The Impact of FPV Drone Frame Materials on Motor Thermal Conditions: Experimental and Numerical Analysis

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Keywords: FPV drone, carbon fiber, drone thermal management

1. Introduction

Effective thermal management of FPV (First Person View) drone motors is critical for enhancing their performance and durability, particularly under high-load conditions characteristic of competitive applications. This problem has become even more pressing now that FPV drones originally intended for amateur and sports purposes have begun to be used over longer distances (and therefore with a heavier battery) and with a large additional load. This significantly increases the load on the motors and can bring their thermal state to a critical point. Recent studies highlight the role of frame materials in dissipating heat generated by motors in UAV (Unmanned Aerial Vehicle) systems. Research such as [1,2] emphasizes the need to incorporate thermal properties into frame design, underlining the relevance of this study. The aim of this work was an experimental and theoretical study of the thermal conditions of the frame of an FPV drone flying with an additional load and a heavy battery. As an option for improving the thermal conditions of the drone, replacing the frame material from carbon fiber to aluminum alloy was considered.

2. Materials and methods

This study combines experimental and numerical approaches to assess the thermal behavior of a 7-inch FPV drone (Figure 1a) with carbon fiber and aluminum alloy frames (Figure 1b). In the experimental setup (Figure 2a), the drone was mounted on a force sensor to control thrust while motor and frame temperatures were monitored using an infrared camera BOSH GTC 600 C.

a) b)

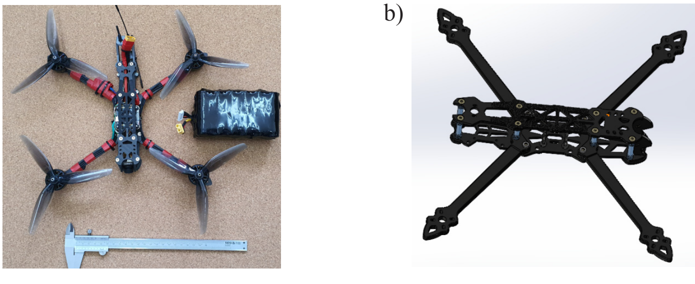

Figure 1. Illustration of a 7-inch FPV drone (a) and the CAD model of its frame (b)

The project is co-financed by funds from the state budget, granted by the Minister of Science as part of the Excellent Science II Program, project no. KONF/SP/0109/2024/02, subsidy amount 67 870 PLN.

Doskonała Nauka II

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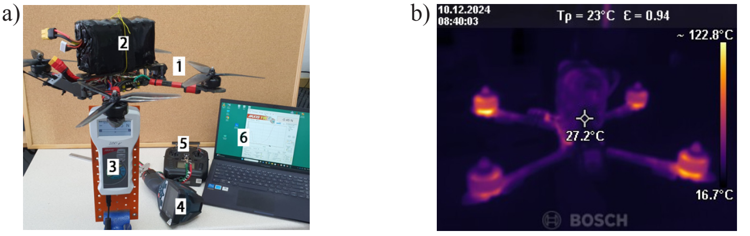

Figure 2. Experimental setup for steady-state drone flight testing: (a) 1 – FPV drone; 2 – battery 6s2p; 3 – force sensor (AXIS FM); 4 – infrared camera; 5 – remote drone control device (Radiomaster TX12); 6 – computer for recording force measurements; (b) example of a drone image captured by the infrared camera

During the experiment, the drone is connected to the force sensor, and, using the control equipment (Radiomaster TX12), the thrust is brought to the value of the payload (in our experiments it was 20N). The drone weighed 5.4 N, and the 6s2p battery weighed 8.8 N. After 10 minutes of physical simulation of the flight under load, the temperature of the motors and frame fragments in contact with the motors was measured. Subsequently, a numerical simulation of the steady-state thermal distribution in the arm was performed, leveraging inverse analysis to estimate the heat flux transferred from the motor to the frame. For thermal simulation, the SolidWorks 2022 program was used. The following thermal conductivity coefficients were adopted for the simulation: K_{carbon} = 10 W/mK; $K_{aluminium}$ = 170 W/mK.

3. Results and discussion

The experimental tests showed, that for the carbon fiber frame, the motor and arm beneath it reached a temperature of 120°C (Figure 2b). Replacing the carbon fiber frame with an aluminum alloy frame in the FEM simulation demonstrated a significant reduction in maximum temperatures, with values dropping to 50°C due to aluminum's superior thermal conductivity (Figure 3). These results were validated experimentally by integrating an aluminum arm into the drone, confirming the superior heat dissipation properties of aluminum compared to carbon fiber.

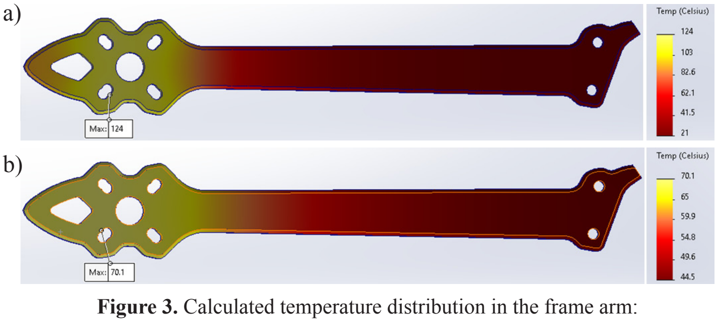

Figure 3. Calculated temperature distribution in the frame arm: (a) made of carbon fiber; (b) made of aluminum alloy

4. Conclusions

The findings indicate that aluminum alloy frames can substantially improve the thermal conditions of FPV drone motors by functioning as effective radiators. This dual functionality of aluminum - structural support and heat dissipation - positions it as a promising material for applications requiring enhanced thermal management. These insights underscore the potential for optimizing drone frame materials to improve both thermal performance and component longevity.

References

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