Collision Tolerant Gimbal Drone for Sewage Treatment and Industrial Pipelines

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Abstract - *This report presents the design and development of a lightweight mechanical gimbal ring system enclosed within a protective cage for unmanned aerial vehicles (UAVs), commonly known as drones. The objective of this project was to create a drone that can be safely operated by unskilled individuals without causing damage to the drone itself. The mechanical gimbal ring system ensures stability during flight while maintaining independent movement between the drone and the protective cage. By implementing this innovative design, the drone can be effectively used for industrial inspection in environments such as large pipelines and Indian sewage tunnels, reducing the risk to human safety by minimizing the need for human presence in hazardous locations. The components were carefully selected and calibrated, and the gimbal rings and cage were fabricated using Fused Deposition Modeling (FDM) technology.*

Keywords: *UAV, Safety, FDM.*

I INTRODUCTION

Industrial pipeline and sewage inspections pose significant risks to human safety [1,2]. To address this issue, our research focuses on developing a safe and accessible drone system. Currently, drones require skilled pilots, limiting their market reach [3]. We aim to design a lightweight mechanical gimbal ring system enclosed in a protective sphere, ensuring drone integrity during collisions. This report highlights the importance of our research in mitigating risks, improving inspection efficiency, and exploring broader applications for drones [4,5]. Industrial pipeline and sewage inspections often result in accidents and fatalities [6,7]. In recent years, numerous incidents and deaths have occurred during these operations. This creates an urgent need for safer alternatives. Our research aims to address this social problem by developing a drone solution that minimizes human exposure and enhances safety during inspections [8,9].

In addition to industrial inspections, our drone system has potential applications in defense, recreation, goods delivery, and more. By expanding the scope of drone usage, we aim to enhance safety, efficiency and reduce risks in various industries. The Figure 1 shows the details of the effects of cleaning.

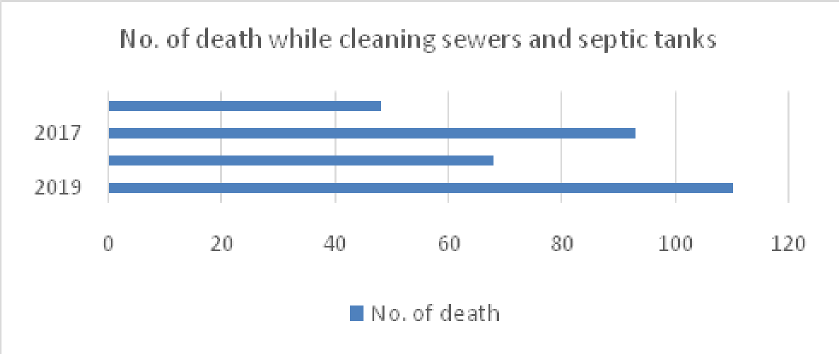

Figure 1: No. of Death While Cleaning Sewers and Septic Tanks

II OBJECTIVES

1. To select the optimal drone size and shape as per the applicable environment.
2. To model a protective outer structure and Gimbal.
3. To find the ideal material for 3d printing with respect to its physical properties.
4. To do weight estimation.
5. To finalize the components of the drone according to weight estimation and the required thrust-to-weight ratio of 2:1.
6. To determine the tolerance between the drone, gimbal, and outer sphere, keep the prototype operable and make the dimensions as small as possible.
7. To analyse the protective outer structure.
8. To fabricate the prototype of the external structure and gimbal.
9. To do the stability and control testing during the flight test.
10. To test whether the drone is in operable condition even after the collision.

III METHOD

Materials: The drone comprises a 250mm carbon fiber frame, four Readytosky GT2205 motors, four Dshot 600 30A ESCs, and an Omnibus Fc-F4 V3S Plus flight controller. It utilizes a 2200mAh 30c battery and is equipped with four tri-blade 5-inch diameter 5045 propellers. The Flysky fs-i6 radio controller enables remote operation. The gimbal rings are made of ABS using FDM, and the protective cage is constructed from a combination of ABS and carbon fiber rods.

Method: The project progressed through the following stages: Firstly, a drone was carefully selected to determine the dimensions of other components and the external structure. Next, Autodesk Inventor software was employed to model the gimbal rings and outer structure. Subsequently, gimbal rings were fabricated using Fused Deposition Modelling (FDM) technology and ABS material. ANSYS software was utilized to perform structural analysis and assess the strength of the external structure. The flight controller was calibrated using beta flight software, followed by the drone assembly, gimbal ring, and outer structure. Finally, a comprehensive flight test was conducted to evaluate the performance of the completed system.

Work Details: The work progress encompassed the following steps: Firstly, the drone was successfully assembled, and the gimbal rings and cage were fabricated. Following this, the entire system was built, and subsequent flight tests, namely Flight Test 1 and Flight Test 2, were performed. Comprehensive prototype performance observations were diligently recorded during these flight tests.

IV GALLARY

4.1 Gimbal System

Figure 2: Drone Bed 3-d Modal

Figure 3: Gimbal 3-d Modal (Bearing Section)

Figure 4: Gimbal 3-d Modal (Nut and Bolt Section)

4.2 Cage

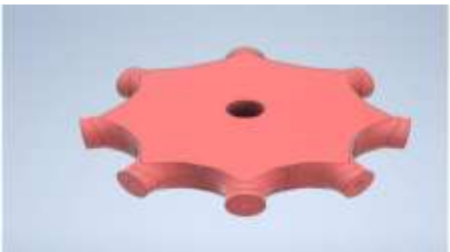

Figure 5: Cage Cap 3-d Modal

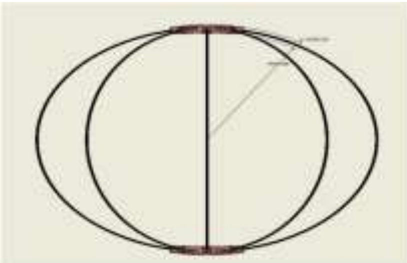

Figure 6: Outer Cage 3-d Modal (Carbon Rod)

4.3 Working Modal

Figure 7: Working Modal

V Results And Discussion

Weight Discrepancy: The estimated weight of the drone system, including the gimbal and protective cage, was 1350 grams, but the actual weight is measured to be 1143 grams. This indicates that the system is lighter than expected.

Flight Time Discrepancy: The calculated flight time of the drone was estimated to be 5.28 minutes, but the actual flight time achieved is only 4 minutes. This suggests that the drone's battery is not performing as expected, leading to a shorter flight duration.

Instability and Drifting: The drone is observed to be unstable and prone to drifting, particularly in windy conditions. This instability could be due to various factors, such as a suboptimal weight distribution, insufficient power or control, or aerodynamic issues caused by the additional gimbal and protective cage.

Take-off Ability: Despite the extra weight of the gimbal and cage, the drone is still able to take off from the ground. This suggests that the propulsion system and motors are capable of generating enough thrust to overcome the added weight during takeoff.

Landing Difficulty: Landing the drone proves to be challenging due to the extremely elastic nature of the external cage. The elasticity likely causes the drone to bounce or rebound upon contact with the ground, making it difficult to land safely and precisely.

VI Conclusion

In conclusion, this report has detailed the design, development, and applications of a safe and versatile drone for industrial inspection in challenging environments. The lightweight mechanical gimbal ring system enclosed within a protective cage ensures stability and protection for the drone, enabling even unskilled individuals to operate it safely. The successful implementation of this innovative design paves the way for the increased adoption of drones in various industries, particularly for inspections in hazardous locations where human safety is a primary concern. Future enhancements and refinements to the drone's capabilities are anticipated, opening up new opportunities for safe and efficient operations in challenging environments.

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