International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 12 Dec. 2024, pp: 387-391 www.ijaem.net ISSN: 2395-5252

Recharging the battery of an unmanned aerial vehicle, providing reliable automatic charging during flight

Cherkasova[1] O.A., and Skripkin[2] A.A.
[1] National Research Saratov State University, Saratov, Russian Federation
[2] Yuri Gagarin State Technical University of Saratov, Russian Federation

Date of Submission: 15-12-2024 Date of Acceptance: 25-12-2024

ABSTRACT
The authors earnestly present a novel charging device designed for an aircraft-type unmanned aerial vehicle (UAV). This innovative system includes two monoelectret blocks, one with a positive charge and the other with a negative charge, strategically installed in the UAV's wing. The setup also comprises a threshold device, supercapacitor with control unit, and electrically insulated skin sheets on the UAV wing's console and surface. As the UAV flies, it encounters aerodynamic drag influenced by factors such as flight speed and air density. This interaction generates static charges through triboelectric effects—primarily at the wing edges—resulting in significant electrostatic potential. The design ingeniously harnesses this potential: electrons knocked from air molecules accumulate on structural elements like wing consoles. However, when managed effectively by this system, they recharge the supercapacitor. This process extends flight duration and range by periodically boosting battery levels. Moreover, during flight-induced frictional interactions between air and structure surfaces—aided by secondary electron emissions from treated aluminum layers—a positive charge forms on specially designed skin sheets. These sheets continuously recharge the positively charged monoelectret block throughout flights. This earnest proposal underscores how leveraging natural phenomena can enhance UAV performance significantly while maintaining structural integrity through careful management of electrostatic interactions.

Keywords: wireless power transfer; unmanned aerial vehicles (UAVs); charging; battery capacity

I. INTRODUCTION

Currently, innovative research works on the use of unmanned aerial vehicles (UAVs) in various fields are gaining popularity, such as monitoring of various objects, public safety and traffic surveillance, military operations, exploration of hidden or dangerous areas, damage assessment, 3D mapping, navigation, agriculture and logistics [1-8]. Despite the promising innovative solutions for the use of UAVs, there are several key factors that limit their performance. The most significant factors are limited battery life, limited mobility, limited autonomy and limited flight time.

In addition, another significant limitation for the use of UAVs is the requirement for qualified pilots and operators, which increases the cost of personnel training. It is also worth considering the regulation and legislation in the field of aviation, which may limit the use of UAVs in certain areas. Moreover, the problem with using UAVs is also the limited ability to transmit large amounts of data in real time, which can hinder their effective use in some areas, such as monitoring and surveillance. Thus, despite the potential and prospects for the development and use of UAVs, there are a number of limitations that must be taken into account when deciding on their use. Limited flight time is usually due to the size of the aircraft (drone), atmospheric conditions and battery capacity. To increase mobility and autonomy, it is necessary to either increase the capacity of the battery on board the UAV or provide recharging of power sources during the flight, without returning to the base station. Increasing the capacity of batteries entails an increase in their overall dimensions and weight, which is not always advisable, taking into account the specifics of the UAV operation. As for recharging during the flight, at the current technological stage of technology development, the concept of wireless power supply is used. This concept is not new, and UAV (drone) manufacturers use various methods based on laser and microwave radiation. The essence of the method is that the source creates an alternating electromagnetic field, which is then converted into electrical energy by the receiver on board the UAV or drone. Thus, the device can be charged without the need to connect to the power grid. However, this method has a significant drawback - low efficiency of energy transfer and limited transmission distance. As the distance between the transmitter and receiver increases, the energy transfer power decreases, and worsening weather conditions also reduces the transmission power. Based on this, the article proposes a version of charger that will extend the battery life.

II. METHODS OF CHARGING UAV BATTERIES

Currently, there are two ways to recharge UAV batteries - contact through base or autonomous stations and contactless [9-10]. Stations can be two- or single-contact.

Two-contact platforms are devices with two traditional connectors (plus and minus), which provide a common direct charging current, including power sources and an on-board battery. As a rule, such designs have a very simple design and high efficiency. The disadvantages are increased requirements for the quality and reliability of the galvanic connection, as well as a very precise landing of the UAV on the charging platform to avoid incorrect connection. In addition, a two-contact terminal may be less resistant to vibration and other external influences.

Single-contact platforms operate on the principle of transmitting energy only through one wire, which eliminates the need for precise positioning of the UAV, but the efficiency is much lower than that of a two-contact platform.

For example, SkySense offered an automatic charging station for multi-rotor drones. Universal additional equipment is installed on the drone. The platform itself, in turn, has many contacts. As soon as the drone lands on this platform, a contact electrical connection is automatically established and the on-board battery charging process begins. At the same time, the American company Impossible Aerospace is developing drones that are literally made of batteries. And their charging is also carried out by contact through a base station or platform.

In the case of contactless charging, wireless terminals of stations or power lines can be used. In the first case, the drone must be near a station that has a source of electromagnetic waves with a frequency of 10 kHz-10 MHz connected to the UAV battery through a resonant circuit.

Some developers, for example, the Russian company Optoenergotrade, propose charging devices directly in the air, using a laser or electromagnetic field for this. In the first case, the detection and guidance system directs the laser emitter to the UAV photoelectric converter in the air, thereby charging the battery. Powered by laser energy, the drone can spend more time in the air, but so far the efficiency of such systems is relatively low - up to 12%. Another disadvantage of this approach is that there should be no obstacles between the laser and the device, and such charging is not possible in fog or bad weather. It is also necessary to accurately track the drone's position in the air in order to direct the laser beam at it. And if another object gets under the beam, it is necessary to immediately turn off the laser, because it can be dangerous to humans. The American company WiBotic offers a wireless solution for full-fledged power management and charging of UAV batteries, which includes a wireless power transmission system (PowerPad), an intelligent battery, and software for implementing power management on the scale of an unmanned robotic fleet [11].

III. BATTERY CHARGING DEVICE AND ITS OPERATING PRINCIPLE

The authors propose a charging device that is located on board an aircraft-type unmanned aerial vehicle [12-15]. The UAV battery charging device (Fig. 1) contains two monoelectret blocks installed in the aircraft wing: a monoelectret block with a positive charge 2 and a monoelectret block with a negative charge 3. The battery charging device contains a threshold device 4; a supercapacitor 5 with a control unit; a skin sheet 6; electrically insulated from the other structural elements, located on the console 1 of the UAV wing; a skin sheet 10, electrically insulated from the other structural elements, located on the entire surface of the UAV wing. Input 9 of the monoelectret unit, having a negative charge 3, is connected to the edge of the wing of the unmanned aerial vehicle, and input 8 of the monoelectret unit, having a positive charge 2, is connected to a special sheet of skin 6, electrically insulated from the other elements of the structure, located on the console of the wing 1. The outputs of the monoelectret units, having a negative charge 3 and a positive charge 2, are connected to the input of the threshold device 4,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 12 Dec. 2024, pp: 387-391 www.ijaem.net ISSN: 2395-5252

the output of which is connected to the input of the supercapacitor with the control unit 5.

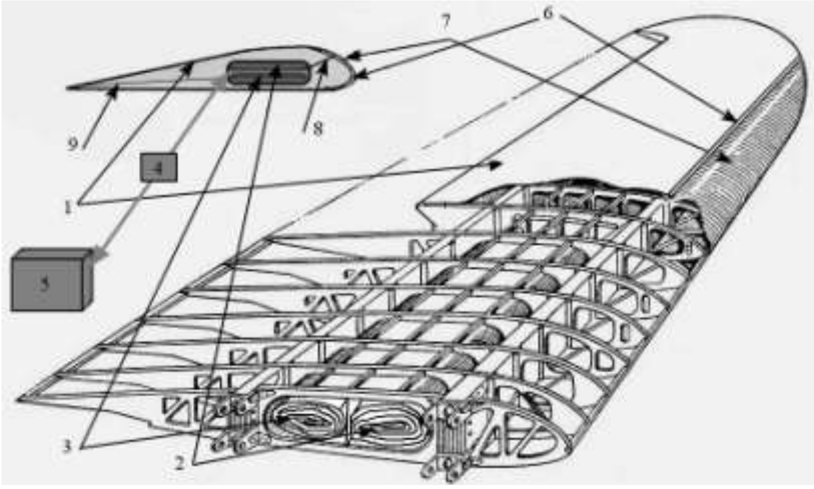

Fig. 1. Block diagram of the proposed device

1 – wing console,
2 – monoelectret block with a positive charge,
3 – monoelectret block with negative,
4 - comparator,
5 - ionistor with control unit,
6 – sheathing sheet, electrically isolated from other structural elements,
7 – thin layer of aluminum oxide (Al_2O_3), treated with cesium vapor (Cs_2O),
8 – input of a monoelectret block having a positive charge,
9 – input of the monoelectret block with a negative charge.

The static charge accumulated on the UAV is proportional to the aerodynamic drag, that is, first of all, to the area of the aerodynamic drag of the structure, the flight speed, the density and humidity of the air, which depends on the flight altitude. During the UAV flight, due to friction with the air, a triboelectric effect is constantly observed - a set of electrostatic charges in the aerodynamic elements of the structure, primarily the wing edge. In this case, a negative charge of an average of 200 ... 300 μC accumulates, increasing the electrostatic potential to 200 ... 300 kV, and the electric capacity can reach values of about 1 nF. During flight, the aerodynamic elements of the UAV structure "knock out" electrons from the oncoming air flow - from the molecules of the gases that make it up. The negative or positive charge generated by the triboelectric effect flows along the outer paint and plastic, increasing the voltage and is capable of causing a breakdown of the insulating coating to the metal underneath or flowing onto metal fasteners or structures and becoming part of the charge of a kind of "capacitor", which is the UAV. The captured electrons repel each other and accumulate on the ends of the wing consoles and control surfaces of the UAV. In this case, if the accumulated captured charge is not used, the static voltage increases to the level of the corona, that is, a corona discharge. Depending on the speed and altitude of the flight, when the static voltage reaches about 12 kV, the surrounding air begins to ionize and then the capacitor, which is the UAV body, is discharged. After this, the electrostatic potential drops, and a similar cycle begins and repeats again during the flight. When the UAV battery charge decreases during the flight to a certain level, the threshold device 4 performs additional recharging of the supercapacitor - the ionistor with the control unit 5, which is then periodically connected to the drone batteries, increasing the battery charge, thereby increasing the duration, range and speed of the UAV flight. A special sheet of skin (6 Fig. 1), electrically insulated from the other elements of the structure, on which a positive electrostatic charge is formed during the UAV flight, can be made of a similar aluminum alloy, from which other sheets of the UAV skin are made, on the surface of which a thin layer (7 Fig. 1) (20 ... 50 μm) of aluminum oxide (Al2O3), treated with cesium vapor (Cs2O) with a thickness of about 1 (μm) is applied. Since during the UAV flight, due to friction with the air, a triboelectric effect is constantly observed - a set of electrostatic charge in the aerodynamic elements of the structure, primarily the wing edge, then also due to the emission of the dielectric layer - the Molter effect, an intense secondary electron emission occurs in the aluminum layer. This leads to the formation of a positive charge on the surface of a special sheet of skin electrically insulated from the other elements of the structure (6 Fig. 1), which contributes to the constant "recharging" of the monoelectret block, which has a positive charge (2 Fig. 1) during the flight.

IV. CONCLUSION

The proposed device presents a pioneering solution for enhancing the autonomy of Unmanned Aerial Vehicles (UAVs) by efficiently harvesting electrostatic charge generated during their flight. This accumulation of charge, resulting from friction with the atmosphere, is converted into a usable recharging voltage for the UAV's onboard battery. By enabling continuous recharging while in flight, the device significantly extends operational range and flight time, eliminating the need for frequent returns to the base for battery swaps or recharges. Beyond UAVs, the versatility of this technology allows for its application in a wide array of aerial vehicles, including airplanes, helicopters, airships, and even satellites operating at the edge of space (around the Karman line). Its adaptability makes the device an attractive solution for diverse sectors such as military, commercial aviation, and space exploration.

The compact design of this charger ensures that it can be seamlessly integrated into existing UAV architecture without compromising performance or adding significant weight. This integration is crucial for developers and manufacturers seeking innovative solutions to improve the operational efficiency and battery life of their devices.

Ultimately, the development of this electrostatic charge-harvesting charger could play a critical role in advancing UAV technology. By addressing the challenges of battery limitations, it opens up opportunities for prolonged missions and a broader range of applications, paving the way for future innovations in the field of unmanned aerial systems.

REFERENCES

[1]. Ahmed, F.; Mohanta, J.; Keshari, A.; Yadav, P.S. Recent Advances in Unmanned Aerial Vehicles: A Review. Arab. J. Sci. Eng. **2022**, 47, 7963–7984.

[2]. Liang, H.; Lee, S.C.; Bae, W.; Kim, J.; Seo, S. Towards UAVs in Construction: Advancements, Challenges, and Future Directions for Monitoring and Inspection. Drones **2023**, 7, 202.

[3]. Pina, P.; Vieira, G. UAVs for science in Antarctica. Remote Sens. **2022**, 14, 1610.

[4]. Ghamari, Mohammad, et al. "Unmanned aerial vehicle communications for civil applications: A review." IEEE Access 10 (2022): 102492-102531.

[5]. Guo, Wei, et al. "UAS-based plant phenotyping for research and breeding applications." PlantPhenomics (2021).

[6]. Phadke, Abhishek, and F. Antonio Medrano. "Towards resilient UAV swarms—A breakdown of resiliency requirements in UAV swarms." Drones 6.11 (2022): 340.

[7]. M. Ghamari, P. Rangel, M. Mehrubeoglu, G. S. Tewolde and R. S. Sherratt, "Unmanned Aerial Vehicle Communications for Civil Applications: A Review," in IEEE Access, vol. 10, pp. 102492-102531, 2022, doi: 10.1109/ACCESS.2022.3208571.

[8]. Telli, K.; Kraa, O.; Himeur, Y.; Ouamane, A.; Boumehraz, M.; Atalla, S.; Mansoor, W. A Comprehensive Review of Recent Research Trends on Unmanned Aerial Vehicles (UAVs). Systems **2023**, 11, 400. https://doi.org/10.3390/systems11080400

[9]. Chittoor, Prithvi Krishna, Bharatiraja Chokkalingam, and Lucian Mihet-Popa. "A review on UAV wireless charging: Fundamentals, applications, charging techniques and standards." IEEE access 9 (2021): 69235-69266.

[10]. Mohsan, S.A.H.; Othman, N.Q.H.; Khan, M.A.; Amjad, H.; Żywiołek, J. A Comprehensive Review of Micro UAV Charging Techniques. Micromachines **2022**, 13, 977. https://doi.org/10.3390/mi13060977

[11]. https://www.wibotic.com/

[12]. Cherkasova O.A., Skripkin A.A. UAV battery charger: Patent for invention № 2794005 C1 RU, 2023
[13]. Cherkasova O.A., Skripkin A.A. UAV battery charger: Patent for utility model № 212660 U1 RU, 2022
[14]. Cherkasova O.A., Skripkin A.A. UAV battery charger: Patent for invention № 2812512 C1 RU. 2024
[15]. Cherkasova O.A., Skripkin A.A. Unmanned aircraft system battery charging device: Patent for invention № 2822473 C1 RU. 2024