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ADAPTIVE CORRECTION NETWORK INCORPORATING RATE GYRO WEIGHTING FOR HEAVY LAUNCH VEHICLE ATTITUDE CONTROL

Abstract

The Heavy Launch Vehicle (HLV) serves as a pivotal spacecraft carrier for large-scale human space activities, playing a crucial role in future space endeavors. This study addresses the challenges posed by the HLV's elastic nature, characterized by low-frequency first-order vibrations with notable rigid-elastic coupling. These elastic vibrations, detected by inertial platforms and rate gyros, can disrupt the control loop, potentially jeopardizing the success of launch missions. Consequently, the design of HLV attitude controllers has garnered considerable attention. Conventional approaches predominantly employ correction networks or notch filters to mitigate the impact of elastic vibrations on the control system, representing the prevalent engineering solution. However, as elastic vibration frequencies decrease, the design complexity of correction networks escalates. Furthermore, the adaptive capability of these networks becomes crucial due to uncertainties and time-varying characteristics in the launch vehicle model parameters.

This paper introduces an innovative attitude control method, leveraging rate gyro weighting and an adaptive correction network to address these challenges. Initially, an attitude tracking error dynamics model is formulated, incorporating multiple rate gyros positioned across the rocket body. The interpolated discrete Fourier transform method is then applied to convert rate gyro measurement signals into the frequency domain, facilitating the identification of elastic frequencies. Subsequently, a rate gyro adaptive weighting method is proposed to minimize the entry of elastic vibration signals into the control loop. Finally, an adaptive correction network is devised to rectify the attitude angle channel and angular velocity channel individually. This network exhibits the capability to dynamically adjust pertinent parameters based on frequency identification results, preventing the unwarranted excitement of elastic vibrations and thereby upholding the stability of the control system. The stability of the proposed control method is substantiated through frequency analysis.

Numerical simulations, considering diverse parameter deviations, validate the performance of the proposed attitude control method. Results demonstrate that the rate gyro adaptive weighting method significantly suppresses elastic vibration signals in rate gyro measurements, mitigating their adverse effects on the control system at the source. This enhancement improves the HLV attitude controller's performance and reduces the complexity of controller design. The adaptive correction network demonstrates its effectiveness in maintaining stability under time-varying model parameters. Notably, the proposed control method proves applicable in scenarios with deviations in mode shape slopes and frequencies of elastic vibrations.