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STUDY ON THE STABILITY OF NONLINEAR TIME-VARYING SPACECRAFT CONTROL SYSTEM

Abstract

The stability of spacecraft control system is a precondition to guarantee the stable operation of spacecraft. With the increasing complexity of spacecraft structures and the increasing demand for the function and performance of spacecraft, the stability analysis of spacecraft control system is getting more and more difficult. Early spacecraft are mainly rigid-body satellites. Usually PID controllers are designed, and fly-wheels or thrusters with pseudo-rate modulators are used as actuators. The closed-loop control systems for this kind of spacecraft are linear and time-invariant. Thus Nyquist criterion can be applied to analyze the stability of these systems. And the gain margins and phase margins of these systems can also be obtained, which meets the engineering requirement for parameter uncertainty margins. Later large-scale liquid-filled spacecraft appears, such as large-scale communication satellite with large amount of liquid propellants. This type of spacecraft shows slowly time-varying feature with liquid propellant consumption during orbital maneuver. In such case Nyquist criterion is no longer applicable. Although Lyapunov stability theory is suitable for the stability analysis of time-varying systems, it is not convenient to provide the stability margins, which limits its practical application. For this type of slowly time-varying systems, mostly frozen coefficient method is selected in engineering. For modern spacecraft, nonlinearity and time-varying are getting more and more prominent. The controller is more complex than PID controller. For these nonlinear time-varying systems, no suitable stability analysis method is found in engineering so far. Sometimes describing function method is applied as approximate analysis. But its credibility is not satisfactory. Therefore, to verify the stability of these nonlinear time-varying systems, a large number of mathematical simulations are performed to verify the stability of these nonlinear time-varying systems. And the stability margins are determined according to the results of worst case and parameter deviation simulations. However this method lacks the theoretical support. In order to solve the above problem, we began to study the method of stability analysis based on computer simulation one year ago. We expect to find a new way for the stability analysis of nonlinear time-varying systems and it is applicable for practical engineering. Fortunately, some preliminary results have been achieved. In this paper, the stability analysis methods used in practical engineering for different kinds of spacecraft will be introduced. And the stability analysis method based on computer simulation will be presented.