Assessment and Experimental Development of an Ion Thruster

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Abstract

Ion propulsion is a specific type of propulsion that has many applications in vessels that travel in space. For multitudes of satellites make use of this propulsion inorder to stay in orbit. In addition, NASA has made space missions that have vessels solely relying on ionic propulsion. This propulsion system is completely electric as it ionizes gas, and accelaerates outward to create propulsion. The applications for space are limitless, but due to the limited thrust from this propulsion, it is difficult to apply it in the conditions of our Earth. This propulsion is still being developed, and the current dilemma is making it generate large amounts of thrust while simultaneously managing its weight and mass. With the miniature ionic propulsion device created and simulations tested, the efficiency and viability of this propulsion was determined, and proved to be not very practical.

Safety Statement: "In this experiment, high voltages and currents were used, if not properly monitored or aware of could lead to serious burns and offset cardiac cells. To avoid these risks, one should not interact with the circuit while active, not use both hands when handling the electronics, and stay a safe distance from any high voltage source. In addition, when dealing with high voltage one should only use one's right hand with the left behind one's back. For more information visit "https://lasers.colostate.edu/wp-content/uploads/2019/04/High-Voltage-Safety-Manual.pdf ."

Introduction

When contemplating how spacecraft traverse space, most people are familiar with the use of combustion engines and reactions that are used to propel the rocket out of the earth's atmosphere. However, these combustion engines are only practical for leaving earth's gravity, but considering the short duration of this reaction as well the extreme weight of the rocket fuel, this propulsion method would not be suitable for space travel. Alternatively, the other form of propulsion that is used in space is known as ionic propulsion; in fact, it is the most efficient propulsion system to traverse space known to man.

To describe how ionic propulsion works, you are first essentially trying to accelerate charged particles and use Newton's third law to propel you in the direction opposite to the direction of the ejected charged particles. In the case of this experiment, charged particles are created through an extremely powerful electric field with 200kV applied between 3cm. When this electric field goes through the air, it pulls the electrons from the air molecules creating positively charged air between the applied voltage. This rate of ionization is calculated with Fowler-Nordheim equation and the Townsend's first ionization coefficient. When the air is ionized, the electrons striped from the air are pulled to the higher potential of the field and the ionized air is accelerated in the direction of the electric field as it follows the equation F=qE. In space, however, there is no air to charge to create a propulsion, so argon containers are used instead. Argon is what is most commonly used due to its heavier mass creating a greater thrust when ejected.

In this experiment, the goal is to evaluate the efficiency and concept of ionic propulsion by making a homemade version; however, as it is only the first attempt in being made and not that expensive to make it shouldn't be extremely efficient.

Materials and Method

Materials:

- Ender 3 3d printer
- Plastic
- DC 3v-6v to 400kV 400000V Boost Step-up Power Module High-Voltage Generator
- SHONAN Pure Nickel Strip 99.6% Nickel .15mm thickness and .02 cm^2 area.
- 20 cm^2 of aluminum foil
- EEMB Lithium Polymer Battery 3.7V 2000mAh
- DaierTek Waterproof Toggle Switch 12V DC 30A
- 4 Breadboard jumper wires.
- Soldering iron
- Lead free solder
- Hot glue gun

Method:

1. First the website https://www.printables.com/model/553679-ionic-thruster was accessed and 3-d object files for the thruster was obtained. Then the 3d printer was preheated and its infill settings. The infill settings are 30% infill triangular patterns. The next step was to 3d start uploading the file to the printer which in this experiment took an hour to print.
2. After this process was done, the nickel strip was cut to make 8 triangular spikes. The excess nickel was then discarded. Next hot glue was used to attach the nickel strip to the smaller of the two loops produced from the 3d prints.
3. Next, the larger hoop was then covered with the aluminum so that the larger end of the hoop would be completely covered with aluminum.
4. Then both loops were hot glued to the 3d printed platform, which was then hot glued to the flat surface of the voltage booster near the high voltage wires.
5. Next, the whole thing was wired as shown in figure 1. The positive end of a battery was connected to the switch, which was then connected to the positive terminal of the voltage

booster. Next, the negative terminal of the battery was connected to the negative terminal of the voltage booster. Then the positive high-voltage was connected to the nickel strip and the negative wire was connected to the aluminum.

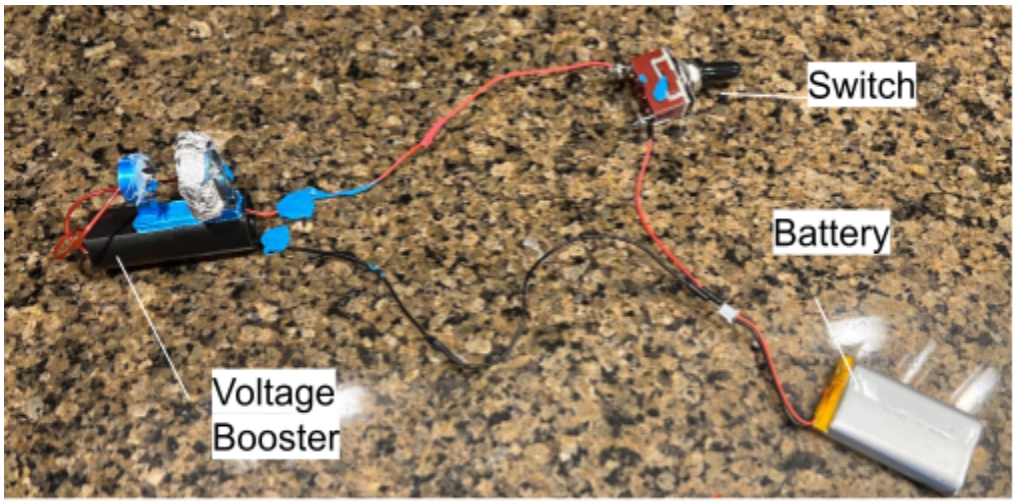

Figure 1: An Image of the wiring of the ionic propulsion circuit.

Results/ Discussion:

The observed ionic propulsion device that was made had worked suboptimally as predicted. One thing to note is that when the nickel loop was moved 1-3 mm closer to the larger loop it would create lightning arcs between the two potentials, which is not the goal of the device. On average, when measured with an anemometer, it reads, at an optimal distance of 3 cm, .4 m/s. The design this was based on was around 8 times faster, so it can be concluded that somewhere in the creation of this device there was a deviation that led to a slower propulsion. For instance, the design this was built on used copper plating instead of aluminum foil, and in this experiment, a less accurate 3-d printer was used

Conclusion:

In conclusion, this device could create wind at the equivalent of .4 m/s, having lots of room to improve, but it should be noted that the concept of the device was proven to be feasible in a homemade device as shown in Figure 2.

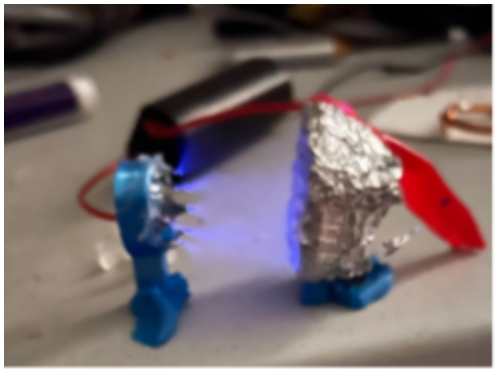

Figure 2

References

https://www.researchgate.net/topic/Ion-Thruster/publications

https://www.nasa.gov/wp-content/uploads/2015/08/ionpropfact_sheet_ps-01628.pdf