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Definition of Aerodynamic Coefficients for Microgravity Unmanned Aerial System

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Abstract : The evolution of Unmanned Aerial Systems (UAS) has made it possible to develop new vehicles capable to perform microgravity experiments which due its cost and complexity were beyond the reach for many institutions. In this study, the aerodynamic behavior of an UAS is studied through its deceleration stage after an initial free fall phase (where the microgravity effect is generated) using Computational Fluid Dynamics (CFD). Due to the fact that the payload would be analyzed under a microgravity environment and the nature of the payload itself, the speed of the UAS must be reduced in a smoothly way. Moreover, the terminal speed of the vehicle should be low enough to preserve the integrity of the payload and vehicle during the landing stage. The UAS model is made by a study pod, control surfaces with fixed and mobile sections, landing gear and two semicircular wing sections. The speed of the vehicle is decreased by increasing the angle of attack (AoA) of each wing section from 2° (where the airfoil S1091 has its greatest aerodynamic efficiency) to 80°, creating a circular wing geometry. Drag coefficients (Cd) and forces (Fd) are obtained employing CFD analysis. A simplified 3D model of the vehicle is analyzed using Ansys Workbench 16. The distance between the object of study and the walls of the control volume is eight times the length of the vehicle. The domain is discretized using an unstructured mesh based on tetrahedral elements. The refinement of the mesh is made by defining an element size of 0.004 m in the wing and control surfaces in order to figure out the fluid behavior in the most important zones, as well as accurate approximations of the Cd. The turbulent model k-epsilon is selected to solve the governing equations of the fluids while a couple of monitors are placed in both wing and all-body vehicle to visualize the variation of the coefficients along the simulation process. Employing a statistical approximation response surface methodology the case of study is parametrized considering the AoA of the wing as the input parameter and Cd and Fd as output parameters. Based on a Central Composite Design (CCD), the Design Points (DP) are generated so the Cd and Fd for each DP could be estimated. Applying a 2nd degree polynomial approximation the drag coefficients for every AoA were determined. Using this values, the terminal speed at each position is calculated considering a specific Cd. Additionally, the distance required to reach the terminal velocity at each AoA is calculated, so the minimum distance for the entire deceleration stage without comprising the payload could be determine. The Cd max of the vehicle is 1.18, so its maximum drag will be almost like the drag generated by a parachute. This guarantees that aerodynamically the vehicle can be braked, so it could be utilized for several missions allowing repeatability of microgravity experiments.

Keywords : microgravity effect, response surface, terminal speed, unmanned system
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