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ADAPTIVE GUIDANCE LAW FOR TRAJECTORY CONTROL OF A REUSABLE LAUNCH VEHICLE DURING AIR-BREATHING ASCENT PHASE

Abstract

An adaptive guidance scheme is developed for air-breathing ascent phase of a Reusable Launch Vehicle (RLV). Reusable Launch Vehicles with air-breathing propulsion are being considered as promising candidates for the future low cost space transportation systems. These vehicles provide more effective way to launch satellites and other vehicles to Low Earth Orbit (LEO) than rockets. The near minimum fuel trajectory for such vehicles is, however, substantially different from that of a rocket powered expendable vehicle. Whereas a rocket powered vehicle leaves the dense atmosphere quickly to minimize the drag losses, an air-breathing vehicle dwells much longer in the dense atmosphere where the air-breathing propulsion is more efficient. Thrust generated by the air-breathing engine is highly sensitive to flight path and angle of attack. This has a major impact on the nature of the optimal trajectories. Moreover, the amount of aerodynamic uncertainty is more compared to conventional launch vehicles. This points to the fact that guidance and control strategy dependent on pre-launch, predetermined trajectory as used in conventional launch vehicles is inadequate for air-breathing RLVs. RLV needs a fully autonomous guidance scheme with on-board trajectory planning for generating reference profile on-line along with an adaptive guidance law for generating the commands required to follow the reference profile. The guidance approach has two loops. The outer loop is a trajectory planning loop (parameter adjustment loop). The inner loop is a normal feed back control loop with adaptive feature of modifying the feed back gains on-line depending upon the current performance of the vehicle and nature of disturbance. The onboard trajectory planning is achieved using simplified trajectory optimization based on energy state approximation method. Present study addresses the development of an adaptive guidance law that controls the vehicle lift force using a Proportional Derivative (PD) controller. The gain adaptation algorithm modifies the feed back controller gains on-line, in response to the altitude and velocity deviations from desired reference trajectory making use of the current estimate of states from Navigation. The system dynamics is propagated to the end of atmospheric ascent phase considering angle of attack as the active control variable. The adaptive guidance law is validated through extensive flight simulations for air-breathing engine off nominal performance, aero parameter uncertainties and atmospheric density perturbations. The simulation results presented establish the robustness of the newly developed algorithm to meet the mission requirements, satisfying the path constraints and terminal constraints.