ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (9)

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RACS QFR ALGORITHM FOR VEGA FPSA PROGRAM

Abstract

This paper describes the design and tuning methodology of the RACS (Roll and Attitude Control System) for VEGA launcher vehicle (LV), in the frame of the development of an Alternative Flight Program Software (FPSA). The performances of this algorithm are also discussed in terms of control accuracy, fuel consumption, number of RCT (reaction control thrusters) activations, missionization complexity, and robustness to system uncertainties.

The control law of the proposed Quaternion Feedback Regulator (QFR) algorithm consists of linear error-quaternion feedback (proportional action), linear body-rate feedback with a feed-forward term (introducing an artificial damping factor, i.e. derivative action), and a nonlinear body-rate feedback term that counteracts the gyroscopic coupling torque. The quaternion error, considered in the control torque computation, represents the rotation that the LV shall perform to obtain the programmed quaternion. Both the control action gains can be related to the full inertia matrix and for this reason, the QFR algorithm presents fully MIMO characteristics. The independence of the closed loop dynamic behaviour from the LV inertia is guaranteed by a generic characterization of the control gains, valid and applicable for all mission types. In particular, the desired linear dynamic behaviour is obtained by tuning the proportional and derivative gain as function of damping ratio and natural frequency of an equivalent linear second order system.

A dead zone prevents thruster activation when the error is within the expected performance, reducing the opening times of the RCT valves. The selection of the deadzone thresholds depends on the inertia matrix through the external disturbance torques and the actuation nonlinearities (maximum and minimum torque). In this way, a particular criteria which takes into account these dependences, regulates the thresholds tuning.

The thrusters and the vehicle dynamics are equivalent to a low pass filter reacting only to the mean value of the imposed torque, allowing to use a Pulse Width Modulated torque command signal. Starting from the desired torque, the thrusters assignment logic computes the PWM duty-cycle and respective opening time required for each thruster.

Algorithm effectiveness has been assessed on a representative numerical simulation environment, considering the main critical flight phases for RACS function and key performance criteria (fuel consumption,

number of activations and control accuracy). Algorithm robustness has been evaluated using a Monte Carlo analysis, against a set of uncertainties and dispersions on LV conditions, Mass, Center of Gravity and Inertia characteristics, RCT performances and sloshing models.