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Dioelectrophoretic Control of Macroscopic Media for In-Space Applications

Jason Cassibry

1. Dielectrophoretic Control of Macroscopic Media for In-Space Applications

2. Faculty or Research Mentor

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3. Proposal Identifier: RCEU21-MAE-JTC-01

4. Project Description

Dielectrophoresis is a phenomenon in which a dielectric material is subjected to the force exerted upon it due to its placement in a non-uniform electric field. This is a rare body force generated by voltage which acts on uncharged media in which the relative permittivity is any value other than unity. This force is highly nonlinear with position, but qualitatively is at least quadratic with voltage, inversely proportional to anode/cathode separation, and linear with relative permittivity of the dielectric medium. The phenomenon has been studied primarily for biomedical science for cell separation and to some extent for aerospace applications. At UAH, our interest in dielectrophoresis is to investigate its application to cryogenic fluid control and the possibility of generation of artificial gravity. This study emerged as an outgrowth of our research in fusion propulsion and the utilization of high voltage. During the spring of 2020 when the pandemic forced everyone out of the laboratory, the PI of this proposal utilized the down time to develop a proof-of-principle system which was able to actively move various objects using electric field gradients, including a ping pong ball, a battery, plastic filings, and various liquid droplets. Following this effort, the PI collaborated with a graduate stuent to develop a 3D electric static and polarization field solver to be able to conduct general purpose calculations and make predictions about macroscopic forces appropriate for aerospace scale applications.

Our advanced propulsion laboratory is now located in building 400 of the executive plaza. We are now staging one of the areas of our lab to specifically study dielectrophorectic phenomena with the efforts conducted mostly by Pongkrit Darakorn, one of our PhD students, and Sumontro Sinha, our primary research staff member. The undergraduate student will assist Mr. Darakorn, in conducting the experiments and/or setting up and testing numerical models. Experiments will include measuring and recording the force on dielectric materials subject to nonuniform electric fields created by cylindrical and spherical electrodes as a function of electrode radius of curvature, spacing, and applied voltage. The student will work closely with the PI, Mr. Sinha, and Mr. Darakorn in running experiments and recording data.

5. Student Duties, Contributions, and Outcomes

The student will be taught how to 3D print and additively manufactur parts from CAD drawings they have made to be used as test articles for verification of the body forces generated in nonuniform electric fields. The 3D shapes may or may not contain additives including barium titanate powder or other materials to augment the electric properties, especially permittivity. He or she will collaborate with a PhD student to develop electrode geometries (mostly cylindrically and/or spherically shaped metalic plates) and insulate them with wax paper, pvc pipe, and/or high voltage epoxy. Experiments conducted will use a mixture of analog and digital techniques for measuring the force and compared with numerical simulations. The student may or may not get involved in the numerical simulations, which largely depends on the constraints imposed by the pandemic. The numerical modeling will be primarily the contingency in case the student is unable to participate in person. Either way the student will be heavily involved in an important aspect of the work.

The PI, graduate student, and other lab staff will work closely with the RCEU student to complete these tasks successfully. Specific duties in addition to the experimental and/or numerical work include the documentation of the probes he/she constructs, collection of data, and and determination of calibration factors and sensitivity against known voltage sources we test. The student will also assist in providing inputs for presentations and conference papers using these data, and will lead on his/her poster for the von Braun symposium in the Fall of 2021. We have had success in this approach, as in 2019 one of our students, Shelby Westrich, won a best paper award in engineering. The student will be collaborating with her and two of last year's RCEU recipients this coming year as well, leveraging their previous experience and success supported by the RCEU program. At no point will we be putting anyone at risk, as the tests will be conducted with appropriate safety protocols at low stored energies. The experiments require voltages of 50 to 60 kV, but will be controlled remotely. The students work will benefit the faculty by providing data for a publication in the AIAA ASCEND conference in collaboration with Mr. Pongkrit Darakorn and the PI. We will use the data from the student's independent work in follow on proposals with our NASA colleagues.

Specific outcomes for the RCEU student are related to the development and use of diagnostics, oscilloscopes, verification and validation of experimental data against a multidimensional tool, and dissemination of the work through scholarly activities. In addition to the hands on laboratory experience, the student will be lead author on a paper presented at the Fall 2010 von Braun Symposium and will be a coauthor on the conference paper.

6. Student Selection Criteria

Applicants need to have completed their first year of school by Summer 2021 and be a declared major in engineering, with preference given to electrical or aerospace engineering. The applicant is expected to have a 3.5 GPA. Required coursework includes Physics II, Linear Algebra and Differential Equations. The coursework requirements are to support the contingency plan in case circumstances require the student to work remotely. Some experience with matlab, circuits (coursework and/or labwork), oscilloscopes, multimeters, and signal generators are preferable. The rest of the work will be taught on site, and the PI and the graduate student will work with the RCEU student to learn what is necessary in order to be successful. Preference will be given to a student with demonstrated (coursework or other) writing skills. We emphasize scholarly activity through the dissemination of our research work through presentations, conference papers, and journal articles, and we expect the student to participate in this process with us.

7. Contingency Plan

The ongoing pandemic and other unpredictable setbacks may preclude the student from participating in the laboratory. In anticipation of such circumstances, the student will be able to perform other critical duties to help advance the research while working remotely. Specifically, we will have the student conduct four major tasks. First, he or she will conduct materials research for us to identify good candidate materials, to include the properties of dielectric strength for high voltage standoff, high permittivity, and density. This will provide us with a collection of materials to be used together for maximizing the body force on dielectrics, which generally requires high voltage. Second, the student will generate 3D stl files for electrode geometries and shapes of interest to be tested, which we can both simulate and 3D print. Third, we will teach the student to use our 3D electrostatic and polarization field tool to import these shapes and run parametric studies to estimate total force as a function of electrode geometry and applied voltage. Finally, we will have the student post process the results and assist in writing a paper for the upcoming AIAA ASCEND conference in 2021 to be held next November. The student will be a coauthor on this paper.