Water Bomber Pump Optimization for Wildfire Control

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Abstract

- This project aims to regionally optimize stop-and-go unmanned aerial water bombers and prove their viability as a superior alternative to skimming aircrafts.

Figure 1: Fire boss [1]

- BC is used as a case study due to the prevalence of wildfires in the province. The ideal UAV for BC's geographical data is designed using genetic algorithms.
- A pump is optimized for the ideal UAV and compared to off-the-shelf models.

Figure 2: Current render of the UAV with the NACA TN 2481 Tail [2]

Citations

[1] D. VA, Wikipedia, 2017 [Online]. Available: https://en.wikipedia.org/wiki/Air_Tractor_AT-802#/media/File:Air_tractor_arrendado_por_CONAF_(modified).jpg. [Accessed: 05-Mar-2023]

[2] R. Ward, B. Readman, B. O'Yeung, and W. S. Hinman, "Regional optimization of remotely piloted amphibious aircraft for wildfire air attack," [Manuscript submitted for publication], 2022.

Introduction

- Current skimming aircrafts can only utilize 55 lakes across BC for wildfire control.
- A smaller, more agile aircraft can target up to ~400,000 lakes.
- Fire-to-lake distance decreases exponentially as the size of the lake decreases.

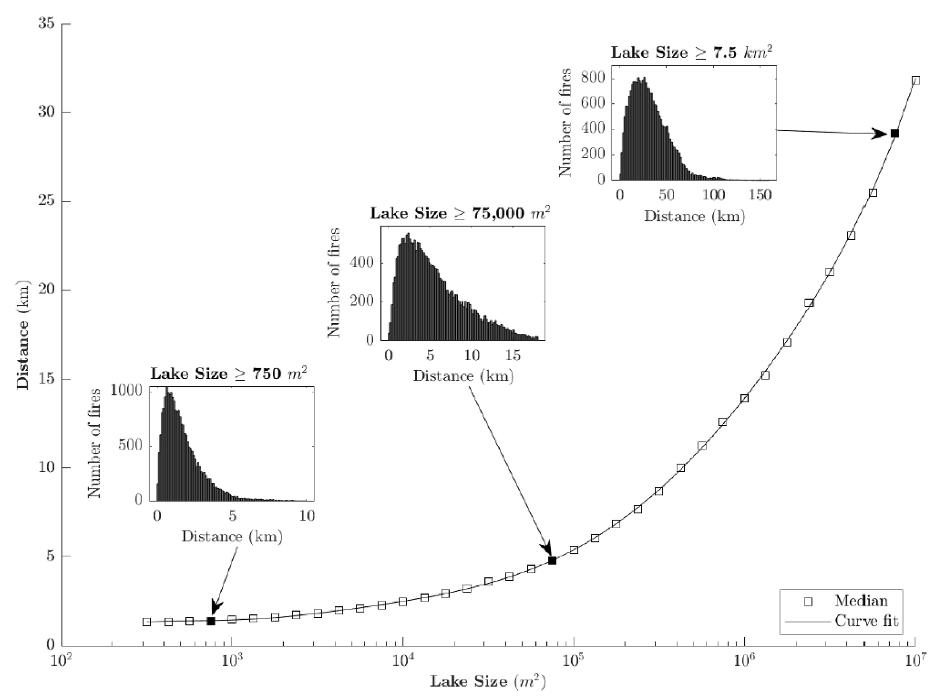

Figure 3: Relationship between median fire to lake distance with respect to lake size [2]

Objectives

Past project phases were used to develop equations to computationally model the ideal UAV. The goals for this project phase were

1. to design the UAV's fill and dump system
2. to compare this pump system to its existing off-the-shelf counterparts
3. to develop a functioning prototype of the pump system as proof of concept
4. to integrate the results into the computational model and run an optimization to achieve the ideal aircraft and its ideal pump system

The initial quantitative goals used to start the optimization were

- a maximum fill time of 6.6 L/second
- a maximum pump system weight of 12% of the total aircraft weight

Design Process

1. Pump type — Based on various selection factors, a decision matrix was used to determine that the ideal pump type for this project is a gear pump.

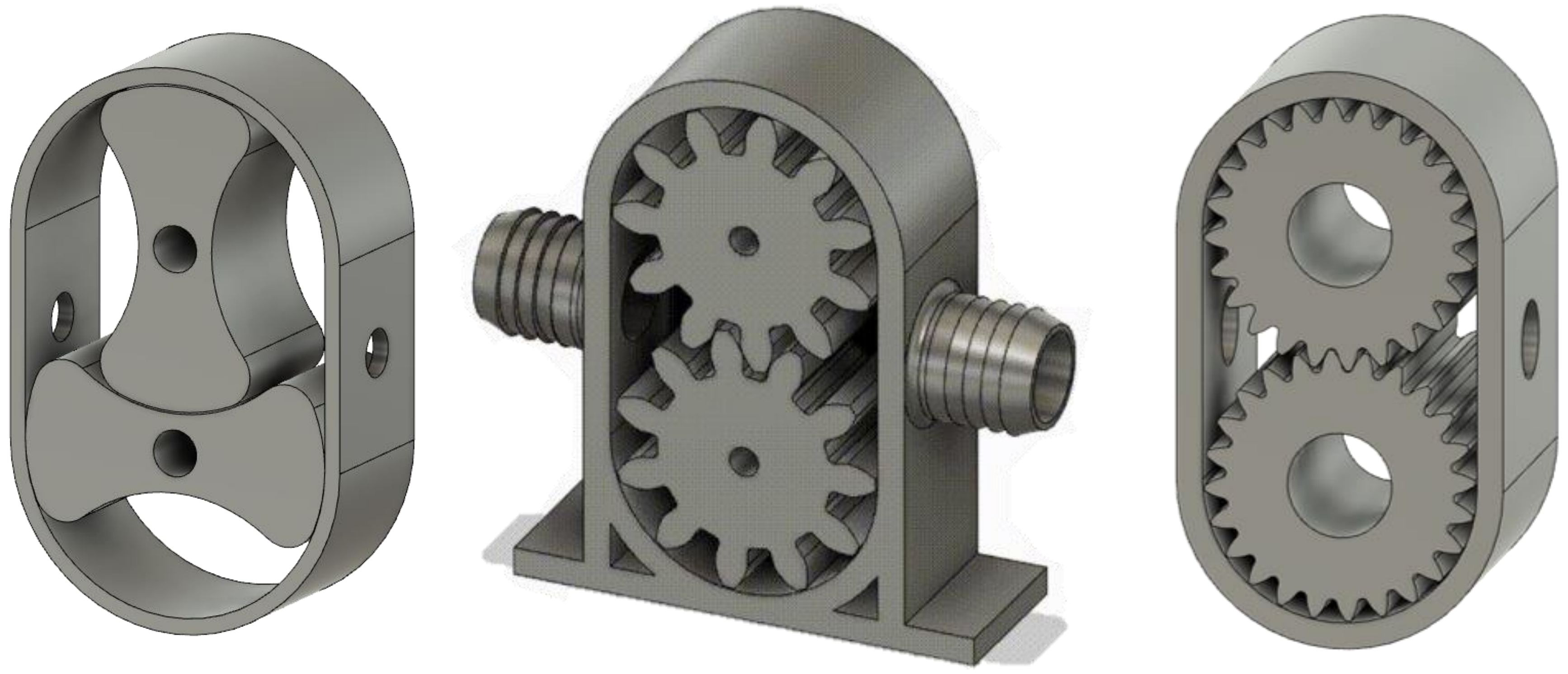

Figure 4: Various gear pump designs considered; The middle model was chosen as the final iteration.

2. Power transmission type — Initially, the onboard engines were considered as a power source for the fill system; however, this would require detachable propellers. Instead, a battery-driven electric transmission was selected.
3. Integration of the fill system into the optimization model was done as follows:

Aircraft Inputs	Pump Inputs	Geographical Inputs
Wing Loading Power Loading Volume of Water Volume of Fuel	Internal Displacement Flow Rate Battery Size	BC Historical Wildfire Data BC Water Source Data

Optimization

Genetic Algorithm

Calculate Population → Score Population (Fitness Test) → Select and Retain Elite Parents → Produce Crossover Children / Produce Mutated Children → Convergence/Pareto Efficiency

Pump Specific Calculations

Internal Displacement → Dimensions, Pressure, PRM → Power Efficiency → Pump Mass

Flow Rate → Fill Time → Battery Size → Battery Mass

Pump Mass, Battery Mass → Total Mass

Outputs	Flow Rate to Fire Aircraft Cost

Figure 5: Integration of fill system into optimization model

Prototype & Experiments

- A testing apparatus was built using a 3D-printed gear pump and RC scale airplane motor, battery, and control systems.
- The experiments allow the correlation of input power and output flow rate, and the empirical validation of equations used in the optimization.
- Motor RPM is controlled by the transmitter and the time elapsed to move a known volume of water from the 1st tank to the 2nd is measured.

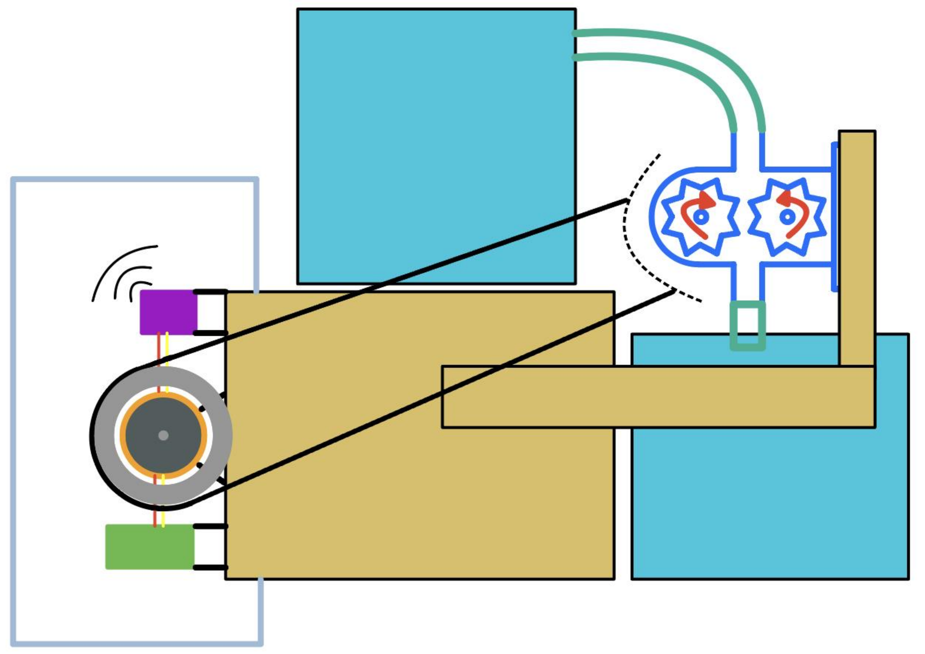

Figure 6: Schematic of testing apparatus

Results & Conclusions

The following graphs show current results:

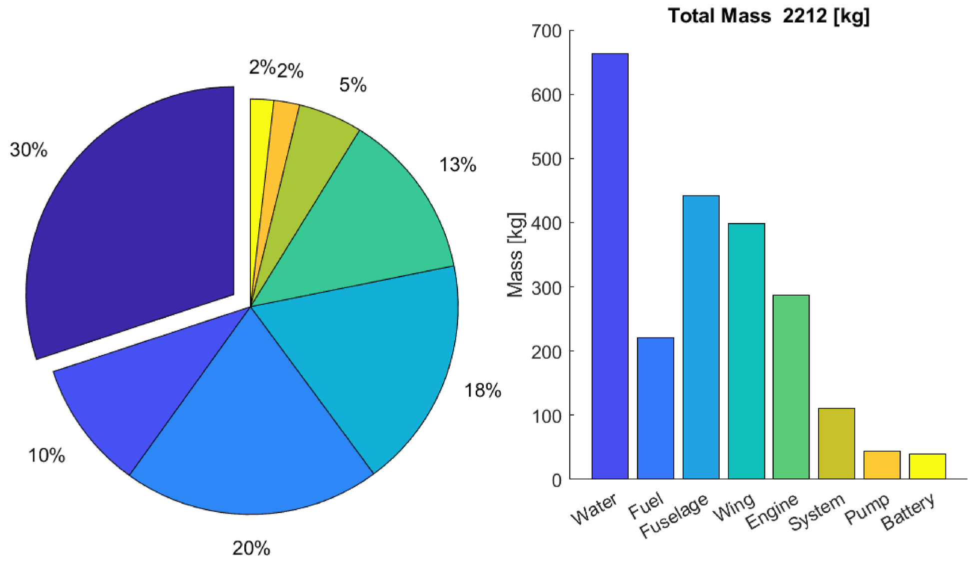

Figure 7: System mass breakdown

Preliminary findings suggest that the selection of the battery-operated pump has a notable effect on the drone's performance. The pump designed successfully represents a small fraction of the pareto-optimal aircraft's mass whilst providing rapid filling times.

UAV – unmanned aerial vehicle
BC – British Columbia
RC – remote-controlled
RPM – revolutions per minute

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