Development of a power plant for an unmanned airship

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In this work, a power plant layout for an unmanned airship was designed and tested. The layout is designed to provide power to the target load with a rated power of not more than 500 W, peak power of not more than 1000 W and daily energy consumption of not more than 2600 W · h (of which in the dark - no more than 1300 W · h) with a daily total solar radiation not less than 5.51 kW · h / m² (daily average for July in the Moscow region is given). Testing the layout, which consists in checking the characteristics of individual elements of the layout in ground-based conditions, has shown the feasibility of using airships in the service sectors.

1. Introduction
Over the past decades, discoveries in the field of chemical power sources, renewable energy and composite materials have made significant advances.
Spheres of application of secondary chemical current sources are becoming more extensive, one of which was the automotive industry and helicopter construction. In these areas, batteries are used as a power source. Tesla cars can be especially distinguished, which have established themselves as reliable, economical, and most importantly environmentally friendly. [1].
The development of composite materials is due to rocket engineering, especially rocket carriers for space flights. The main task of rocket scientists was to lighten the weight of the rocket without losing the strength of the hull. Composite materials are a combination of dissimilar substances, leading to the creation of a new material whose properties are quantitatively and qualitatively different from the properties of each of its components. Composite materials surpass traditional materials and alloys in their mechanical properties and at the same time they are lighter.
Renewable energy sources have been actively developed in the world after the events that took place at the Fukushima-1 nuclear power plant. As a result of the accident, the share of renewable energy sources increased, as it is more safe and environmentally friendly. Solar and wind power plants began to be more actively built in the world, which prompted the development of these industries. [2].
This development made it possible to draw attention to the possibility of the return of airships. Dirizhabi, unlike airplanes, always have positive volatility and can soar in the air for an arbitrarily long time. Replacing explosive hydrogen with neutral helium, using modern composite materials to create the casing, you can increase the life of the airship to several tens of years. The area of the airship dome is measured in hundreds of square meters and for the most part is absolutely free. This is an ideal place to place a solar array. The energy they produce will be enough to drive electric motors. As an energy storage device, lithium batteries are best suited, the use of which will significantly reduce overall costs and increase resource.
Airships can be used in the field of cargo transportation, which will significantly speed up the delivery of goods in comparison with trucks, and cheaper in comparison with airplanes.
2. Development of a power plant

2.1. Justification for the location of the solar battery

The shell shape of the unmanned airship for calculations is taken as a cylinder, the vertical section of which, respectively, is directed to the coordinate system (the direct direction of the coordinate system is used, the positive direction of the ordinate axis, which corresponds to the initial part of the stern to the bow). The abscissa axis of the shell is oriented to the surface, the pitch and roll angle is 0 °. The calculated angle, which should be simplified, is calculated unchanged during the day (0 ° corresponds to the value to the north, the corner point is clockwise). Thus, its radiation is constantly and constantly reflected at 180 ° (Figure 1).

Figure 1

Various databases contain the following data on insolation (daily or average monthly) taking into account the region (taking into account the geographical latitude, cloud cover and atmospheric pollution by dust and gases) and season:
- on a horizontal surface (has no azimuthal orientation);
- on a vertical surface oriented south;
- on a vertical surface oriented to different cardinal points (only for a cloudless sky - SNiP 23-01-99 (hereinafter - SNiP);
- on an inclined surface oriented to the south (in various versions: the angle of inclination α (Figure 2) is equal to the geographical latitude of the place, the latitude of the place ± 15 °);

Figure 2

- on an optimally oriented inclined surface (azimuthal orientation to the south) (angle of inclination α changes monthly) - in NASA databases;
- on the surface following the sun (i.e., the panel during the day in the angle of inclination and azimuth rotates behind the sun).

The complexity of the task lies in the inconstancy of the airship’s orientation in azimuth during the day, in the curvature of the surface and the lack of the necessary complete set of data on insolation (different azimuthal orientations of the panel and various tilt angles), and also in the fact that the
airship operates in a wide range of geographical latitudes. Therefore, when modeling, various approximations, assumptions, and approximations are used. [3].

Since the unmanned airship operates in a wide range of heights, modeling will be carried out according to the worst case scenario - for insolation values at the level of the earth's surface. In addition, the most complete database contains information specifically on the values of insolation at ground level. The change in insolation in the atmosphere in height, especially in various regions, has not been practically studied.

2.2. Battery Choice
Two high-energy batteries LG INR18650MJ1 and Panasonic NCR18650B-1 are being investigated. To assess the capacity of the batteries, charge-discharge tests were carried out. Secondary current sources were tested at a temperature of 250C. The charge was carried out using the CC-CV method (the first half of the charge is carried out by a constant current, the second is supported by a constant voltage, while the current is constantly reduced to zero, in this experiment to 10 mA). Charge current 1.5 A. Discharge batteries with direct current.

Fig. 3 Discharge characteristic of the INR18650MJ1 battery. (CC method). Discharge Current 3A.

Fig. 4. Discharge characteristic of the battery NCR18650B-1 Discharge current 3A.
Table 1. Battery options.

|                  | INR18650MJ1 | NCR18650B-1 |
|------------------|-------------|-------------|
| Battery Capacity, Ah | 3.3854      | 3.3570      |
| Charge time, s    | 16835       | 18037       |
| Discharge capacity, Ah | 3.3650      | 3.3050      |
| Discharge time, s | 4039        | 3966        |
| Energy, Wh        | 11.778      | 11.301      |

Based on the data obtained, we conclude that the LG battery has a larger capacity than the Panasonic battery. [4-5].

The operation of batteries at different ambient temperatures is an important point in the study. The height of the barrage of an unmanned dirigin is in the range from 15 to 25 km. At such heights, the ambient temperature drops below -200°C.

The documentation for both batteries indicates the percentage of discharge capacity at different temperature conditions. The INR18650MJ1 battery has 70% of the discharge capacity at an ambient temperature of -20 °C, NCR18650B-1- 80%, which is much better than that of LG.

Battery weight is one of the comparison criteria. The mass of the secondary current source of LG is 50 g, Panasonic 48 g, which is less than the first by 2 g. Panasonic achieved this indicator due to the thinning of the walls of the battery, so the “chemistry” was not affected.

Generalization of data obtained during testing.

The LG/INR18650MJ1 battery has a capacity of 60mAh more than that of the Panasonic NCR18650B-1. From PanasonicNCR18650B-1, at a temperature of -200C, 80% of the capacity is removed during the discharge, from LG/INR18650MJ1 70%. Based on this, we can conclude: since the rechargeable battery will be used at an ambient temperature of -200C, the rechargeable battery based on PanasonicNCR18650B-1 batteries will have a larger discharge capacity than on the basis of LG/INR18650MJ1

3. Power installation tests

The layout is designed to provide power to the target load with a rated power of not more than 500 W, peak power of not more than 1000 W and daily energy consumption of not more than 2600 W · h (of which in the dark - no more than 1300 W · h) during the day total solar radiation of at least 5.51 kW · h / m2 (average daily value for July in the Moscow region is given).

Fig. 5. Test power plant.
Testing the layout consists in checking the characteristics of the individual elements of the layout in the conditions of ground operation.

Tests of the layout were carried out on the roof of a two-story building.

Equipment in the layout:
- solar battery (SB);
- rechargeable battery (battery);
- software-controlled charging converter (ПУЗП);
- battery balancing device (BUB);
- thermal container with thermostatic control system;
- useful load (fan) and shell layout.

The composition of the equipment for testing the layout includes:
- a stand for monitoring the battery pack for self-discharge and tightness;
- simulator of the solar battery (power supply AKIP);
- mobile terminal (laptop with installed special software);
- electronic load of Aktakom ATN-8180;
- Fluke-177 multimeter;
- pyrheliometer (or actinometer), pyrameter (it is allowed to use a lux meter instead of the listed devices);
- outdoor thermometer;
- clock.

The list of parameters to be registered during testing:
- electric voltage LIAB;
- electric current LIAB;
- electric capacity of LIAB;
- is the LIAB charge level (discharge depth);
- charge time LIAB;
- LIAB discharge time;
- temperature LIAB;
- voltage of groups of parallel-connected battery cells;
- electric current of parallel-connected groups of battery cells;
- temperature in the thermal container;
- SB voltage;
- SB electric current;
- short circuit current SB;
- open circuit voltage SB;
- electric current consumption in the payload circuit.

Simulation of the daily discharge / charge cycle of accumulator batteries when powered by SB and working on a payload. Battery, BUB and PUZP are placed in a thermal container. The thermocontainer is powered from the layout of the SEA. The experiment is conducted outdoors. The ambient temperature, actinometric data (the magnitude of direct and diffuse solar radiation, the magnitude of the energy illumination), the duration of daylight hours (when the energy illumination exceeds the minimum operating value) are recorded. The experiment begins when the level of energy illumination allows the Security Council to provide power to the payload. The batteries at the time of the start of the experiment are discharged to the maximum permissible value. During the experiment, the entire set of telemetric information about the operation of the SB, battery, payload and thermostabilization system is constantly recorded. The experiment continues throughout the day. The results are considered successful if, by the beginning of the daylight of the next day (when the level of energy illumination again becomes sufficient to supply the payload from the SB), the degree of discharging of the battery will not reach the maximum permissible value. The experiment serves to verify the mathematical model of the energy supply system (SEA) and refine the parameters of the nodes included in the layout.
Testing of the layout should be carried out using a test bench based on the received telemetry information with the SB turned off and the power supply provided by the SB simulator indoors under the following climatic conditions:

- ambient temperature in the range from 15 to 25 °C;
- relative humidity in the range from 45 to 90%;
- atmospheric pressure in the range from 86 to 106 kPa (from 645 to 795 mm Hg).

Fig. 6. Voltage indications: voltage on blocks 1-7, cell imbalance, battery voltage.

Fig. 7. Current reading: current to the battery, current to the solar battery.
Fig. 8. Temperature readings: temperature at 1 battery pack, temperature at 2 battery pack, temperature at 3 battery pack, temperature at 4 battery pack, temperature at 5 battery pack, temperature at 6 battery pack, temperature at 7 battery pack

Fig. 9. Indications of solar power
Measuring the voltage at the LIAB output "has shown the following results:
- total available LIAB capacity was 65 Ah;
- change of open circuit voltage depending on the degree of discharging was 8.88 V (from 29.32 to 20.44 V);
- voltage change under load, depending on the degree of discharge, was 10.85 V (from 28.35 to 17.50 V).
- the amount of energy received by LIAB from the SB simulator: 1454 Wh;
- experiment duration: 24 hours 33 minutes;
- temperature of LIAB did not exceed the permissible limit, the maximum value was 21.2 °C;
- voltage imbalance on the blocks of the accumulator elements amounted to 0.05 V, which corresponds to an acceptable level.

Examples taken from published papers

Acknowledgments

The relevance of this work lies in the fact that the airship is a safer, environmentally friendly and cost-effective means of both transportation and cargo transportation. To justify the location of the solar battery, we took the insolation values at ground level.

We have chosen the NCR18650B-1 battery since at negative ambient temperatures it gives 10% more capacity than the INR18650MJ1 and is also lighter.

As a result of the conducted tests, when the following were monitored: the capacity of the battery, the change in idle speed depending on the degree of rarefaction, the amount of energy received from the SB, we can conclude that this power plant is able to operate autonomously for 24 hours. And this, in turn, shows the feasibility of using airships in the service sectors.

Examples taken from published papers:

[1] Forton V.E., Popel O.S. Energy in the modern world. Dolgoprudny: Intellect Publishing House, 2011, 168 p.
[2] Grigoryeva A.V., Kulova T.L., Skundin A.M., Gudilin E.A., Garshev A.V., Tretyakov Yu.D. // Alternative energy and ecology. 2008. No. 8. P. 86.
[3] Popel OS, Tarasenko A.B. Analysis of the effectiveness of using autonomous photoelectric outdoor lighting systems in the climatic conditions of Moscow and the south of Russia // Thermal Engineering. 2012, No. 11. S.19-25
[4] Xiao T., Tang Y., Jia Z., Feng S. // Electrochim. Acta. 2009. V. 54. P. 2396.
[5] Huang X.H., Tu J.P., Xia X.H., Wang X.L., Xiang J.Y., Zhang L., Zhou Y. // J. Power Sources. 2009. V. 188

Last numbered section of the paper.