IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁓ Peer-reviewed & Refereed journal ⁓ Vol. 11, Issue 5, May 2024

DOI: 10.17148/IARJSET.2024.11514

Literature study and design of self- propelling wing

Prof. Prabhu Jadhav[1], Nithishkumar S[2], Praveen HG[3], Mohammad Faizulla[4], Vikram Pradeep Naik[5]

Assistant Professor, Department of Aeronautical Engineering, East West College of Engineering, Bangalore, India[1]

Students, Department of Aeronautical Engineering, East West College of Engineering, Bangalore, India[2-5]

Abstract: This project aims to design a self-propelling ionic thrust wing, combining aerodynamics and ionic propulsion technology. The system utilizes ionized particles for propulsion, generating thrust by interacting with a charged grid. The wings design incorporates lightweight materials and aerodynamic principles to optimize lift and efficiency. The integration of advanced control systems ensures stable flight, while the ionic thrusters provide a clean and efficient means of propulsion. This innovative approach holds potential for unmanned aerial vehicles with extended flight endurance and reduced environmental impact. The system utilizes a compact and efficient propulsion mechanism to generate thrust. The design also focuses on optimizing weight distribution, control systems and propulsion efficiency to achieve stable and agile flight.

Keywords: Self-Propelling, Wing, Propulsion, Aerodynamic, Efficiency, Unmanned Aerial Vehicle, Endurance, Environmental Impact.

I. INTRODUCTION

The first use of solar-electric propulsion (SEP) on a deep space mission began with the launch of the Deep Space 1 (DS1) spacecraft on October 28, 1998. This marks a milestone in the development of advanced propulsion for deep-space missions.

The DS1 spacecraft uses a single xenon-ion engine, provided by the NASA Solar electric propulsion Technology Applications Readiness (NSTAR) project, as the primary onboard propulsion system. This propulsion system is designed to deliver a total ΔV of 4.5 km/s to DS1 while using only 81 kg of xenon.

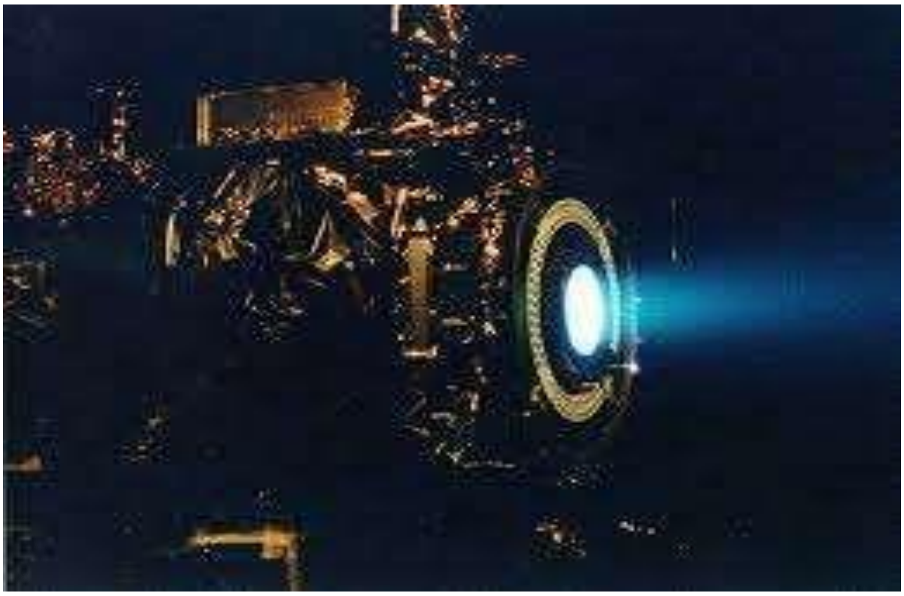


Fig 1 ; NSTAR Ion Thruster

In comparison to traditional aviation propellers (piston engines and jet engines), ion propellers have the following advantages:

(1) simple structure with no moving parts, long fatigue life,
(2) ultra-quiet flight and reduced noise pollution and
(3) zero fossil fuel combustion

An ion thruster, ion drive, or ion engine is a form of electric propulsion used for spacecraft propulsion. It creates thrust by accelerating ions using electricity. An ion thruster ionizes a neutral gas by extracting some electrons out of atoms, creating a cloud of positive ions. Ion thrusters use beams of ions (electrically charged atoms or molecules) to create thrust in accordance with momentum conservation. Ion thrusters are categorized as either electrostatic or electromagnetic. The main difference is the method of accelerating the ions. Electrostatic ion thrusters use the Coulomb force and accelerate the ions in the direction of the electric field. Electromagnetic ion thrusters use the Lorentz force to accelerate the ions in the direction perpendicular to the electric field.

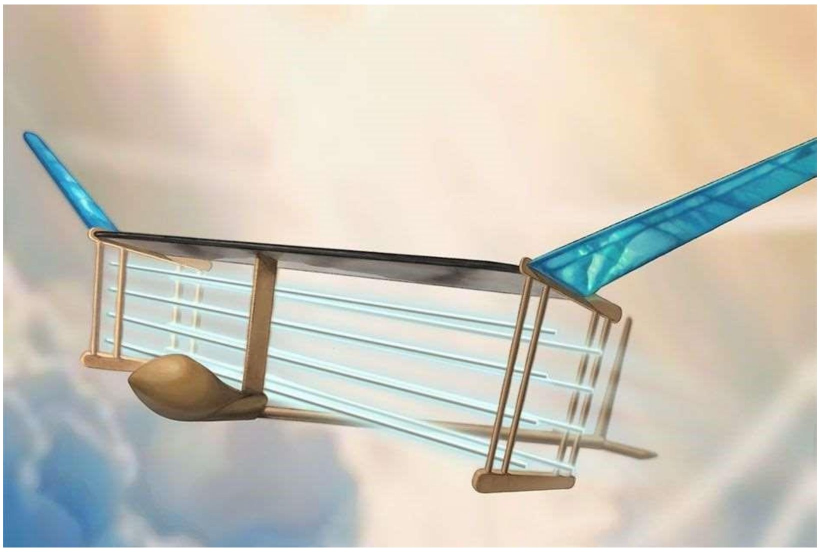


Fig. 2 First ever plane with no moving parts.

Identifying challenges

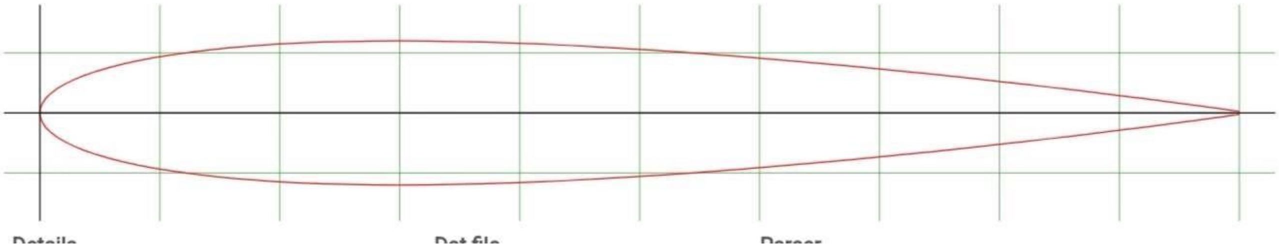
1. Ionic thrusters require a significant amount of electrical power to operate. This power is often provided by solar panels, limiting their effectiveness in locations where sunlight is limited.
2. ionic propulsion systems are complex and can be more difficult to design, build, and maintain compared to traditional chemical rocket systems. The ionization and acceleration processes involve intricate components.
3. Ion thrusters generate heat during operation, and effective thermal management is crucial to prevent overheating of the components. This adds complexity to the overall design.
4. The ionized propellant expelled by ion thrusters can interact with the surrounding space environment, potentially leading to issues such as spacecraft charging and electromagnetic interference
5. Ion thrusters produce low thrust when compared to traditional chemical rocket systems.

Main objectives are

1. Cost effective manufacturing making it easily available.
2. Designing a self-propelling wing through electrode ion thruster technique
3. Compact and lightweight design making it suitable for unmanned aerial vehicles.
4. Precise control which involves creating technologies for adjusting ion thrust levels.
5. Cost effective manufacturing making it easily available.

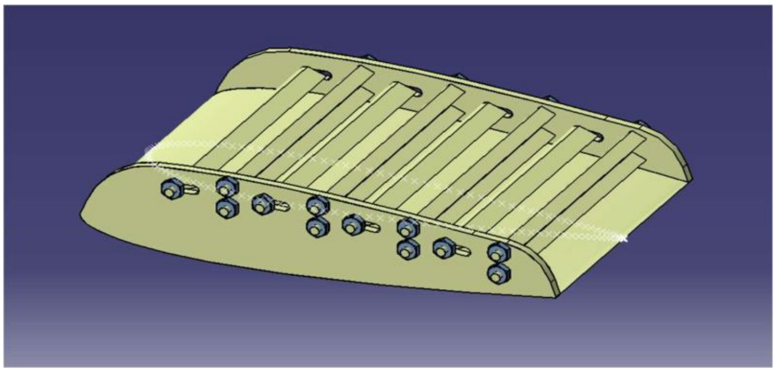
Selection of Air foil

THE NACA 0012 AIRFOIL IS WIDELY USED IN VARIOUS APPLICATIONS. IT FEATURES A SYMMETRIC PROFILE WITH A CAMBER OF 0% AND THICKNESS TO CHORD RATIO OF 12%. THIS AIRFOIL OFFERS RELATIVELY LOW DRAG AND GOOD LIFT CHARACTERISTICS, MAKING IT SUITABLE FOR MANY PURPOSES.



It offers relatively low drag characteristics at moderate lift coefficients, which is advantageous for applications where efficiency is crucial, such as in general aviation or unmanned aerial vehicles. Its symmetric shape provides inherent stability, making it suitable for applications where predictable aerodynamic behaviour is essential.

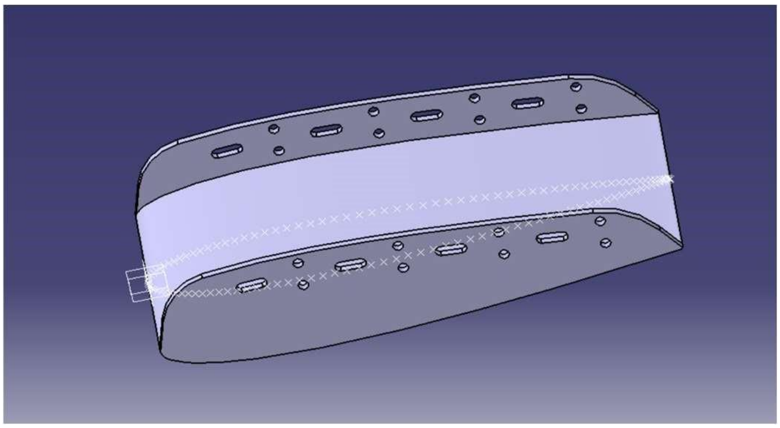
Design concepts of self-propelling wing
For self-propelling wing we have the designs of wing body along with positive and negative electrodes



Fig; 3D Catia model

1. Wing Body

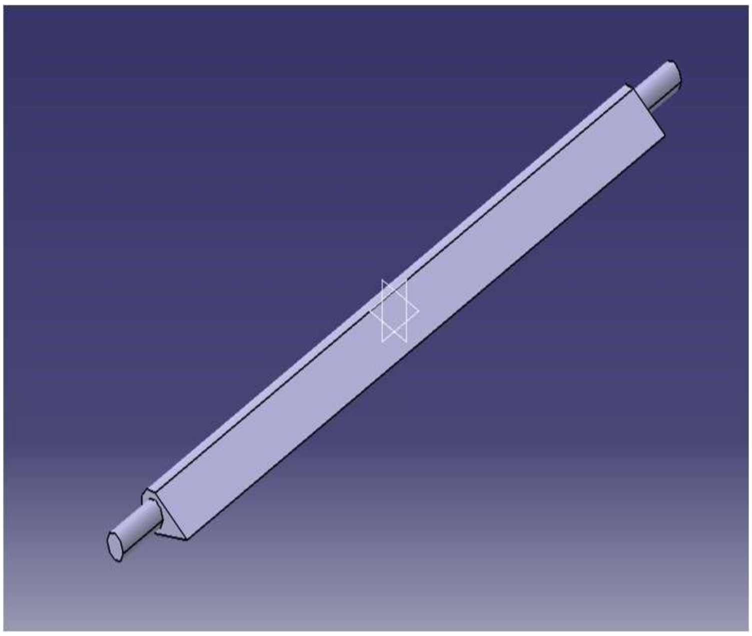
The self-propelling wing body, meticulously crafted with precise dimensions, showcases the culmination of aerodynamic engineering, offering unparalleled efficiency and manoeuvrability in flight. Its innovative design seamlessly integrates propulsion systems with aerodynamic surfaces, revolutionizing aerial dynamics.



Chord Length	100mm
Quantity	1
Air foil	60mm
Width	64mm
Side wall thickness	2mm
Diameter of the hole	2mm
Side wall height	9.5mm

2. Positive electrode

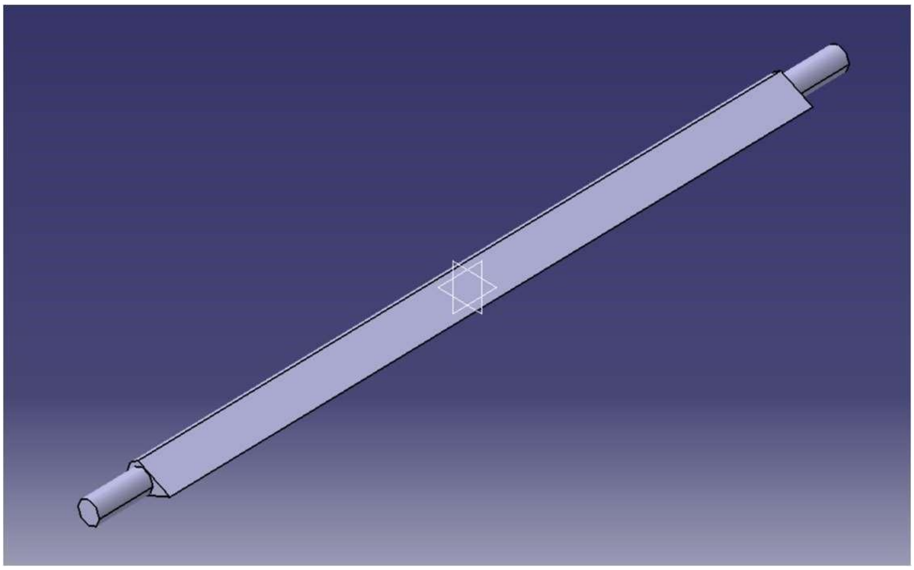
The self-propelling positive electrode, engineered with meticulous attention to specific dimensions, enhances the efficiency and longevity of energy storage systems. Its tailored design optimizes ion flow and electron transfer, maximizing the performance and reliability of battery technology.



Quantity	4
Length	5.784mm
Width	60mm
Diameter	3.036mm
Diameter of the thread	2mm

3. Negative electrode

The self-propelling negative electrode, precision-crafted with exacting dimensions, augments the energy density and charge-discharge capabilities of batteries. Through tailored geometry and material composition, it enables enhanced electron mobility and ion diffusion, driving advancements in energy storage technology.



Quantity	4
Length	4.728mm
Width	60mm
Diameter	2.7mm
Diameter of the thread	2mm

Material selection

PURE NYLON

Nylon is known for its high tensile strength, making it strong and durable. It is often used in applications that require a material to withstand significant stress or impact. It is flexible and resilient, which allows it to bend and deform without breaking.

Nylon has a low coefficient of friction, which means it has good lubricity . It has good thermal properties, including a high melting point and resistance to heat. This makes it suitable for use in high temperature applications.

Density	1.15 g/cm3
Electrical conductivity	10-12 S/m
thermal conductivity	0.25 W/(m-K)
Melting point	190 – 3500C
Modulus of elasticity	2.7 GPa
Creep strength	6 – 24 MPa
Shear strength	44.8 – 75.8 MPa
Coefficient of friction	0.04 – 0.6
Hardness, Rockwell M	80 - 88

II. LITERATURE REVIEW

A Title: Electric Propulsion System-Ion Thruster.
Author: Akshat Mohite1, Akhilesh Desai2A.P. Shah Institute of Technology, Maharashtra, Hyderabad, INDIA.

Ion thrusters have emerged as a highly efficient alternative to traditional propulsion systems, characterized by low fuel demand and high specific impulse. Despite their lower thrust output, ion thrusters find applications in various missions, such as geostationary satellite station keeping, orbit and attitude control, and multi-goal endeavours. The technology enables cost effective and faster space exploration, aligning with the strategic goals of space agencies like NASA. The paper offers a comprehensive review of electric propulsion systems, with a specific focus on ion thrusters. The introduction outlines the appeal of ion propulsion for interplanetary travel, combining efficient fuel usage and electric power. The underlying physics involves Newton's Third Law, with ion propulsion relying on the expulsion of mass to generate thrust. The advantages of ion propulsion are discussed, emphasizing its approximately tenfold efficiency compared to traditional chemical propellants. Ion thrusters utilize xenon propellant particles ejected at high speeds (20-50 km/s), requiring relatively small electric power, typically a few kilowatts. NSTAR, an electrostatic ion thruster, operates at critical conditions and offers low thrust ideal for long missions and their role in advancing propulsion technology.

B. Electric Propulsion Using Ion-Ion Plasmas.
Author: Ane Anniesland, Albert Meige and Pascal Chabert Laboratories' de Physique et Technologies des Plasmas, Ecole Polytechnique, 91128 Palais au, France.

The scientific history of space propulsion and exploration traces back to the early 20th century, led by pioneers like Robert H. Goddard, Konstantin E. Tsiolkovsky, and Hermann J. Oberth. Theoretical works by these visionaries laid the foundation for modern spaceflight principles. Tsiolkovsky's rocket equation, derived in 1903, remains a crucial equation for space scientists today. Traditional chemical rockets achieve high thrust but are fuel intensive. To address this, electric propulsion has gained popularity due to its higher exhaust velocities, reducing propellant consumption. Gridded thrusters (ion engines) and Hall effect thrusters are existing electric propulsion systems, but concerns about the plasma plume's effects on spacecraft components persist. A novel concept, the PEGASES thruster (Plasma propulsion with Electronegative GASES), explores ion-ion plasmas for propulsion. Using electronegative gases like iodine, this concept aims to create high-density plasmas without the need for downstream neutralizers. Iodine, despite its corrosiveness, presents itself as a costeffective propellant for ion-ion plasmas. Efficiency challenges in ionion plasmas include creating and maintaining high density plasmas.

C. Development Status of The NASA 30-cm Ion Thruster and Power Processor.
Author: James S. Sovey, Thomas W. Haag, John A. Hamley, Maris A.
Mantenieks, Michael 1. Patterson, Luis R. Pinero, and Vincent K. Rawlin NASA Lewis Research Centre Cleveland, Ohio
The paper discusses the development of xenon ion propulsion systems for both small-body planetary and Earth-orbital missions, with a focus on the NASA Solar Electric Propulsion Technology Applications Readiness (NSTAR) program. The ion propulsion systems are intended to provide significant advantages over traditional chemical propulsion systems, offering shorter mission times and increased payload capacity.

For small-body planetary missions, such as rendezvous with asteroids and comets, solar electric ion propulsion is shown to reduce trip times by approximately 2 times compared to chemical propulsion, leading to significant cost savings in mission operations. The paper outlines the requirements for near-term missions, including the need for a power capability of 10 to 14 kW and the use of 250 to 350 kg of xenon propellant. The NSTAR program aims to demonstrate thrust subsystem life and reliability through ground tests and a flight demonstration in Earth orbit. The program includes the development of engineering model ion thrusters and breadboard power processors. The paper provides details on the ion thruster development, including the design and testing of a 30 cm diameter xenon ion thruster with throttleable capabilities.

D. Ion Propulsion System (NSTAR) DS1 Technology Validation Report
Author: John R. Brophy, Roy Y. Kakuda, James E. Polk, John R. Anderson, Michael G. Marcucci, David Brinza, Michael D. Henry, Kenneth K. Fujii, Kamesh R. Mantha, John F. Stocky, (Jet Propulsion Laboratory California Institute of Technology Pasadena, California).

The Deep Space 1 (DS1) spacecraft utilized a xenon ion propulsion system provided by the NASA Solar Electric Propulsion Technology Applications Readiness (NSTAR) project. The technology-validation process involved addressing key risks through ground testing and the DS1 flight. Risks included engine life, guidance, navigation and control (GN&C), mission operation costs, spacecraft contamination, impacts on science instruments and communication, and electromagnetic compatibility (EMC). The NSTAR project successfully validated the ion propulsion technology by demonstrating sufficient engine life through ground and flight tests. The ground test program included engineering model thrusters, with an 8000-hour life test achieving historic results. The flight test on DS1 addressed integration, compatibility, and operational issues associated with deep space missions using solarelectric propulsion (SEP). Results from ground tests validated design .

E. Static Aeroelasticity of The Propulsion System of Ion Propulsion Unmanned Aerial Vehicles.
Author: Shuai Hao, Tielin Ma, She Chen, Hongzhong Ma, Jinwu Xiang, Fangxiang Ouyang, (School of Aeronautic Science and Engineering, Beijing University, Beijing 100191, China)
In this study, the authors analyse the thrust characteristics and static aeroelastic properties of "ionic wind" propulsion systems used in ion propulsion unmanned aerial vehicles (UAVs). The electrode array in the propulsion system is prone to deformation under flight loads due to its large size and poor stiffness. The researchers establish a simulation model coupling a two-dimensional gas discharge model with a gas dynamics model to investigate the impact of electrode voltage, spacing, size, and shape on the propulsion system's performance. The study reveals that factors such as operating voltage, electrode spacing, and emitter radius significantly influence the thrust of the propulsion system. While the system contributes minimally to lift, it has a substantial impact on drag. In the elastic state, the propulsion system generates an upward moment around the centre of mass, influencing the pitching moment derivative of the entire aircraft. After elastic deformation, the thrust action point shifts upward, resulting in reduced lift related pitching moments.

III. CONCLUSION

The integration of self-propelling wing bodies with meticulously designed positive and negative electrodes, each tailored to exact specifications, represents a leap forward in aerospace and energy storage technology. This convergence of precision engineering not only enhances flight efficiency and manoeuvrability but also heralds a new era of sustainable propulsion, where even a modest thrust yields significant advancement in both aviation and battery technology. innovating beyond traditional propulsion, our self-propelling wing, integrated with precise positive and negative electrodes, redefines flight dynamics without moving parts. This breakthrough, optimizing aerodynamics and energy transfer, revolutionizes aviation with unparalleled efficiency.

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