Journal of
Instrumentation Technology &
Innovations

ISSN: 2249-4731 (Online)
ISSN: 2347-7261 (Print)
Volume 14, Issue 3, 2024
September–December
DOI (Journal): 10.37591/JoITI

https://journals.stmjournals.com/joiti

Research JoITI

Technological Advancements in Fire Extinguisher Drones: Materials, Fabrication Methods, and Performance Analysis

Sunil Kumar[1], Rachit Srivastava[2,*], Arun Kumar Yadav[3],
Anurag Verma[1], Jai Prakash[1], Punit Singh[1]

Abstract

Numerous industries have been revolutionised by drone technology, and the firefighting sector is no exception. A fire extinguisher drone is a cutting-edge, remote-operated device designed to carry and release fire extinguishing agents, offering a highly efficient and safer approach to firefighting. In order to supplement traditional firefighting methods, this study explores the potential integration of fire extinguishing balls into a system that integrates drone technology and remote sensing. Developing a fire extinguisher drone involves creating a lightweight, agile drone capable of withstanding high temperatures and harsh environmental conditions. Equipped with a fire extinguisher and a precise control system, the drone allows operators to discharge extinguishing agents with accuracy. One of its key advantages is the ability to quickly access hard-to-reach areas, such as the rooftops of tall buildings, enabling it to extinguish fires that traditional methods may struggle to reach. Additionally, the use of a fire extinguisher drone reduces the risk of injury to firefighters, as it can be operated remotely, keeping them out of harm's way. Moreover, the drone can save time and resources by completing firefighting operations more efficiently than traditional methods. However, challenges such as high development costs, regulatory issues, and technical obstacles like battery life and communication must be addressed in the deployment of fire extinguisher drones. Based on our calculations, a drone equipped with Fire Extinguisher Ball having weight of 3.6 kg can fly for 8.21 min, providing sufficient reach for up to 200 m.

Keywords: Fire extinguisher drone, UAV, design analysis, Li-Po battery, mission planner

***Author for Correspondence**
Rachit Srivastava
E-mail: srivastava.rachit94@gmail.com

[1]Students, Department of Electrical Engineering, Bansal Institute of Engineering and Technology Lucknow, Uttar Pradesh, India
[2]Assistant Professor, Department of Electrical Engineering, Bansal Institute of Engineering and Technology Lucknow, Uttar Pradesh, India
[3]Associate Professor, Department of Electrical Engineering, Bansal Institute of Engineering and Technology Lucknow, Uttar Pradesh, India

Received Date: September 02, 2024
Accepted Date: September 07, 2024
Published Date: September 20, 2024

Citation: Sunil Kumar, Rachit Srivastava, Arun Kumar Yadav, Anurag Verma, Jai Prakash, Punit Singh. Technological Advancements in Fire Extinguisher Drones: Materials, Fabrication Methods, and Performance Analysis. Journal of Instrumentation Technology & Innovations. 2024; 14(3): 33–40p.

INTRODUCTION

The fire extinguisher drone aims to develop a drone capable of extinguishing fires in hard-to-reach areas, providing a safer and more efficient method of firefighting. The work involves designing and building a fire extinguisher drone that can be remotely operated and equipped with a fire extinguishing agent [1]. The development of the fire extinguisher drone involves several crucial components, including the drone itself, the fire extinguisher, and the control system. The drone must be built to be tiny, manoeuvrable, and resistant to high temperatures and harsh weather. The fire extinguisher must be appropriately sized and capable of discharging the extinguishing agent effectively [2]. The control system is essential for the operator to navigate the drone and control the

© STM Journals 2024. All Rights Reserved

fire extinguisher. The primary objective of the fire extinguisher drone is to provide an effective solution for firefighting in hard-to-reach areas, such as rooftops of tall buildings, where traditional firefighting methods may not be able to reach. The drone's ability to manoeuvre through tight spaces and inaccessible areas provides a precise and efficient means of extinguishing fires [3–5]. The effort's ultimate goal is to lower the chance of fire fighter injuries. Traditional firefighting methods often require fire fighters to enter burning buildings or climb onto rooftops, putting them at risk of injury or death. The fire extinguisher drone can be operated remotely, keeping fire fighters out of harm's way [4]. The fire extinguisher drone faces several challenges, including technical challenges such as battery life and communication, as well as regulatory issues and the high cost of development. However, the potential benefits of the fire extinguisher drone, such as increased safety and efficiency, make it a promising solution for firefighting [1].

Literature review examines the current research on fire extinguisher drones, emphasizing their design, functionality, effectiveness, applications, and future directions. Studies have explored the design considerations, the integration of fire detection systems, and various fire suppression mechanisms. Fire extinguisher drones have shown promise in combating fires across different environments, with researchers evaluating their performance and addressing safety considerations. The reviewed literature highlights the need for ongoing research and development to enhance their effectiveness and ensure safe integration into firefighting operations. Future advancements in drone technology have the potential to revolutionize fire suppression efforts and reduce the risks associated with fire incidents [6–8].

The United States Department of Agriculture published "Charts for Interpreting Wildland Fire Behaviour Characteristics" by Andrews and Rothermel as General Technical Report INT-131 in 1982. This publication contains important charts and interpretation guidelines for a variety of wildland fire behaviour aspects. Firefighters, researchers, and fire management professionals can all benefit greatly from these tools, which cover signs such as flame length, intensity, and propagation of the fire. They can enhance fire suppression efforts and make more informed judgements by utilising these technologies to evaluate and forecast the behaviour of fire in various settings [4].

The United States Department of Agriculture released General Technical Report RMRS-GTR-253 in 2011 with the publication "How to Generate and Interpret Fire Characteristics Charts for Surface and Crown Fire Behaviour" by Andrews *et al*. This document offers instructions on creating and analysing fire characteristics charts for surface and crown fire behaviour.

The document likely includes detailed instructions on using the Behave Plus fire modelling system, which allows users to predict fire behaviour based on fuel and environmental inputs. It may cover topics such as fire spread rates, flame lengths, fire-line intensities, and crown fire behaviour. This resource serves as a valuable reference for fire managers and researchers involved in fire behaviour analysis and decision-making processes [5].

COMPONENTS REQUIRED

The components required for a hex copter fire extinguisher drone typically include:

- *Hex copter frame:* The structure that provides stability and holds all the components together.
- *Flight Controller:* An electronic module that controls the drone's flight dynamics, including motor control and sensor integration [9].
  Six motor-propeller units provide force and lift to maintain the drone's altitude and allow for multidirectional mobility.
- *Power system:* A battery or power source that provides electrical energy to the motors, flight controller, and other electronic components.
- *Fire extinguishing mechanism*: This includes a tank or reservoir to store the fire suppressant agent, a pump or sprayer mechanism to release the agent, and appropriate plumbing or nozzle systems for efficient delivery [10].

© STM Journals 2024. All Rights Reserved

- *Sensing and navigation systems*: Sensors such as GPS, altimeter, gyroscopes, and accelerometers that enable the drone to navigate and maintain stability during flight. Additional sensors like thermal cameras or smoke detectors may be included for fire detection and location purposes.
- *Communication system*: Transmitter and receiver modules for remote control and communication with ground stations or other drones.
- *Onboard Computer:* A computer or microcontroller that processes sensor data, controls the flight behaviour, and manages the fire extinguishing operation [10–14].
- *Payload release mechanism*: A mechanism to release or disperse the fire suppressant agent effectively.
- *Safety Features:* Redundant systems, fail-safe mechanisms, obstacle detection sensors, and emergency landing systems to ensure safe operation and mitigate risks [2].

HARDWARE IMPLEMENTATION

Frame of Body

When making the chassis of a hex copter drone using aluminium, the following steps can be followed:

- *Design and planning*: Start by designing the chassis structure based on the desired dimensions, weight, and payload capacity of the drone. Consider factors such as motor placement, centre of gravity, and mounting points for components.
- *Material selection*: Choose a suitable grade of aluminium for the chassis, such as 6061 or 7075, known for their strength-to-weight ratio. Aluminium sheets or plates with a thickness appropriate for the drone's size and intended use are commonly used.
- *Cutting the aluminium sheets*: Use a saw, CNC machine, or laser cutter to cut the aluminium sheets according to the design dimensions. To ensure correct alignment and fit throughout assembly, make sure your cuts are precise and accurate.
- *Drilling holes:* Drill holes in the aluminium sheets as per the design requirements. These holes will be used for mounting the motors, landing gear, flight controller, and other components. Use appropriate drill bits and ensure accurate hole placement.
- *Bending and shaping*: If required, use a bending machine or appropriate tools to shape the aluminium sheets to match the desired chassis design. This may involve bending the sheets to create the hexagonal shape or other structural features.
- *Assembly*: Begin assembling the chassis by connecting the cut and shaped aluminium sheets together. Align the holes properly and use screws, nuts, and bolts to secure the components. Ensure tight and secure connections for structural integrity.
- *Mounting*: Attach the motor mounts to the chassis. These mounts should be designed to accommodate the specific motors being used and provide a secure attachment point. Landing Gear Mounting: Install the landing gear onto the chassis. Ensure proper alignment and stability for safe landings.
- *Component mounting*: Mount the flight controller, power distribution board, battery, and other electronic components onto the chassis. Securely attach these components using suitable mounting hardware.
- *Finishing*: The aluminium sheets' edges should be sanded to remove any burrs or sharp edges. To improve the chassis' resilience to corrosion, strength, and appearance, paint or apply a protective coating.
- *Evaluation and adjustment*: After the drone's chassis is put together, check its operation, stability, and balance. Make any necessary adjustments to ensure proper performance.

Mounting of Motors

To mount motors on aluminium bars of a hex copter drone chassis, you can follow these steps:

- *Determine motor placement:* Decide on the position and orientation of the motors on the aluminium bars. This will depend on the specific hex copter configuration and the design of the chassis.

© STM Journals 2024. All Rights Reserved

- *Mark mounting hole locations:* Using a marker or a centre punch, mark the locations where the motor mounting holes will be drilled on the aluminium bars. Ensure the markings are accurate and aligned with the motor mounting pattern.
- *Drill mounting holes:* Drill holes in the aluminium bars at the designated positions using a suitable drill bit. The holes' diameters ought to correspond with the motors' mounting hole sizes. Drill holes with precision and straightness.
- *Align motor mounting holes*: Place the motor on the aluminium bar, aligning the mounting holes of the motor with the drilled holes on the bar. Make sure the motor is positioned correctly according to the intended orientation.
- *Fasten the motor to the bar*: Drive screws or bolts into the aluminium bar's drilled holes and through the motor's mounting holes. To properly fasten the engine to the bar, use nuts and washers. Make sure it fits snugly to avoid any movement or vibrations.
- *Repeat for remaining motors*: Repeat steps 3 to 5 for each motor, mounting them one by one onto their respective aluminium bars. Ensure consistency in motor placement and alignment.
- *Double-check tightness:* Once all the motors are mounted, double-check the tightness of the screws or bolts. Make sure they are securely fastened to avoid any slipping during flight.
- *Wiring management*: Organize and route the motor wires neatly along the aluminium bars to prevent tangling or interference with other components. Use zip ties or cable clips to secure the wires in place.
- *Test motor functionality*: Before finalizing the assembly, test the functionality of each motor to ensure they are operating correctly. Connect the motors to the appropriate electronic speed controllers (ESCs) and verify that they respond to throttle commands.
- *Finalize chassis assembly*: With the motors securely mounted on the aluminium bars, continue with the remaining assembly steps for the hex copter drone, such as attaching the landing gear, flight controller, and other components to the chassis drone.

Mounting of all Components

Implementing all drone parts within an aluminium body involves assembling and integrating the various components onto the aluminium frame/chassis. Here is a step-by-step guide on how to implement the drone parts within an aluminium body.

Frame assembly: Begin by assembling the aluminium frame, connecting the arms, and securing them to the centre plate of the frame. Ensure proper alignment and tighten the screws to hold the frame securely.

Motor mounting: Attach the motors to the designated positions on the arms of the aluminium frame. Use suitable screws and ensure that the motors are securely fastened.

Electronic speed controllers (ESCs): Mount the ESCs on the frame or the arms near the motors. Connect the motor wires to the respective ESCs, ensuring the correct motor to ESC mapping.

Flight controller: Mount the flight controller, such as the Pixhawk 2.4.8, onto the frame's designated mounting area. Connect the necessary cables from the ESCs, GPS module, and other peripherals to the flight controller according to the manufacturer's instructions.

Power distribution board (PDB): Install the PDB onto the frame, ensuring proper electrical connections. Connect the LiPo battery to the PDB to provide power to the entire drone system.

Propeller attachment: Attach the propellers to the motor shafts, ensuring that each propeller is mounted on the correct motor in the designated direction. Secure the propellers with suitable nuts or locking mechanisms.

© STM Journals 2024. All Rights Reserved

ISSN: 2249-4731 (Online), ISSN: 2347-7261 (Print)

Battery mounting: Depending on the design of the aluminium frame, mount the LiPo battery securely onto the frame using straps, Velcro, or other mounting mechanisms. Ensure that the battery is centred and balanced for optimal flight performance.

Payload and payload release mechanism: If your drone has a payload and payload release mechanism, mount and integrate them onto the aluminium frame. This could involve attaching the servo motor and the payload mechanism securely to the frame, as well as connecting the necessary wiring.

Wiring and cable management: Arrange and fasten the cables and wires all over the drone, making sure they are correctly routed and fastened to prevent interference with propellers or moving parts. To organise and fasten the cables, employ cable ties or other techniques.

Testing and calibration: Before flying the drone, perform thorough testing and calibration. Check all the connections, confirm the correct motor rotation and propeller orientation, calibrate the flight controller, and ensure that all systems are functioning properly.

Final checks: Double-check all the connections, screws, and overall stability of the drone. Perform a pre-flight checklist to verify that all components are in good working condition and that the drone is ready for flight. Figure 1 shows final look of the Fire Extinguishing Drone.

SOFTWARE IMPLEMENTATION

Click the system icon to launch Mission Planner after installation is finished. Upon completion of Mission Planner and driver installation, the MP will first launch with multiple pop-ups. See Mission planner perspective in Figure 2. Choose the icon on the Install Firmware screen (e.g., Quad, Hex) that corresponds to your car or frame type; then choose from a variety of drone specifications.

CALCULATIONS

Weight Calculation

2.3 kg (Total Weight of Drone) + 1.3 kg (Fire Extinguisher Ball) =3.6 kg

Thrust Calculation

Using the same formula as before, we can calculate the thrust generated by each motor:

Thrust = Motor Kv × Battery Voltage × Propeller Diameter^2 × Propeller Pitch/1352

Figure 1. Final look of fire extinguishing drone.

© STM Journals 2024. All Rights Reserved

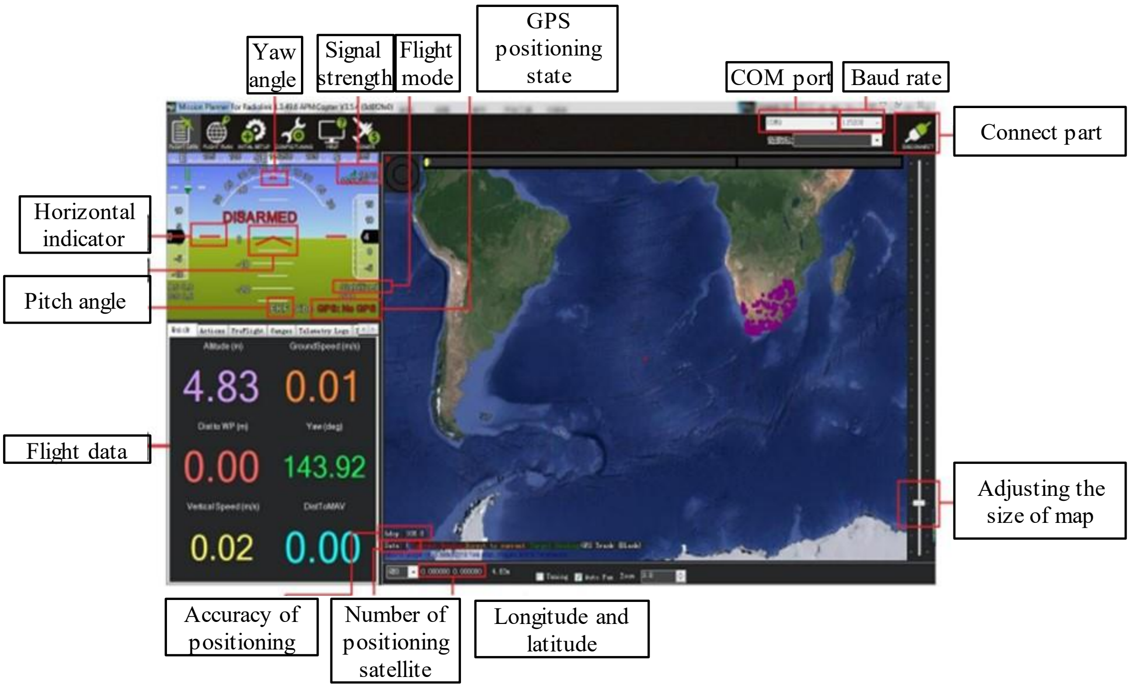

Figure 2. Mission planner introduction.

Assuming a propeller diameter of 10 in (0.254 m) and a pitch of 4.5 in (0.1143 m), and a battery voltage of 11.1 V

Thrust $=935\times11.1\times(0.254\text{^}2)\times0.1143/1352=0.8977$ N

Since we have six motors, the total thrust generated by all six motors would be Total

Thrust $=6\times0.8977$ N$=5.3862$ N

Power Calculation

Assuming an average current draw of 10 A per motor, the power consumption of each motor would be:

Power per Motor = Battery Voltage × Current =11.1 V×10 A=111 W

Total Power for all six motors =6×111 W
Total Power for all six motors =666 W

Thrust-to-weight ratio

The thrust-to-weight ratio is an important parameter to assess the performance of the drone. It is calculated by dividing the total thrust by the weight of the drone:

Thrust-to-Weight Ratio = Total Thrust/Drone Weight
= 5.3862 N/2.3 kg
= 2.3405 N/kg

Flight time estimation

To estimate the flight time, we need to consider the average current draw of all the motors, the battery capacity, and the drone's weight. Assuming an average current draw of 60 A for all six motors and an average efficiency of 80%, we can calculate the estimated flight time as follows.

Battery Capacity (in ampere-hours) =3300 mAh/1000=3.3 Ah

Average Current Draw =60 A

© STM Journals 2024. All Rights Reserved

Estimated Flight Time = (Battery Capacity × Battery Voltage)/(Average Current Draw × Efficiency × Drone Weight)

$$= (3.3\ \text{Ah} \times 11.1\ \text{V})/(60\ \text{A} \times 0.8 \times 2.3\ \text{kg})$$
$$= 0.1368\ \text{h}$$

Estimated flight time =8.21 min

RESULTS AND OUTCOMES

The development of the drone has successfully met its objectives. It has effectively demonstrated multitasking capabilities by integrating a real-time streaming camera with night vision, in addition to implementing a gripper arm for pick and place operations. The primary goal of cost-effectiveness has been achieved, positioning the drone as a viable and economical alternative to existing models. The project encountered several challenges, but after persistent efforts, the team overcame these obstacles and completed the project successfully.

CONCLUSION

Fire extinguisher drones represent a significant leap in firefighting capabilities, offering rapid response, enhanced safety, and more efficient firefighting strategies. By accessing hard-to-reach areas and providing real-time situational awareness, they play a crucial role in minimizing property damage and potentially saving lives. However, it is essential to recognize and address limitations such as payload capacity, weather conditions, flight time restrictions, regulatory compliance, and technology constraints to ensure their responsible use in firefighting operations. Looking forward, advancements in technology, including enhanced extinguishing agents, autonomous capabilities, swarm technology, and advanced sensors, hold great promise for further enhancing firefighting effectiveness.

Future Scope

The future of fire extinguisher drones is extremely promising, with numerous potential advancements and developments on the horizon. Here are some areas of future growth and improvement for fire extinguisher drones:

- *Enhanced firefighting capabilities:* Future fire extinguisher drones are poised to feature improved extinguishing agents, such as advanced foam or chemical compounds, that will be more effective in suppressing different types of fires. This could include the development of specialized extinguishing agents for specific fire hazards, such as oil fires or electrical fires.
- *Increased autonomy and AI integration*: Advancements in autonomous navigation and artificial intelligence (AI) will enable fire extinguisher drones to operate more independently. They will possess the capability to autonomously detect fires, analyse fire behaviour, and make informed decisions about the most efficient firefighting strategies.
- *Swarm technology*: Swarm technology, which entails the smooth coordination of numerous drones operating as a cohesive team, holds the key to the future of fire extinguisher drones.
- *Extended flight duration and payload capacity:* As battery technology and energy efficiency continue to progress, fire extinguisher drones will soon be able to fly for much longer periods of time and carry much more cargo.

REFERENCES

1. Yuan C, Zhang Y, Liu Z. A survey on technologies for automatic forest fire monitoring, detection, and fighting using unmanned aerial vehicles and remote sensing techniques. Can J For Res. 2015; 45(7): 783–792.
2. National Park Service. Wildfire Causes. Fire and Aviation Management, U.S Department of Interior. Key Findings from the 2017 Verisk Wildfire Risk Analysis. [Online]. (Accessed on 2 December 2017).
3. National Interagency Fire Center. (2017). Year-to-Date Statistics. [Online]. https://www.nifc.gov/fireInfo/nfn.htm (accessed on 2 December 2017).

© STM Journals 2024. All Rights Reserved

4. Andrews PL, Rothermel RC. Charts for Interpreting Wildland Fire Behavior Characteristics; General technical Report INT-131. Ogden, UT, USA: United States Department of Agriculture; 1982.
5. Andrews PL, Heinsch FA, Schelvan L. How to Generate and Interpret Fire Characteristics Charts for Surface and Crown Fire Behavior; General Technical Report RMRS-GTR-253. Fort Collins, CO, USA: United States Department of Agriculture; 2011.
6. MacSween-George SL. A public opinion survey-unmanned aerial vehicles for cargo, commercial, and passenger transportation. In Proceedings of the 2nd American Institute of Aeronautics and Astronautics (AIAA) “Unmanned Unlimited” Systems, Technologies, and Operations-Aerospace, San Diego, CA, USA. 2003 Sep 13–18.
7. Herron KG, Smith HCJ, Silva CL. US Public Perspectives on Privacy, Security, and Unmanned Aircraft Systems. Technical Report. Norman, OK, USA: University of Oklahoma; 2014.
8. Reddy LB, DeLaurentis D. Opinion survey to reduce uncertainty in public and stakeholder perception of unmanned aircraft. Transp Res Rec. 2016; 2600(1): 80–93.
9. Rothermal RC, Anderson HE. Measuring and Interpreting Fire Behavior for Correlation with Fire Effects; General Technical Report INT-93. Ogden, UT, USA: United States Department of Agriculture; 1980.
10. AFO Ball. Fire Extinguishing Balls. [Online]. http://afofireball.com/ (accessed on 7 December 2017).
11. Laurenti A, Neri A. Remote Sensing, Communications and Information technologies for vegetation Fire Emergencies. In Proceedings of the TIEMEC 96, Montreal, QC, Canada. 1996 May 28–31; 101–111.
12. Hassanalian M, Abdelkefi M. Classifications, applications, and design challenges of drones: A review. Progr Aerosp Sci. 2017; 91(4): 99–131.
13. Yuan C, Liu Z, Zhang Y. Aerial images–based forest fire detection for firefighting using optical remote sensing techniques and unmanned aerial vehicles. J Intell Robot Syst. 2017; 88(2): 635–654.
14. Clothier RA, Greer DA, Greer DG, Mehta AM. Risk perception and the public acceptance of drones. Risk Anal. 2015; 35(6): 1167–1183.

© STM Journals 2024. All Rights Reserved