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Lateral-Directional Control Law Design, Handling Qualities and Uncertainty Analysis for a Re-entry Vehicle HL-20 Flight Control System

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Abstract

Re-entry vehicles are spacecraft or missiles that return to Earth's atmosphere after traveling in space. The flight control of these vehicles involves controlling their trajectory, speed, and orientation during re-entry to ensure a safe landing. This is achieved through a combination of aerodynamic control surfaces (such as flaps, fins, and drogues), attitude control thrusters, and guidance systems. These systems work together to guide the vehicle through the harsh conditions of re-entry and make necessary adjustments to ensure a safe landing [1].

Typically, the re-entry vehicle is guided by on-board computers and doesn't require a pilot to fly it. However, in some emergency situations, a pilot may have limited control over the re-entry vehicle, but it is not a common scenario. In such cases, the primary objective is to ensure the safety of the crew and the vehicle. For this, it is critical to have good handling quality. Handling quality in a re-entry vehicle flight control system is determined by its ability to control the vehicle's attitude, speed, and trajectory during re-entry. High handling quality means that the vehicle is stable, responsive, and easy to control. This is achieved through careful design of the aerodynamic control surfaces, control thrusters, and guidance systems, as well as thorough testing and validation. Factors that affect handling quality include vehicle design, atmospheric conditions, and the skill of the operator. Good handling quality ensures a safe and controlled re-entry, minimizing risk to the vehicle and its occupants [2].

Designing control law for aerospace vehicles is a challenging task specially once a comprehensive design criteria is set to obtain optimum handling qualities and performance specification in the presence of uncertainties. When designing a control law for a re-entry vehicle, uncertainty must be considered and handled appropriately to ensure safe and reliable performance. This ensures that the control system is reliable and able to handle the various uncertainties that may arise during re-entry. In this paper, preliminary design activity for lateral-directional control laws of HL-20 re-entry vehicle [3] is described to meet a comprehensive set of stability, handling qualities, and performance specifications. Both time domain and frequency domain methods were used to tune the gains to obtain optimum handling qualities. Optimised set of gains were tested for parametric uncertainties in mass-inertia , aerodynamic coefficients and hardware parameters to produce a clearance region. The results thus obtain complemented our systematic approach towards a multi-objective design of lateral-directional control law for an aerospace vehicle.

References

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