Paper ID: 63346
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (1) (8)

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MAGNETICALLY CONTROLLABLE ATTITUDE TRAJECTORY CONSTRUCTED USING THE PARTICLE SWARM OPTIMIZATION METHOD

Abstract

The three-axis magnetic attitude control for a satellite is considered. Active magnetic control systems are especially attractive for small satellites. These satellites are very popular and valuable as a technology demonstration and educational missions, delivering new technologies and ideas into space as fast as possible. Small satellites missions may require mediocre accuracy. Stabilization "on average" per orbit with about 5-7 degrees accuracy is acceptable in some missions with little effect of the short-term degradation of the accuracy. Magnetic attitude control is well suited for the considered problem. The torque direction is restricted – it cannot be applied along the geomagnetic induction vector. This hinders local capability of the disturbance rejection. However, the induction vector changes its direction during the satellite motion along the orbit. The uncontrollable direction changes and all directions become available with time. This leads to general controllability of the attitude stabilization problem. The paper proposes specific control construction procedure that ensures even local controllability. A cost function is suggested that ensures the calculated control torque direction close to the plane orthogonal to the geomagnetic induction vector. Since the cost function is not suitable for classical gradient optimization methods, non-gradient biologically inspired global optimization method – particle swarm optimization (PSO) – is utilized in the paper. First, PSO is used to construct an optimal magnetically controllable attitude trajectory. The control torque projection onto the geomagnetic induction vector is minimized. The calculation takes into account the initial conditions and the motion in the gravitational field. The implicit solution to the linearized equations of motion is utilized. The solution contains oscillating part corresponding to the stable attitude channel and exponential part due to the unstable equilibrium position in the gravitational field. The trajectory construction ensures zero coefficient for the positive exponential part. This directly counters the disturbing influence of the gravitational field. Second, the constructed torque is implemented using magnetorquers. The control and corresponding attitude trajectory are adjusted once per revolution. Simulation also considers different disturbance factors. The resulting motion satisfies the given constraints and initial conditions. Overall, PSO method is used to construct a controllable trajectory, which is realized with a magnetic attitude control system with a given accuracy "on average".