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DEVELOPMENT OF MINIATURE CONTROL MOMENT GYROSCOPE FOR SMALL SATELLITES

Abstract

With the development of aerospace technology, the industry is seeing an increasing role for small satellites. The agility of small satellites is the critical parameter, from the perspective of application field expansion and mission return maximization. The Control Moment Gyroscope (CMG) exhibits better performances in terms of torque-power and mass-torque characteristics, which make it a key actuator for agile, precise attitude control. Traditionally, CMGs were dedicated to large spacecraft, such as International Space Station and large earth-observation satellites. However, if effective miniaturization technology is adopted, without significant impacts on performance characteristics, the CMGs are considered to be one of the most promising actuators for small satellites. In this paper, a miniature CMG is developed for small satellites in the size range of 20-100 kg. This CMG exhibits a nominal angular momentum of 100 mNm-s, and output torque up to 100 mNm. An innovative tuning-fork flywheel structure is developed to guarantee the structure miniaturization as well as the mechanism robustness in severe environmental condition, especially for the application on small satellites. The dual incremental encoders system is designed for both volume compactness and high resolution gimbal angle measurement for high precision gimbal rate closed-loop control. The miniature CMG has the volume as low as 115mm x 60mm x 56mm, and the weight about 690 g. The control electronics is a Digital Signal Processor (DSP) and FPGA based system. The CMG FPGA provides gimbal angle data resolving, analog single sampling, PWM generation, and RS422 interface, which allows the communication with the flight computer. Whereas, the onboard DSP includes gimbal velocity and angle controllers. The control electronics are capable of driving 4 CMGs and executing a complex steering law to synthesize individual actuator commands. The performances of the CMG in terms of maximum output torque, power consumption, gimbal rate control stability and bandwidth, including environmental test results, are discussed in this paper, which demonstrates that this miniature CMG perfectly meets the requirement of small satellites attitude control.