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CHARACTERISTIC MODEL BASED GOLDEN SECTION PHASE PLANE ADAPTIVE CONTROL METHOD AND ITS APPLICATION IN RENDEZVOUS AND DOCKING

Abstract

Chinese unmanned and manned spacecraft Shenzhou-8, Shenzhou-9 and Shenzhou-10 have successfully completed automatic rendezvous and docking (RVD) with Tiangong-1 for four times. In these tasks, the guidance, navigation and control system onboard Shenzhou spacecraft is responsible for the control of RVD. Due to frequent orbital and attitude manuevour, severe flexibility of solar panels, thruster plume disturbances, coupling between attitude and position in the near range, and large system delay, the accurate and stable control of Shenzhou spacecraft for RVD is a difficult problem.

Phase plane control is a classical jet control method and has been applied in spacecraft attitude control. But it has more than ten controller parameters which are adjusted usually by trial and error procedure. For complicated high-order plants with uncertain parameters, such as Shenzhou spacecraft, it is not easy to find a group of suitable controller parameters especially when large system delay exists. In order to solve such kind of problems in practical engineering, characteristic model based golden section adaptive control method was proposed in 1992 and has been sucessfully applied in more than 400 practical systems. And it was develped to solve the problem of phase plane controller design of Shenzhou spacecraft for RVD.

In this paper, at first a multi-input and multi-output characterisitc model is derived in detail for spacecraft with flexible solar panels. The model expressed with low-order slowly time varying difference equations is used for controller design. Besides model derivation, computer simulation taking Shenzhou spacecraft as an example is performed to demonstrate the soundness of the established characteristic model. Then based on the characteristic model, golden section phase plane adaptive control method is presented. In this new method the ratio of golden section is used in the calculation of the parameters of phase plane controller. Finally the results of the in-orbit flight tests of Shenzhou spacecraft are introduced. The results show that the characteristic model based golden section phase plane adaptive control method has strong rubustness with respect to disturbances, uncertainty of parameters and unmodeled dynamics, and it yields low fuel consumption. It should be mentioned that this method is convenient for application and can also be applied to other jet control systems.