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MAGNETIC ATTITUDE CONTROL OF SATELLITES USING COARSE PULSE-WIDTH-MODULATION OF MAGNETORQUERS

Abstract

Magnetorquers are reliable and low-cost actuators due to their simple mechanisms, and especially microsatellites prefer magnetorquers as an attitude control actuator. Since magnetorquers generate magnetic moment by passing electric currents through coils, the magnitude of the magnetic moment is constant. To avoid dealing with such constant control inputs, magnetorquers are usually operated with pulse-width-modulation (PWM) so that variable magnetic moments can be averagely generated. However, microsatellites have limitations on their component capability, and high-frequency PWM actuations are difficult to implement. Thus coarse PWM actuations should be explicitly considered for the magnetic attitude control of microsatellites. Moreover since the magnetorquers generate control torques into a plane orthogonal to the geomagnetic field, three-axis attitude control using only the magnetorquers is a challenging problem. In this context, this study deals with the magnetic attitude control of satellites using only magnetorquers that are driven with coarse PWM. The coarse PWM actuations in this study mean that the magnetorquers are successively actuated by on-state and then off-state in each actuation cycle of a few seconds. The difficulties of the coarse PWM actuations stem from the followings: 1) Conventional techniques for feedback controllers are hard to be applied because the magnitude of the magnetic moment is constant. 2) The dynamics of the satellite has nonlinear terms in control torques due to coarse PWM actuations. First, the dynamics of the satellite with on-off inputs are formulated as a discrete system in order to deal with the coarse PWM actuations of the magnetorquers. The stability of the satellite attitude is studied in the discrete system. Then, to tackle with the nonlinearity of the control torques, exact linearization is used for considering the actuation time of the magnetorquers as the control inputs. Although the magnetic moment of the magnetorquers is constant, the exact linearization enables dealing with the actuation time as the control inputs whose magnitude vary. Some numerical simulations for satellites in sun-synchronous orbits are shown to verify the effectiveness of the proposed method.