ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Control, Sensors and Actuators (7)

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ATTITUDE CONTROL DESIGN AND TEST OF KSLV-I UPPER STAGE

Abstract

This paper introduces the upper stage attitude control system of KSLV-I which is the first two-staged space launch vehicle in Korea. The upper stage control system has the aim of controlling the attitude errors from the time of stage separation until payload separation in order to target the flight direction exactly to the payload mission orbit. The KSLV-I upper stage attitude control system consists of two electro-hydraulic actuators and a reaction control system using nitrogen gas as its fuel. The electro-hydraulic actuators change the direction of thrusting force to produce lateral torques, which controls the pitch and yaw attitude errors during the upper stage accelerating phase. The nitrogen gas reaction control system, which has twelve 22 N gas-jet nozzles, controls the three axis attitude errors during coasting phases of upper stage. An onboard software switches the control algorithm automatically according to the change of flight phases. A proportional, derivative, and integral controller (namely PID controller) is designed for the electro-hydraulic thrust vectoring system, and a bending filter is added to remove the unwanted effects from high frequency flexible modes. The PID parameters are scheduled with respect to operating time of upper stage. The stability margin analysis shows the designed controller satisfies the design criteria. Schmidt trigger ON/OFF controllers are designed for nitrogen gas-jet system. The limit cyclic motions on the error phase plane are analytically investigated. Constraints on gas consumption, limit cyclic period, and time delay margin are included into the controller design problem. The stability and performance of KSLV-I upper stage attitude control system integrated in system level are verified for parametric variational cases through six degree of freedom nonlinear simulation (namely 6-DOF simulation) and hardware in the loop simulation (namely HILS). In HILS, the attitude controllers are loaded onto an onboard computer which includes the navigation and guidance module also. The 6-DOF simulation program is loaded onto a real-time computer which calculates the translational and rotational motions of KSLV-I in real time. A flight motion simulator provides three axis rotational attitudes to the onboard inertial measurement unit according to real time calculation of flight motion. The nozzle angles resulting from the electro-hydraulic actuation are measured by potentiameters and fedback to the 6-DOF program in real time simulation computer. The actual thrusting forces of nitrogen gas-jet nozzles are measured by pressure sensors and fedback also to the 6-DOF program. By making the HILS loop closed, we have accomplished the final stability and performance test of onboard control systems of KSLV-I upper stage before launch campaign. We have increased the possibility of successful flight of KSLV-I through repeated sequential HILS tests.