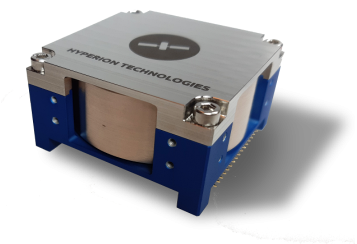
Designing reaction wheels with less vibrations

Satellites in space are subject to perturbing forces. These could come from solar pressure, atmospheric drag or celestial bodies. Somehow, the satellite needs to be able to counteract these perturbations and stay stable in its orbit around a planet. This is often done with reaction wheels. However, one problem with reaction wheels is that they induce vibrations in the satellite and lower the precision of the space mission. Reducing these vibrations is therefore crucial as the request for high precision space missions is increasing. In my thesis, I have shown how these micro-vibrations could be reduced in the reaction wheels at Hyperion Technologies by utilising a more complex motor control method.

Reaction wheels are based on the conservation of angular momentum. Spinning the reaction wheel in one direction will result in the satellite moving in the opposite direction. They consist of an electric motor mounted to a high inertia flywheel.



The Hyperion Technologies reaction wheel. (Image courtesy of Hyperion Technologies).

An electric motor normally consists of a permanent magnet and windings divided into three current paths. When current flows through these windings, an electromagnetic field will be induced. It is the interaction between this electromagnetic field and the magnetic field from the permanent magnet that will cause the motor to spin. The current through the windings has to be regulated in a certain way to generate a rotating motion. This process is called commutation.

Currently, Hyperion Technologies, a satellite component company in the Netherlands, uses six-step commutation in their motor control algorithm. This method is known to result in more torque ripple, which results in vibrations, than other common motor control methods. In this thesis, I have instead used a more complex control method known as Field Oriented Control (FOC).

This method has been evaluated through step responses in simulations and on the real reaction wheel, where the results have been promising. FOC results in a smoother control performance and uses the available current more efficiently. Also, the controller with FOC behaves better when crossing zero speed, a region which is problematic. When it comes to the vibrations, the simulation results show that FOC generates less torque ripple. However, no vibration measurements could be performed on the real reaction wheel to confirm this.

The idea with FOC is to control the currents in a rotating orthogonal reference frame. The current in the windings can be decomposed into two components. One that causes torque, called the quadrature component and one producing flux, called the direct component. These two components are controlled separately in FOC.

By making sure that the direct current is always zero, torque will theoretically always be maximised. Six-step commutation, on the other hand, can only produce maximum torque six times per revolution. It is this difference between the two methods that result in FOC having better performance.

Of course, there are also other contributions to vibrations in the reaction wheel but using FOC would be a way to avoid one of them.

Popular science summary of Master's Thesis: *Vibration Attenuation for Satellite Reaction Wheels through the use of Field Oriented Control*. Linnéa Rosenbecker. Master's Thesis report TFRT-6119, Department of Automatic Control, LTH, Lund University, Sweden. Available for download at: http://www.control.lth.se