1. Classification of Torques

- Support dependent (SD) - torques caused by suspension system operation
- Support independent (SI) - torques caused by anything else

Support Dependent Torques:
- Caused by relative accelerations (difference of squares of electrode voltages)
- Caused by preloads and misalignments.

Support Independent Torques:
- Housing-fixed inertially fixed
- Housing-fixed nearly fixed

No misalignment position housing-fixed SI torques known/detected

2. Torque Theory

Systematic theory of electrostatic Support Dependent torques complete to lowest order in small parameters is developed:
- Independent derivations based on: a) direct torque calculation, and b) energy conservation + symmetry lead to the same results.
- ‘Magic’ general formula

Torque = \( \tau(\psi) = |\tau(\psi)| \cos(\theta + \phi) \)

3. Pre-Flight Estimates of Classical Drift

Based on torque theory, requirements, ground measurements and best parameter estimates when measurements not available.

Example: torque coefficient K

4. Pre-Flight Estimates - II

Top Sheet of Pre-Flight Error Tree for Gyro 4 (Unsuspected Gyro 4, Drift Rate in marc-sec/year)

- Top Torques, Motional, gyro #4
- Total drift rate due to classical torques is computed for each gyro through its Error Tree, an Excel Workbook with:
  - >120 input parameters (mechanical, electrical, and magnetic parameters of the rotor, various S/N parameters, such as orbital ones; torque coefficients, preload accelerations, etc.)
  - residual accelerations by formula from input parameters
  - >100 individual torques grouped according to their classification by formulas from input parameters and residual accelerations
  - drift rates in 147 inliers, EW and NS

5. Pre-Flight Estimates - III

Important result: not more than 6 torques contribute >99% of classical drift rate for each gyroscope in either of the directions.

6. Post-Flight Estimates of Classical Drift

In work currently. Are obtained using on-orbit measurements and calibrations.


Example 2: Flight Calibrations of Torque Coefficient K

7. Post-Flight Estimates - II

8. Misalignment Torque: Patch Effect

Anomalously large drift rate detected in post-flight calibrations with spin-to-roll axis misalignment deliberately enhanced (from <10^-6 to several degrees). It grows with the misalignment in a non-linear way, but is linear for smaller misalignments within five tens of a degree. It is measured drift rate below:
- Proportionality coefficient up to 1 – 3 \times 10^{-6}/deg/day
- Direction perpendicular to the misalignment
- Thus fully separable from relativity drift fixed in the inertial space

9. Patch Effect: Modeling

Complete theory of Patch Effect Torque is developed. Potential distributions on the rotor and housing surfaces are characterized by constant coefficients of their spherical harmonics expansions in the rotor- and housing-fixed frames, respectively. By rotating the first frame to the second one, we solve the electrostatic boundary value problem in the gap, compute electromotive energy (to lowest order in gap/radius ratio), and vary it in three independent angles (spin phase, roll phase and the misalignment) for all the torques. The 3° is responsible for the observed drift and should be taken out of the signal.

**Graphs and Data**

- Measured MU\(,_{\text{G1}}\) in marc-sec/year
- Pre-Flight Estimates
- Spin Axis Align. before science
- Calibration, after science
- Units of spin, \(\hat{O}_x\), roll, \(\hat{O}_z\), misalignment vector, \(\hat{\psi}\), and misalignment angle, \(\psi\).
- Gyro Spin Motion Equation (roll averaged model to linear order in \(\mu\))

**References**

- Hansen Experimental Physics Laboratory • Stanford University, Stanford, CA 94305-4085 • http://einstein.stanford.edu

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