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Robust dynamic output feedback control for attitude stabilization of spacecraft with nonlinear perturbations

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Abstract. This paper investigates the robust dynamic output feedback non-fragile control (RDOFNFC) strategy for spacecraft attitude stabilization problem with nonlinear perturbations. The spacecraft attitude dynamics model takes the actuator saturation limits, external disturbances, controller perturbation and model parameter uncertainty into account. To make spacecraft attitude system satisfy H_∞ performance and quadratic stability, with respect to the additive perturbation in initial state and multiplicative perturbation in decay phase, the corresponding RDOFNFC is designed respectively. Based on Lyapunov theory, the controller design is transformed into a multi-objective convex optimization problem based on linear matrix inequalities (LMIs). Simulation results based on the on-orbit servicing spacecraft show good performance under external disturbances, model parameter uncertainty and controller perturbation, which validates the effectiveness and feasibility of the proposed control method.

Keywords: spacecraft attitude stabilization, dynamic output feedback, robust non-fragile control, nonlinear perturbations, linear matrix inequality

1. introduction

To meet the requirements of future space missions, the high-precision and high-stability attitude control problem of spacecraft has become more and more important. However, many uncertain factors such as environmental and non-environmental disturbances, parameter uncertainty, and other nonlinear perturbations widely act on spacecraft [1,2]. Moreover, the structural perturbations of actuator, which can also be regarded as controller perturbations on the role of influence, usually occur in maneuvers, which seriously affect attitude control performance [3,4]. These problems pose a huge challenge for attitude control system designers, and thus good control approaches are required to improve robust performance and control accuracy to solve these problems.

State feedback controller requires all the state information, which is difficult to meet for high-order systems, and some components of state vector may be virtual and cannot be measured, and the output is always able to be obtained, then the output feedback controller embodies its own advantages. Over the last decades, many researchers have performed extensive studies on the spacecraft attitude control system. Early in the 1980s, the attitude stabilization problem of flexible spacecraft has been discussed in [5,6] and [7]. Afterward, to improve robust and non-fragile performance in the presence of external disturbances and model parameter uncertainty, many control methods have been studied for the spacecraft attitude control system. Jovan D et al. [8] proposed two globally stable control algorithms for robust stabilization of spacecraft in the presence of control input saturation, parameter uncertainty, and external disturbances. Hu et al. [9] proposed the robust adaptive variable structure output feedback control algorithm for stabilization of a three-axis stabilized flexible spacecraft in the presence of parameter uncertainty, external disturbances and control input nonlinearity. Tayebi [10] proposed a dynamic output feedback control approach based on quaternion for spacecraft attitude tracking problem, but he didn't consider the problem of input limit and nonlinear perturbation of controller, which brought difficulty for engineering practice. The attitude tracking control problem of rigid spacecraft without knowing angular velocity has been studied in [11,12] and [13], in which the observer was adopted to estimate the angular velocity used in the control law. The adaptive output feedback control method for the rotational maneuver and vibration suppression of flexible spacecraft only considering the output variable (pitch angle) was studied in [14]. The robust H_∞ output feedback control approach based on linear matrix inequality was studied to achieve attitude stabilization of a flexible spacecraft in [15]. Taking actuator misalignment into account, the mixed finite time control and control allocation method for attitude stabilization of a rigid spacecraft was investigated in [16]. In [17], robust adaptive terminal sliding mode control method was used in the relative position and attitude tracking control problem during autonomous rendezvous and docking of two spacecraft. In addition, robust non-fragile control method has been widely applied in many other systems. The robust output tracking control problem of nonlinear multi-input multi-output systems has been discussed in [18] and [19], with sliding mode technique and fuzzy approach, respectively. The problem of non-fragile H_∞ static output feedback controller design for a class of continuous-time semi-Markovian jump linear systems has been studied in [20]. The non-fragile finite-time filtering problem has been studied for a class of nonlinear Markovian jumping systems with time delays and uncertainties in [21]. The non-fragile controller design for an offshore steel jacket platform with

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