

CTF RESEARCH REPORT

ELECTRIC PROPULSION SYSTEM

TEAM MEMBER: DURGA A

This report is to interpret the results obtained from a small HET fully designed and manufactured by the scholars at Western University of Michigan. Their objective was same as our research to design and build a low-cost HET that could be operated at lower power and low flow rate for testing at smaller vacuum facilities.

These interpretations could help our team in simulating the HET with varied values for different parameters of parts used in a HET.

DESIGN AND FABRICATION OF A LOW COST SMALL SCALE HET:

HETs have relatively simple geometry compared to other electric propulsion thrusters, placing them within the manufacturing capability. The design focuses on the main characteristics of an HET: channel dimensions, magnetic circuit, and anode. First the target discharge power is to be fixed to 250W so that other parameters such as channel width, outer radius, width, thrust, propellant flow rate can be determined using COMSOL Multiphysics.

Magnetic field considerations

- The magnetic lens design has direct implications on lifetime and performance of HETs. An ideal magnetic lens is designed in such a way that magnetic field is strongest near the exit plane and quickly approaches zero just before the anode surface.
- The curvature of the magnetic field lines may also be designed to decrease ion bombardment with the channel walls and increase thruster life. The iron (core material) and MuMetal (shielding material) magnetically saturate around 1.6 and 0.6 Tesla, respectively.
- The effects of various shielding thicknesses and widths were simulated using COMSOL Multiphysics and the dimensions chosen provide a balance between a strong exit plane magnetic field and the desired magnetic field shape along the channel. The number of coils were found to be optimum at 300.

Anode design

The anode was designed to provide even gas distribution and, thus, discharge within a channel. The continuum approach treats the fluid as a whole and disregards intermolecular interactions.

It can be used as an approximation for the flow simulations in ANSYS.

From the ANSYS simulations, it is clear that from a continuum perspective, the gas is evenly distributed within the channel between 2 and 5 mm from the anode plate.

Fabrication

The anode is made up of four parts: the front plate with twenty 0.76-mm-diameter holes, the channel with two 1.59 mm gas tube holes, and two gas tubes. All anode components were machined from 316 stainless steel.

The anode front plate and anode channel were spot welded together, at the inside lip, at 6 points. The gas tubes were brazed onto the channel part.

The channel is made with Boron nitride which starts cracking after prolonged testing of thruster for 5 hours so the material should be reconsidered.

The anode was held in place by twin gas tubes with stainless steel push nuts and ceramic washers.

$$v_i = \left(\frac{2eV_b}{m_i} \right)^{\frac{1}{2}}$$

$$T = \dot{m}_a v_i$$

$$\eta_o = \frac{P_d}{P_T} = \frac{P_d}{P_k + P_d + P_{mag}}$$

$$\eta_c = \frac{\dot{m}_a}{\dot{m}_p} = \frac{\dot{m}_a}{\dot{m}_a + \dot{m}_c}$$

$$\eta_T = \frac{1}{2} \frac{T^2}{\dot{m}_a P_d} \eta_o \eta_c$$

Calculated values using these formulas:

The ion exit velocity and thrust are estimated and yield 18.5 km/s and 17.8mN.

Discharge power is approximated by multiplying the discharge area by our estimated current density of 0.1 to 0.15 A/cm².

The power ranges from 144-216 W. The coil resistance is calculated using a resistivity at an exaggerated temperature of 600K to yield a total coil power consumption of 0.53W. The electrical utilization efficiency of 0.998. The cathode mass flow rate will be an estimated 0.3 mg/s. The cathode efficiency is roughly 0.762.

From these values our research aims to improve the efficiency, thrust and various other parameters by simulating in iterations.

ROCKET PROPULSION HALL THRUSTER

REPORT

MOHANA KRISHNAN D:

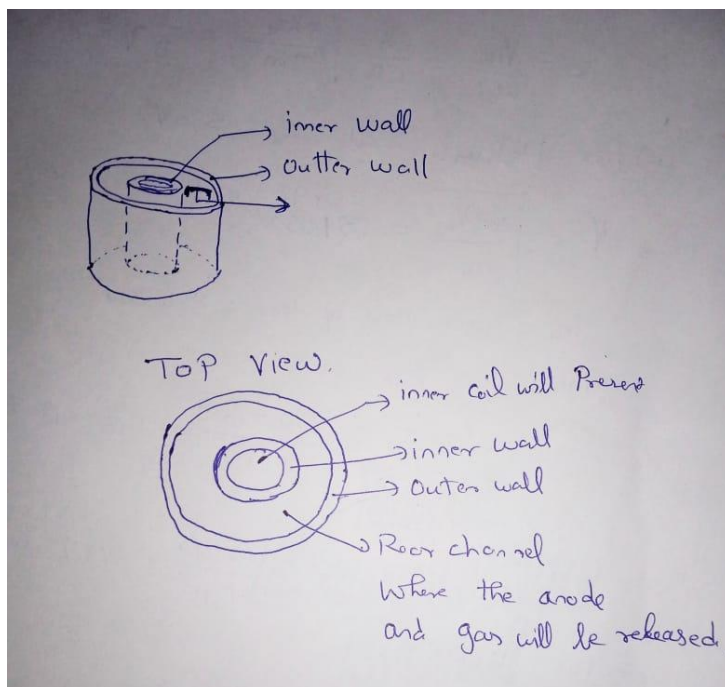
INTRODUCTION:

Hall thrusters are futuristic systems used in rocket propulsion. They are advantageous in many ways. In this report, I will discuss the principle and some information to encourage the readers to dive deep into modeling hall thrusters.

PRINCIPLE:

The core principle of this hall thruster is the hall effect where the electric and magnetic will be mutually perpendicular to the flow of the electron. The hall thruster's cathode will emit the electron and move towards the anode due to the electric field. The main goal is to ionize the electron with the help of noble gases like argon, xenon etc. But the electric field causes the electron to move towards the anode in a minimal interval of time which is not sufficient for the gases to ionize. So we use the magnetic field which causes the electron to rotate in a circular motion towards the anode, due to this motion there will be sufficient time for the gases to ionize the electrons. So the role of the magnetic field is to slow down the electron in order to ionize the electron.

DISCHARGE TUBE:



The outer wall, inner wall, and the rear of the channel are the important component. This covers both the anode and discharge tube. Actually the inner wall experiences more heat than the outer wall. This is due to the following reason

1. **Plasma Density and Ion Bombardment:**
 - The plasma density tends to be **higher near the inner channel wall** in many Hall thrusters.
 - As a result, the **ion bombardment rate** is higher on the inner wall compared to the outer wall.
 - This ion bombardment transfers kinetic energy to the wall, causing localized heating.
2. **Channel Geometry:**
 - The **inner wall** is closer to the central axis and generally has a **smaller surface area** than the outer wall.
 - Since the energy deposition from the plasma is concentrated over a smaller area, the **heat flux per unit area** is higher for the inner wall.
3. **Magnetic Field Configuration:**
 - The **magnetic field lines** curve differently near the inner and outer walls due to the thruster's design.
 - These differences can result in **asymmetric electron and ion trajectories**, leading to uneven heat deposition.
4. **Plasma-Wall Interaction:**
 - The **plasma sheath** (a thin layer of charge near the walls) forms differently on the inner and outer walls due to the thruster's annular geometry.
 - This affects the rate of electron and ion collisions with each wall, leading to different thermal loads.
5. **Material Properties and Heat Conduction:**
 - Even if the walls are made of the same material, the geometry and attachment points may cause heat to dissipate differently.
 - The outer wall, having more surface area, may radiate and conduct heat more effectively than the inner wall.

GENERAL INFORMATION ABOUT THE MATERIAL USED IN THE DIFFERENT PARTS OF THE DISCHARGE CHAMBER:

- **Rear of the Channel with Embedded Propellant Distributor**

Purpose:

Distribute the propellant gas (like xenon) evenly into the channel. Acts as a structural component that supports the anode.

Material Requirements:

Thermal Consideration: This part doesn't experience significant heating because it's shielded from direct plasma exposure.

Material Used: ABS plastic (Acrylonitrile Butadiene Styrene).

Chosen for ease of printing and its mechanical properties.

Challenges: Low glass transition temperature (~105°C), meaning it softens or melts under prolonged heating.

- **Inner Channel Wall**

Purpose:

Directs and contains the plasma flow.

Experiences intense heating due to exposure to high-energy plasma.

Material Requirements:

High Thermal Resistance: Must withstand the highest temperatures without degradation.

Dielectric Properties: To prevent electrical conduction, maintaining proper thruster function.

Material Used: Glazed Ceramic.

Ceramic is heat-resistant and can maintain structural integrity at elevated temperatures.

Produced via molding and firing, with ~3% shrinkage accounted for.

- **Outer Channel Wall**

Purpose:

Acts as a structural outer layer for the thruster.

Provides thermal insulation.

Material Requirements:

Must endure elevated temperatures but experience slightly lower thermal stress than the inner wall.

Material Used: ULTEM (Polyetherimide).

High glass transition temperature (~200°C), providing better thermal stability compared to ABS.

Suitable for environments with prolonged heating.

Why Different Materials for Different Parts?

Each part of the thruster has unique thermal, structural, and electrical requirements:

Rear Channel/Propellant Distributor: Faces minimal heat → ABS suffices.

Inner Channel Wall: Faces maximum heat → Glazed ceramic is ideal.

Outer Channel Wall: Faces moderate heat → ULTEM provides optimal balance.

This is done for
 SPT-100 ($P = 2,200 \text{ kW}$)
 ($T = 123 \text{ mN}$)

Larmor radius is:

$$r_e = \frac{V_{th}}{\omega_c} = \frac{m}{eB} \sqrt{\frac{8kT_e}{\pi m}} = \frac{1}{B} \sqrt{\frac{8}{\pi} \frac{m}{e} T_e} \ll L$$

$\Rightarrow$ For Helium! Let $V_d = 350 \text{ V}$.

$$V_i = \sqrt{\frac{2eV_d}{m_i}} = \frac{20,985 \text{ m/s}}{\cancel{21,652}}$$

$$m_i = \text{ionic mass of Xenon} = 2.18 \times 10^{-25}$$

Mass flow rate:

$$\dot{m} = \frac{T}{V_e} = \frac{2.2 \times 10^{-3}}{20,985} = 1.05 \times 10^{-7} \text{ kg/s}$$

Specific impulse

$$I_{sp} = \frac{V_e}{g} = \frac{20,985}{9.81} = 2139 \text{ seconds.}$$

$\Rightarrow$ for Argon:

$$V_i = \sqrt{\frac{2eV_d}{m_{ar}}} = 38,052 \text{ m/s}$$

$\Rightarrow$ mass flow rate:

$$\dot{m} = \frac{T}{V_e} = \frac{2.2 \times 10^{-3}}{38,052} = 5.78 \times 10^{-8} \text{ kg/s}$$

$\Rightarrow$ Specific impulse

$$I_{sp} = \frac{V_e}{g} = \frac{38,052}{9.81} = 3880 \text{ seconds.}$$

OVERALL PARAMETERS OBTAINED:

Inner Diameter (mm)	60
Outer Diameter (mm)	100
Plasma Density (m^{-3})	2.4×10^{17}
Neutral Density (m^{-3})	2.0×10^{18}
Ion Velocity (m/s)	18,455
Neutral Velocity (m/s)	280
Ion Temperature (eV)	1.0
Neutral Temperature (K)	750
Electron Temperature (eV)	6.0
Plasma Potential (V)	15

IONIC THRUSTERS

T Sudarshan Karthik

2022104020

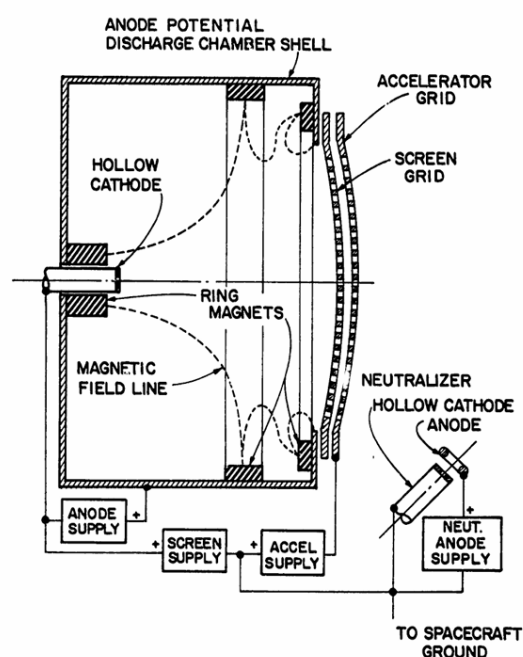
Electron bombardment ionic thrusters are used for both primary and secondary propulsion. Earlier, development requirements for these thrusters were achieved by physically varying the parameters, but this had the following consequences:

1. The whole process was expensive.
2. The solution achieved was not always optimal.
3. Every thruster built requires the entire process to be repeated.

Hence there was a requirement for an analytical model to provide an iterative procedure and provide guidance in describing the thruster design.

There was a lack of theoretical understanding due to the complexity of the working of the discharge chamber. The most accurate model was proposed by Masek in 1969 which requires detailed knowledge of plasma properties, and this is achieved by a semiempirical approach which consisted of using a probe to measure the ion density, temperature of plasma.

Working:



The Ionic thruster consists of a cylindrical steel structure called the discharge chamber with 1 end closed by a circular metal plate and the other end closed by 2 closely spaced grids. The inner grid is called the screen grid, and the outer grid is called the accelerator grid

During the operation of the thruster, neutral propellant gas such as mercury vapor gas or rare gases such as Argon, Krypton or Xenon is injected into the discharge chamber and is uniformly spread across the discharge chamber.

Hollow cathode is used as a source for electrons since it has a very long-life span and can be restarted after exposure to air. The electrons injected into the discharge chamber are accelerated using magnetic fields produced by supplying walls of the discharge chamber with a DC power supply of 30V to 50V and these accelerated electrons are called primary electrons. The energy of these accelerated electrons depends on the difference in voltage between the anode (walls of the chamber) and the cathode (hollow cathode).

The difference in voltage must be set such that:

1. Collision cross section for primary electron is large
2. Collision cross section for production of multiple charges ions by the primary electron is small.

These primary electrons collide with the atoms of neutral propellant and due to inelastic collision, energy is transferred from the electrons to the neutral atom and hence these collisions is essential for thruster operation and hence maximizing the number of accelerated electrons while keeping the formation of multiple charges is crucial for thruster operation.

At neutral atom density, ionization mean free path for primary electron is of order of few meters while the dimensions of discharge chamber is of 10s of centimeters, hence magnetic fields are used to restrict the direct access of primary electrons to discharge chamber surface(anode) to maximize efficiency. This magnetic field is created by rings of magnets located along back and sides of chamber of alternating polarity and the strength of this magnetic field affects the performance of the thruster.

The magnetic field lines guide the electrons across the volume of the chamber and terminates at the walls of the chamber (anode). On average, magnetic flux density of 0.1T is required.

This magnetic field reduces the probability of primary electron being collected directly at the anode without inelastic collision with neutral atom. This probability depends on:

1. Size of the chamber
2. Neutral atom density
3. Configuration of magnetic fields
4. Cathode location
5. Distance travelled by primary electron before being collected at anode which is also called containment length.

Out of all the ions produced, some of the ions are collected at the anode and some are ejected as beam through the 2 grids. The accelerator grid has a negative potential to prevent back streaming of electrons and screen grid is at a positive potential to accelerate electrons out of the chamber as beam and the final velocity of the ions in the beam is determined by the sum of the positive potential applied to the thruster cathode and the discharge voltage.

During thruster operation ionized gas density is less than the neutral atom gas density but the ion flux through the grid is greater because of attraction to the grid whereas neutral gas density move to grid due to free molecular flow.

Propellant utilization efficiency is the ratio of beam current (rate flow of ions ejected through grid) to total propellant flow rate (rate at which propellant gas is injected into discharge chamber) and increasing this efficiency requires an increase in average energy required to produce beam and the variation between propellant utilization efficiency and average energy required to produce beam is called performance curve.

Theoretical Model

The result of this model will be a simple algebraic equation representing the performance curve of the thruster.

Average discharge plasma ion energy cost expressed as a function of propellant flow rate and propellant utilization efficiency.

Assumptions and Limitations:

1. Steady state discharge operation
 2. Applicable to discharge chambers which produce low pressure partially ionized optically thin plasma
 3. Maxwellian electron temperature (1 – 10eV)
 4. Primary electron energy (30 to 50eV)
 5. Electron energy loss due to inelastic collision neglected
 6. Single charged electrons assumed
 7. Effect of metastable atomic states on ion neglected
 8. Neutral gas density uniform across chamber
- Beam Ion Energy Cost:

Beam Ion Energy Cost

The average energy cost per beam ion is defined as,

$$\epsilon_B \equiv (J_D - J_B) V_D / J_B, \text{ [eV/beam ion]}$$

J_B = Ion beam current (A)

J_D = Discharge current (A)

V_D = Discharge (Anode) voltage (v)

In a similar manner, the average energy expended in creating ions in the discharge chamber plasma may be defined as,

$$\epsilon_p = \frac{(J_D - J_B) V_D}{J_B} \left(\frac{J_B}{J_p} \right) - \frac{J_C V_D}{J_p}$$

J_p = Total ion current production rate expressed as a current (A)

For steady state operation, the total ion current produced (J_p) must be equal to the total ion current leaving the plasma. For ion thruster discharge chambers, ions can only leave the plasma by going to cathode potential surfaces, anode potential surfaces or by being extracted into the beam. Thus, the total ion current produced is given by,

$$J_p = J_B + J_C + J_A$$

Rewriting the terms and substituting, we get:

$$\epsilon_p = \epsilon_B f_B - f_C V_D \quad .$$

Solving this equation for ϵ_B gives the result,

$$\epsilon_B = \epsilon_p / f_B + f_C V_D / f_B \quad .$$

$$f_B \equiv J_B / J_P \quad , \quad f_C \equiv J_C / J_P \quad \text{and} \quad f_A \equiv J_A / J_P$$

This equation describes the beam ion energy cost as a function of the plasma ion energy cost (ϵ_p), the extracted ion fraction (J_B), the fraction of ion to cathode potential surfaces (J_C) and discharge voltage (V_d).

ϵ_p / f_B represents the energy loss in producing the ions in discharge chamber and extracting a fraction of it into the beam.

$1/f_B$ represents the average number of times a beam ion undergoes ionization from neutral state before sent out as beam

$(f_C)(V_d)/f_B$ represents energy wasted in accelerating plasma ions into interior cathode potential surfaces undesirable since it leads to discharge energy loss and sputter erosion on surface

To obtain efficiency curve, each term on right hand side of equation must be given as a function of propellant utilization efficiency.

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2022104050

***Development and Characterization of a Miniature Hall-Effect Thruster using Permanent Magnets
IEPC-2019-634***

Provides an idea of the design of a small scale hall thruster with permanent magnets. Main content is the inability to vary the magnetic field due to the use of permanent magnetic field. As a measure to address this concern they have used a magnetic shunt. This magnetic shunt works in such a way that when it is moved over the outer pole piece, the peak flux density decreases. Hence this facility can be used to vary the magnetic field strength while using a permanent magnet. The advantages of using a permanent magnet is the reduction of weight and the size of the thruster.

The disadvantages of a small scale thruster is that due to its decreased surface to volume ratio, power losses to the channel walls due to electron bombardment is increased. Reducing its lifetime by eroding the channel walls. This issue is addressed by modifying the magnetic circuit design such that the thruster is magnetically shielded. This magnetic shielding aligns the magnetic field lines tangentially to the walls, reducing energy losses and extending lifetime by 10–100 times.

Inferences:

- 1) We can consider the use of permanent magnets for the generation of the radial magnetic field necessary .
- 2) Or even if we use electromagnets, we can still employ the magnetic shielding design which can be used to reduce the electron bombardment with the channel walls, increasing the efficiency of our thruster even more.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056; p-ISSN: 2395-0072

This paper mostly contained the basic principles of Hall Effect Thrusters, and it explained the two types commonly used:

- 1) Stationary Plasma Thruster (SPT),
- 2) Anode Layer Thruster (TAL)

The design parameter in which I gained some idea about is the Generation of radial magnetic field

The radial magnetic field is set up to hold the electrons from the cathode to make them rotate near the exit of the coaxial acceleration channel. These trapped electrons act as a volumetric zone of ionization for the neutral propellant atoms.

Inferences:

Generation of the radial magnetic field:

- *For this purpose, two permanent magnets or two electromagnets (coils) are to be used.
- *One acts as the inner magnet and the other acts as the outer magnet.
- *The inner magnet is placed at the center, typically ring or cylindrical in shape.
- *The outer magnet is placed in the outer region mostly in the shape of a ring.

*The polarity of these two magnets are decided such that their magnetic field lines are in the opposite direction which leads to the resultant magnetic field being radial.

*The magnitude of the radial magnetic field is 100-200G (where 1T= 10000G, meaning 0.01 - 0.02 T is enough)

*The lower value of magnetic field is because this value is sufficient to trap the electrons without holding the ions (which are heavier) that provide the needed thrust

Procedure to attain the required magnetic field strength to be analyzed, the magnetic field strength can be varied in a simulation to check for any improvements in efficiency.

International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653

Designing of Light Weight Hall Thrusters with Key Discharge Parameters

Gathered the key parameters to be tested for testing the efficiency of the design.

Parameters defining the thrusters initial design are : Thrust, Specific impulse, and power

Inferences:

The main parameters that affect the thrusters overall efficiency:

- 1) Discharge voltage
- 2) Propellant mass flow rate
- 3) Magnetic field strength

Discharge voltage: It is the voltage applied to the thruster for generating the axial electric field. Higher discharge voltage increases the electric field strength which in turn can increase the speed at which thruster pushes out the ions (which are then neutralized), increasing thrust. Higher discharge voltage increases the ionization rate which may cause losses at the channel wall, and as stated earlier this can be rectified by using the shielding design mentioned in the first inference.

Propellant mass flow rate: It determines the number of propellant atoms present within the thruster channel for ionization. With more propellant flowing through the thruster, there are more atoms in the channel. This makes it easier for electrons to collide with them, which helps increase ionization rates. However, if the mass flow rate gets too high, there might not be enough electrons to ionize all the propellant atoms. This can end up lowering the overall ionization efficiency.

Magnetic field strength: If we use permanent magnets then this parameter may not come into picture, but when we use electromagnetic coils this is a main parameter. The strength of the magnetic field affects how electrons move inside the thruster's discharge channel. A stronger magnetic field keeps the electrons more tightly confined, improving ionization efficiency and helping to keep them away from the thruster walls. However, excess magnetic field strength also has several drawbacks. Reduced electron mobility and limited ion acceleration. If the magnetic field is too strong the electrons may not be able to move much decreasing the ionization rates. As the magnetic field strength increases, the ions being heavier, may still be affected and held back, while they were not affected by the magnetic field previously.

Two more research papers were also referred, but they didn't provide any significant details other than the already stated ones.

NAME : VEDA VARSHINI R

MECHANICAL 2ND YEAR

ROLL NO: 2023111031

REPORT FOR RESEARCH PROJECT –HALL EFFECT THRUSTER

Advantages of HETs:

- Plasma in HETs is quasineutral, avoiding thrust density limits of ion thrusters.
- HETs can achieve higher thrust than gridded ion thrusters.

Working Principle:

- Neutral propellant is released into an annular channel.
- A radial magnetic field traps free electrons, which collide with the propellant, generating positive ions.
- Positive ions are accelerated out by an electric field, forming a high-speed plasma plume.
- Additional electrons neutralize the plasma plume.

Key Design Areas:

- **Magnetic Field:** Influences electron trapping and plasma generation.
- **Channel Dimensions:** Affects plasma production and collision rates.
- **Anode and Electric Field:** Critical for ion acceleration.
- **Cathode:** Supplies initial high-energy electrons for thruster ignition.
- **Materials:** Impact performance, durability, and resistance to erosion, cracking, or demagnetization.

Focus on HETs:

- Their ability to produce higher thrusts compared to other ion thrusters makes them a preferred choice.

Magnetic Field Constraints in Hall Effect Thrusters

The magnetic field in Hall Effect Thrusters must meet the following key requirements to ensure efficient operation:

1. **Radial Field:**
The field should primarily be radial. A strong radial field, combined with the axial electric field, traps electrons inside the channel by making them drift in circular paths. If the radial field is too weak, electrons will quickly move toward the anode and reduce the ability to ionize the propellant.
2. **Peak at the Exit Plane:**
The magnetic field should be strongest near the channel's exit. This ensures that electrons are concentrated at the right location, where they collide with the propellant to produce ions. If the field strength is spread out or peaks in the wrong place, there won't be enough collisions to create ions effectively.
3. **Strong Enough to Trap Electrons:**
The field needs to be strong enough to keep electrons in the ionization region. If it's too weak, energetic electrons can escape and hit the channel walls, reducing the number of electrons available to ionize the propellant.

4. **Weak Enough to Let Ions Escape:**

While trapping electrons, the field must not trap ions. It needs to be weak enough so that ions can move freely out of the thruster to generate thrust. If the field is too strong, ions will get stuck in the channel, and the thruster won't produce thrust.

This balance ensures that electrons stay where they're needed for ionization, and ions are free to accelerate out and produce thrust.

Achieving Magnetic Field Constraints

To ensure a radial magnetic field that peaks near the exit plane (constraints 1 and 2), three common methods are:

1. **Electromagnets:** Effective but have high current requirements.
2. **Radially-Aligned Permanent Magnets:** Effective but expensive.
3. **Axially-Aligned Permanent Magnets with a Magnetic Shunt:** A cost-effective method that uses a ferromagnetic shunt to guide the magnetic field into the desired configuration.

Design Choice: Magnetic Shunt

- A non-magnetic shunt becomes ferromagnetic when influenced by permanent magnets, shaping the field to be radial and peaking near the exit plane.
- The shunt geometry draws the magnetic field through the channel's outer edge and into the inner core, achieving the desired field shape.

Magnetic Field Simulation and Testing

- **Simulation Tool:** COMSOL Multiphysics software was used to model the magnetic field.
- **Magnet Configuration:** Six cylindrical magnets (6.35 mm diameter, 3.18 mm thickness, 10.4 kG magnetization) were chosen based on simulations.
- **Predicted Field Strength:** The model estimated a peak field strength of 28.0 mT in the channel
- **Measured Field Strength:** A Hall probe measured the actual strength at 22.5–25.6 mT, confirming the design's reliability.

This approach balanced cost and performance while ensuring that the magnetic field met the necessary constraints for effective thruster operation.

Cross-Section of the Magnetic Shunt

- **Components:**
 - **Iron Shunt:** Shown in red, responsible for guiding the magnetic field.
 - **SmCo Disk Magnets:** Shown in green, provide the magnetic field.
 - **Aluminum Retaining Ring:** Shown in yellow, holds the structure together.

Meeting Magnetic Field Constraints 3 and 4

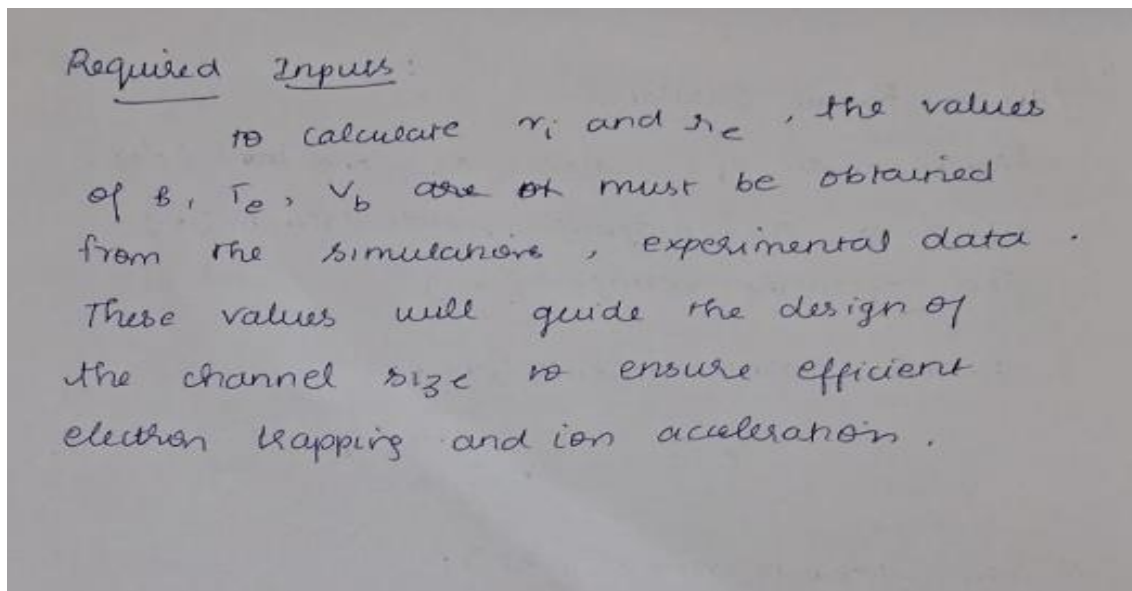
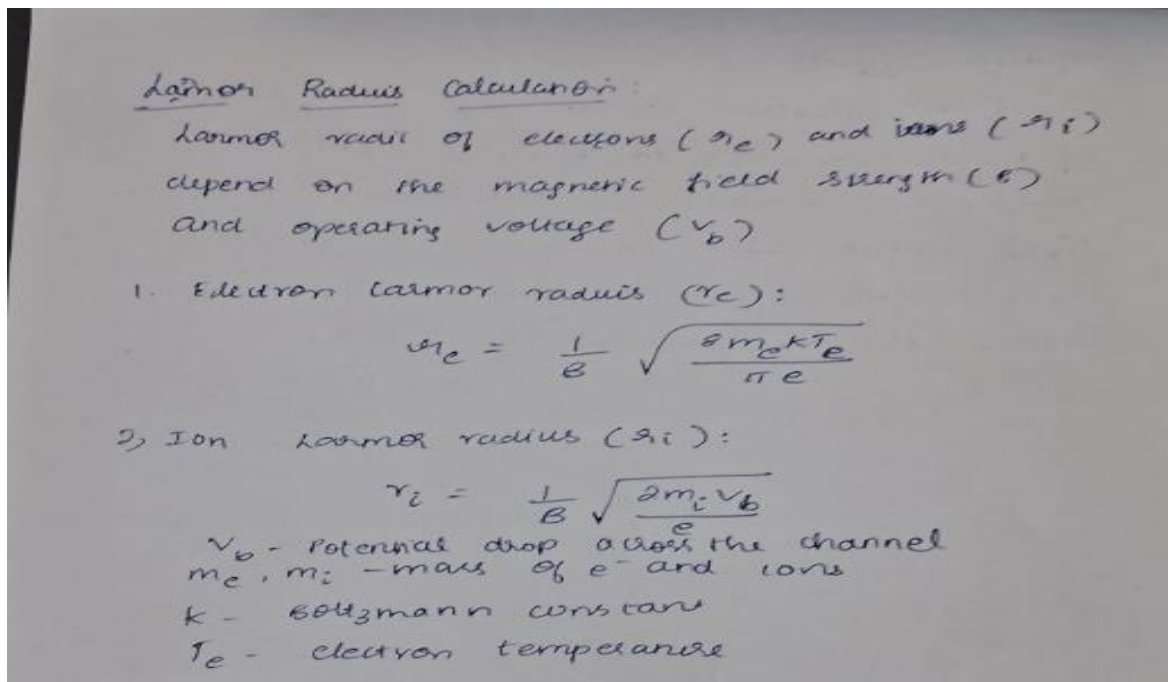
Constraint 3: The magnetic field must trap electrons.

Constraint 4: The magnetic field must allow ions to escape.

These constraints are addressed by:

- **Fixing the Anode Voltage:** Controls the energy of ions.

- **Sizing the Channel:** Ensures it fits between the electron and ion Larmor radii.



conclusion

The Larmor radius formulas provide a critical framework for designing the magnetic field and channel dimensions in a Hall Effect Thruster. By obtaining accurate values for the magnetic field strength, electron temperature, and potential drop, the channel can be appropriately sized to balance efficient electron trapping and ion acceleration. These calculations form the foundation for ensuring the thruster operates effectively while meeting practical manufacturing constraints.

CTF RESEARCH REPORT

ELECTRIC PROPULSION SYSTEM

TEAM MEMEBER: MADHAN R

BASIC PRINCIPLE OF HALL EFFECT THRUSTER

The Hall Effect Thruster (HET) operates on the principle of using a magnetic field and electric field to ionize and accelerate a propellant, generating thrust.

1. Ionization of Propellant:

A neutral gas, commonly xenon, is used as the propellant. The gas is injected into the thruster's discharge chamber.

2. Electric Field:

A high electric potential is applied between an anode (inside the chamber) and a cathode (outside the chamber). The electric field accelerates electrons from the cathode toward the anode.

3. Magnetic Field and Hall Effect:

A strong magnetic field, perpendicular to the electric field, is created near the chamber exit using electromagnets. The magnetic field traps electrons, forcing them to spiral around magnetic field lines (Hall Effect). This increases the probability of collisions between electrons and propellant atoms, leading to ionization.

4. Acceleration of Ions:

The newly created positive ions are accelerated by the electric field, exiting the thruster at high velocity to produce thrust. Neutralizing electrons from the cathode are introduced to balance the charge of the ion beam.

DESIGNING OF LIGHT WEIGHT HALL EFFECT THRUSTER WITH KEY DESIGN PARAMETER

We referred to a research paper which conducted study was to design and fabricate a light-weight Hall thruster with all key discharge parameters. Hall thrusters are firmly used as the primary electric propulsion in the current field of space propulsion. The concepts of electric and magnetic fields are studied to improve the thrust and specific impulse of the light-weight Hall thruster. This model is intended to work within a range for certain near-Earth missions. The Hall thruster is designed in CAD software with all the required parts, dimensions and the materials that had to be used for its lightweight consideration.

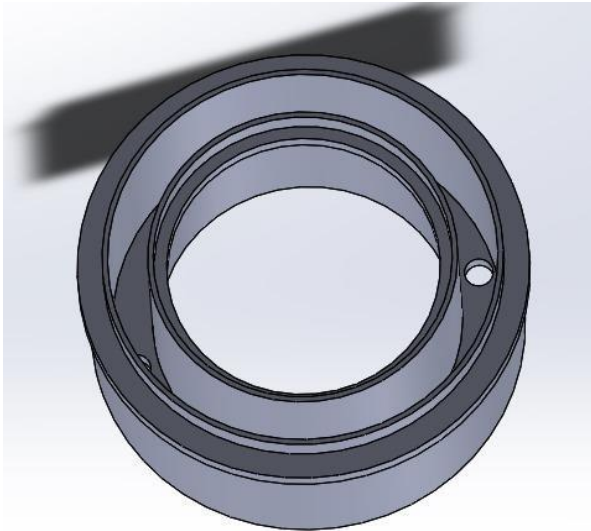
MAJOR PARTS FOR DESIGNING HALL THRUSTER

- Channel
- Bottom core
- Front core
- Anode channel
- Anode top plate
- Outer core

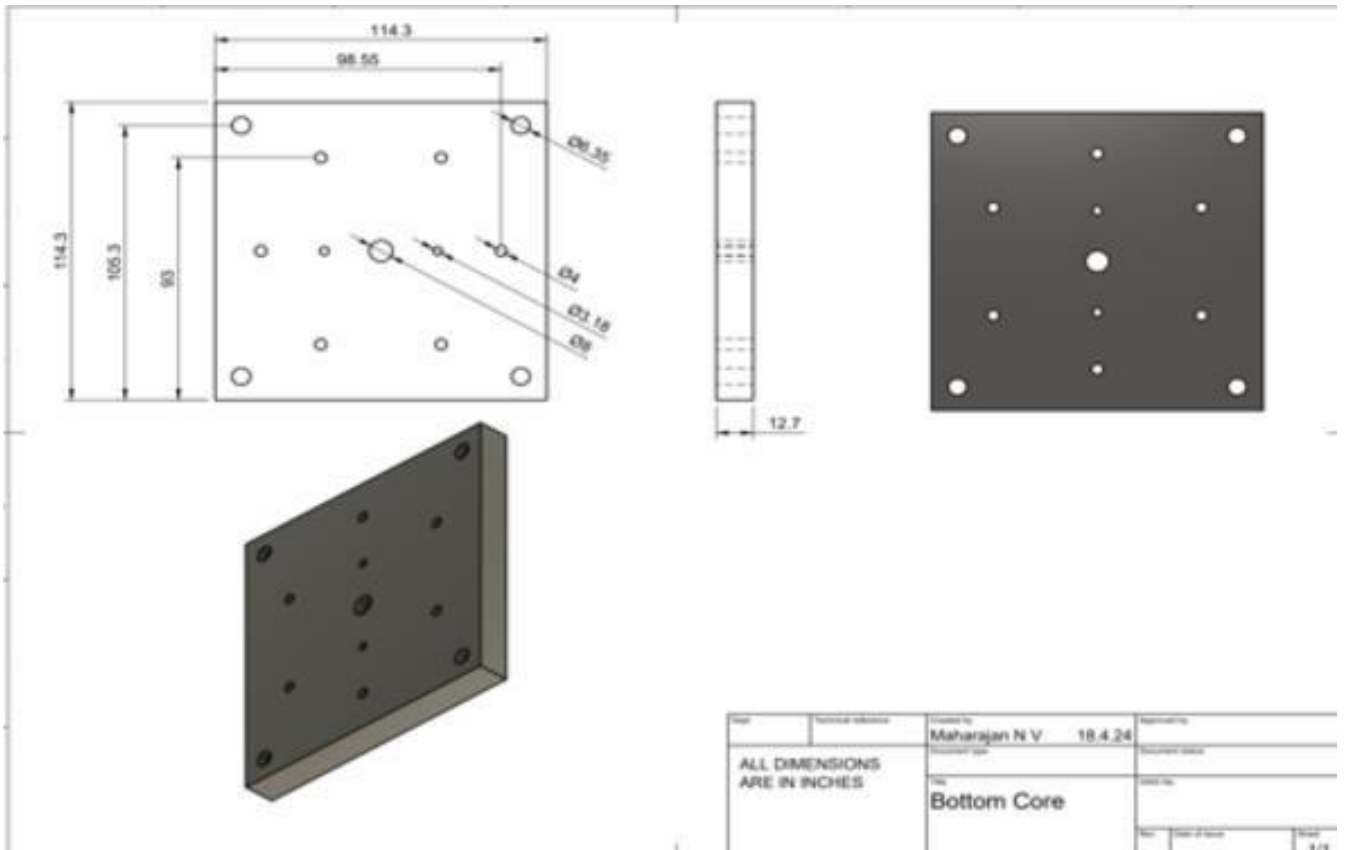
REFERENCE DRAFT AND 3D MODEL OF PARTS

1. CHANNEL

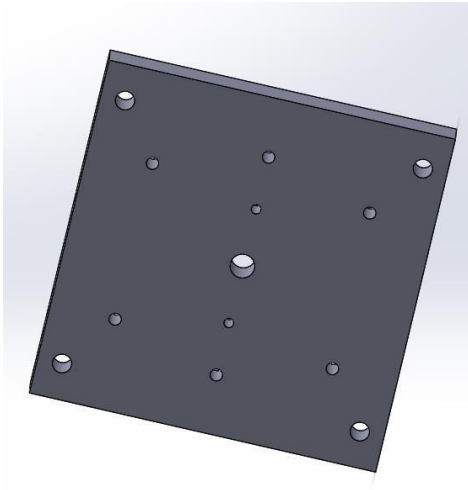




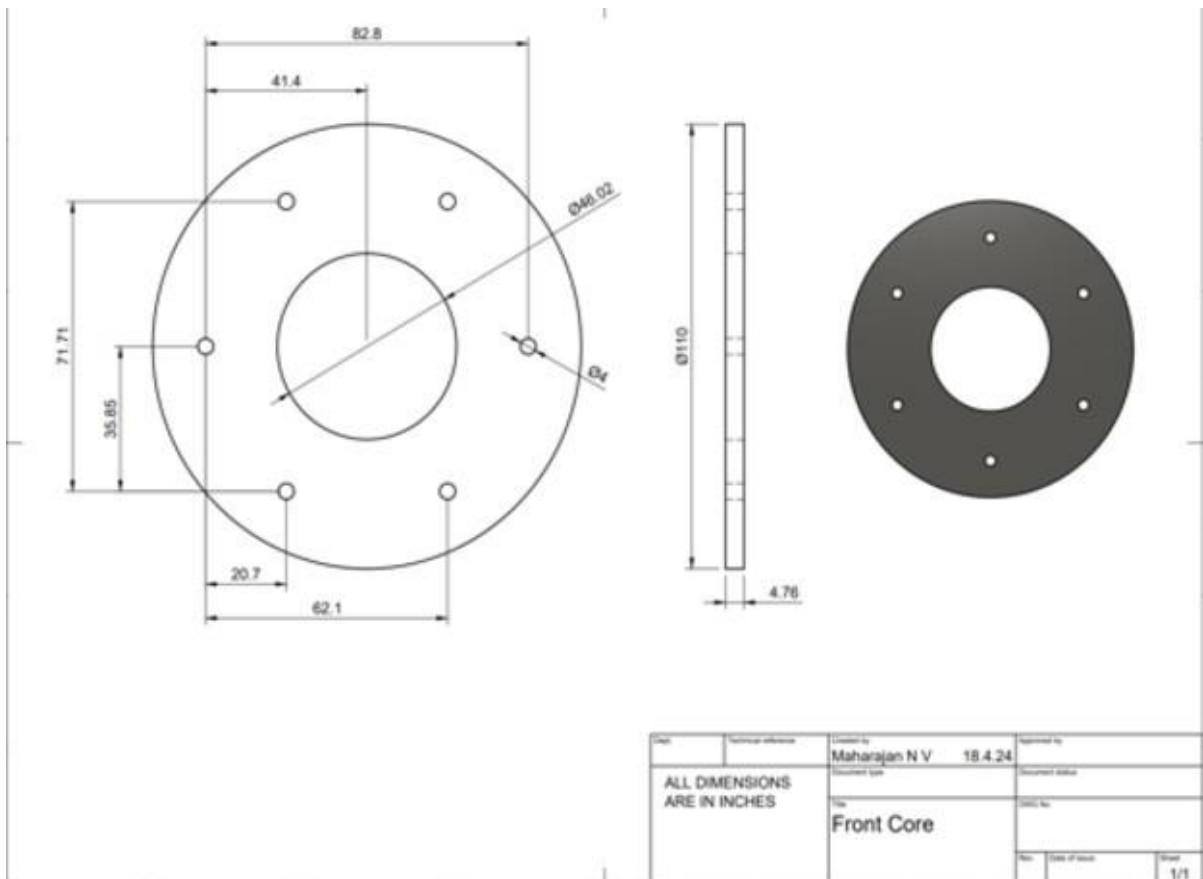
BOTTOM CORE

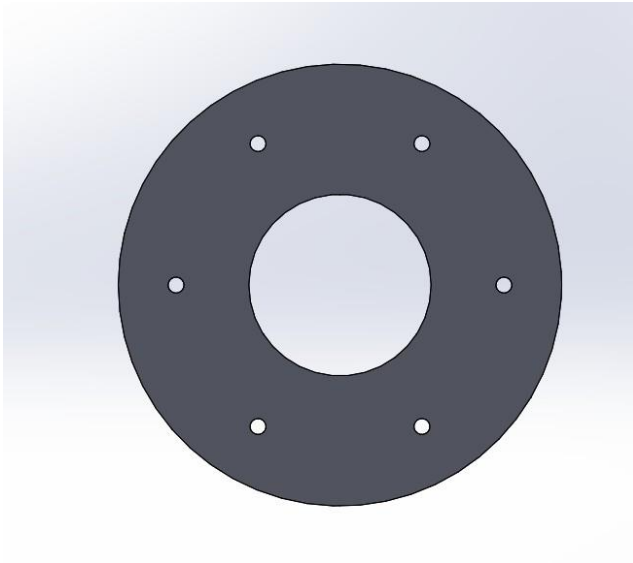


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ALL DIMENSIONS ARE IN INCHES		Document name	Document status
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		Rev.	Date of issue
			1/1

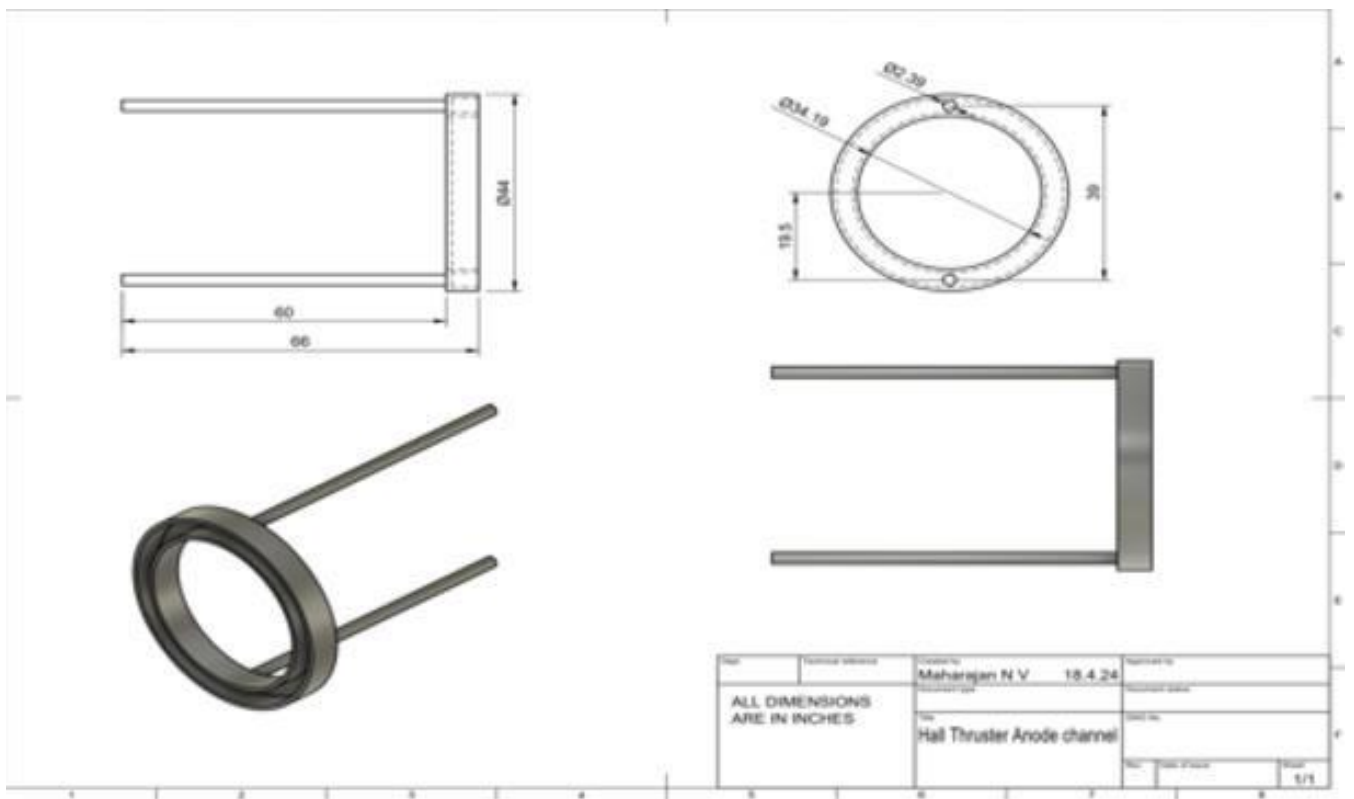


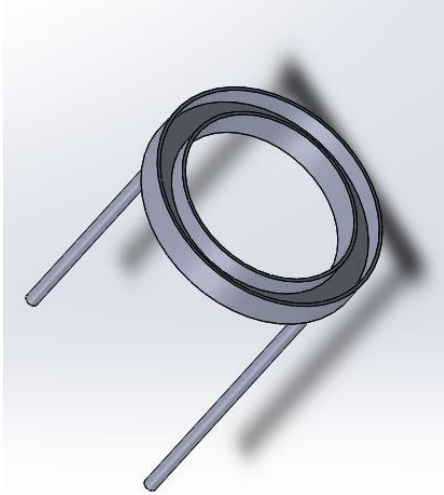
FRONT CORE



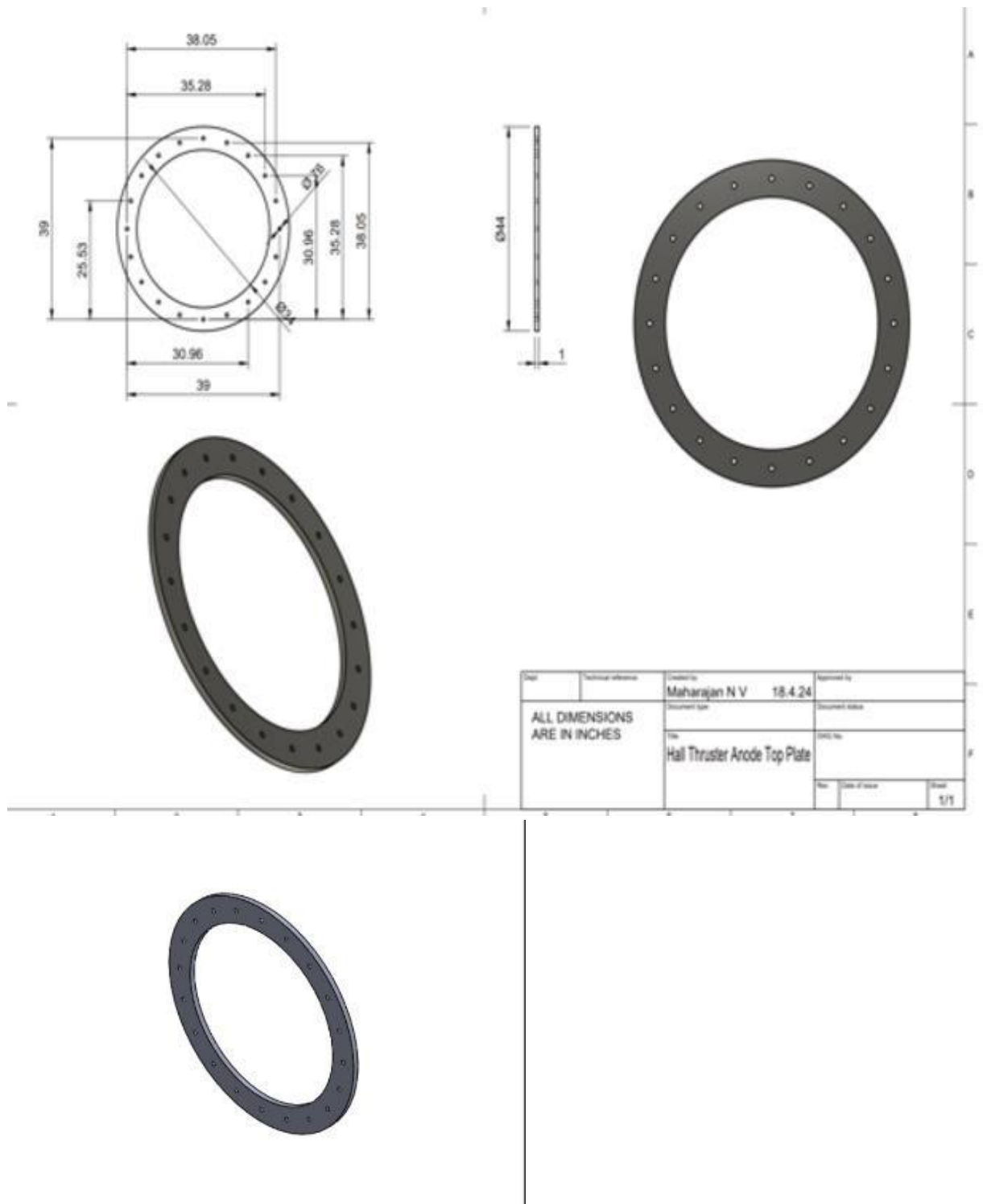


ANODE CHANNEL

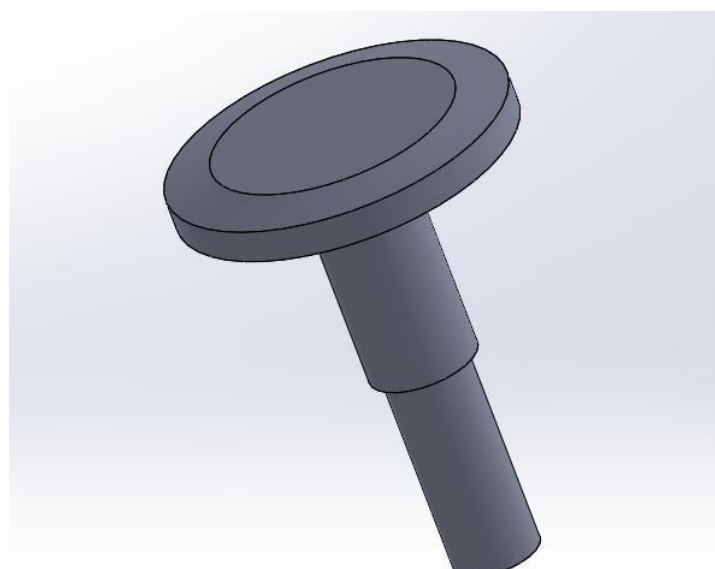
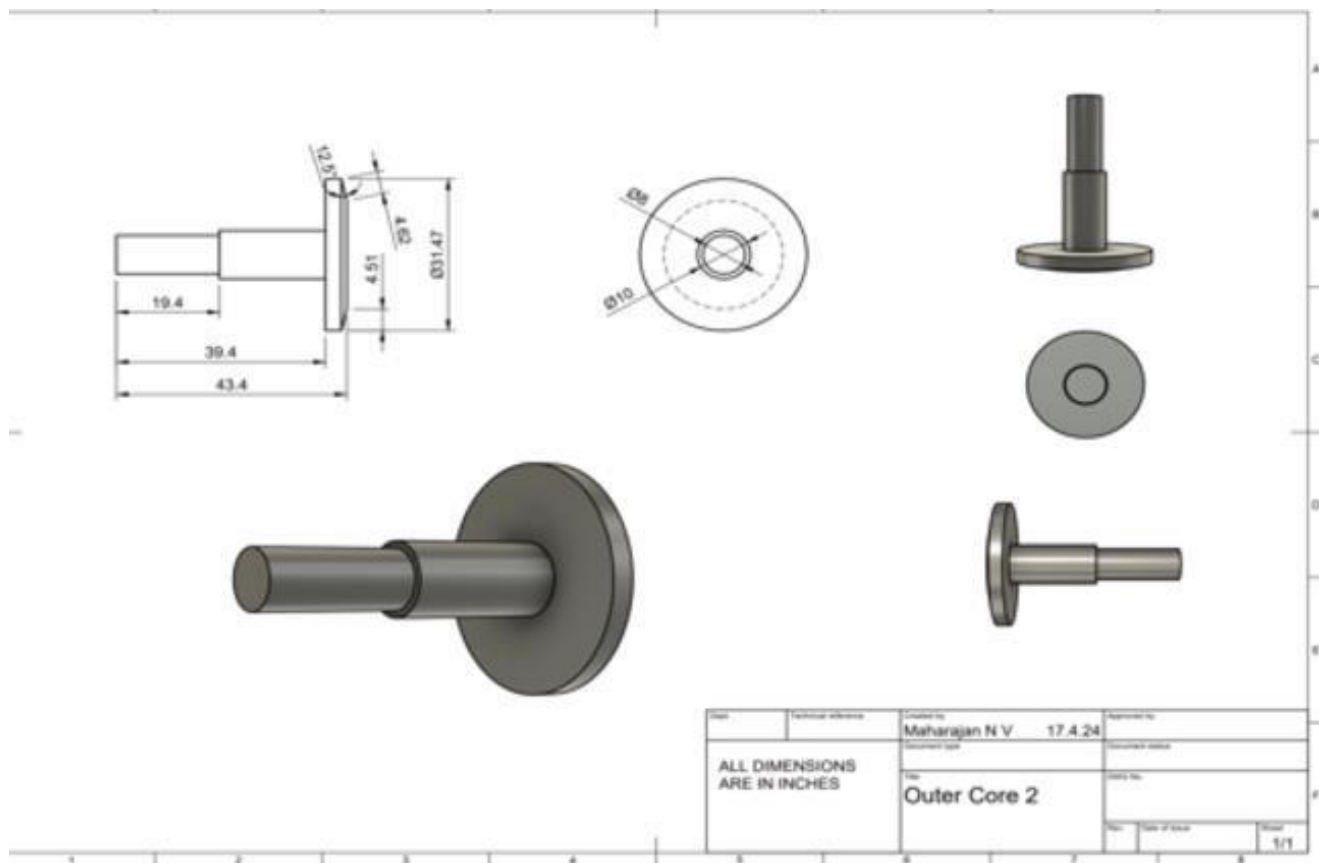


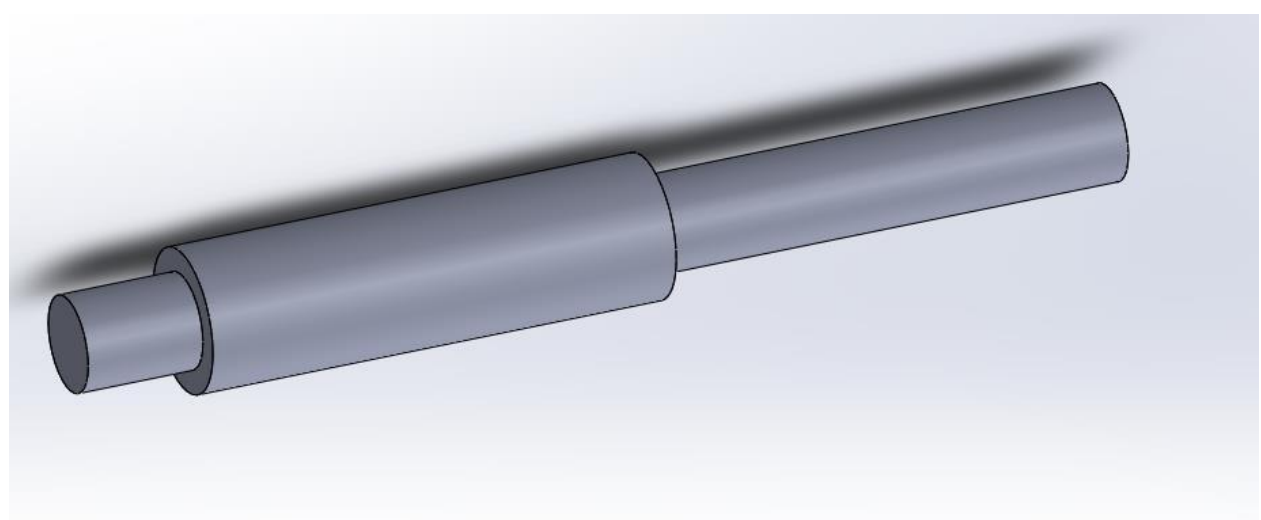
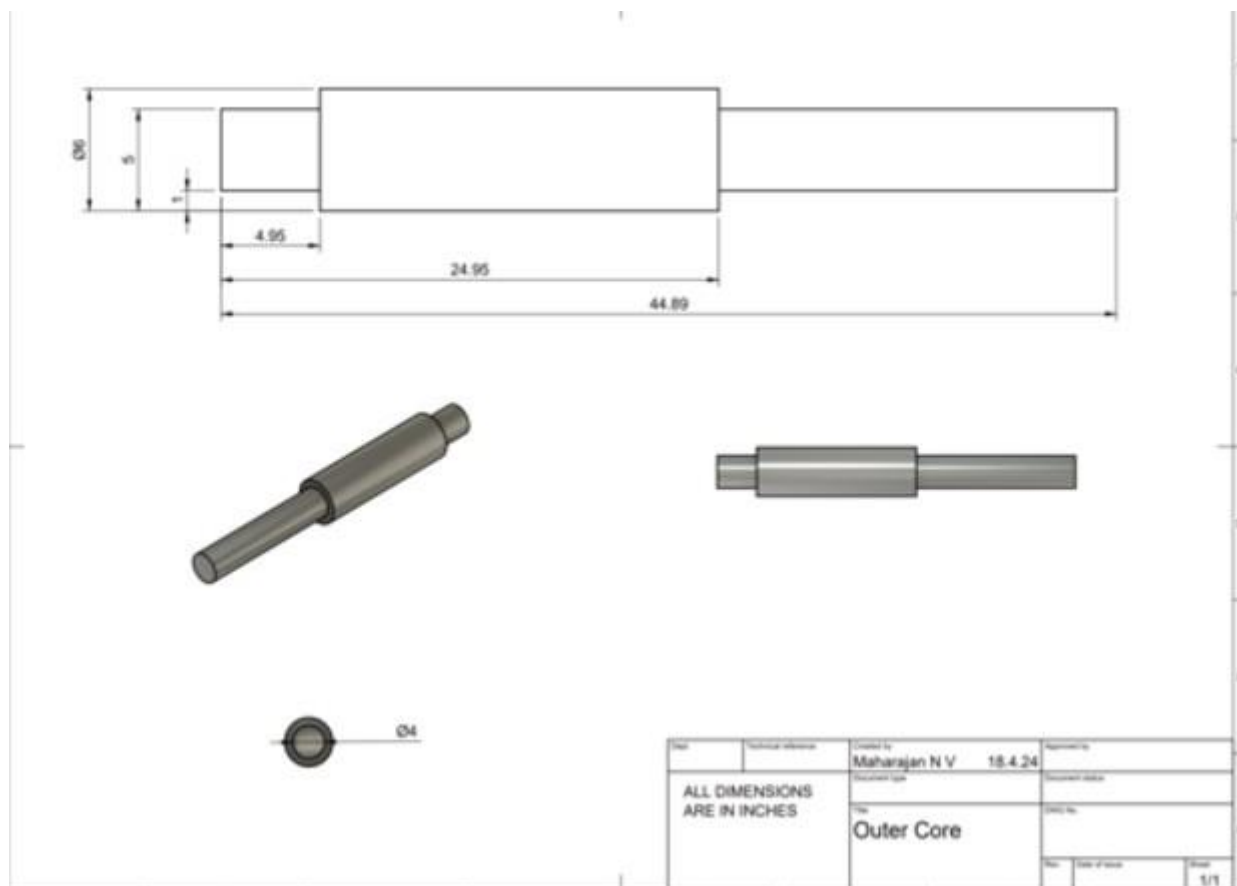


ANODE TOP PLATE



OUTTER CORE





HALL THRUSTER ASSEMBLY

