Passive Attitude Control to Decrease CubeSatellite Complexity

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Motivation

McMaster NEUDOSE was initially a 3U CubeSat, which required an active ADCS. After some design alterations, NEUDOSE changed to a 2U CubeSat, which no longer had space or a need for an active ADCS. A passive magnetic attitude control system (PMAC) was chosen for the 2U design due to it's simplicity and small volume requirement.

Attitude Control System Design

NEUDOSE's PMAC system is comprised of a permanent magnet along the satellite's y axis, with hysteresis rods along the z and x axes.

The main design constraints are:

1. Pointing error, β, must be < 60°
2. PMAC must be successful up to an initial angular velocity, ω = 5°/s , on each axis
3. Bar magnetic moment m < 0.51 A $\cdot \mathrm{m}^2$

Preliminary mounting of hysteresis rods along the satellite's x axis. The hysteresis rod housing will be mounted tot the bottom of the payload enclosure support tray.

Attitude Simulation

A simulation was developed using a combination of Matlab and STK, to model the PMAC system.

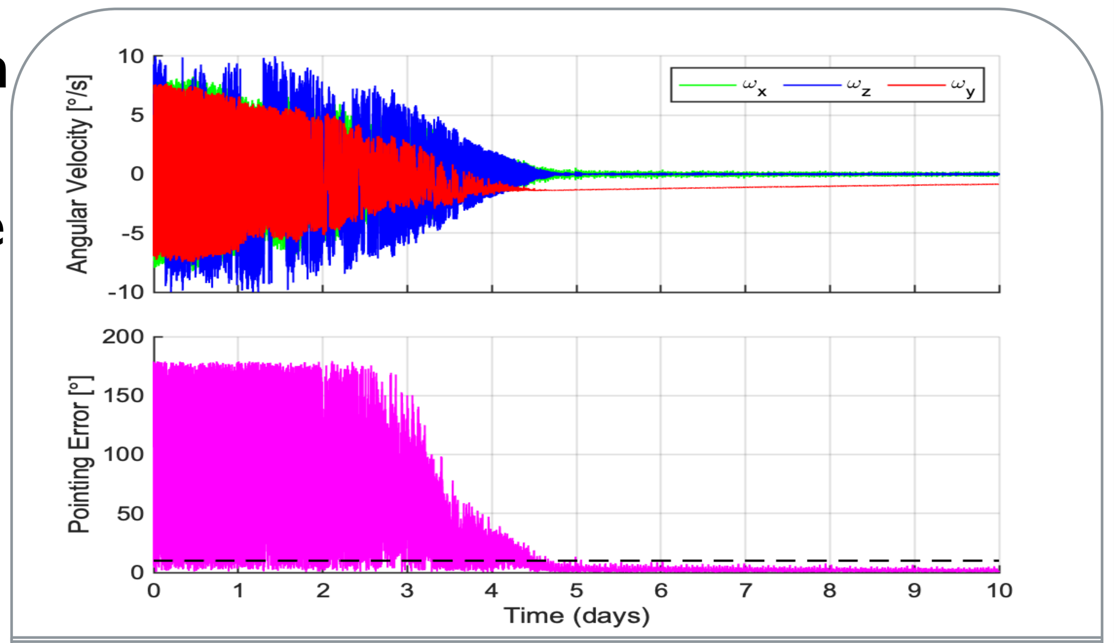
External Torque Source	Maximum Torque
Gravity Gradient	$3.3{\times}10^{-8}$ N · m
Aerodynamic	$4.8{\times}10^{-8}$ N · m
Solar Pressure	$4.8{\times}10^{-10}$ N · m
Eddy Current	$6.7{\times}10^{-8}$ N · m

Above is the worst case environmental disturbance torques simulated. These torques are calculated at each timestep as part of the attitude simulation, using input from STK. This simulation was used to run a variety of test cases, with varying hysteresis volumes, to determine their impact on the PMAC system's settling time and steady state error.

Results

Pictured below is a simulation of the PMAC system using $2{\times}10^{-7}\mathrm{m}^3$ of hysteresis material per axis, and a bar magnetic moment of 0.45 $\mathrm{A} \cdot \mathrm{m}^2$.

This simulation also included the worst case initial angular velocities, showing the PMAC system can meet the mission's pointing goals.



NEUDOSE Simulated PMAC System. Pictured top is the satellite angular velocities. Pictured bottom is the pointing error

Varying hysteresis volumes were simulated, and yielded the expected effect of decreasing settling times with increasing amount of hysteresis material.

Conclusion

Passive magnetic attitude control proved to be a simple solution to McMaster NEUDOSE's pointing requirements, after changing to a 2U CubeSat, with the new design requiring no power and occupying very little volume. CubeSatellite missions should consider passive attitude control systems when their missions do not require precise pointing to operate, as the decreased complexity of a passive system can decrease mission risks and allow for more freedom in designing a successful CubeSat mission.

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References

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