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ZERO-PROPELLANT ATTITUDE MANEUVER PATH PLANNING OF SPACE STATION BASED ON SIMPLE GIMBAL CONTROL MOMENT GYROSCOPES

Abstract

Thrusters are replaced by control moment gyroscopes (CMGs) to execute attitude maneuver of space station. Through the path planning of space station attitude maneuver, the saturation and singularity of CMGs are obviated and zero-propellant maneuver (ZPM) is successfully accomplished. ZPM is an advanced concept of attitude control, which has been applied in International Space Station (ISS) by double gimbal control moment gyroscopes (DGCMGs) in 2006 and 2007. With the background of China space station project, this paper studies ZPM path planning problem based on simple gimbal control moment gyroscopes (SGCMGs). Relative to DGCMGs, the saturation and singularity problems of SGCMGs are more complex, it is required to introduce the SGCMGs steering law into path planning models. These differences between SGCMGs with DGCMGs will bring difficulties to establishing the planning models and solving the planning problem. Firstly, the dynamical and control models of ZPM are established. The dynamical equations of space station and SGCMGs are formulated, Penrose-Moore steering law is introduced, while controller adopting the classical PD algorithm. Secondly, the path planning models of ZPM are presented. The attitude angle, angle velocity, momentum and gimbal angle of SGCMGs are selected as state variables. The initial and terminal values of these variables and singularity measurement of SGCMGs are taken as constraints. While choosing the minimization of the function of momentum peak value as optimization goal, then ZPM path planning would be described as multi-constraint two-point problem with the consideration of optimization. Finally, the optimization flow and planning strategy are studied. In allusion to characteristics of ZPM path planning problem, two-step optimal flow is proposed, and the ZPM path of space station is obtained by a hybrid planning strategy based on Gauss pseudo-spectral method and direct shooting method. Numerical simulation is executed in order to verify the rationality and feasibility of ZPM planning method. The simulation results indicate that the planned ZPM path can satisfy all constraints perfectly, and that the saturation and singularity of SGCMGs are obviated in the whole attitude maneuver process. Consequently, the proposed method is effective to ZPM path planning of space station. These research achievements mentioned above have practical significance for the operations of space station and other large-scale spacecrafts equipped with CMGs.