# PERFORMANCE EVALUATION OF HEATRESISTANT DRONE WITH ALUMINUM ALLOY PROPELLER

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**Abstract -** Recently, high-rise buildings and large complex structures are rapidly increasing due to the advancement of construction technologies. Hence, fire accidents could be critical, and accessing the situation at an early stage is very important to suppress the fire and evacuate the residents. For this background, drones are expected to support fire rescue missions. A firefighting drone has advantages because of its ability to access place that is hard to reach. However, its components such as motors, propellers, and body frame have weaknesses in heat resistance. In this study, a heat-resistant experiment of drone with an aluminum alloy propelleris conducted for flight in a high-temperature environment. The purpose of this study is to evaluate the heat-resistant performance of the developed drone using a heating furnace.

**Keywords** - Firefighting Drone, Heat Resistance Experiment, Rescue Assistance Robot.

## I. INTRODUCTION

Fire incidents are getting more dangerous, complicated and larger scaled because buildings are becoming higher and more complicated. Firefighting operations are inherently challenging, requiring rapid response, precise situation understanding, and safety. A potential technical solution for this problem could be the application of drone technology for firefighting. The utilization of drone in high-rise firefighting operations is the solution for reaching the fire scene on high floors quickly and effectively. The research on firefighting drone has attracted much attention in recent years [1]-[3].

A firefighting drone has advantages because of its ability to access place that is hard to reach. However, its components such as motors, propellers, and body frame have weaknesses in heat resistance. In the previous study [4], the drone with heat resistant insulation has been developed. Furthermore, heat resistance performance was evaluated by the fire experiment. On the one hand, heat resistant paint was coated to carbon fiber reinforced plastic (CFRP)propellers to improve the heat resistance performance of the drone. However, the significant improvement has not been achieved.
In this study, heat resistant drone has been developed using aluminum alloy propellers instead of CFRP propellers. Heatres istant experiment of drone with aluminum alloy propellers is conducted for flight in a high-temperature environment. The objective of this study is to evaluate the heat-resistant performance of the drone developed using aluminum alloy propellers and heat resistant insulation.

## II. HEATRESISTANT DRONE

In this study, a drone with aluminum alloy propellers and a drone with CFRP propellers are used for the experiment to confirm the effectiveness of the aluminum alloy propellers. Therefore, two drone's performances are compared in the experiment. The drone with aluminum alloy propellers is referred to as Drone 1, and the drone with CFRP propellers is referred to as Drone 2. The appearance of drone 1 and drone 2 are shown in Fig. 1 and Fig. 2, respectively. The heat-resistant insulation material used in this study is Bio-Soluble Fiber (BSF) paper manufactured by Isolite Insulating Products Co., Ltd. The heat resistant insulation material is attached to the frame of the drone and around the motor using heat-resistant adhesives, heat-resistant thread, and heat-resistant tape. A dummy drone consisting of similar motor, frame, and heat resistant insulation is also prepared as shown in Fig. 3 to measure the temperature of drone inside. The properties of Drone 1 and 2 are listed in Table 1.



**Fig. 1 Drone 1 (aluminum alloy propellers)**



**Fig. 2 Drone 2 (CFRP propellers)**

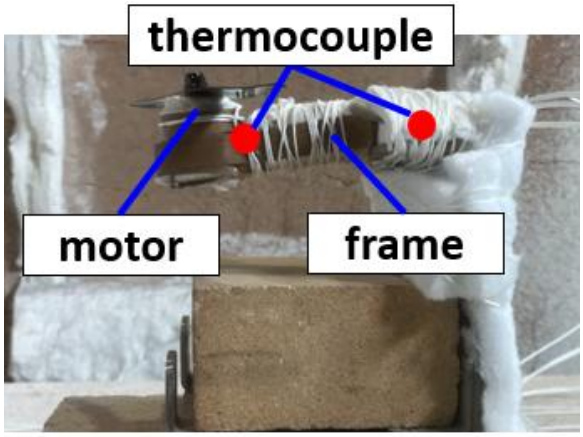



**Fig. 3Dummy drone**

| | Drone1 | Drone2 |
|---|---|---|
| Overall Drone weight(g) | 399.49 | 414.28 |
| Propeller Material | AlSi10Mg | CFRP |
| Weight per propeller(g) | 8.0 | 4.3 |
| Frame Material | CFRP | CFRP |

**Table. 1 Drone Properties**

## III. HEATING EXPERIMENT

### 3.1. EXPERIMENTAL SETUP

A schematic diagram of the heating experiment is shown in Fig. 4. This experiment was conducted using a large heating furnace installed in the Yawata Engineering Laboratory at the Osaka Institute of Technology. An overview of the furnace is shown in Fig. 5. The experimental setup in the furnace is shown in Fig. 6.

In the experiment, temperatures of the furnace, motor, and heat-resistant drone frame are measured at 1.3 second intervals using thermocouples. The heating conditions are set as the ISO834 heating curve shown in Fig. 7.The voltage applied to each ESC, which controls the speed of the drone's motor, is measured at 1.0 second intervals using a voltage logger. During the experiment, the voltage and current applied to each ESC of Drone 1 and Drone 2 are 11 V and 14 A, respectively.

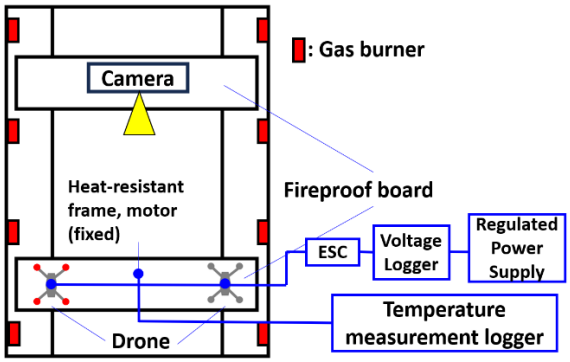



**Fig. 4 Experimental setup**

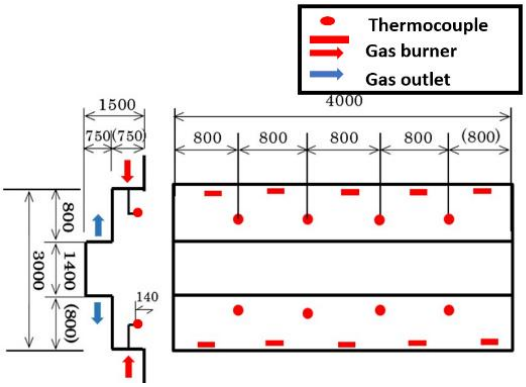



**Fig. 5 Schematic view**



**Fig. 6 Experimental setup in furnace**

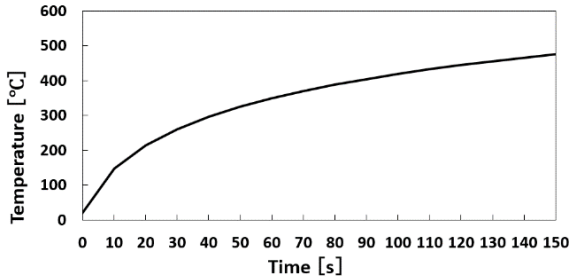



**Fig. 7Time history of the temperature**

### 3.2. EXPERIMENTAL RESULTS

Table. 2 shows the experimental results obtained from the camera images and thermocouple temperature measurements. The thermocouples attached to dummy drone and the temperature inside the furnace are shown in Fig. 8. These results show that the temperatures inside the frame and motor are lower than the temperature in the furnace. That means the temperature rise is suppressed by heat resistant insulation.

The voltage measurement results are shown in Fig. 9 and 10; the voltage applied to the ESC is equivalent to the voltage output from the power supply when the brushless motor is stopped. The voltage logger recordings show that the voltage rises to around 11V when the motor stops for each drone in the video, indicating that the motor has stopped even from the voltage measurement results.

Fig. 11 and 12 show the appearance of Drone 1 and Drone 2 after the experiment, respectively. From Fig. 11 and Fig. 12, it was confirmed that the frame deformation was suppressed by attaching heat-resistant insulation to the frame. Next, we focus on the propeller. It was confirmed that the aluminum alloy propeller did not deform after the experiment. However, the CFRP propellers were confirmed to be seized after the experiment, and all the propellers were confirmed to be damaged.

In addition, it was confirmed that the heat-resistant protection on the motors of Drone 1 and Drone 2 was damaged after the experiment, and that the motors were unable to rotate.

### 3.3. CONSIDERATION

The results of the heating experiment confirmed that drone 1 crashed in 36 seconds from the start of heating and drone 2 crashed in 37 seconds. However, the aluminum alloy propeller was not deformed even at the maximum temperature of 635°C, whereas the CFRP propeller was damaged after the experiment. The propellers of Drone 1 and Drone 2 after the experiment are shown in Fig. 13 and Fig. 14. The aluminum alloy propeller was confirmed to fly normally when the motor was replaced, and flight tests were conducted after the experiment. Therefore, the propeller was not considered to be the cause of the crash.

Next,video images taken during the heating experiment confirmed that the heat-resistant protective material attached to the motor had peeled off just before the crash. Fig. 15 and Fig. 16 show the heat-resistant motor before and after the experiment. The heat-resistant protective material attached to the motor was damaged, which wasconsidered to be the main cause of the thrust reduction and the crash. The heat-resistant protective material was damaged because Drone 1 and Drone 2 were located close to the gas burners of the furnace, and the heat-resistant motors were heated rapidly by direct contact with the injected fire, which is thought to have caused the damage. Furthermore, from Fig. 9 and Fig. 10, it was confirmed that the motors of Drone 1 and Drone 2 were damaged during the crash, resulting in unstable voltage.

Based on the above results, it is necessary to design a heat-resistant motor that will not be damaged in high-temperature environments in order to extend the flight time of heat-resistant drones.

| | Time[s] | Temperature[℃] | | |
|---|---|---|---|---|
| | | furnace | Dummy drone | |
| | | | motor | frame |
| Crash (Drone1) | 36 | 40.7 | 34.5 | 19.7 |
| Crash (Drone2) | 37 | 51.8 | 35.3 | 21.1 |
| All motors stop (Drone1) | 91 | 440.8 | 134.7 | 46.5 |
| All motors stop (Drone2) | 119 | 498.3 | 169.5 | 60.6 |

**Table. 2 Temperatures at each event time**

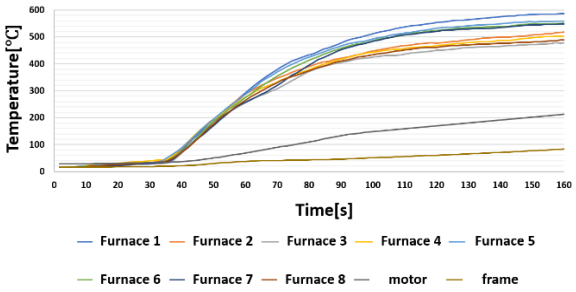



**Fig. 8Time histories of temperatures**

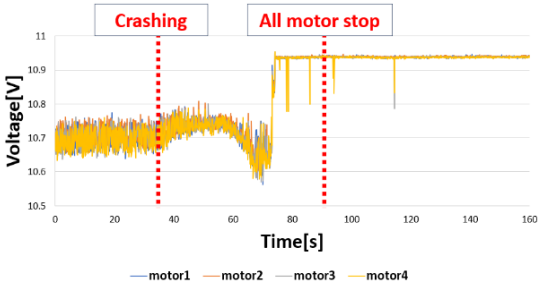



**Fig. 9Time histories of voltages (Drone 1)**

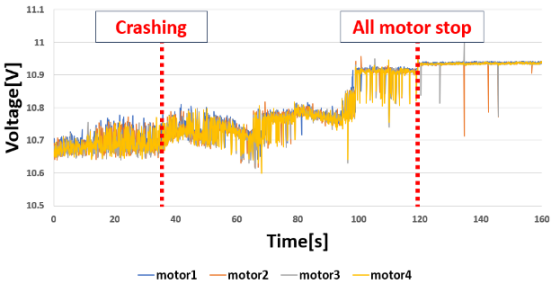



**Fig. 10Time histories of voltages (Drone 2)**



**Fig. 11Drone 1 (after experiment)**

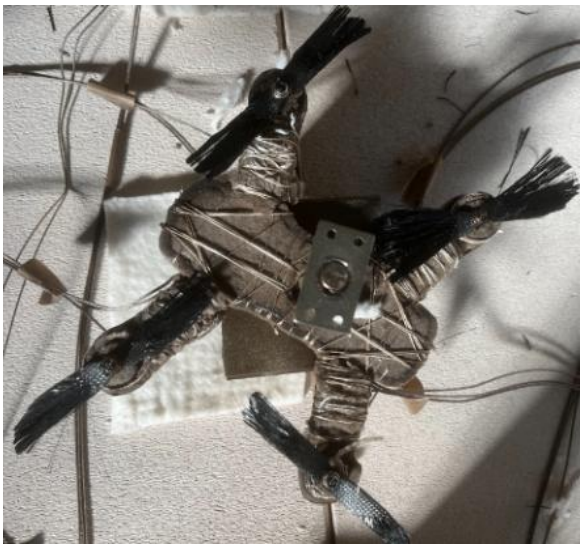


**Fig. 12Drone 2 (after experiment)**




**Fig. 13Aluminum Alloy Propeller**




**Fig. 14CFRP Propeller**




**Fig. 15 Motor (Drone1)**

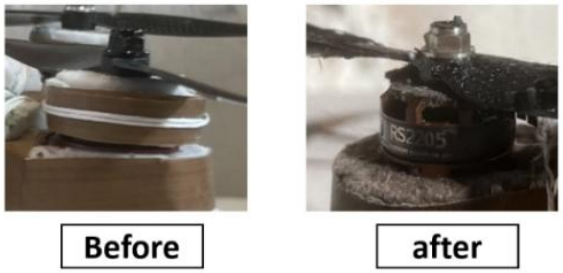



**Fig. 16 Motor (Drone2)**

## IV. CONCLUSION

Heat-resistant drone was developed using aluminum alloy propellersto extend the flying time of drone and to suppress propeller deformation in a high-temperature environment. The experimental results showed that the use of aluminum alloy propellers did not significantly extend the flying time of the drone. However, the use of an aluminum alloy propeller suppressed propeller deformation in high-temperature environments.

To improve the heat resistant performance of motor is considered to be essential for the extension of the flying time. To consider the effective way of preventing the damage of motor from the high temperature environment is a future work.

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