Use of the infrared thermography method to develop discharging rules for lithium polymer batteries

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Abstract. The results of using the infrared thermography method for studying the discharging process in lithium polymer batteries have been presented in this article. The general rules of discharging a lithium polymer battery are shown in the maximum mode of drone engine operation, namely, regardless of the external temperature, the process of heating the battery has a nonlinear character with a clear maximum temperature. In the course of operation of unmanned aerial vehicles under reduced temperatures, special attention is required before making a decision to connect an additional battery and fulfilling the "home" command. Testing the battery temperature during a flight with an autonomous control system can be carried out not by a thermographic camera, but by means of temperature sensors.

Keywords: infrared thermography, lithium polymer battery, dron supply, autonomous flight control.

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1. Introduction

Experts consider drones with electric motors to be the most advanced for both civilian and military purposes according to a trends analysis in the development of unmanned aerial vehicles (UAVs).

Currently, the main manufacturers of drones (UAVs) are practising the so-called "fixed-time flights". It means that user knows the duration of sufficient battery charge for high-quality performance in advance, and these data are taken into account when considering the flight plan [1, 2]. But the problem arises, if weather conditions can change suddenly: the battery in this case dramatically loses the power level and the UAV system can not only bangle the task, but also to be wrecked. And this entails not only ecological and economic losses, but also the loss of important information during using UAV in wartime. Another side of this problem is that during overdischarging battery or permanent underdischarging the battery loses its properties and its operation time is significantly reduced.

Lithium polymer batteries (LPB) have high specific energy datum, high voltage and low self-discharge. Lithium polymer batteries have truly deserved the title of "the most obsessive, dangerous, short-lived". But despite all these disadvantages, the use of these batteries in the aircraft model is rapidly increasing, as they have an unsurpassed specific (by mass) energy value, and are able to give large discharge current. At the same time, the lack of a liquid electrolyte makes these battery current sources safer in operation than previous-generation lithium-ion batteries. So, in models with electric power unit these batteries, practically, have no alternatives yet. There are no significant design model limits, and the batteries can be made of any configuration. Usually, the external body parts of lithium polymer batteries are made of metallized polymer [3].

However, when using lithium polymer AB, the following situations are not acceptable:

- excessive charge or discharge currents;
- short-circuit failure;
- recharge of batteries above or below certain levels of voltage;
- exceeding the maximum allowable value of battery temperature.

Not meeting these requirements may lead to emergencies.

LPB allows formation of parallel chains of *n* accumulators to provide the required capacity. The required LPB voltage is provided by a series type connection of separate batteries or chains. Thus, it is possible to construct LPB of a given capacity and voltage by connecting the batteries along a parallel-serial connecting scheme. However, each battery or every chain of parallel connected batteries requires some testing. The charge of separate elements is uneven during charging LPBs with series type connected batteries (or series connection type of chains with *n* parallel batteries), due to the technological differences between the internal battery resistances, or the uneven decrease in the capacity of the batteries, which is caused by their aging during operation. Low-capacity or high internal resistance level batteries tend to cause a large variation of voltage values during charging and discharge. With strictly fixed final voltage and discharge for a separate battery, the difference from the cycle (charge-discharge) to the cycle will increase and lead to a gradually increasing undercharge and underdischarge of LPB, that is, in fact, to decrease the capacity [4].

It is necessary to protect the batteries from overheating during charging and discharging. It is desirable to obtain information on the performance characteristics of LPB, the main of which is its capacity (reserve and nominal) for easiness of use for the consumer or the system (which includes LPAB). Direct measurement of reserve and nominal capacitance is related with the direct discharge of LPB, which takes a long duration and requires the disconnected battery from the system that consumes energy (which in flight conditions of BPS is conceptually unacceptable).

Taking it into account, methods of operative testing the LPB state are based on the characteristics obtained indirectly as a result of parameters analysis that can be measured quickly enough. The values of the measured parameters allow us to assess the technical condition and predict the value of the reserve and nominal capacity of the battery.

It is clear that the methods of testing and evaluation of the state should be non-destructive: without losses of energy or with low losses. The most desirable: one-stage testing within the shortest time. During such a procedure in the chemical current source in the unified state, all these diagnostic parameters can be measured.

Accordingly, the need of using the testing and operating system is dictated by the need to solve the above mentioned and other issues that arise during operation of LPB.

Due to the fact that lithium is a chemically active element, it is not in clear form during using in modern batteries, but in emergency situations (excessive charge or discharge currents, short-circuit currents, overcharging or charging below certain voltage levels on batteries) can be flash on the internal battery electrodes, which in certain cases can lead to fire and explosion.

In order to prevent the battery from breakage or exploding in the course of charging, a balancing system is used – a device that tests and aligns the voltages (up to 4.2 V) on each battery section in a series type battery connection. In this case, the charging device will disconnect the charge in time, without battery faults.

In turn, during operation of AB, it is desirable to use an autonomous testing and operating system [5], which is based on the physical phenomena that provides the discharge of the battery.

In the article [6], the IR thermographic method was used in studying the process of LPB discharge during simulation in the laboratory conditions of power of drone electric motor. For the first time, the authors received a nonlinear dependence of the battery temperature on the time of discharge, which made it possible to determine the operation time before giving the command "home". But this article did not take into account the possibility of changing weather conditions, namely external cooling, which can effect operation of the drone power supply system.

2. Objective

The objective of this work was to study operation of the power system during cooling down to the temperature +4 °C outdoor (in the street) and a comparison with its operation at room temperature in laboratory conditions.

3. Research methodology and experimental results

For studying the influence of external temperature on operation of the drone power system, the method of work outlined in [6] was used and the EasIR-4 thermographic camera with the following characteristics (Table).

One new fully charged battery was used. This battery was previously investigated [6] in laboratory conditions at 22 °C.

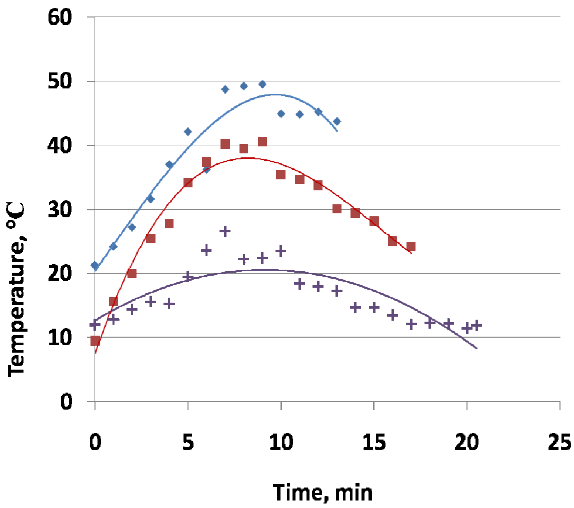
The results of studies and for the temperature analysis influence are shown in the figure.

4. Discussion of results

Our analysis of plots in the figure allows seeing that at a reduced temperature a nonlinear character with a clear temperature maximum repeats. At the same time, the maximum heating temperature of the battery is 2.6 times lower with an external temperature of 4 °C (plot 2), compared with the temperature in the laboratory (22 °C – plot 1). But the duration at maximum mode operation at a reduced temperature is 1.6 times higher than at room temperature.

Table. Technical characteristics of the EasIR-4 thermographic camera.

Type of detector	Microbolometer UFPA 160×120 pixels, 25 μm
Spectral range	8...14 μm
Focus	11 mm
Overview	20.6°×15.5°
Thermal sensitivity	≤ 0.1 °C at 30 °C
Image display	256 levels, 8 colour arrays (Rainbow, Iron, B&W, ETC)
Optics	
Embedded digital video	CMOS sensor,1600×1200 pixels, 224 original colons
External display	3.6″ TFT high colour resolution LCD
Thermal range	–20 °C up to 250 °C (350 °C, 1200 °C optionally)
Accuracy	±2 °C or ±2%
Image modes	Spot analysis, without indistinctness
Image storage	
Type	2 GB SD built-in memory card
File format	Standard JPEG
Signal	60 s
State of the indication system	
LCD display	Battery status, indications of power
Classification	Semiconductor laser diode A1GalnP
Power supply	
Type	110/220V AC adapter / AA Alkaline battery
Operation time	More than 3 hours of continuous operation
Charge system	AC adapter or charging device
Characteristics of the environment	
Operation temperature	–10 °C up to 50 °C
Storage temperature	–20 °C up to 60 °C
Moisture load	Operation and storage 10% up to 95%, non-condensing
Sealing action	IP54
Tolerance of impact	Correspond: 25g, IEC 68-2-29
vibratory action	Correspond: 2g, IEC 68-2-29
Fault testing	2 m
Interface device	
USB 2.0	Transfer video and images to computer on a real-time basis, camera control on PC
Size and weight	
Size	111×124×240 mm
Weight	0.73 kg



Experimentally obtained dependences of the battery temperature on the time of discharge: ◆ – in the laboratory at the temperature 22 °C, ■ – outdoor at the temperature 8 °C, + – outdoor at the temperature 4 °C.

At the same time, both in the laboratory conditions and in the external studies, the peak coincides with the time of discharge, but is significantly lower. That is, when the drone operates at low temperatures, it is recommended to use an additional battery, which, according to the command corresponds to the maximum temperature, one needs to connect an additional battery to the engine power supply and give the command "home". Temperature testing the battery can be carried out not by the thermographic camera, but using temperature sensors that are connected to the control system.

5. Conclusion

The researches that were carried out by the method of infrared thermography showed availability of the general rules for discharging the lithium polymer battery during the time *t* in the maximum mode of drone engine operation, namely, regardless of the external temperature, the heating process of the battery has a nonlinear character with a clear temperature maximum. At the same time, the maximum heating temperature of the battery is 2.6 times lower at the external temperature close to 4 °C, as compared with the temperature in the laboratory (22 °C). But duration at maximum mode operation at a reduced temperature is 1.6 times longer than at room temperature.

When drones operate at low temperatures, it is recommended to use an additional battery, to which, according to the command corresponds to the maximum temperature, it needs to be connected an additional battery to the engine power supply and give the command "home". Temperature testing the battery can be carried out not by the thermographic camera, but using the temperature sensors.

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