DESIGN AND EXPERIMENTAL EVALUATION OF AN ION WING PROTOTYPE

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Abstract: *Ion propulsion, traditionally utilized for adjusting satellite and space station trajectories, also holds considerable promise for aeronautical applications. This paper explores the viability of an ionic wing designed to ionize atmospheric air using a grid-based system thus eliminating the necessity for external gases such as xenon. The proposed wing features a rectangular configuration equipped with multiple grids, enabling selective application of electrical voltage to facilitate controlled tilting and directed flight maneuvers. Preliminary propulsion calculations are presented, linking voltage requirements to achievable speeds and the resulting thrust. These findings contribute to developing an aircraft model capable of self-propulsion without reliance on fossil fuels, highlighting the potential to replace conventional kerosene-based propulsion with simpler, more cost-effective, and environmentally sustainable alternatives.*

Keywords: *Aerospace, ionic wind, ionic wing, ionic interferences*

1. INTRODUCTION

The ionic wing represents a complex propulsion system composed of multiple grid-based subsystems. Its conceptual development is grounded in both theoretical and experimental contributions of Jack Wilson (ASRC Aerospace Corporation, Cleveland, Ohio), as well as Hugh D. Perkins and William K. Thompson (Glenn Research Center, Cleveland, Ohio). The present design iteration incorporates significant optimizations that reflect a reevaluation of the classical ionic propulsion model. [1,2,3,4]

These enhancements primarily involve a reconfiguration of the emitter–collector arrangement. In the traditional setup, the ionic propulsion mechanism utilizes an electrode emitter and an electrode collector. However, in the current study, the collector has been replaced with an anodic element, transforming the system into an anode–cathode configuration. This redesign allows for the ionization process to occur over a distance that is directly proportional to the applied electric potential, thereby enabling more efficient thrust generation. [1,3]

In parallel, the Hall-effect thruster system—specifically, the low-cathode flow fraction configuration developed by Scott J. Hall, Benjamin A. Jorns, and Alec D. Gallimore—has been studied. The analytical framework of this propulsion model supports the development of the grid-type structural architecture for the ionic wing and facilitates the estimation of its power output under defined operational conditions. [1,3]

2. POWER SUPPLY SYSTEM

Li-ion 18650 Rechargeable Cell

The 18650 lithium-ion cell is a highly prevalent energy storage component, frequently utilized in applications ranging from DIY electronics and portable power banks to electric mobility systems. The designation “18650” corresponds to the cell’s standardized physical dimensions: 18 mm in diameter and 65 mm in length.

The key electrical characteristics of this cell type include:

- Nominal voltage: 3.7 V
- Maximum charging voltage: 4.2 V
- Minimum discharge voltage: 2.5 V
- Capacity range: 1200 mAh to 3500 mAh
- Discharge current: 1C to 30C, contingent upon the specific model

Among the advantages of the 18650-cell architecture, we find:

- High energy density, enabling compact power systems
- Rechargeability, which enhances cost-efficiency over extended usage periods
- Broad applicability across various technological domains
- However, these benefits are accompanied by notable limitations, such as:

Disadvantages:

- The necessity for protective circuitry to prevent overcharging and deep discharge, which can degrade cell performance
- Sensitivity to high temperatures, which may compromise operational safety
- Risk of catastrophic failure (e.g., thermal runaway or explosion) in cases of mechanical damage or short-circuiting

In order to estimate the discharge time of the battery, the following formula is used:

$$T = \frac{C}{I} \qquad (1)$$

Where:

- T is the discharge time (in hours)
- C is the battery capacity (in Ah)
- I is the current draw (in A)

For a battery with a capacity of 2500 mAh (equivalent to 2.5 Ah) and a current consumption of 0.5 A the estimated discharged time is:

$$T = \frac{2.5}{0.5} = 5\ hours$$

This means the battery can theoretically sustain the 0.5 A load for 5 continuous hours under ideal conditions.

FIG.1 Li-ion 18650 Rechargeable Cell

FIG. 2 High-voltage generator module (1000 kV output, 3–6 V input), used in ionic propulsion experiments.

FIG. 3 Alligator clips (crocodile clamps) used for temporary electrical connections in the test circuit.

3. THE IONIC WING (GRID-BASED SYSTEM)

The initial design concept is based on a rectangular wing geometry, specifically configured to house an internal grid-type subsystem. The wing is intended to have dimensions of approximately 24–25 cm in length and 18–20 cm in width, and will be modeled using 3D CAD software. Physical fabrication will subsequently employ materials such as cardboard or lightweight composites, in combination with adhesives and modular joining elements to facilitate assembly.

The grid system itself is composed of several smaller independent grid units rather than a single centralized propulsion unit. This modular architecture enables greater directional control by adjusting the electric potential of individual grid elements, allowing localized thrust vectoring. While this approach introduces added complexity in terms of voltage regulation and distribution, it offers a significant performance advantage in terms of control authority over the wing's orientation and flight path.

First Iteration of Grid System Design (3x3 Configuration)

3D CAD Model Development

For the initial prototype, a unit composed of a 3×3 grid configuration was proposed. The base structural component of the grid was modeled using 3D CAD software with the following dimensions:

- Length: 119 mm
- Width: 40 mm
- Each unit features three slots, each with a width of 1 mm and length of 15 mm, as illustrated in Fig. 4.

These slots are designed to house the high-voltage electrode elements necessary for ionic generation, while maintaining a modular layout that facilitates experimentation with various grid configurations.

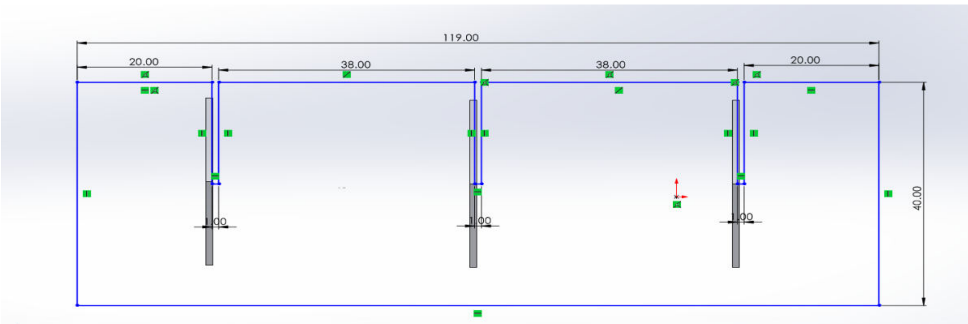

FIG.4 Lateral view grid configuration

Using the Boss-Extrude feature, the component was given a thickness of 1 mm, as illustrated in Fig. 5.

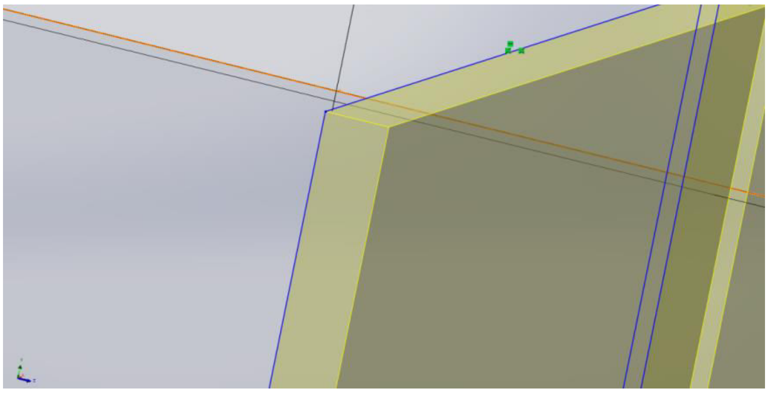

FIG.5 Grid rib width

For the second component, the following dimensions were selected:

- A width of 30 mm
- A base length of 119 mm
- A top surface length of 99 mm

All parts will be replicated three times and assemble together, as shown in Fig. 6.

Additionally, three slots were created, each with a thickness of 1 mm and a length of 15 mm, to accommodate the insertion of grid elements Fig. 7.

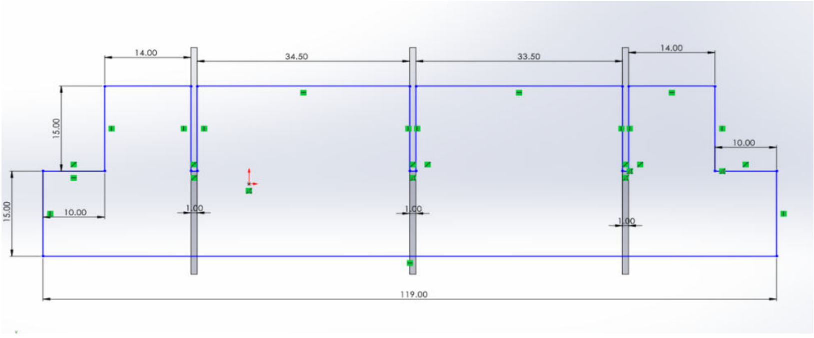

FIG.6 Lateral view of the grid assembly

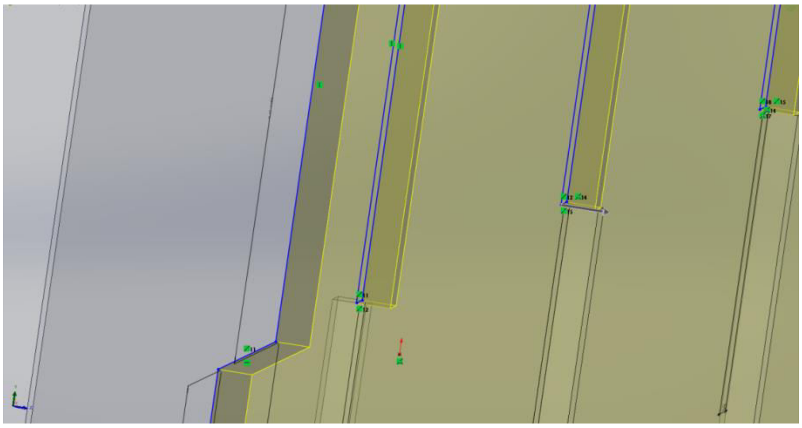

FIG.7 Grid slots designed for assembly

In the next stage, all the designed components were integrated into an assembly environment, where the final 3×3 grid system was mounted together, as illustrated in Fig. 8.

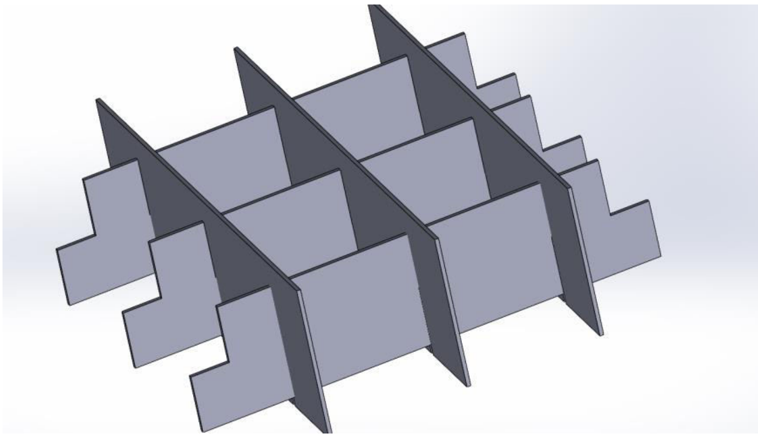

FIG.8 Base structure of the grid unit for the ionic wing

4. PHYSICAL CONSTRUCTION OF THE 3×3 GRID SYSTEM PROTOYPE

The ribs were fabricated from 280 g/m² cardboard sheets with an approximate thickness of 1 mm, as shown in Fig. 9. The dimensions were directly extracted from the CAD assembly. The fabrication process involved tracing the outlines using a 0.8 mm marker, ensuring alignment with a ruler, and manually cutting the components with scissors.

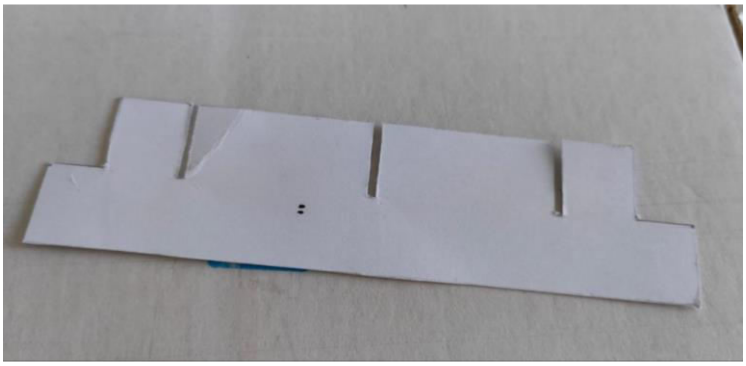

FIG.9 Grid rib

Once all the ribs were fabricated, aluminum foil was cut using the pre-marked template piece, as illustrated in Fig. 10. The cutting process was carefully executed to maintain a consistent gap of approximately 0.8–0.9 mm, a parameter considered critical for achieving optimal air ionization within the grid system.

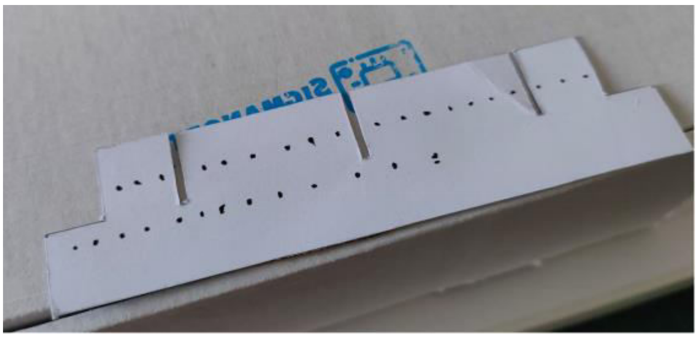

FIG.10 Grid rib with wire holes

Following the cutting of the aluminum foil according to the template markings, polyvinyl acetate (PVA) adhesive was applied to securely bond the foil to the surface of the component, as illustrated in Fig. 11 and Fig. 12.

FIG.11 Grid gluing proces

Upon completion of the previous steps, the component is fully assembled, as illustrated in Fig. 13.

FIG.12 Attaching the aluminum foil to the grid rib

FIG.13 Grid ribs with aluminum foil attached

After covering the components with aluminum foil within the defined limits—ensuring a spacing of 0.8–0.9 cm between the two extremities—the elements were assembled to form the final product, representing Iteration 1 of the grid-type system, as illustrated in Fig. 14.

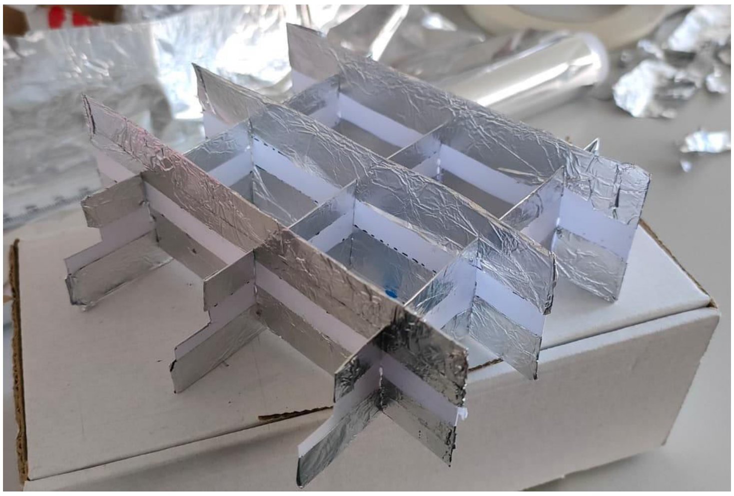

FIG.14 Final assembly of ionic wing module

5. DEVELOPMENT OF THE GRID SYSTEM – SECOND ITERATION (6×6 CONFIGURATION)

3D Modeling

To increase the number of active ionization zones while maintaining optimal spacing that prevents electrical arcing, a 6×6 grid configuration was selected. This design enables the creation of smaller and more numerous square/rectangular cells, improving overall ionization control.

The following dimensions were established for the base component, which was replicated six times to complete the structure:

- Length: 119 mm;
- Width: 40 mm;

As shown, each unit includes six slots, each with a width of 1 mm and a length of 15 mm, spaced at 16.14 mm intervals.

The construction process followed the same steps used in the previous (3×3) iteration up to the point of physical manufacturing. The goal of this iteration is to develop a more structurally refined model with enhanced air ionization potential, thanks to the increased number of active electrodes and improved spatial distribution.

6. PHYSICAL FABRICATION OF THE 6×6 GRID SYSTEM

Due to the reduced dimensions and increased complexity of the 6×6 configuration, the decision was made to fabricate the component using 3D printing technology. The printing material selected was PLA (Polylactic Acid), with the following printer settings:

- Extruder Temperature: 230 °C;
- Build Plate Temperature: 60 °C

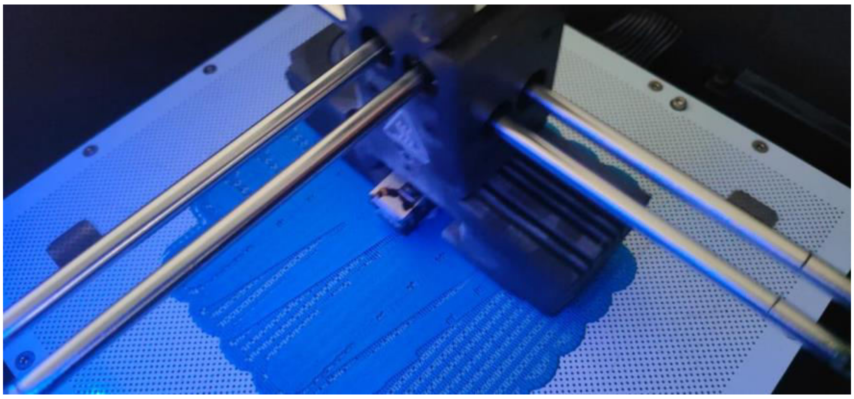

FIG.15 Printing the new grid unit

The component was processed on a 3D printer with a total print time of 13 hours and 30 minutes, as shown in Fig. 15 and Fig. 16.

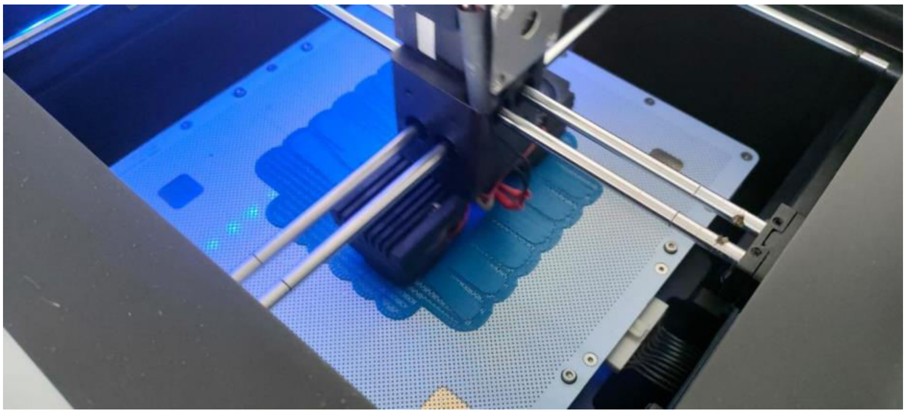

FIG.16 Intermediary steps on printing the new grid unit

The component was completed following the pre-set 3D printing program with a total duration of 13 hours and 45 minutes, as illustrated in Fig. 16 and Fig. 17.

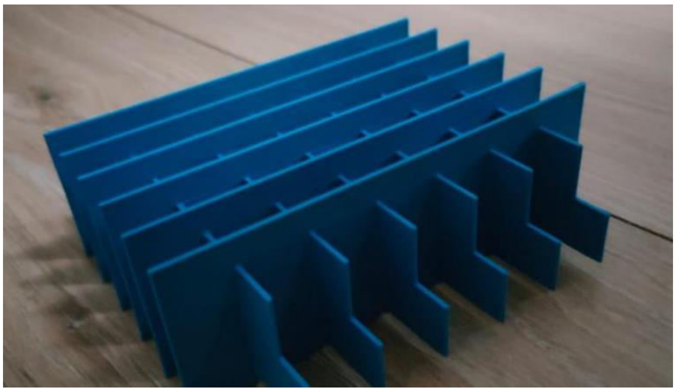

FIG.17 The new printed grid unit

7. FINAL SURFACE TREATMEANT AND OPTIMIZATION STRATEGY

With the grid model completed, two surface treatment approaches are considered to ensure proper conductivity and maintain the critical 0.8–0.9 cm ionization gap. The first option involves applying a conductive paint, while the second involves placing copper adhesive tape along the designated paths.

Should further optimization be required, a revised structural approach is proposed: perforating the grid structure and, based on experimentally determined optimal spacing, routing copper wire along both the top and bottom surfaces. This would result in a revised electrical network configuration, different from the initial iteration, potentially improving performance and efficiency.

CONCLUSION

Based on multiple experimental iterations, the system demonstrated structural adaptability under consistent voltage conditions. A key observation is that electrical concentration points significantly influence the effectiveness of air ionization. Additionally, it became evident that alongside geometric optimization, the integration of a parallel-distributed internal grid system enhances the overall thrust generation capability.

Furthermore, future iterations will incorporate a voltage regulation system, which is expected to provide a broader range of performance data. Varying the input voltage will be essential in exploring the optimal distribution and directional control potential of the ionic wing.

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