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The thrust generated by DIY Ion Thruster

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ABSTRACT

Nowadays, Electronic propulsion is the most used technology for controlling the precise motion of the satellites or explorers. As a Physics enthusiastic, I wanted to experiment with the Electronic propulsion engine and calculate the thrust generated with the small electronic propulsion engine at atmospheric conditions near sea level. In this experiment, we made a small setup of ion thruster, which can gessnerate very small thrust; we also tried to explain the mathematical model of the thrusts of such designs.

Keywords— *Ion thruster, DIY Ion thruster, Mathematical model of DIY ion thruster*

1. INTRODUCTION AND HISTORY

Electronic propulsion technology is used in space for the accurate movement of satellites. This technology always aimed at achieving thrust with high exhaust velocities so that that launch mass will be reduced. Though there are many advantages and disadvantages of electronic thrusters, scientists are mainly interested in thrust.

Robert Goddard (1) in 1906, proposed the idea of accelerating ions to generate the thrust. This idea then further studied, described by Tsiolkovskiy (2). The systematic analysis of electric propulsion systems can be found in the book Propulsion for space flight by Ernst Stuhlinger (3). The physics behind this phenomenon can be found in the book Physics of Electronic propulsion Thruster by Robert Jahn (4). A collaborative and in-depth study of principles and working processes of different types of propulsion systems was presented by S. Grishin and L. Leskov (5) .

2. MATHEMATICAL MODEL

The efficiency of the ion thruster is dependent on thrust created by the ion thruster. Here We will try to make a mathematical model give the thrust created by the ionic wind. To write this equation, we made some assumptions those are as follows:

(a) ~78% Atmospheric air is consisting of N_2, so in this experiment, nitrogen will be the fuel for the thruster. Neglecting the other gases
(b) The Energy loss is minimum.
(c) All the electrical power provided by the transformer is used for ionization of nitrogen
(d) Ionized molecules are accelerated without colliding with any other molecules.
(e) The total thrust created by the thruster is direct function the momentum transferred by the thruster due to coulombic repulsion between two electrodes.

$$F = \frac{dp}{dt}$$

$$where\ p\ is\ the\ momentum\ \ F\ is\ thrust\ genrated\ by\ the\ device$$

This momentum will be the function of kinetic energy (T) which will be the result of the potential difference between the electrodes (40keV in our case)

$$T = \frac{1}{2}mv^2$$

$$v^2 = \frac{2T}{m}$$

$$mass\ of\ the\ N_2\,(m) = \ 2 \times 14.01 \times {}^{E}/{}_{c^2}$$

$$= 28.02 \times \frac{931 \times 10^6}{(3 \times 10^8)^2}$$

$$= 2.80 \times 10^{-7} kg$$

$$v^2 = \frac{2 \times 4 \times 10^4}{2.8 \times 10^{-7}} = 28.57 \times 10^{10}$$
$$v = 5.34 \times 10^5$$

By definition of the Thrust, it is equal to the product of mass and velocity of the one nitrogen ion times number of ions per second. To get the number of ions per second, we will use the value of one coulomb which is $\sim 6.24 \times 10^{24}$charges per second at 1A current.

$$F = \frac{dp}{dt} = \ m_{N_2} \times v \times I \times 6.2 \times 10^{18}$$

By substituting the value of v from the above calculations, current (I)=0.3A and converting the mass of N2 into Atomic Mass Unit,

$$F = 28.02 \times 1.66 \times 10^{-27} \times 5.34 \times 10^5 \times 0.3 \times 6.2 \times 10^{18}$$
$$= 461.988 \times 10^{-4}$$
$$= 0.0462\ N$$

The thrust created by the ionic wind will be 0.0462 Newtons. Now, we will check with the experimental value of the force.

3. EXPERIMENTAL SETUP

To make a small backyard ion-thruster module design from the Make magazine (6) was followed with some modifications. following arrangements and setup (Fig.)

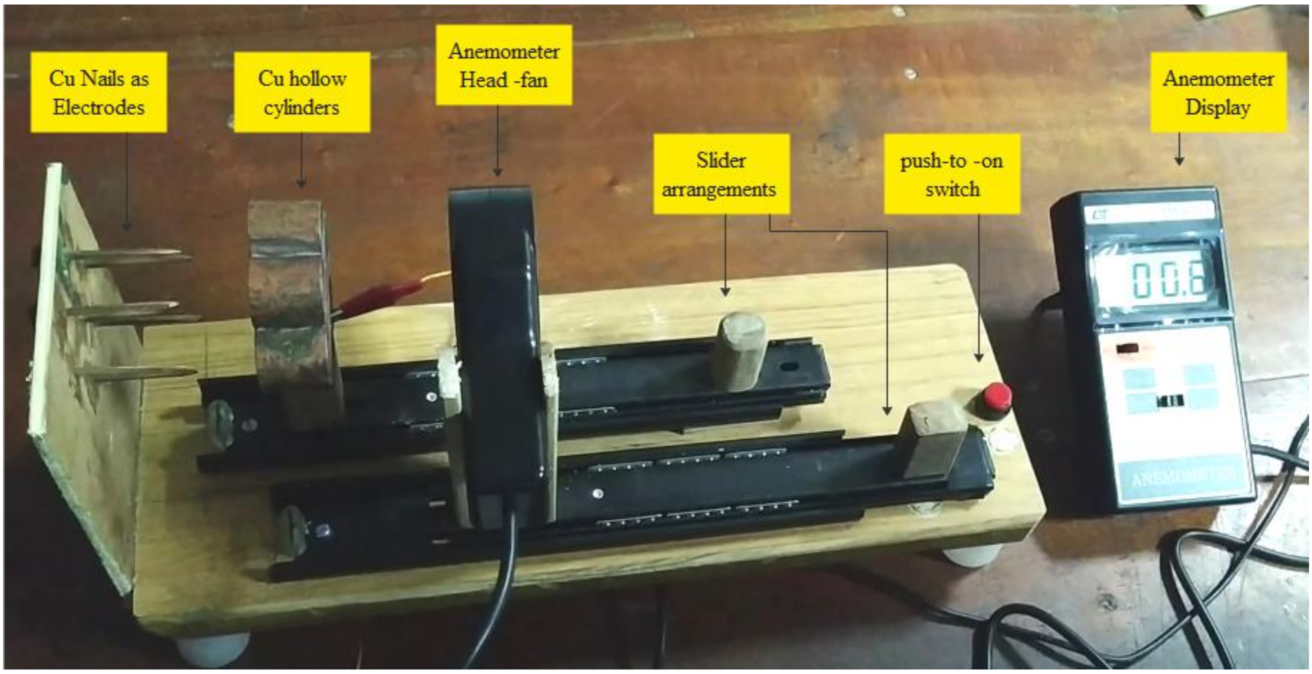

Fig. 1: Actual image of Experimental setup

3.1 High Voltage Supply (Direct current)

The high voltage DC supply, which can provide a potential difference up to 10kV(kilovolt), is the basic requirement for the ion thruster. To accomplish this requirement here, buck regulator and Phenovo DC 3.7 to 7.4V to 1000kV high voltage generator Transformer Boost Inverter module (7) through a push to on switch. Although the distributor claims to get the 800kv-1000kv potential difference, the output received was 45kV~50kV at 5.6V and 0.3A, calculated by arc length method subscribed by Jochen Kronjaeger (8) though this method is not very efficient, without the access of high voltage measuring tools this is one of the reliable method.

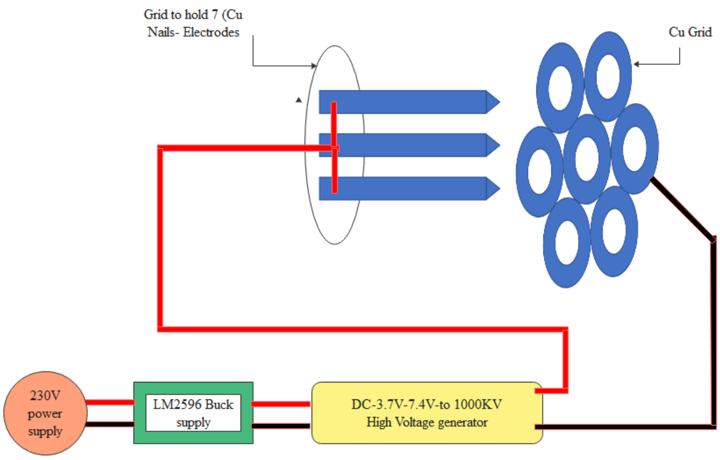

Fig. 2: Schematics of the entire setup of ion thruster

3.2 Hollow Metal Cylinder – grid

The grid is the most important part of the ion thruster. Here we are using multiple pieces of hollow copper cylinders (**Error! Reference source not found.**) roughly length to diameter(25.5mm) to length (25mm). We attached such seven copper pieces in circular geometry- to get maximum channels for the ionic wind and cover the maximum area (Fig. **3**). This circular grid is then mounted on the ball slider arrangement so that we can change the distance of the grid from the sharp edge electrodes

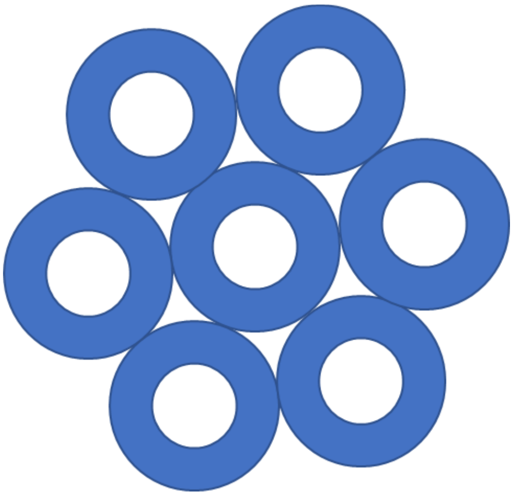

Fig. 3: Copper Grid Used As One Of The Electrodes

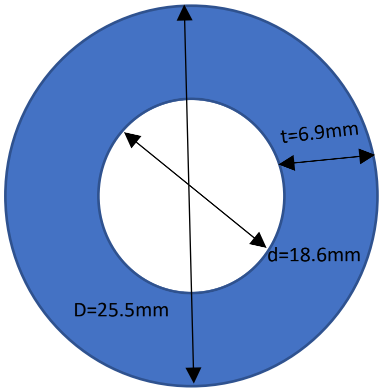

Fig. 4: Front Veiw Of The Cu Cylinder

3.3 Sharp Edged Metal Electrode (Fig.)

Copper nails (5cm length) with a sharp edge are used as one of the electrodes so that the charge flow will be highly directional also, the corona discharge will be achieved. The thickness of the nails is chosen in such a way so that it will not fail at a high voltage above 100kV.

Fig. 5: One Of The Copper Nail Used As Electrode

3.4 Thrust detector- Anemometer

To detect the wind thrust Anemometer is the most reliable instrument. We generally measure the wind velocity with the help of anemometer, and based on the area of the detector; we can easily estimate the amount of thrust generated by the wind. In this experiment, we used Lutron AM-4201 portable anemometer with a range of 0.4 - 30 m/s, resolution of 0.1 m/s and ±2% accuracy.

Fig. 6: Anemometer Used For The Experiment

4. EXPERIMENTAL PROCEDURE AND OBSERVATIONS

4.1 Experimental procedure

Once done with the setup, move the grid cylinder slider 5cm away from the sharp edge electrodes to avoid the direct spark. Start the power supply to the circuit. We can control the circuit with push to on button. Push the button to start the ionization process between grid cylinders and sharp edge electrodes. Try to keep the circuit on for a maximum of 10-15 seconds to avoid heating issues. Adjust the face of the fan of anemometer at such an angle so that fan shows maximum reading for the specific distance between grid cylinders and sharp edge electrodes. Now fix the anemometer slider with a grid cylinder slider with tape to maintain the maxima for readings with an anemometer. Maintain this setting throughout the experiment.

Now move the grid cylinder slider very slowly away from the sharp edge electrodes and note the wind speed from the anemometer. Take three readings for each point and take the average of all the three readings.

4.2 Observations and calculations

The observations for the distance and the speed are recorded in (Table 1).

Table 1 : Distance of grid cylinders from the Electrodes and speed

Distance $*10^{-2}$	Speed(m/s)	Speed(m/s)	Speed(m/s)	Average speed	Force/Thrust (Newtons)
5.1	0.4	0.4	0.5	0.433	0.009
5.2	0.5	0.5	0.5	0.500	0.010
5.3	0.5	0.6	0.6	0.567	0.011
5.4	0.6	0.5	0.6	0.567	0.011
5.5	0.6	0.6	0.6	0.567	0.011
5.6	0.6	0.6	0.6	0.600	0.012
5.7	0.6	0.6	0.5	0.567	0.011
5.8	0.6	0.8	0.7	0.700	0.014
5.9	0.7	0.7	0.7	0.700	0.014
6.0	0.7	0.7	0.7	0.700	0.014
6.1	0.7	0.7	0.7	0.700	0.014
6.2	0.6	0.9	0.8	0.767	0.015
6.3	0.8	0.9	1.0	0.900	0.018
6.4	0.7	0.7	0.9	0.767	0.015
6.5	0.7	0.8	0.8	0.767	0.015
6.6	0.8	0.7	0.7	0.733	0.015
6.7	0.7	0.8	0.6	0.700	0.014
6.8	0.5	0.5	0.6	0.567	0.011
6.9	0.3	0.5	0.5	0.500	0.010
7.0	0.4	0.5	0.4	0.433	0.009
7.2	0.4	0.3	0.3	0.333	0.007
7.3	0.4	0.5	0.5	0.467	0.009

To calculate the force or thrust, we use $F = A_m a^2$ this formula. Where A_m is the air mass passing through the area (a) of the sensor head, we will plot the distance values in meter vs. force /Thrust generated by the thruster (

7). We observe that the value of thrust increases and at a certain point the peak is observed. This nature of the graph can be justified by the argument that the thrust is the function of the mass of the propellent(Nitrogen/air) in our case and the coulumbic force between two electrodes. At the maxima, both contribute maximum which results in the higher value of thrust. The left side of the maxima in the graph explains that reducing the mass of the propellant will cause to decrease in the total thrust. The right side of the maxima can be explained by the fact that the coulumbic force reduces with an increase in the distance between the electrodes.

The Maxima value can be compared with the theoretical value. Our assumptions can justify the discrepancy of the two values. The values match in the range.

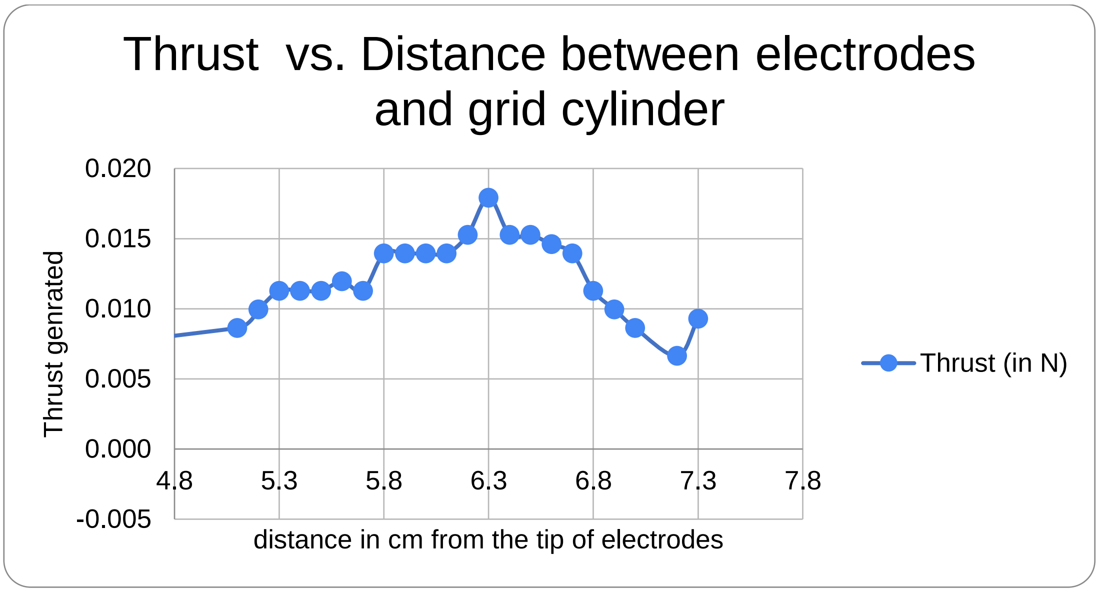

Fig. 7: Thrust vs. distance between sharp edge electrodes and grid cylinder

5. CONCLUSION

The experiment shows that ion propulsion in atmospheric conditions can be modeled mathematically. The thrust generated by such ion thrusters are mainly functions of the mass of the propellant and the distance between the two electrodes. This experiment can be repeated to improve the results with more accurate and more precise techniques. Although the internet is full of this type of thruster project but failed to try the mathematical modeling of such DIY ion thrusters.

6. REFERENCES

[1] R.H.Goddard. The Green notebooks,vol. 1. Worchester,Massachusetts : The Dr. Robert H Goddard Collection at the Clark University Archives, 1906.
[2] Mel'kumov, T. M. Pioneers of rocket technology: selected works. [trans.] 1965. translated from the 1964 Russian text by NASA as NASA TT F-9285. Moscow : Academy of Sciences of the USSR, Institute for the History of Natural Science and Technology, 1965. Vols. Volume 9285 of NASA TT F-.
[3] Stuhlinger, E. Ion Propulsion for Space Flight. New York : McGraw-Hill, 1964.
[4] R.G.Jahn. Physics of Electric Propulsion. New York : McGraw-Hill, 1968.
[5] Leskov, S.D.Grishn and L.V. Electrical Rocket Engines of Space Vehicles. Moscow,Russia : Mashinostroyeniye Publishing House, 1989.
[6] Reifsnyder, Alexander. Build an Ionic Thruster like NASA Uses for Space Propulsion. Make magazine community. [Online] Make faire, 27 August 2015. https://makezine.com/projects/ionic-thruster/.
[7] Amazon india . Amazon india . [Online] Phenovo. https://www.amazon.in/Phenovo-3-7V-7-4V-Generator-Transformer-Inverter/dp/B076CF1PCQ.
[8] Kronjaeger, Jochen. Jochen's high voltage page. kronjaeger.com. [Online] 2000-2006. http://www.kronjaeger.com/hv/hv/msr/spk/index.html.

