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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

There are many types of rocket which are used: Chemical rocket and electric rocket. Chemical based rocket produce energy from the chemical reaction whereas electric propulsion ionized the gases and accelerated with the help of electrostatic field to provide thrust. Specific impulse of the electric rocket are ranges from 1100 to 2000 + seconds. The advantage of the electric engine, it has the high specific impulse use less propellant on the satellite. The main advantage of the electric propulsion it can restart the engine many times.

Applied field magnetoplasma dynamics thruster has is the best and prominent method or alternative propulsion system for the electric propulsion. Magnetoplasma dynamics thrusters (MPDs) is recently research propulsion in the aerospace industry. The application of the MPD thruster is used in maximum competition such as deep exploration, mission for Mars, Orbit transfer etc. Although the power unit for the thruster is more than any engine type. The electric propulsion uses the 200 kw of power either by solar power or nuclear. Although the engine performance and thrust requirement for space exploration is concerned. Since the thrust of an AF-MPD is self-field, applied field, and gas dynamic. The gas propellant is ionized and accelerated by electromagnetic exhaust as plasma. Electric propulsion has aimed to provide thrust with high exhaust accelerated particles, which ultimately reduces amount of fuel and cost of the space mission. It is the most convenient application in the aerospace industry. Capacity of carrying the reduced propellant mass can results to the reduces in the mass of a satellite, which leads to the low cost in orbit.

Generally, electric propulsion contains propulsion unit in which electricity is used. There are many advantages in the Electric rocket but the main focus area is specific thrust and total efficiency and performance of the engine. Thrust is a force, which displace the aircraft from one position to other. It is used to overcome the drag and weight of the aircrafts. The ³⁰ specific impulse is defined as how much or thrust

produced **per unit of** the use of the propellant. It is either measured in the pounds or in the seconds.

In 1911, the first person who introduced and who wrote the paper was Konstantin Tsiolkovsky. Thrust is ionized at the high altitude which is considered to be the near vacuum. Electric propulsion discovered by the Robert Goddard in 1906. Many electric propulsion theories for space application were written in the Hermann Shepherd, Oberth in Germany in 1929 Cleaver in Britain. The experiment was made by Ernst Stuhlinger and it was described by the Robert Jahn in 1968.

¹⁸ Electric propulsion research was established in the 1960s at the, ⁷ Hughes Research Laboratories, NASA ⁷ Jet propulsion Laboratory (JPL), National Aeronautics and Space Administration (NASA) Glenn Research Centre. ²⁷ The first experiment ion thruster was ²⁷ launched into orbit in the early 1960s.

From 1971 when soviet launches the pair of the SPT-60. Japan first launched the communication satellite in 1955. The commercial use of ion thruster successfully tested in 1997 with a launch in, ¹⁸ NASA deep-space mission using the NASA Solar Electric Propulsion Technology Application Readiness (NSTAR), Hughes Xenon ion propulsion System ion ¹² thruster was launched in 1998. The European ¹² Space Agency has used Snecma's PPS-1350-G Hall thruster on its ²⁷ SMART-1 mission and Japanese had successfully test and returned mission of ²⁷ prime propulsion of the Hayabusa asteroid sample.

In last 20 years, Electric propulsion developed more widely, and the advance electric thruster has evolved in many missions and a alternative to chemical thruster. Continuous change ³⁴ in the field of the electric propulsion to reduce the mass of the propellant. The U.S and Russians have tested over hundreds of thrusters in communication satellite.

1.1.1 Basic principle

Lorentz Force: The force which act on the charged electrons which are moving with velocity v in the electric and ³² magnetic field. The ³² current flow through the ¹³ conductor creates a magnetic field, and the interaction between electric charge ¹³ and the magnetic field produce a force on the rod that acerate away from the current source.

The gases we used contains charged electrons which are able conduct electricity and acts as a conduct in the rails. Sparks that are generated in between the rails are due the hot gases. After heating effect to the gases in the magnetic field create plasma.

¹³ The resultant force is a cross product of the current and magnetic field vector, and the force is normal to the J and B plane

$$F = J \times B$$

Summing, yields the relationship

$$F = q (E + v \times B)$$

1.1.2 Ideal equation

The basic equation also called the Tsiolkovsky rocket equation. This equation proves the conversation of momentum. The movement of the spacecraft in the space is the momentum change.

³ Propellant which is ejected from the MPD thruster at high speed.

$$\sum F = ma$$

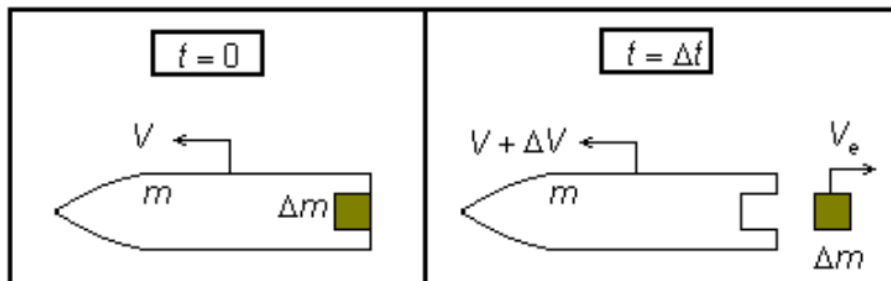


Fig 1.1 : Reacting force

The rocket start with the ejcteion of intial mass and velocity. As it propells and release dm at a velocity V_e . Here we assume, no external force is act on the ⁴⁰ system

$$Mv = (m - dm) * (v + dv) + dm (v - v_e)$$

By expanding,

$$mdv = dmV_e$$

If we examine this over time dt ,

$$m \frac{dv}{dt} = v \frac{dm}{dt}$$

where $\frac{dv}{dt}$, of change in velocity is acceleration, and $\frac{dm}{dt}$, mass flow (m) yielding

$$ma = -v_e \dot{m}$$

the rocket ³ increase in momentum and is equal to the exhaust momentum in opposite direction. The force that results the change in momentum

$$T = v_e \dot{m}$$

The ideal equation for the rocket. If we solve for the electric engine in space this equation will gives us the many advantages over chemical rocket. If we compare the electric to chemical rocket, we will find the major difference in the exit velocities. For the chemical rocket it is 3000 m/s; which required the large amount of propellant while in the electric rocket it is ³ 20 km/s to gain the same change in momentum.

The electric rocket is studied due to its performance which is:

$$I_{sp} = \frac{T}{gm} = \frac{Ve}{g}$$

Specific impulse is used to measure thrust per unit weight flow and in seconds. To calculate the specific impulse I_{sp} , we use the g, constant equal to the gravitational acceleration, $9.80655 \frac{m}{s^2}$.

1.1.3 Theory of the MPD thruster

A MPD thruster is an electric thruster.

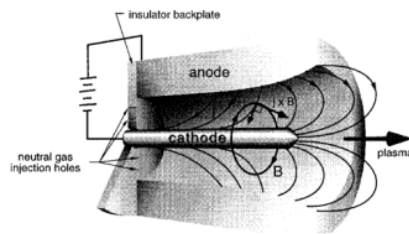


Fig 1.2 MPD thruster

There are four important parts of the MPD ³ thruster are the propellant diffuser, anode, and cylinder surrounding by magnets on both sides. Cathode is used to supply the

electrons to the MPD thruster. A power supply is also needed and convert to power required.

³⁶
In the theory of the MPD thruster, radial magnetic field created in inner and outer ³
electric field established between the anode and cathode. The electrons are ejected from the cathode. ²⁷ Due to the magnetic field electrons got trapped and exit in the $E \times B$ direction. ³

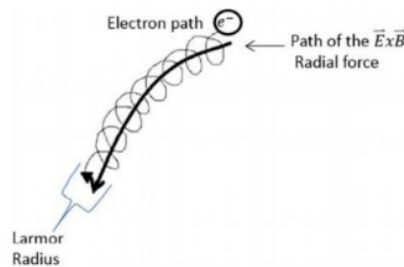


Figure: 1.3 Hall current

That direction and the motion of the electron is called Hall current. The hall current trapped the greater number of electrons. Trapped electron moves at a very high velocity which created a swirling cloud of electrons. After that we release the argon gas from the cathode of the thruster. The collision of the electron in the thruster leads to the ionization and ejection from the thruster. The bombardment of the electron and ionize and expelled by the electric field. The argon gas electrons got trapped due to the Larmor radius length shown in fig 1.3. Bombarded electrons create plasma.

Table 1: Ionization energy

Ionization energy for	
Argon	
Argon	15.7595 ev

The collection of ionized gas and electrons must be neutral called as quasi-neutral state. Other definition is also introducing such as ³ Debye length, cyclotron frequency, and Larmor radius.

In the plasma theory, Debye length is the scale over which mobile charge carries screen out electric field in plasma and other conductors. The Debye length is the distance where the separation of the charge occurs.

In space, where the electrons density is comparatively low, the Debye length considered in macroscopic values, such as in intergalactic medium, Magnetosphere, interstellar medium and, Solar wind.

$$\lambda_D = \sqrt{\frac{\epsilon k T_e}{n e^2}}$$

The cyclotron frequency is the uniform circular around a magnetic field line.

$$\omega_c = \frac{|q|B}{m}$$

Where q is the charge, B is the magnetic field strength, and m is the mass of an electron. The Larmor radius is a result of the centripetal force in which electrons orbits the magnetic field line.

1.1.4 Diffusion mode

Here many of the electrons are there which travel back to anode of the thruster, which help to maintain the neutrality of the plasma and spacecraft. There are more number of back flow of electrons, which tends to decrease in thruster efficiency and life of the thruster.

1.2 PLASMA

Plasma is coined as 4th state of matter in physics. It is a substance which is similar to gas where particles are ionized. Quasineutrality of plasma requires the plasma current closes on them in electric circuits. Many studies have been confirmed the connection with geophysical and astrophysical.

Fusion reaction occurs at very high temperature where the gas is in the plasma state. In fusion research, we use the magnetic field to heat the plasma to the temperature above its ignition temperature. Plasma jet is the most important propulsion unit for space vehicles.

Radio waves in the plasma for the communication in space which differentiate it from the electromagnetic wave in the neutral gas or in vacuum.

1.3 ELECTRIC THRUSTER TYPES

There are many types of electric thruster which are difference due to their thrust producing advancement. There are various types of electronic propulsion devices.

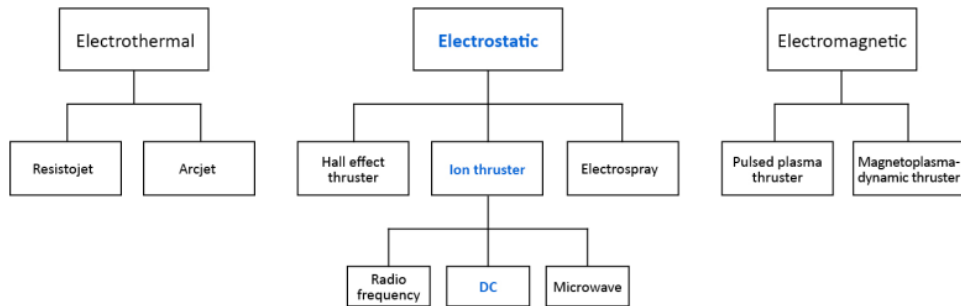


Fig 1.4: chart from electric propulsion

1.3.1 Electrothermal

The electrothermal thruster is defined as the electric heater to give energy to the propellant and expand the gas and produce thrust. The thrust generate is same as the power input voltage. It used electricity to energize electrons.

1.3.2 Resistojet

In resistojet, propellant is heated in heated chamber. The resistive heating which is produce in the circuit. It is the non-reactive fluid.

1.3.3 Arc jet

Arc jet is a device where gases are generated to high temperature. It attained the supersonic or hypersonic speed which is placed between two electrodes.

1.3.4 Electrostatic

Electrostatic thruster is divided into ion, Hall, etc. The electrostatic thruster use the gaseous propellant with no charge. Electrons are bombarded with high energetic. The energetic electrons are accelerated by the electric field.

1.3.5 Hall effect thruster

Hall thruster is consisting of the cylindrical anode and cylindrical cathode. The electric potential is applied between the anode and cathode. The gas is introduced from the cathode. The ion are accelerate towards the nozzle.

1.3.6 Ion thruster

In the ion thruster the main setup is the neutral gas. The neutral gas is ionize by separating the electrons, forming a cloud of positive ions. These electrons are mainly accelerated by the Coulomb force. The ion thruster consumes 1 to 7 kw of power and give the velocities of 20 to 50 km/s.

1.3.7 Electro spray and field emission electric propulsion thruster

Electro spray thruster generates the thrust by using small needles to produce the accelerates ions at high speed. It uses charged liquid as a propellant which is used to extracts the ions.

Electro spray thruster spray the charges liquid propellant. The charged liquid ejected by the electric field.

1.3.8 Electromagnetic

Electromagnetic thruster is use the simple technique. The electricity is used to create the magnetic field. Accelerating the ions in the electric field and magnetic field. The electromagnetic thruster is a type of the magnetoplasma dynamics thruster. The axial electric field and perpendicular magnetic field ejected the electron at high velocities.

1.3.9 Pulsed plasma thruster

Pulsed plasma thruster is an electric propulsion. It is plasma jet engine which is used in space. It has simple as compare to the other electric propulsion. It generated the heat by the arc between plate allow the current to flow.

1.3.10 Magnetoplasma dynamics thruster

Magnetoplasma dynamics is a type of the thruster which use the Lorentz force and electromagnetic field. The both forces generate the thrust. MPD thruster are of two types: Self-field and Applied-field.

1.4 EQUATION AND BASIC CONCEPTS

Basic concepts and formulas are used from the Goebel's and Katz's book.

1.4.1 Specific impulse (*I_{sp}*)

Specific impulse is defined as the how the energy in the propellant is used in the engine. Specific impulse is measure in seconds. It is efficiently the mass of the propellant is used.

1.4.2 Thrust

Thrust is the force which accelerate the engine with some speed. The force which let the aircraft to move through the air. In the engine the thrust is generated by some means of the propulsive system. The thrust is generally generating the reaction on the mass. The mass is pushed which create forward force. There are many types is thrust producing system which are responsible for the movement of the aircrafts.

Thrust follow the Newtons third law of motion. Thrust describe the how much force the engine produces. Thrust is describe as the how the engine pushed strongly.

1.5 MPD THRUSTER COMPONENTS

MPD thruster is used to work by bombardment of the neutral propellant. All these electrons were created by the hollow cathode. After that electrons are send to the discharge chamber where they procedure to the anode. When the electrons are attracted towards anode, the neutral propellant in the discharge chamber which generates plasma. The plasma is collected by the grids and accelerate to high speed. We use the cathode to neutralize the electron otherwise it returns towards the thruster which are responsible for the decrease in the thrust.

1.5.1 Design for the thruster

Our aim to design a thruster in working model which would enable testing of propellant and enable the use of 3D printing. The plan also was to keep costs as low as possible to make the concept more feasible for small satellite projects.

Basically, in our case we don't have the limitation for the thruster because we are using the main power. We only need to fit the thrust on the thruster stand or either in the suitable setup. The only problem is the time, money

and availability of the parts. Since we are using the 3D printing technique for the printing the Teflon and the base and other parts. 3D printing enables us to modify the model.

1.5.2 Discharge chamber

The design of the thruster and decided length and diameter is kept small as possible.

On the design, we decided to keep the length/diameter ratio close. Basically, due to the size complexity, we it is connected to the Teflon and anode together.

3D printing helps us to place and adjust the magnets wherever we want. The magnets close to the end part are either disc one around the cathode is a ring magnet.

The challenging part is to insulate the thruster carefully. For the time purpose we insulated with the glue gun paste. The insulation parts would only be the wire area and hollow cathode. Using the Teflon for the anode, insulated it from the cathode.

CHAPTER 2

Literature Survey

- Kalaiselvan P, Venkatesh B, Premkumar H. et al carried-out experiment has for the thrust generation by using the microwave electric propulsion. The Thrust measure by the weighing technique. The setup is kept in front to measure the value of the thrust. The tested for the accepted which is achieved in the experiment of .23 newton. In the analysis of the thrust value there are many fluctuations.
- Benjamin W. Longmier, Jared P. Squire and Chris S. Olsen et al. are carried their experiment on the testing of the Variable Specific Impulse Magneto plasma Rocket VX-200 engine. They use the power of 200 kw as the input level in the vacuum chamber. Argon gas was the propellant in the experiment. They use the ion flux for the trapping and RF power. The experiment is tested with the various propellant like krypton. Krypton which provide a wide helicon plasma.
- Daniel G. Courtney and Manual Martinez-Sanchez et al. experiment is carried out cusped field Hall thruster which is developed for the testing of the changes in the magnetic field and arrangement of the magnets. They measure at different levels and testes. They divide it, where they tested for thrust and magnetic field creation. It was run for many hours which took understand observation. Applied magnetic field and its arrangement leads to change in thrust value.
- Richard R. Hofer, Dan M. Goebel, Ioannis G. Mikellids and Ira Katz et al. experiment is carried out magnetic shielding in Hall thruster. They mainly concentrate on the efficiency and the input power of the thruster. In this experiment, they use the magnetic shielding method to observe the profiles of the magnetic field line and ion acceleration. The experiment carried for the stability and performance. They tried the physics method to find the best observation by using the magnetic shielding.
- Jian Li, Yu Zhang Jianjun Wu, Yuqiang Cheng and Xinru Du et al. experiment is carried out for the test on the voltage and mass flow rate. They proceed through the Carlo collision method. The experiment done for the simulation and characteristic of the discharge plasma. At the plasma region, there are many process, excitation, and ionization. The direction of the force towards the cathode at the left of anode lip.
- Nimesh Singhal, Igor Levchenko, Shiyong Huang, et al. experiment is carried out the different way. They use the tank and pressurised gas for the propellant feed. They tested for different inert gas in the tank. The experiment mainly focused for the

nano satellite or small spacecrafts. They use 3D printing method to print the propellant. There are many limitation in the experiment. Proposed material for the tank to feed the inert gas. To built the 100 g of fuel for mission.

- Ning Guo, Kan Xie, Miguel Sangregorio et al. experiment is carried out the 3D printing methods. This experiment is based for the use of the different laser technique. Laser melting method allow to change in the thermal expansion. The fabrication method allow to reduce or change in the erosion pattern. They use the different types of the fabrication technology for the dimension and finishing accuracy. Involving of the SLM process of refractory metals.
- Jack Hollingsworth experiment are carried out an orifice hollow cathode with a lanthanum hexaboride is used for argon gas feeding. The cathode is made of the graphite which is efficient for the thruster. Hollow cathode use in the experiment to increase in the life expectancy for the electric rocket. The test is unclear to use the graphite cathode or not. However it is seen that graphite can be a option for the MPD thruster. Changing the geometry of the thruster can change the thrust and cathode replaced can effect the temperature.
- Scott McGrail and Sam Parker et al. experiment is carried out in small cylindrical thruster. They test in many aspects to increase the performance of the thruster. The investigation on the many parameters of the thruster. Input voltage, channel depth, cathode voltage. They focus on the many different areas in which can be made. Changes in the miniature thruster may promising changes in the potential for future works
- Robert J. Vondra, Keith Thomassen and Albert Solbes et al. experiment is carried out for a specific type of satellite. They are intended and tested on various band in microwave. They took the features of the device to explain the model. Apparatus set to measure the magnetic pressure for the total change on the momentum of the gas.
- William J. Coogan and Edgar Y. Choueiri et al. experiment is carried out the applied field effect topology on the thruster. It plays and important and play a key role in the finding its radius, the magnetic field can generate a pressure confining the plasma within a certain boundary. The thrust stand, is an inverted pendulum that supports only the solenoid. With this using the applied field thrust component measurement made in order to determine, and we can use existing thrust data.

CHAPTER 3

AIM AND SOPE OF THE PRESENT INVESTIGATION

3.1 AIM

When the Thruster have been studied from 1960s and till 1970s. The study of the plasma thruster is still incomplete ³ as well as complex and difficult to solve problems and even simulate. The purpose of this research is to operate at different environment and components.

3.2 SCOPE

The main aim of this project will be measuring the changes in thrust, plasma potential, and visualization from a source with or without permanent magnets.

CHAPTER 4

MATERIALS AND METHODS

4.1 EQUIPMENT

4.1.1 Plasma generator

There are three different types of plasma generators: Direct current electron (DC) discharge, radio frequency (RF) discharge and microwave (MW) discharge. Here we will use the direct current discharge the generation of the plasma.

Direct current is having anode and a discharge channel with a hollow cathode, which works as a source for electrons. Plasma is generated into the discharge chamber and expelled from the nozzle. The propellant is then ionized with the electrons that are generate from the hollow cathode.

4.1.2 Hollow cathode

Hollow cathode is the toughest part of the thruster. It creates electron which further ionize the propellant. The hollow cathode is made hard because it deals with the highest temperature in the thruster. Hollow cathode is made very accurate and perfect and compact. We use the brass anode for the manufacturing, which is cheap and efficiency and easy to design. We are not using the tungsten due its complex handling. Instead, we use the brass anode which is thermic emission lower temperature.

4.1.3 Propellant feeding system

Propellant feeding systems are typically simple system where you can control the propellant flow with a valve. Different propellants might have different requirement, for example, adamantane might clog the feeding system if the temperature drops inside the feeding system. To avoid this typically a modified system is built where it is possible to control the temperature inside the system. Since the feeding system are out of the scope of this study they are not covered more in this study.

4.1.4 Propellants

To make the thruster efficient we take ionization threshold low and cross-section high. Mass is unimportant because thrust is base on the electrostatic forces and ion charge. But the mass of the propellant increases the efficiency.

2 4.1.5 Argon gas

Argon is a noble gas and third common gas in the Earth's atmosphere. As Xenon gas it is also a inert gas. Argon gas have no other dangerous effects. It do not harm the satellite. Argon is cheapest propellant as compare to the Xenon. As argon is the inert gas and have noble properties. It has low weight.

But the argon gas has the low molecular mass as compare to the Xenon molecular mass. So it has the high threshold energy. Firstly, we increase the power which would increase the thrust accordingly. 2 Finally, at the higher specific impulse rates, the efficiency of the argon reaches almost on the same level as Xenon.



FIG 4.1: Argon gas cylinder

4.1.6 Power supply unit

The power supply unit is the most important component of the MPD thruster. The electric propulsion is used more power as compared to the other propulsion engine. The electric propulsion basically uses the high-power supply unit of more than 10 kilo voltage. We used many different power units to supply the required power.

4.1.6.1 Generator

Generator is used to convert the power to electricity. And if we reverse the process then it works like an electric motor. They both work on the same principle.

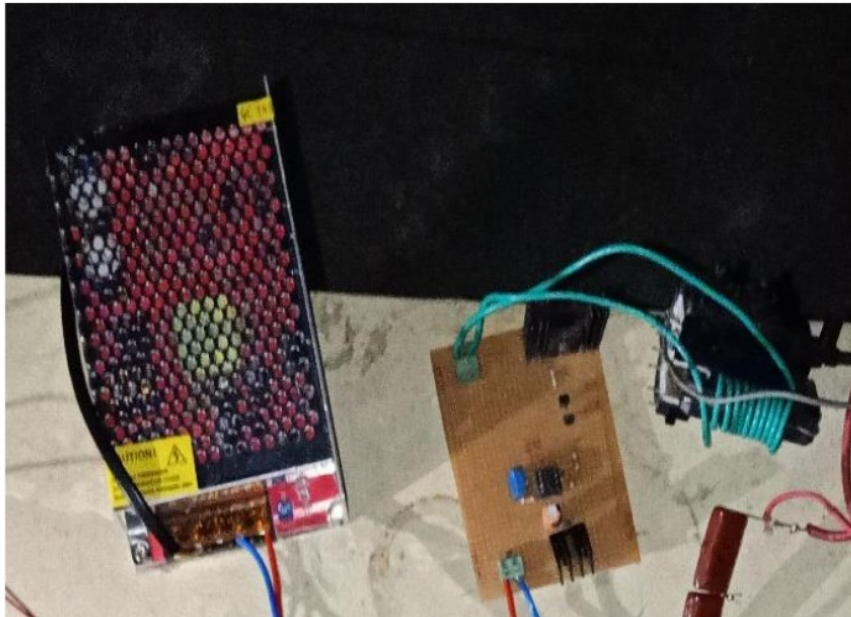


Figure 4.2: Generator

4.1.6.2 Batteries

A battery is an electrochemical cell which is used to power other devices. When batteries generate electricity, its cathode is connected to the positive terminal and anode is connected to the negative terminal. In the working of the batteries the redox reaction takes place.



Fig 4.3: Batteries

4.1.6.3 Neon power supply

We use the transformer to produce the raw power for neon supply. We use the fluctuation voltage, different shape of transformer. Neon power supply have self-adjusting transformer to provide the accurate amount of power.



Fig 4.4: Neon power supply

4.1.6.4 Capacitors

Capacitor is a device to store electrical energy. It consists of two conductors together and insulated from each other. For example, Parallel plate capacitors.

They are used for many purposes for example for the computer chips to store memories, they can be used in the electric energy during power losses. Capacitors used in the most important places, at the time of the diverting of the high signal.



Fig 4.5: Capacitor

4.2 ELECTRICAL CIRCUITS

4.2.1 Arduino Board

The Arduino board is facilities with the sets of analog input and output pins which allows to connect to the many other boards like breadboards and circuits. The board have serial ports for the communication with Universal Serial Bus.



Fig 4.6: Arduino Board

4.2.2 Load cell

A load cell is a factor transducer. It converts a force such as tension, compression, pressure, or torque into an electric signal that can be measured. As the force applied to the load cell increase, the electrical signal change proportionally. The most common types of load cell used are strain gauges, pneumatic, and hydraulic, pneumatic.



Fig 4.7: Load cell

4.2.3⁹ ADC (Analog to digital converter)

In electronics, an analog-to-digital converter is a system that converts an analog signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal. An ADC may also provide an isolated measurement such as an electronic device that converts an input analog voltage or current to a digital number representing the magnitudes of the voltage or current.

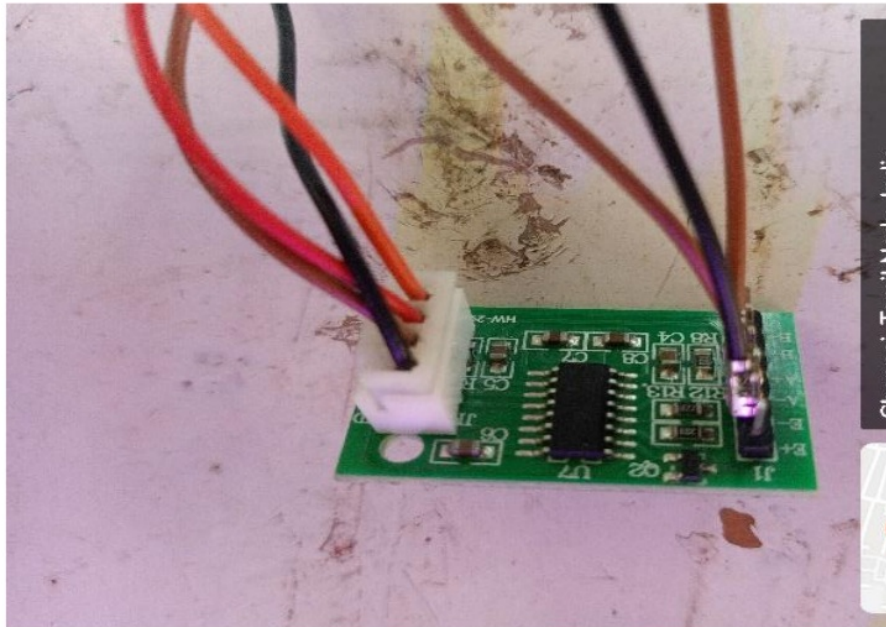


Fig 4.8: Analog to digital convertor

4.3 METHODS

The MPD thruster³ that is used for the experiment is the commercially sourced by the power supply of 24 voltage. The thruster is designed for the variety of spacecraft.

For the thruster like Hall thruster is usually provided the specific impulse of 1500s³ depending on the thruster configuration and efficiency of 40-55 percent.

Our thruster is capable of providing up to 2g or 18730 micro newtons.

The MPD thruster is designed for a cathode to fit and fixed in the centre. The MPD³ is used the brass hollow cathode. The cathode is brought to the temperature by a co-axial.

4.3.1³ Propellant flow control

The MPD thruster and cathode's propellant gas is supplied through the Argon gas cylinder of 10 litres with measured and corrected pressure and flow rate control. The current configuration of the propellant gas is 99.99 % purity. There should be careful

manner when switching of the propellant gas. The pressure in the tank is 200 lbs. There should be a flow control or constant flow in the propellant.

4.3.2 Calibration of the load cell

For the purpose to take the thrust in the load cell we need to calibrate the load cell for the MPD thruster. By applying the particular load initially, we calibrated the load cell. The weight of the 1g to 10g weight are used. The reading is calculated by the Arduino Board.

4.3.3 ³Methodology/procedures and process

The starting procedure of the MPD thruster is the mounting the anode on the 3D printed model. Anode parts is mounting and fixed with correct dimensions. As MPD is a electric propulsion model we need to insulate around the positive and negative connection. Teflon, which is made of 3d printing. Anode is mounted on the Teflon or the insulation between anode and cathode, from the prevention of short-circuit.



Fig 4.9: Thruster

After that we do the wiring to the anode, as the screws are long enough to reach and touch the anode through the Teflon insulating part. Similarly, we do the wiring of the cathode and apply the glue gun near the wiring part from the protection of

short-circuit or loss of the current. In the next part we will mount the assembled parts on the thruster with the help of 3d printed model.

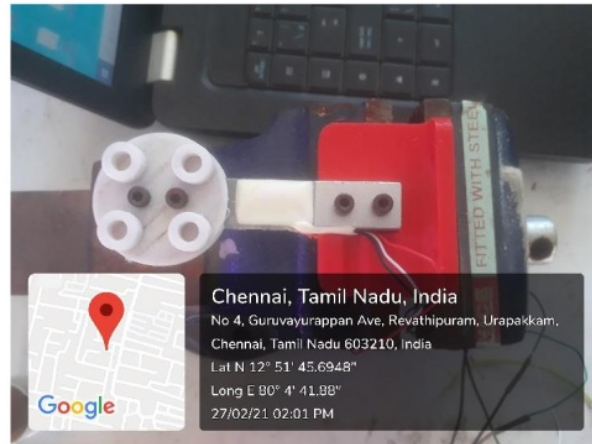


Fig 4.10: Mounting part

With the help of the Allen screws we add the load cell on the thruster base. Tight carefully and attach the load cell to the model part. After that we will fix the thruster on the thruster stand.



Fig 4.11: Assembled

Next step involves connection of the Arduino and load cell with correct pins. The connection of the load cell and Arduino and ADC is complex and should be arranged in the careful manner. The connection of the load cell with the ADC is: the red wire of the load cell is connected to the E+ of the ADC; the blue wire of the load cell is connected to the E-; similarly, the green wire is connected to the A-; and the white wire is connected to the A+. Then we will connect the ADC to the Arduino Board. The ground will connect to the GND of the Arduino board; DT will connect to the 5V; and SCK of the load cell will to the 4V of the Arduino board; VCC will connect to the 5V of the power section in the Arduino board.

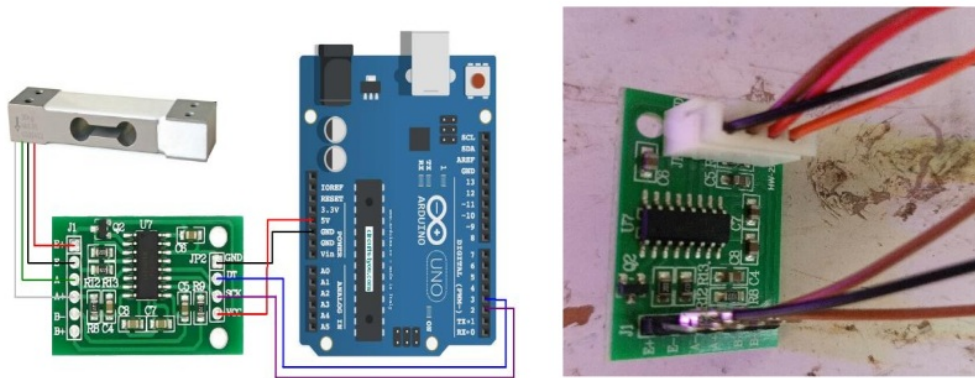


Fig 4.12: Connection interface

Switch on the power and check all the connection with the Arduino board and ADC. Install the hx711 code in the Arduino board and run the program. After successful working of all the circuits and connection. Calibrate the load cell by placing some weight on the load cell on the other end and check the reading in the Arduino software pre-installed in your laptop on the CDOM monitor. After noting the reading, either take it as initial value/ reading or calibrate it to zero for the precision and correct value. After calibration, put the thruster on the load cell and note the reading. For the correct reading minus the initial and calculate value to get the reading.

4.3.3.1 Experimental setup 1

In the Experimental setup 1 we tested the with the power with the common setup including generator and neon power supply unit, capacitors, Arduino board, ADC. In the first setup, we got the spark and magnetic arc inside the thruster. The

discontinuous manner of production of the sparks in the thruster indicated the low power supply to the thruster. Then we arrange and change to the other connection but still we got the same sparked in the thruster we represent the low power. The MPD thruster required more power consumption.



Fig 4.13: setup 1

4.3.3.2 Experimental setup 2

In the experimental setup 2, we used the two batteries of 12v for more power supply. Followed by the same electrical and power but in the pulsed and impulse mode. This time we try to create an environment for thruster for the plasma creation. We setup a transparent glass bottle, fitted the thruster inside the entrance of the bottle and fixed it. First, we try with the impulse mode with 12 v battery and visualize the flow.



Fig 4.14: setup 2 (plasma creation)

Then we connect the batteries in the series 12v and 12v, making it 24v. Switch on the power and visualize the flow with capacitor pulsed mode.



Fig 4.15: Plasma

CHAPTER 5

RESULTS AND DISCUSSION

When the test has started, we had the common issues with wiring, so the primary thing is to rewiring and checking all the connection with the power supplies. After that, calibration should be proper and accurate reading. For this purpose, we calibration it with different weights.

5.1 TROUBLE SHOOTING

Thruster operation is on Argon gas. Firstly, when the thruster is in nonworking condition seen in the figure.

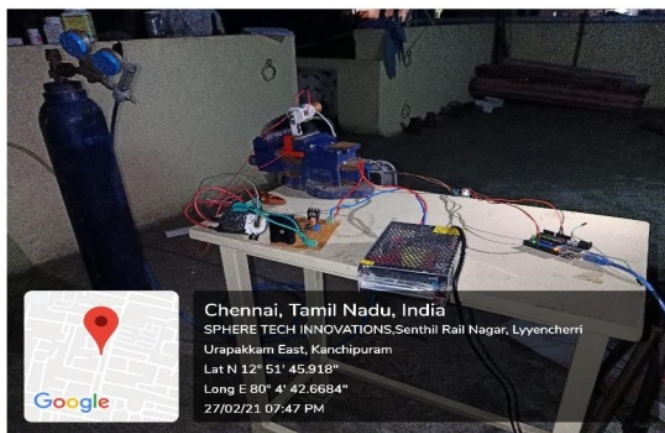


Fig 5.1: complete Setup

When the thruster was in the running condition maximum ³⁹ power and mass flow rate of argon, results in the glow of light from the thruster.

Initially, we got problem with generation of plasma, due to low power supply to the thruster, and problem with false reading, wiring should and connection correct and proper.

The next attempt to fix the problem of the power, and environment setup, so we use the two 12 v batteries connected in the series configuration. The resulting is the generation of the plasma inside the bottle try to create argon environment in the glass bottle. The result it successfully created the plasma.

5.2 EXPERIMENTAL METHODOLOGY

Experiments was conducted in the Sphere tech innovation. We didn't use the vacuum chamber for Magnetoplasmadynamics thruster. By this experiment, we will calculate the ³ Hall current, plasma potential, and visible emission.

During experiments, the mini MPD thruster will be mounted on the thruster stand. The thrust will be measured by the load cell with 1 kg or 3 kg and emission will be recorded on the camera.

One the interesting things is to locate the plasma vortex. By the applying the different pulsed and impulse mode.

³ 5.3 EXPERIMENTAL RESULTS

When the experiments are done the plasma instabilities will be induced by varying voltage and propellant flow to the Magnetoplasmadynamics thruster and cathode. As the test will be happened at different arrangement like pulsed mode. What is unclear is the size and the voltage regulation controlling. The methodology ³ for the analysis of the value will be provide the inner working of the magnetoplasmadynamics thruster. The most important and difficult is the lack of information of the MPD at change in geometry.

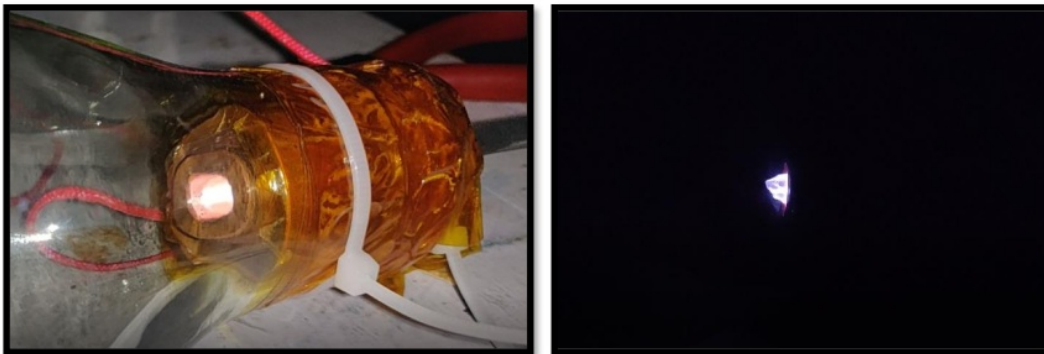


Fig 5.2: Plasma generation

Table 5.1: Thrust Reading

-147.12
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-147.21
-147.22
-147.21
-147.08
-147.09
-146.9
-146.78
-146.78
-146.78
-146.52
-146.45
-146.47
-146.47
-146.2
-146.25
-146.19
-146.18
-146.1
-146.08
-146.04
-145.88
-145.21
-145.45
-145.45
-145.39
-145.38
-145.53
-145.45
-145.88
-146.75
-146.92
-146.45
-146.94
-147.23
-147.2
-147.19
-147.18
-147.12

All the reading value are measured only for few seconds.

As noted, there was a noticeable intensity in the plasma creation. This is due to the complete ionization of argon inside the glass bottle.

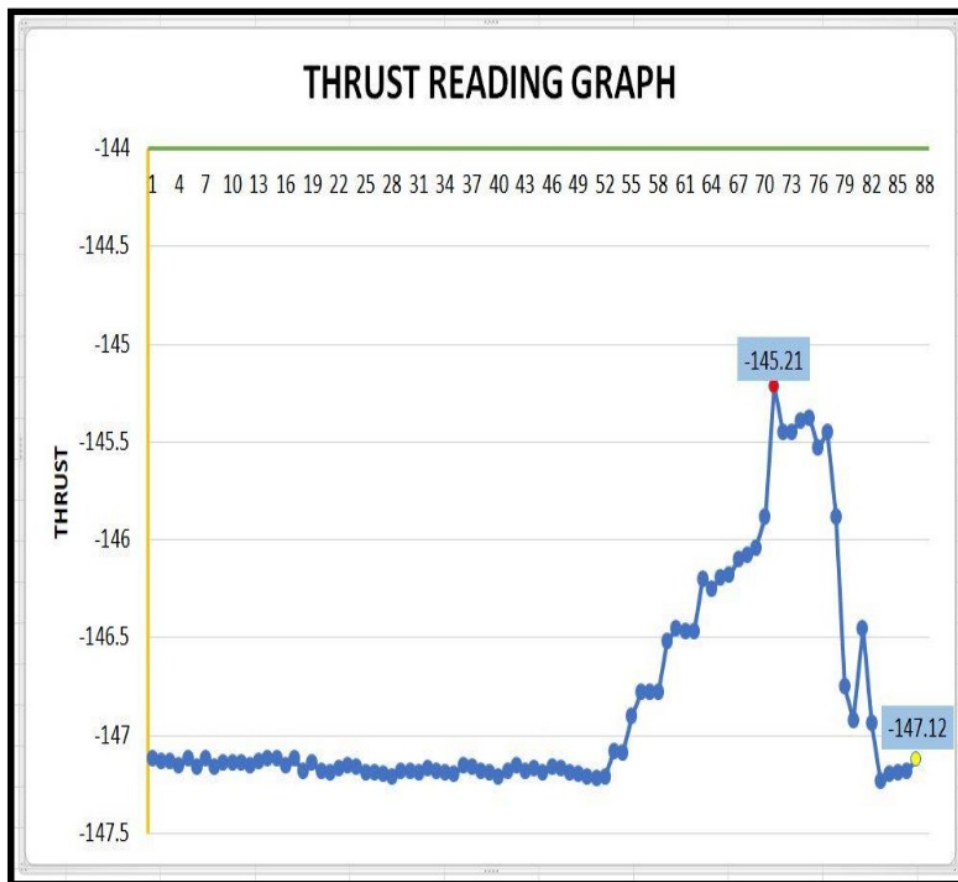


Fig 5.3: Graph for the thrust change

CHAPTER 6

SUMMARY AND CONCLUSION

³ The original research goals for the research were to get the thruster working measure the thrust and visualization and geometry change and plasma voltage. Due to the equipment and source lack we were able to find thrust and able to decrease the size and visualize the plasma, but not the plasma voltage. We tried to test with the magnets but we do not know the life of the magnets. We used the ³⁷ magnets to generate the plasma vortex in the thruster.

³ The MPD thruster tested many times and run many times in the duration of the testing. Further testing was not able to be completed due to the lack of information and knowledge about MPD thruster. This thruster design shows the scope to the futuristic vision for propulsion which can be achieved to evaluate thruster life span and anomalous mode and designs.

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