CHAOS in the Electric Curtain

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***Abstract*—**
The Electric Curtain (EC) consists of a series of parallel electrodes embedded in a dielectric surface driven by a multiphase alternating electric voltage source. The EC has been shown to be able to transport microscopic/mesoscopic particles of a variety of materials and it has great promise for dust mitigation in extraterrestrial environments as well as particle separation. Specifically we focus on the EC effects on particles in simplified models searching for interesting chaotic dynamics. We have found there are multiple modes of particle movement in an EC field though bifurcation diagrams and have shown order in chaotic modes by using Poincaré sections. We investigate interesting particle trajectories in phase space for particles on the surface of the EC and mention some interesting behavior for particles when including out of plane movement as well.

I. Introduction

The Electric Curtain (EC) was patented in 1974 by Senichi Masuda for the application of particle control and containment in an electrostatic powder painting booth [**?**]. The EC is a series of parallel electrodes that are often embedded in a dielectric surface. A standing or traveling wave electric field is created above the surface by applying a multiphase AC power source to the electrodes. The phase difference between electrodes and the wave form of the power source can be chosen allowing for multiple variations in the electric field above the surface without having to alter the physical apparatus. We will focus on the standing wave or 2-phase EC also know as the 2-phase EC. In this configuration the phase difference between adjacent electrodes is π radians. If the phase difference between neighboring electrodes is less than π radians then the field for sinusoidal driving resembles a traveling rotating field. A simple depiction of the EC is shown in figure 1.

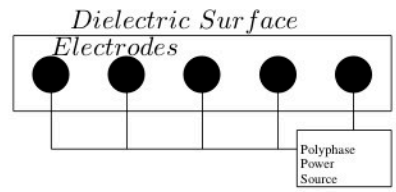

Fig. 1. Side view of EC

In our studies of the EC we have experimentally found stable orbits in a 4-phase EC with square wave driving. The stability of the orbit we found was unexpected because it was a traveling field type EC with a highly irregular field due to square wave driving. We have also seen remarkable particle mitigation off of areas affected with a 2-phase field which was originally not thought to transport particles. In light of these findings we began to research the dynamics of the EC from a chaotic perspective. Our finding of chaos in the standing wave EC show that particle paths are complicated and that the 2-phase EC is capable of dust mitigation for certain parameters. Chaos is also intimately linked to mixing [need citation] and we hope that by understanding the chaotic dynamics of the system we can more carefully understand the conditions necessary for both particle mitigation as well as separation and mixing. Here we comment on our simplified models and show the interesting dynamics they exhibit.

In Masuda's description of the "electric field curtain apparatus" he mentions the ability of the invention to move and separate different types of powders [**?**]. The EC has been researched in many areas of science and industry because of it's ability to manipulate small particles above a surface. The dynamics presented here support the potential use of the EC for separation and mixing application. Some of the work thats been done in these types of particulate separation applications are: separations of cells in solution [**?**], separation of different types of by-products from agricultural processes [**?**], and general particle separation by charge to mass ratio using a variety of different EC designs [**?**]. We see interesting chaotic dynamics in simplified models of the EC and we hope to apply our findings to the development of the EC as a particle separator and mixer. Our findings suggest that we can improve mixing and separation techniques by taking advantage of unique trajectories in phase space that sensitively depend on particle properties like mass and charge.

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