Dielectric Barrier Discharge (DBD) Thrusters – Aerospace Engines of the Future: Invariance-Based Analysis

Alexis Lupo[1] and Vladik Kreinovich[2]
Departments of [1]Physics and [2]Computer Science
University of Texas at El Paso, El Paso, Texas 79968, USA
alupo@miners.utep.edu, vladik@utep.edu

How to Fly on Mars: Dielectric Barrier Discharge (DBD) Thrusters. A large amount of information about Earth comes from air-based observations. It is therefore desirable to have similar studies of planets with atmosphere. One of the problems is that on Earth, flying devices use fuel-based engines. On other planets, we do not have ready sources of fuel, and bringing fuel from Earth is too expensive. The main source of energy for planetary missions is electricity. Electricity can be generated by solar batteries and/or by radioactive energy sources. It is therefore desirable to use electricity to power the flying devices.

A natural idea is to use electrostatic forces between two electrodes. When the voltage is high, an electric arc appears – as in a lightning. The arc means that atmospheric atoms are ionized, into negatively charges electrons and positively changed ions. Ions move towards the negative electrode, while electrons move towards the positive electrode. Since the ions move towards the negative electrode, the density near the negative electrode becomes smaller than nearby. Thus, the atmospheric gases are sucked into this area. These gases also become ionized, so they also move towards the negative electrode. The mass of ions is much larger than the mass of electrons, so the ion flow produces momentum and thus, thrust. This is the main idea behind what is called Dielectric Barrier Discharge Thrusters.

DBD Thrusters Are Useful on Earth Too. While DBD thrusters were originally designed at NASA for planetary research, they are useful on Earth too. They do not have moving parts, so they are durable and reliable. They do not burn fuel, so they do not pollute the environment. They have a higher efficiency, for the following reason. In fuel-using flying devices, energy is wasted on two stages: when fuel is burning – a large part of energy goes into useless heat, and when turbines are used – a part of energy is spent on friction. In the electric device, there are only one stage, so fewer energy is wasted.

What Electric Field E Should We Select. For a given design with given E, the efficiency of a thruster changes with atmospheric pressure p. When the pressure is too low, we do not have enough ions to generate thrust. On the other hand, when the pressure is too high, the air resistance becomes too strong. When the atmosphere is dense, liquid-size, moving through it becomes practically impossible. For each E, there is an optimal pressure at which the thruster is the most efficient. So, for each value of the atmospheric pressure, we should select this optimal E. The atmospheric pressure decreases with height, so we should thus have E changing with height. To find the optimal E, we need to know how the thrust F depends on p.

Problems. At present, we only have an approximate semi-empirical formula $F(p) = c \cdot p \cdot \exp(a \cdot p)$ based on a simplified model. It is therefore desirable to provide a theoretical explanation for this formula.

Another issue is that this formula provides a rather crude approximation to the data. It is desirable to come up with more accurate formulas.

What We Do In This Talk. In this talk, we use the natural notion of shift-invariance to provide a (preliminary) solution to both problems.