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SPS Chapter Research Award Proposal

Project Proposal Title	Physics of Propulsion and Levitation of a Self-Driven Electromagnetic Wheel
Name of School	Northern Virginia Community College, Annandale, VA
SPS Chapter Number	4963
Total Amount Requested	$1,560

Abstract

Northern Virginia Community College, Annandale, VA 22003
We constructed an electrodynamic wheel with Nd magnets of 1 T strength attached to its rim. The rotation of this magnetic multipole near a conducting plate creates both levitation and propulsion forces. We need to upgrade this experiment by doubling the number of magnets to achieve full levitation.

Proposal Statement

Overview of Proposed Project

This project builds on a project that was worked on by this student as well as several other students. The goal of both projects is to achieve full levitation of a conductive plate using a wheel covered in an array of permanent magnets.

A significant amount of time and resources were put into the original project. The original experimental apparatus was composed of a bicycle wheel with a hub motor mounted in a wooden stand. Attached to the outside of the wheel were 36 one Tesla, one-inch cube Nd magnets. These magnets were arranged so as to form Halbach arrays, which amplify the magnetic field on one side of the array (the outside rim of the wheel) and cancel it on the other side. Because of the limited number of magnets, they were spaced roughly one inch apart all the way around the rim of the wheel. The hub motor was powered by a DC power supply.

Spinning the wheel creates a rapidly oscillating magnetic field, which, by Lenz's Law, induced a current in the conducting plate that created an opposing magnetic field. Lift forces of up to one Newton and drag forces of over six Newtons were measured with the original wheel. However, full levitation of the metal plate was never achieved.

To improve upon the original project and reach full levitation, additional magnets would be added to the wheel in the spots now filled up with wood blocks, for a total of 72 magnets. The increased number of magnets would increase the number of North to South reversals of the magnetic field per revolution, which would increase the lift force significantly. In addition to the extra magnets, other improvements would be made to the wheel, such as a more secure magnet mounting system.

Once these upgrades have been completed experiments could be run again with the wheel. The basic procedure involves hanging a conductive metal plate on a force gauge above the wheel and also attaching the back of the plate to a force gauge to measure the horizontal or drag force created by the magnetic wheel. After a baseline measurement is taken, the wheel is then spun at increasingly higher speeds, and at each speed the lift and drag forces are measured by the force gauges. Once the test run is complete the data is plotted to see how it matches with the theoretical prediction formula that the lift/drag ratio increases linearly with angular velocity.

The most obvious real-world application of this technology would be frictionless transport. A vehicle could be outfitted with multiple magnetic wheels like this one. Provided the vehicle has a conductive track to move over, the spinning wheels could provide a lift and drag (or rather propulsion) force.

Background for Proposed Project

Electrodynamic wheels may have applications in the maglev transportation, since multiple electrodynamic wheels could be used on a vehicle to produce by the same mechanism levitation, propulsion and guidance forces over a conductive track. Our configuration of a plate suspended above the rotating wheel can serve also as a model of noncontact conveyance of conductive plates in electrodynamic conveyor belts. We will investigate the performance of the wheel of our own construction. Both as future physics and as future electrical engineering professionals, we will benefit from working with this wonderful electromagnetic machine we built ourselves, and even may be lucky enough to add something to the existing knowledge. In physics as in other sciences, experimental verification of theoretical predictions provides real world confirmation of our understanding of science. While several theoretical papers have been published on permanent magnet inductive magnetic levitation using circular Halbach array Electrodynamic Wheels, few have actually constructed high field

Electrodynamic Wheels. Ours is an independent verification of the theoretical papers and demonstrated partial magnetic levitation, opening the door to development of Electrodynamic Wheel technology.

The idea of a Halbach array was first conceived of by John C. Mallinson in 1973. This special arrangement of magnets amplifies the magnetic field on one side of the array and cancels it on the other side (J. C. Mallinson). Our project utilizes such an arrangement to maximize the magnetic field on the outside of our wheel. The Halbach array was "rediscovered" by Klaus Halbach in 1985 (K. Halbach).

R.F. Post and D.D. Ryutov appear to have been the first researchers to apply the concept of a Halbach array to magnetic levitation (R.F. Post, D.D. Ryutov). J. Bird and T.A. Lipo began investigations into magnetic levitation using circular Halbach arrays (J. Bird, T.A. Lipo).

Expected Results

Doubling the number of magnets on the magnetic wheel will increase the strength of the magnetic field and the frequency of the reversals of the magnetic flux of the rotating wheel. This increase in strength and frequency should make full levitation of a conductive plate possible. We will be measuring levitation and thrust forces on the conductive "track" as functions of "effective" angular velocity, which takes into account the number of Halbach arrays around the wheel, and of the mechanical clearance. Using several different plates, we will find the performance as function of resistivity, inductance and thickness of the levitated plate. Using the total volume of magnets, we will find the lift force per unit volume of magnet and the relation between driving power and the lift force, as a measure of performance.

Description of Proposed Research - Methods, Design, and Procedures

Earlier work:

The wheel was set up on a stand. 36 magnets were attached to the rim. Radial and tangential components of the field were measured on the existing EDW at the magnets' surface, as well as its decrease with the distance. The wheel was at first powered by a 12-V battery, and then by a DC voltage source up to 36 V, permitting higher rotation speeds of the magnetic field. A series of experiments were performed with different conductors ("tracks") suspended above the rotating wheel, in order to compare the results of the levitation and drag/propulsion forces with the theoretical predictions. At low velocities a levitation force of one newton was achieved. But with the relatively weak magnetic field full levitation was not achieved. The results were compared to those of a smaller wheel having different number of magnets.

Current work:

Now, to achieve full plate levitation and investigate it over a wider range of parameters, we plan on doubling the number of magnets on the wheel from 36 to 72, using the existing free spaces between the original magnets. The magnetizations will be carefully arranged in a series of Halbach arrays. This is a difficult process, requiring special engineering design of how to overcome powerful forces and torques existing between cubic magnets at close distances. A method of safely securing of magnets on the rim will be invented. We will measure again the components of the magnetic field around the wheel.
Then, using our new 36-V power supply, we will begin measuring levitation and thrust forces on the conductive "track" as functions of "effective" angular velocity, which takes into account the number of Halbach arrays around the wheel, and of the mechanical clearance. Using several plates, we will find the performance as

function of resistivity, inductance and thickness of the levitated plate. Using the total volume of magnets, we will find the lift force per unit volume of magnet and the relation between driving power and the lift force, as a measure of performance.

The results of our research will be presented at area conferences such as the March APS Meeting in the spring of 2016.

Plan for Carrying Out Proposed Project

The project will involve five SPS members plus non-SPS volunteers. Three of the five participated actively in construction of the wheel and the initial experimentation. They reported the results at several APS, AAPT and SPS meetings, as well as at a meeting of the Virginia Academy of Sciences. The experiments will be done at the NVCC-Annandale Physics Lab under the guidance of the SPS advisor Dr. Walerian Majewski. The department contributes all computer and physics equipment at the lab.

Project Timeline

By April we plan to have installed the additional magnets and run the first series of experiments on the EDW. We will make presentations at the APS meeting in Baltimore, March 2016, at the meeting of the Chesapeake Section of AAPT, and at the Zone 4 meeting of SPS. Following these presentations we will submit the interim report. In the Fall a new group of students will continue the experiments, because most of the current SPS research team will have transferred to a 4-year school.

Budget Justification

We want to double the number of magnets used on our magnetic wheel, from 36 magnets to 72 magnets. This will increase the strength of the magnetic field and increase the frequency of the reversals of the magnetic flux of the rotating wheel through the suspended conducting plate. This denser magnetic wheel should allow for the levitation of the plate plus an additional load placed on the plate. 1-inch Nd cube magnets cost $35 dollars each, so for 36 of these magnets we will need $1,260.

We will need hardware to mount and secure the magnets, as well as other elements such as glues etc. For this we request $300 dollars, bringing the total to $1,560.

Bibliography

J.C. Mallinson, IEEE Transactions on Magnetics, Vol. Mag-9, No. 4, “One-sided Fluxes - A Magnetic Curiosity?”, December 1973

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