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NOVEL GEAR BASED ACTUATION MECHANISM FOR SPACECRAFT'S ATTITUDE CONTROL

Abstract

With the rapid advancement in space technology, the demand for reliable and agile attitude control of satellites has increased to support the complex space missions. Reliable attitude control system requires reliable actuators, which can generate sufficient torque for agile maneuver of the satellites and should be able to tolerate faults autonomously onboard. There has been several research on the development of such reliable actuators, but most of them deal with only software-based fault-tolerant systems and nominal torque producing capability. Such type of systems cannot tolerate or function properly in the scenario of multiple actuator failures. Hence, there is a great demand of fault-tolerant control system, which could incorporate single or multiple actuator failure through hardware and software-based fault-tolerant system. In this study, a new concept of gear based "Multi-Motor Mono-Reaction Wheel System" (MMMRWS) actuation mechanism is proposed and equations are developed to study the stability and control characteristics for spacecraft attitude control. The linking of single reaction wheel with multiple motors in the proposed MMMRWS through a ratchet system that can autonomously handle the multiple actuator failures on board, providing mechanical advantages and further reducing the size of satellite/spacecraft. The implementation of gear system provides the mechanical advantage as it combines the incoming torque from the different motors to run a single reaction wheel, hence it can increase the torque produced previously. The equations for the torque incorporating the mechanical gear properties are derived and actuator failure model is developed. A comprehensive physical analysis of the system dynamics is presented and the mechanical advantages gained by varying the mechanical properties of gears have been studied and incorporated into the dynamics. The proportional-derivative closed-loop control model is considered for finding the desired control output. Based on the actuator failure information, the presented controller could reconfigure itself to give desired output. Meanwhile, the stability analysis of closed-loop attitude control system is performed using Lyapunov approach. Simulations are carried out based on the presented dynamics and control by varying the different control parameters, in order to show the efficacy of the proposed MMMRWS for controlling the global attitude and angular velocity of the spacecraft. Apart from the simulations of normal functionalities, simulations are also performed by introducing single and multiple actuator failures to demonstrate the effectiveness of the developed fault tolerant MMMRWS attitude control system.