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Characterization of Hysteresis Dampers for Passive Attitude Control of Cubesats

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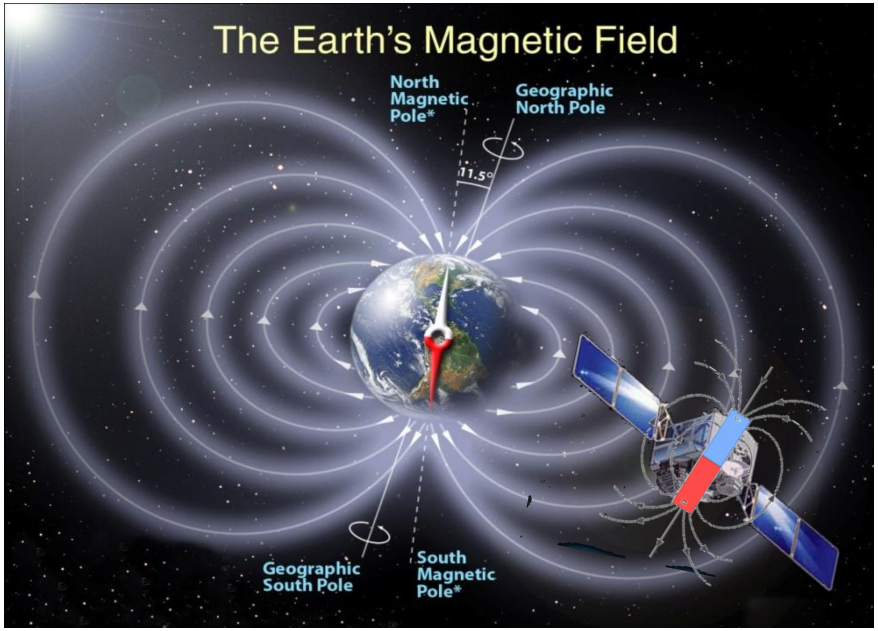
Passive Magnetic Attitude Stabilization System

- Hysteresis dampers
- Permanent magnet
- No sensors



Problem:

Investigate dampers properties to achieve required velocity, deployment restrictions

Beesat-3 Passive ACS

BEESAT-3:

- Developed by TU Berlin
- Launched April 21, 2013

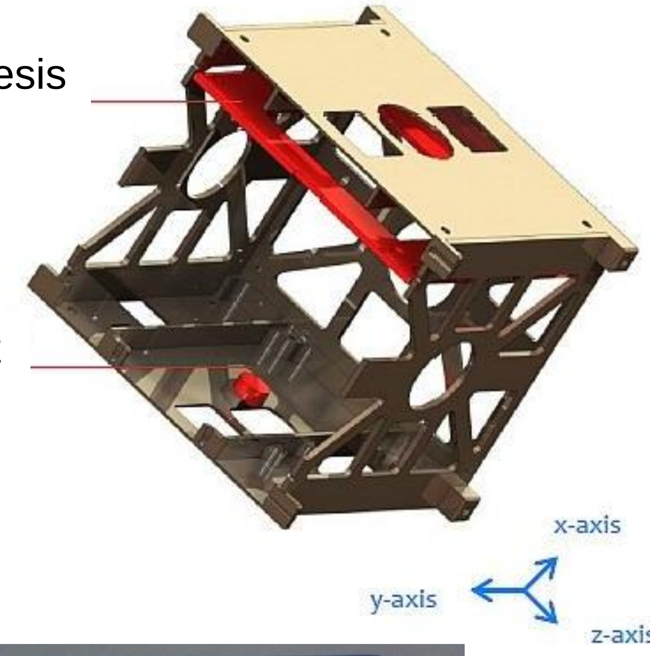
Passive ACS:

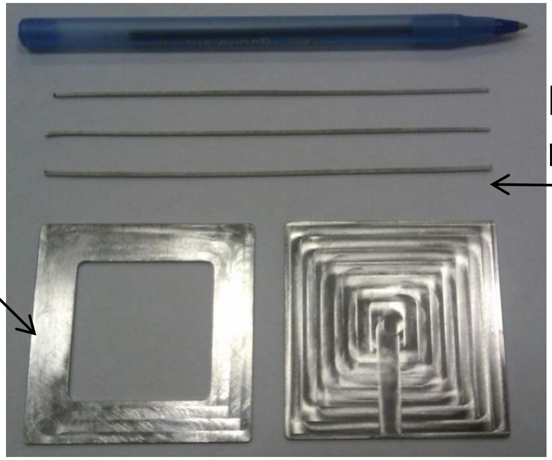
- Permanent magnet
- Hysteresis Plate

Hysteresis Plate Copy:

PERMANORM 5000

57x57 mm with 36x36 mm hole





Damping Effectiveness

- Kinetic Energy

$$T = \frac{1}{2}\left(A\omega_1^2 + B\omega_2^2 + C\omega_3^2\right)$$

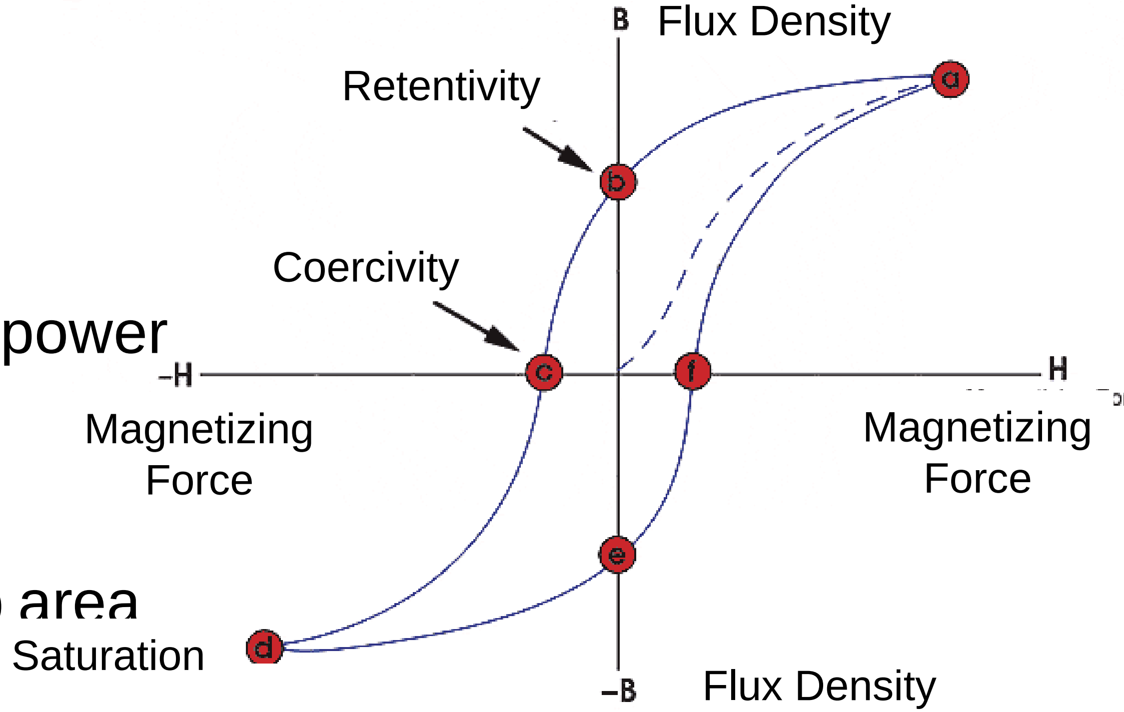
- Hysteresis energy looses power

$$N_{hyst} = \frac{\omega}{2\pi} V_{hyst} S$$

$$S = \oint H_\tau dB - \text{hysteresis loop area}$$

- Estimated damping time

$$t_{fin} \geq -\frac{2\pi\omega_{initial}\left(A+B+C\right)}{V_{hyst} S}$$

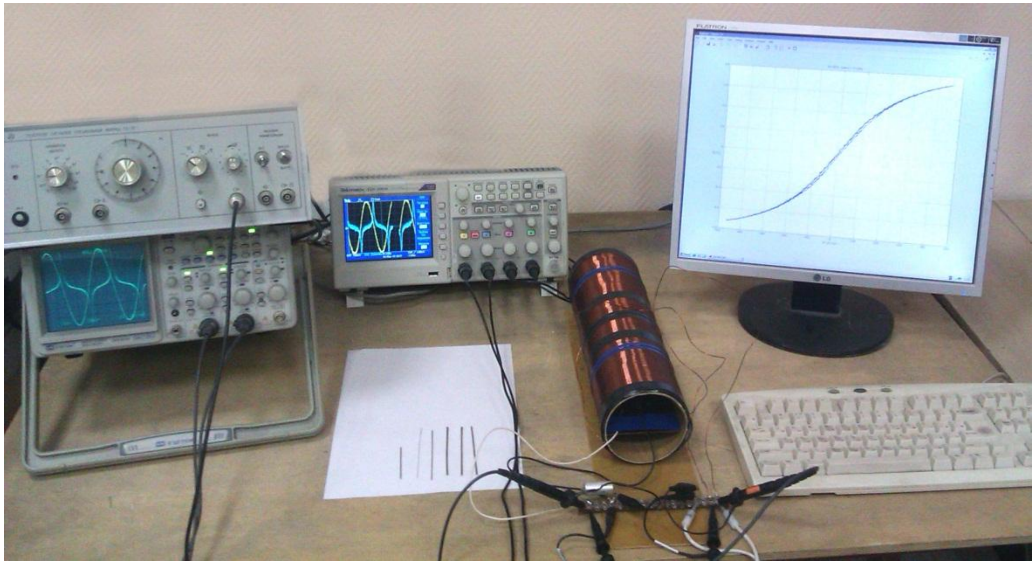


Hysteresis loop

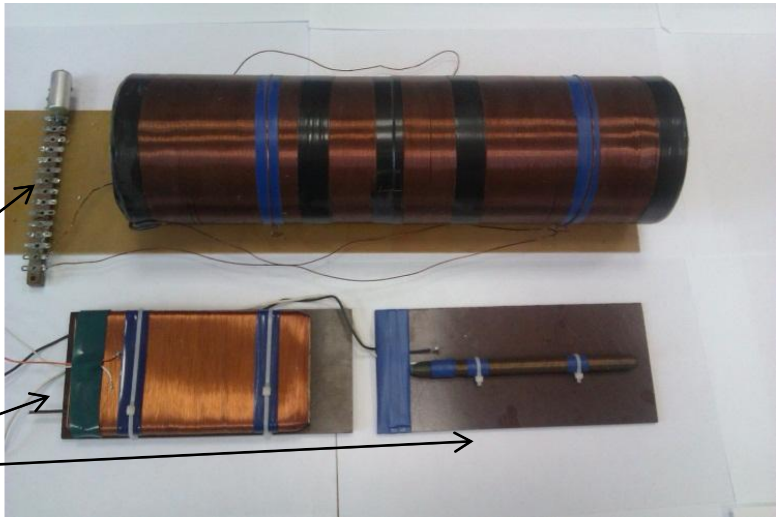
Laboratory Facility

Laboratory facility includes:

- Periodic signals generator
- Imitator of external magnetic field (big coil)
- Measurement coil
- Digital oscillograph



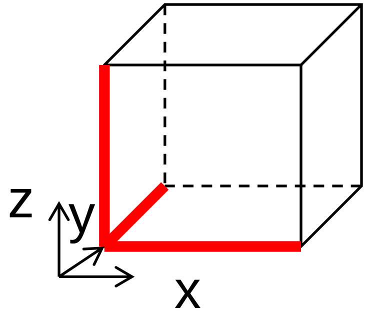
The signals are processed by special software on the computer.



Imitator of magnetic field

Measurement coils

Hysteresis Rod Loop



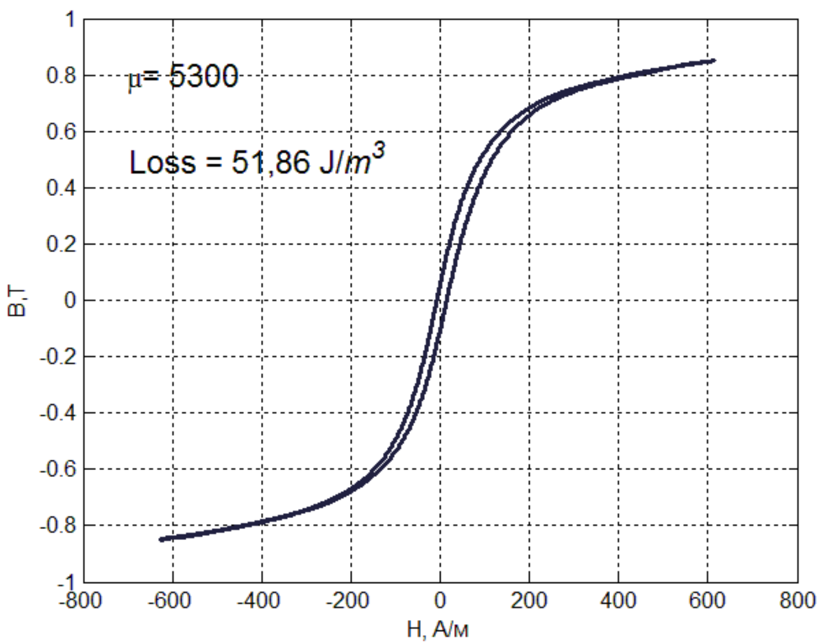
Simulation of damping

with three rods $V = 3 \cdot 10^{-7} m^3$

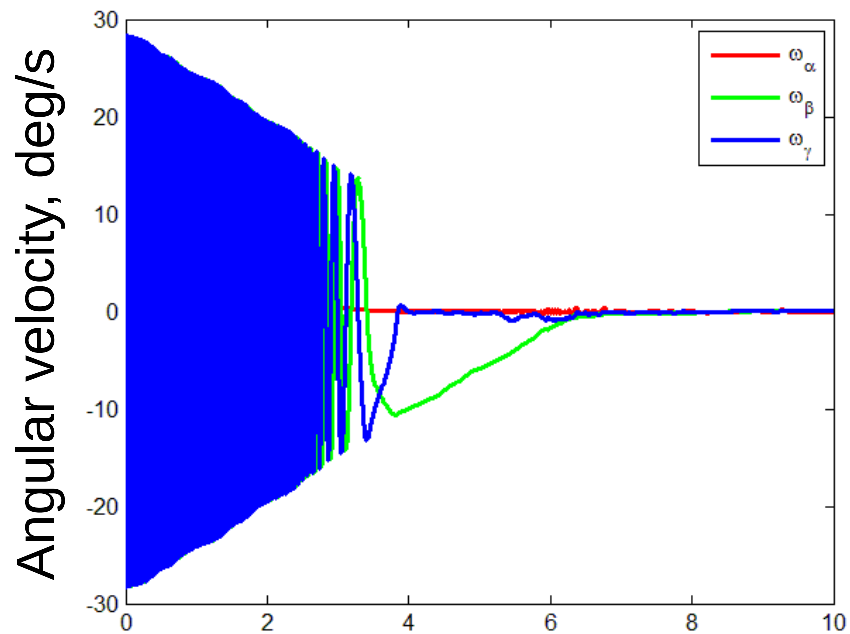
- Initial conditions

$\omega = [20; 20; 20] \deg / s$

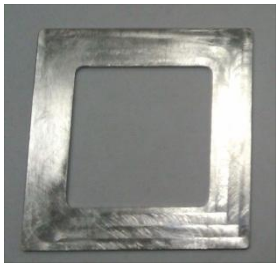
Hysteresis loop for the plate

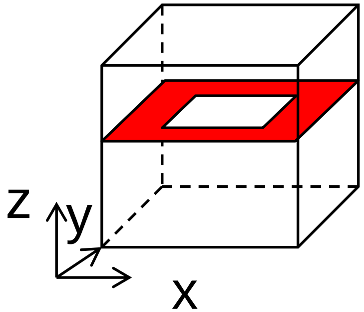


Damping time is about 7 orbits



Hysteresis Plate Loop





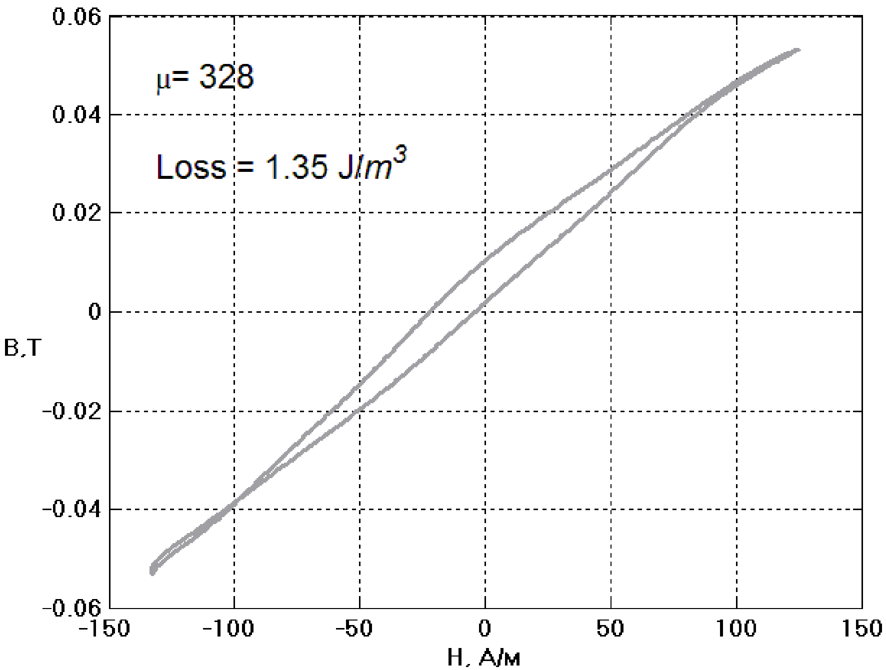
Simulation of damping

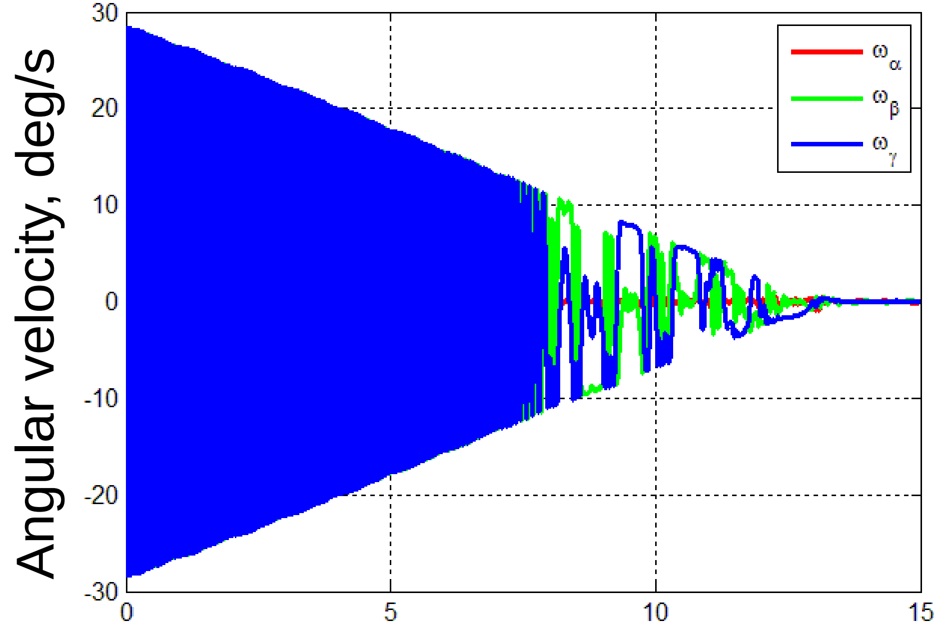
with plate of volume $V = 2.35 \cdot 10^{-6} m^3$

- Initial conditions

$\omega = [20; 20; 20] \deg / s$

Hysteresis loop for the plate





Time, orbits

Damping time is about 14 orbits

Eddy Currents Damping in Plate

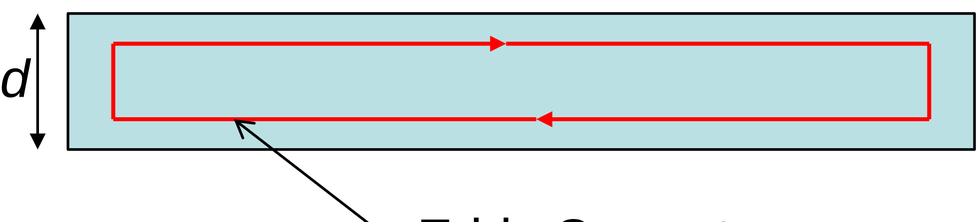
- Energy looses estimation

$$N_{Foucault} = \frac{k\,f^{2}B^{2}d^{2}}{\rho}$$

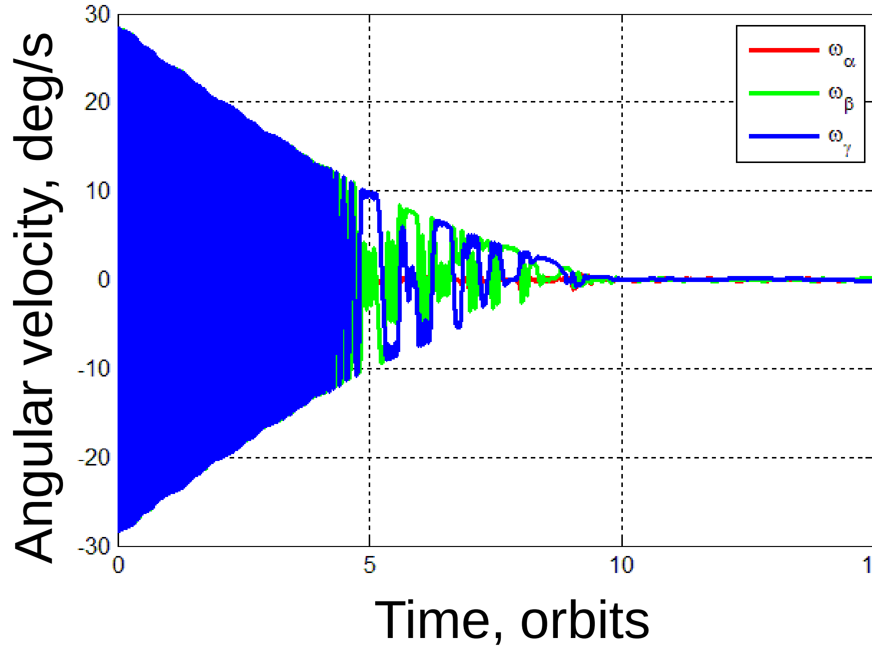
f – frequency of remagnetization

ρ – resistance density

Hysteresis plate



Eddy Current



Damping time is about 9 orbits

Conclusions

- Hysteresis rods are more effective than a plate at low angular velocity
- Eddy currents (hence plate) are more effective at high velocity but has no effect at low
- Developers should investigate the damping characteristics before the launch

Acknowledgments

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Thank you for your attention