The University of Texas Rio Grande Valley
Center for Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS)

Optimization of Lightweight UAV Structures Through Hybrid Material Integration for Enhancing Payload Capacity and Flight Performance

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Abstract

This project aims to introduce lightweight ,optimized UAV systems that provide robust, cost-effective, and reliable methods for detecting hazards like gas, structural cracks, and temperature anomalies. Development will involve use of generative design (GD) [2] and single topology optimization (SMTO), incorporating reinforced carbon fiber composites in 3D-printed components to enhance payload capacity and flight performance. Additionally mechanical properties of 3-D filaments will be analyzed and graphed. This project seeks to improve safety and reduce costs in public infrastructure by maintenance detection.

Introduction & Background

Public infrastructures including bridges, and buildings are critical to our economy and people's daily lives. Traditional inspection methods such as crack and ultrasonic testing have been utilized. However, these methods require high-cost labor, time and are often challenging to apply in hard-to-reach areas. To this end, this project aims to

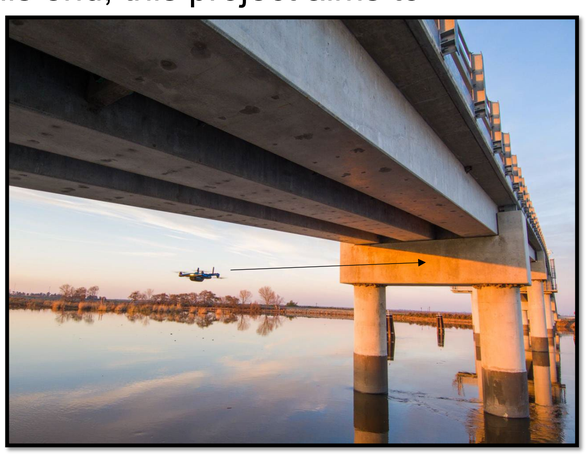


Figure 1: Manual and Drone-Based Bridge Inspections

- ❑ Manufacture lightweight UAV designs
  - ❑ 3-Axis Mill to cut aluminum plates
  - ❑ Water Jetting to cut carbon fiber plates
  - ❑ 3D printed components
- ❑ Improve hybrid drones' structural strength
  - ❑ Reinforcing 3D printed arms
  - ❑ GD/SMTO for lightweight design

GOAL: Optimize payload capacity and flight performance for public infrastructure use with hybrid design

Methodology

Design & Assembly

AUTODESK FUSION 360 — SOLIDWORKS

Material Testing

ASTM INTERNATIONAL Standards Worldwide

- Mechanical properties at different infill densities
- Hybrid Material Testing
- Testing composites, and polymers.

Generative Design & Topology Optimization

Fusion 360 Generative Design Extension

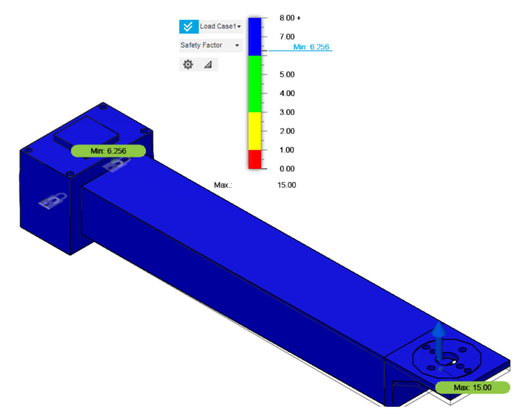
- Prioritize safety factor
- Weight reduction in plates.

Analysis & Building

PRUSA RESEARCH by JOSEF PRUSA

- Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD).
- Manufacturing drone

Data and Results



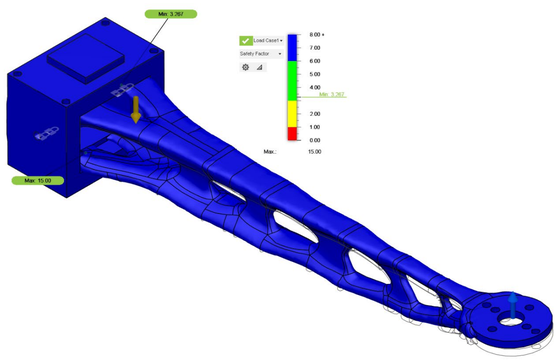


Figure 2: Traditional vs Generative design Finite Element Analysis (FEA) (PLA 100%)

- ❑ Weight reduction using generative design on Fusion 360.
- ❑ Safety factor of 3 or more to avoid failure.
- ❑ Weight of Drone causing downward force vs upward thrust force of motors [2]

Data and Results

Material	Original Design	PLA100
Volume (mm^3)	54,330	39,770.868
Mass (kg)	0.07	0.051
Von Mises Stress (MPa)	8.792	16.837
Safety Factor	6.256	3.286
Displacement (mm)	2.506	3.678

Table 1: Mechanical Properties of Polymers at 100% infill density

Conclusions & Future Work

Conclusion –

- ❑ Table 1 shows GD reduced weight by 20% while maintaining a factor of safety of 3.286.
- ❑ Hybrid design with PLA and PETG meets thrust requirements for T-motors at 1.2kg of thrust per motor.

Future Work –

- ❑ Develop X-Shaped UAV.
- ❑ Implement GD with composite support for 3D printed arms.
- ❑ Optimize Aluminum/Carbon Fiber plates for longer flight times.
- ❑ Achieve flight time of 30 minutes or more.
- ❑ Obtaining mechanical properties of filaments such as PCTG, GF-Nylon(PA6), CF-Nylon(PA6).

Acknowledgments

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References

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[2] Bright, Jerrin, et al. "Optimization of quadcopter frame using generative design and comparison with DJI F450 drone frame." In *IOP conference series: materials science and engineering*, vol. 1012, no. 1, p. 012019. IOP Publishing, 2021.