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Problem Analysis: Causes, Impacts, and Solutions LiPo Batteries in Drone Technology

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Abstract:*Lithium Polymer (LiPo) batteries are the primary power source in most modern drones due to their high power-to-weight ratio and superior energy density compared to other battery types. However, the sensitive chemical characteristics of LiPo batteries make them susceptible to various forms of failure, ranging from swelling and capacity degradation to thermal runaway, which can lead to fires. This article presents a literature review of the main causes of LiPo battery problems in drone systems, their impact on safety and operational performance, and mitigation solutions that can be implemented at both the hardware and operational levels. The review shows that most failures stem from three main factors: overcharging/over-discharging, physical damage due to impacts, and exposure to extreme temperatures. The implementation of a Battery Management System (BMS), standard charging and storage practices, and regular inspections have proven effective in reducing the risk of failure and extending battery life.*

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Introduction

Unmanned Aerial Vehicle (UAV) or drone technology has grown rapidly over the past decade, using applications such as hobbyism, aerial photography, mapping, infrastructure inspection, precision agriculture, and logistics. Most small- to medium-sized drones rely on LiPo batteries as their primary power source due to their ability to deliver high discharge currents while remaining relatively lightweight.

However, LiPo's superior energy density comes with significant safety risks. LiPo electrolyte is flammable, and a combination of mishandling, manufacturing defects, or mechanical damage can trigger an uncontrolled chemical reaction (thermal runaway). Battery failure not only damages the device but can also lead to drone accidents, material losses, and the risk of injury to the operator and those around the flight site.

Based on this background, this article aims to: (1) identify the main causes of LiPo battery problems in drones, (2) analyze the impacts on performance and safety, and (3) formulate solutions and mitigation measures that can be implemented by operators and manufacturers of drone systems.

Research Methods

This article was compiled using a literature review approach, examining technical publications, safety guidelines from battery manufacturers and the UAV community, and scientific articles related to energy management in drones. The data obtained was then synthesized to systematically map the relationships between the causes, impacts, and solutions to LiPo battery problems.

Results and Discussion

Causes of LiPo Battery Problems

Based on a literature review, the causes of LiPo battery failure in drones can be grouped as follows:

1. Overcharging: charging beyond the nominal voltage of 4.2 volts per cell causes unstable chemical reactions inside the cell, triggering the plating of metallic lithium on the anode and the production of gas on the cathode so that internal pressure increases.
2. Over-discharging: using a battery below a safe threshold (generally below 3.0 volts per cell) permanently and irreversibly damages the chemical structure of the cell.
3. Physical damage: a hard impact due to a crash, puncture, or pressure on the casing can tear the internal separator layer (separator film) so that the anode and cathode come into direct contact and trigger an internal short circuit.
4. Exposure to extreme temperatures: too high temperatures accelerate the chemical degradation of the cell, while too low temperatures (below 15°C) reduce the discharge capacity and can trigger the battery's protection mechanisms suddenly.
5. Cell imbalance: in multi-cell batteries, unmanaged voltage differences between cells cause some cells to operate beyond their safe limits.
6. Conductive debris and worn connectors: metal particle or carbon fiber contamination of the terminals, as well as loose/oxidized connectors, can trigger short circuits or contact failures.
7. Improper storage: storing batteries in a fully charged or discharged state for long periods accelerates capacity degradation and increases the risk of swelling.
8. LiPo battery age: Batteries will experience performance degradation over time and usage cycles. The longer they are used, the lower their capacity and performance.

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9. Environmental conditions: Strong winds and extreme ambient temperatures can affect battery power requirements and performance. Drones have to work harder when facing harsh flight conditions.
10. Drone overload (overcapacity): Adding cameras, sensors, or other devices can increase the drone's weight. The motors then require more power to maintain flight, increasing battery consumption.

Impacts Caused

LiPo battery failure impacts several aspects of drone operation, including:

1. Cell swelling: the most common visual indicator of internal chemical degradation, which if left untreated can progress to electrolyte leakage.
2. Thermal runaway and fire: the most dangerous condition, characterized by an uncontrolled increase in temperature that has the potential to cause fire and small explosions (venting).
3. Capacity loss and flight time: cells that experience over-discharge or improper charging cycles gradually lose their effective capacity.
4. In-flight power loss: a drastic voltage drop or loose contact can trigger a sudden power loss, increasing the risk of the drone crashing.
5. Material and operational losses: damage to the drone's frame, motor, and payload, as well as disruption to operating schedules, especially in commercial and industrial use.
6. Third party safety risk: potential injury or property damage if battery failure occurs while the drone is operating in a public area.

Solutions and Mitigation Steps

Various solutions can be implemented to reduce the risk of LiPo battery failure, both through devices and operational practices, including:

1. Implementation of Battery Management System (BMS): monitors the voltage of each cell in real-time, performs cell balancing, and stops the charging process before it reaches a dangerous threshold.
2. Standard charging practices: use a balance charger, limit the voltage to a maximum of 4.2 volts per cell, and apply the manufacturer's recommended charging rate (C-rate), generally 1C.
3. Low voltage threshold setting: activates the low battery alarm at 30% level and stops the flight before the cell voltage drops below the safe limit.
4. Storage according to safety standards: store batteries at a storage voltage of around 3.8 volts per cell, in a cool place, and use a fire-resistant LiPo bag as an additional layer of protection.
5. Routine inspections: checking the physical condition of the battery, connectors and cables before and after flights, including detecting signs of swelling or corrosion as early as possible.
6. Operational temperature management: warm the battery to above 15°C before flight in cold conditions, and avoid charging immediately after the battery has been used in hot conditions.

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7. Periodic battery replacement: replace batteries that show signs of permanent damage, significant capacity reduction, or have passed the recommended number of charge cycles.

Summary of Causes, Impacts, and Solutions

The following table summarizes the relationships between problem categories, their underlying causes, their impacts, and relevant mitigation solutions.

Category	The main cause	Impact	Solution/Mitigation
Electricity	Overcharging (>4.2V/cell)	Cell swelling, thermal runaway, fire	Balance charger, 4.2V/cell limit, 1C charge rate
Electricity	Over-discharging (<3.0V/cell)	Permanent cell damage, capacity drops	30% low voltage alarm, low-voltage cut-off
Mechanical	Impact/puncture during crash	Internal short circuit, fire	Protective casing, post-crash inspection
Thermal	Extreme temperatures (very hot/cold)	Accelerated degradation, decreased performance	Preheat >15°C, avoid charging when hot
Management	Cell imbalance	Uneven performance, short lifespan	BMS with balancing function
Storage	Stored full/empty for a long time	Swelling, decreased capacity	Store at ~3.8V/cell, LiPo bag

Conclusion

LiPo batteries offer significant advantages to drone performance through their high power-to-weight ratio, but their chemical characteristics require careful handling. Most issues stem from mischarging, physical damage, and exposure to extreme temperatures, with impacts ranging from performance degradation to fire and accident risks. Implementing a Battery Management System, standard charging and storage practices, and a culture of regular inspections have proven to be an effective mitigation combination. Further research is recommended to develop operational data-driven battery degradation prediction models to support more precise maintenance decisions.

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