Paper ID: 79729
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IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Technologies for Future Space Transportation Systems (5)

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PARAMETER OPTIMIZATION-BASED AUTOMATIC DESIGN OF LAUNCH VEHICLE'S ATTITUDE CONTROLLER

Abstract

This paper presents a novel approach to designing a linear attitude controller for a launch vehicle during its ascent phase, using parameter optimization techniques. The ascent phase is a crucial stage in the launch of a vehicle, where the rocket must be precisely controlled to achieve its desired trajectory while enduring the aerodynamic instability. Furthermore, the controller must stabilize the structural vibration that can potentially diverge the system. Therefore, designing an attitude controller that satisfies various requirements for numerous design points is difficult and labor-intensive. The proposed approach utilizes a linearized model of the launch vehicle's dynamics, which is obtained by linearizing the nonlinear equations of motion about a reference trajectory. To properly incapsulate the complicated characteristics of the launch vehicle dynamics, the bending, propellant sloshing and engine TWD(Tail-Wag-Dog) effects are included in the linear model. The linearized model is then used to design a feedback controller that stabilizes the vehicle's attitude by regulating its angular rates and angles. The parameter optimization techniques are employed to handle two separated tasks: 1. Obtain the proportional-derivate(PD) gain, 2. Designing the optimal bending filter. The automatic design process undergoes the several iterations of the both task to find a saddle point between the two tasks, which has trade-off in terms of bending attenuation and stability margin. The optimization problem for PD gain is formulated to ensure that the controller provides desirable step response of the vehicle's attitude, while satisfying the given stability criterion. The optimization problem for bending filter aims to maximize the robustness to the structural bending while also ensuing the stability margins. The optimization problems are solved using CEALM, which is free from the singularity of the gradient that occurs in the controller and filter optimization problems. Simulation results show that the proposed controller design approach is effective in achieving the desired performance specifications. The controller is able to stabilize the vehicle's attitude and satisfy the given specifications while maximizing the robustness to the structural bending. The proposed approach has several advantages over traditional design methods, which often rely on heuristic tuning of controller parameters. By using parameter optimization techniques, the proposed approach can systematically explore the design space and identify optimal controller parameters that satisfy the desired performance specifications. This can lead to more efficient and effective controller designs, which could ultimately lower the barriers to designing launch vehicles in the New Space Age.