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LIFT-TO-DRAG RATIO REQUIREMENT ANALYSIS INCLUDING LOW ALTITUDE GUIDANCE FOR RE-ENTRY FLIGHT OF VTOL VEHICLE

Abstract

Lift-to-drag (L/D) ratio of vertical takeoff and landing (VTOL) vehicles is relatively smaller than that of horizontal takeoff and landing vehicles. Also, the ballistic coefficient of VTOL vehicles is small. This means a re-entry flight of VTOL vehicles is deeply affected by the fluctuations of wind. On the other hand, it is important for VTOL vehicles to make L/D ratio small in order to reduce the size of wings since the structural weight and the drag loss of wings at launch can be reduced. To study the minimum required L/D ratio which enables to return for the re-entry flight, it is needed to investigate the effect of wind for VTOL vehicles. In this paper, L/D ratio required for the re-entry flight at given down range is evaluated under the fluctuations of wind. Especially, at the relatively low altitude of the re-entry flight under 27 km, a re-entry guidance strategy is demonstrated for VTOL vehicles, which have small L/D ratio. For the evaluation of the required L/D ratio, a new guidance law is proposed, and trajectory optimization, sensitivity analysis, and Monte Carlo dispersion analysis are performed. As a result, the minimum required L/D ratio for the re-entry flight under the fluctuations of wind for VTOL vehicles is obtained, and it is found that the dependency of the required L/D ratio versus the effect of wind becomes larger as the ballistic coefficient becomes smaller. Moreover, it is shown that the vehicles take a detour to the windward side to maximize the down range when flying in a cross wind. Furthermore, reachability to the landing point in the re-entry flight under the influence of wind can be estimated from the condition of wind speed and direction. These results indicate that the effect of wind should be strongly considered for aerodynamic, trajectory, and guidance law design of VTOL vehicles, which have small L/D ratio and the small ballistic coefficient.