Design of a high wind-resistant Unmanned aerial vehicle (UAV)

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Summary

This paper describes the process and results of a detailed high wind resistant Unmanned Aerial Vehicle (UAV) design for disaster relief purposes proposed by NovelT and Drone Team Twente. A design research is made where a combination of existing designs and iterations of potential ideas are performed. A tail-sitter design approach is chosen as it shows high wind durability and high performance in keeping stability. The tail-sitter is then analyzed in how it could be more stable. Two design directions are emerged, the first design adjusts the center of pressure of the UAV and the second one displaces the center of gravity. Next, is the ideation phase where moving mechanisms and other UAV important components such as the wings, landing, mechanical and propulsion systems part of the drone are iterated. Two conceptual designs are derived, and an aerodynamic analysis takes place where the shaping of the air frames comes next where proportions are calculated to make it a longitudinally static stable design. The change of pressure design outperforms the change of mass concept in terms of stability control and was selected to be further designed.

At this point the design of the exterior shape of the UAV is complete however the units are in ratios, a conversion method is applied to adjust that ratio to dimensions and mass properties. The mass of the vehicle is found, the dimensions of the vehicle are now known, the airflow behavior is examined by calculating the wind behavior for multiple magnitudes and therefore directions to create a total airflow vector in terms of magnitude and direction which is then translated to absolute angle of attack and Mach number. The drone model is then simulated with each of the vector flow magnitudes and directions. The effects of those folding wings are then examined by analyzing the Lift, drag, Inertia, maximum bending stress, and maximum elongation where a material and the thickness of the vehicle are defined. Then the mechanical systems are studied such as the folding wing and locking cargo mechanisms. The design is then validated with the use of flight mechanics where the propulsion and performance of the vehicle are calculated. Finally solid works is used to integrate all those components together and design them in such a way to be ready for manufacturing by 3D printing.

In conclusion, the simulation analysis showed, that displacing the center of mass did not prove to be effective in terms of change of pitching moment coefficient in function with the angle of attack and the only good and effective solution to have a longitudinally stable design for high

angle of attacks proved to be by moving the aerodynamic center for providing high control ability to the drone. That design is very effective as it does not waste thrust when trying to cope with the instability of the wind but instead uses its aero control surfaces to re orient and therefore stabilize itself offering high performance in terms of operational range and maximum speed. The design of the drone has reached an end, it has been aerodynamically, structurally and flight mechanically proven that it can fly with high winds exceeding 40 [km/h] while meeting the investigation and constraints requirements. The current model is a 3D fully printed UAV which has all components made in plastic, plastic is not the most efficient material in terms of stiffness by mass however it is massively used therefore materials not hard to obtain leading to the manufacturing method being cheap. The main application of this drone is to be operational when needed including in high winds, the cost of the mission comes at saving lives and not about energy burning per mile such as how airliners do therefore efficiency is a lower priority and easiness in manufacturing comes first. Finally, that design fulfils the requirements and can fly during high wings. In addition, due to the fact that the drone has the ability in folding its wings, its wingspan could be reduced to allow additional parking space and shipping for logistical applications as well. Finally, this research will help Drone team Twente in understanding how their future drones could be designed to withstand crosswinds and thus increase their operability for disaster relief situations, and perhaps some of the technology such as the folding wings concept, if not all the concept, to be implemented to their future design concept aimed to start in September 2022 and to be introduced to the market as a product if successful development is achieved.

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