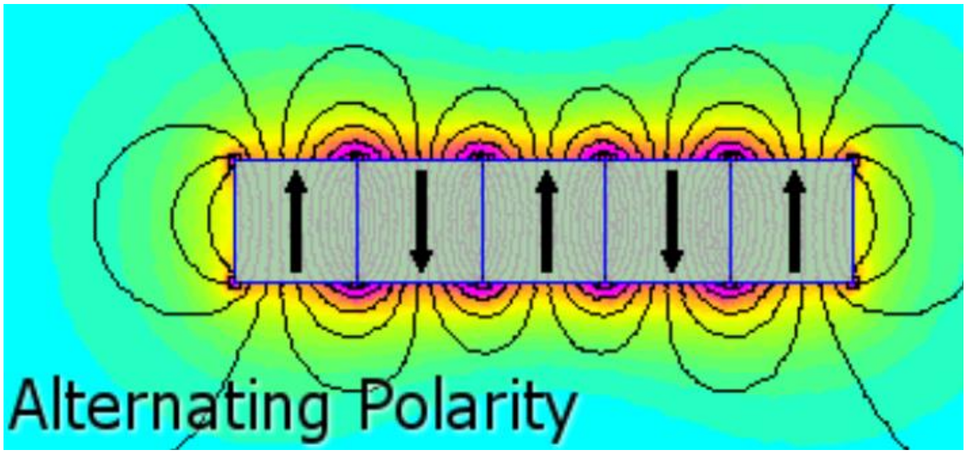
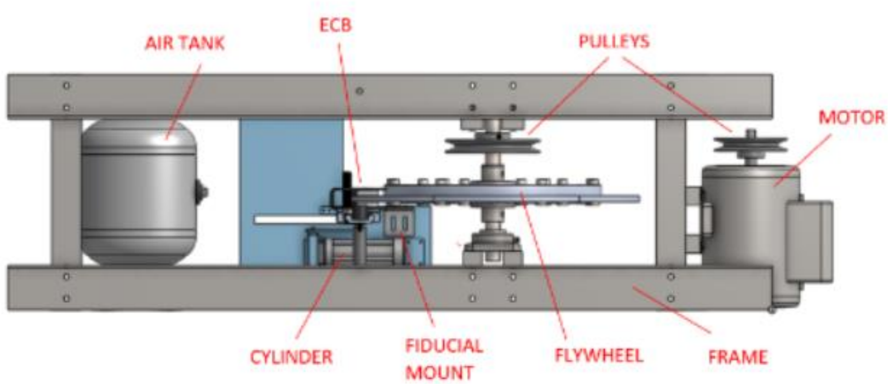


Figure 3: Alternating Polarity Flux Lines

Brake Dynamometer

The main function of the brake dynamometer is to test how the Eddy Current brakes will brake on the full track. It simulates linear motion over the track by using rotational motion. The dyno operates with a motor spinning a flywheel up to approximately 2500 RPM, which represents the track. When the brakes are engaged remotely, the motor stops, and the pneumatic cylinder retracts, which engages the brakes. As the brakes engage, a flange attached to the brake mount hits a force sensor, which measures the braking force.

The goal of this dynamometer is to measure the braking force by adjusting parameters such as the air gap between the magnet channels, the number of magnets used within the array, and also different forms of arrangement. The one we currently have integrated in the dyno uses an alternating polarity array, but there are other arrangements, such as the Halbach array, which maximizes the magnetic field in one direction. This system will be used to optimize our final design of the Brakes for the hyperloop pod.



Tasks

Prototyping

- Designing the main hyperloop brakes
- Prototyping, printing, laser cutting, etc...

Manufacturing

- Material Specification
- Designing Jig for magnets
- Hardware specifications

Testing

Brake Dynamometer

- Testing and collecting force data
- Designing and manufacturing changes for the brake dyno

Actuation

- Testing
- Calibration

Friction Braking

- Working with stability to design friction brakes on the wheel