A Hybrid Microvibration Numerical Model for CubeSat Reaction Wheel Ball Bearing Imperfections

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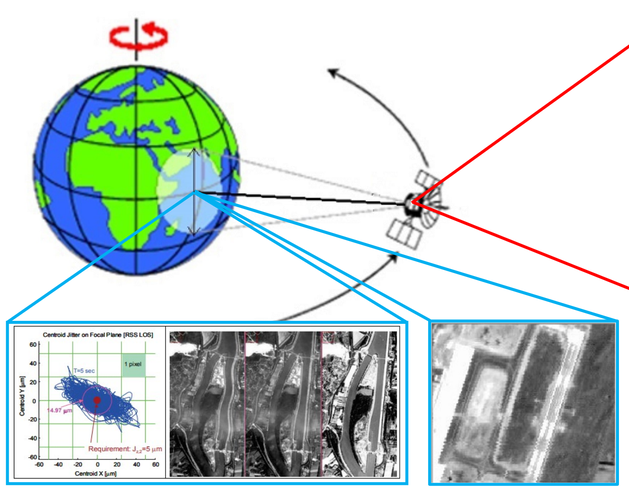


Figure 1 : Image degradation due to unwanted onboard RWA vibrations [1]

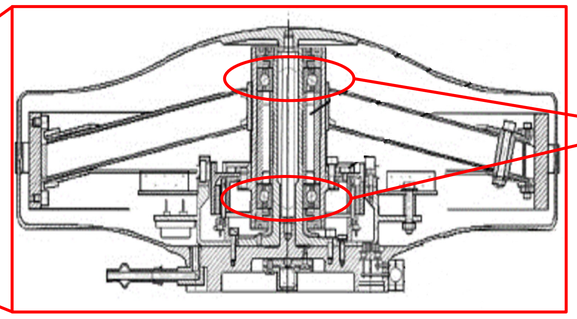


Figure 2 : RWA cross-section [2]

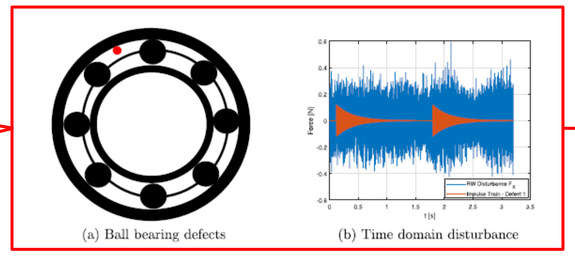


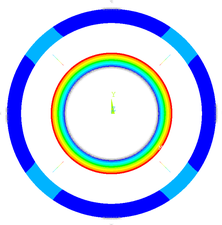
Figure 3 : Ball Bearing operational disturbance

- Material defects
- Ball defects
- Outer/inner race imperfection
- Manufacturing tolerances
- Poor lubrication
- Misalignments

Reaction Wheel Assemblies (RWAs)

are satellite attitude control devices.

- RW cause unwanted onboard disturbances
- Static/dynamic unbalance
- Flywheel material non-uniformities
- Ball bearings imperfections



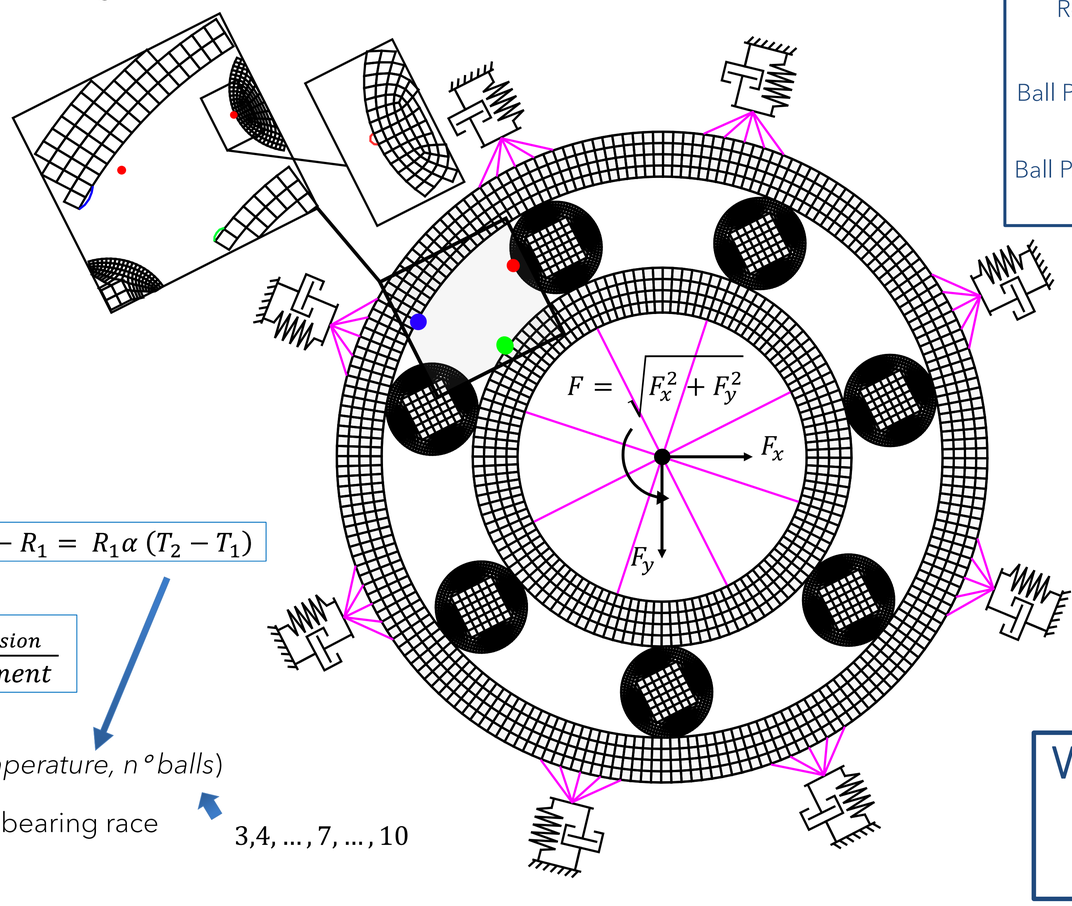
$$\Delta R = R_2 - R_1 = R_1 \alpha (T_2 - T_1)$$

$$k_{ball} = \frac{F_{compression}}{displacement}$$

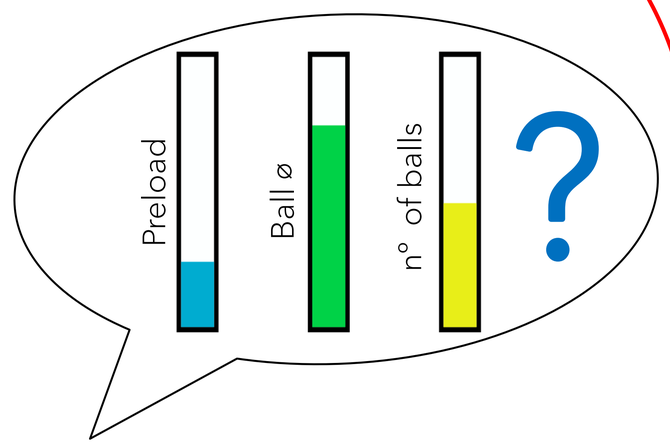
Ball compression force = f (k_{ball}, *temperature*, *n°balls*)

$3,4, \dots, 7, \dots, 10$

Figure 4 : Thermal expanding inner bearing race



Bearing Disturbances	Model
Rolling element spin frequency (ball imperfection)	$H_{BI} = \frac{D}{2d}\left(1 - \frac{d}{D}\cos\alpha\right)^2$
Ball Pass frequency of inner race (inner race imperfection)	$H_{BIR} = \frac{Z}{2}\left(1 + \frac{d}{D}\cos\alpha\right)$
Ball Pass frequency of outer race (outer race imperfection)	$H_{BOR} = \frac{Z}{2}\left(1 - \frac{d}{D}\cos\alpha\right)$



Which combination of parameters minimizes onboard RW microvibration?

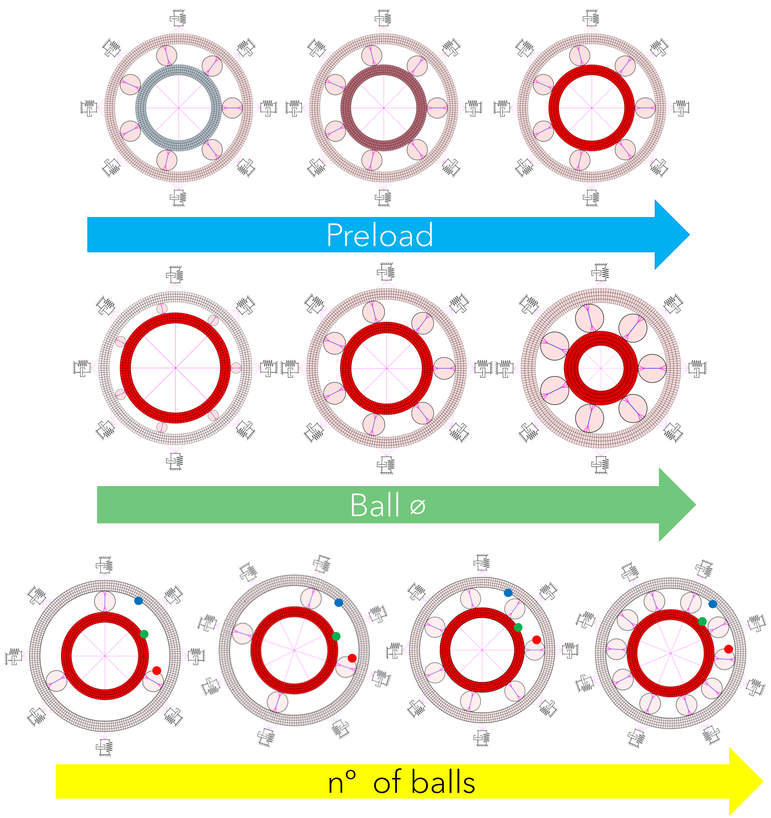


Figure 5 : Different bearing geometries implemented

- Thermal preload expansion of the inner bearing race at different temperatures
- 3 different ball diameters and 3 to 10 number of balls
- Frequency content evaluation of time domain signal
- Derivation of ball bearing microvibration waterfall plot

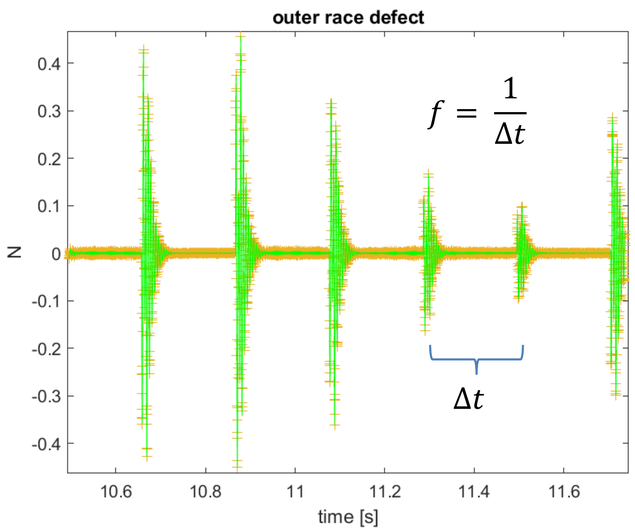


Figure 6 : Time domain disturbance of an outer race defect simulated

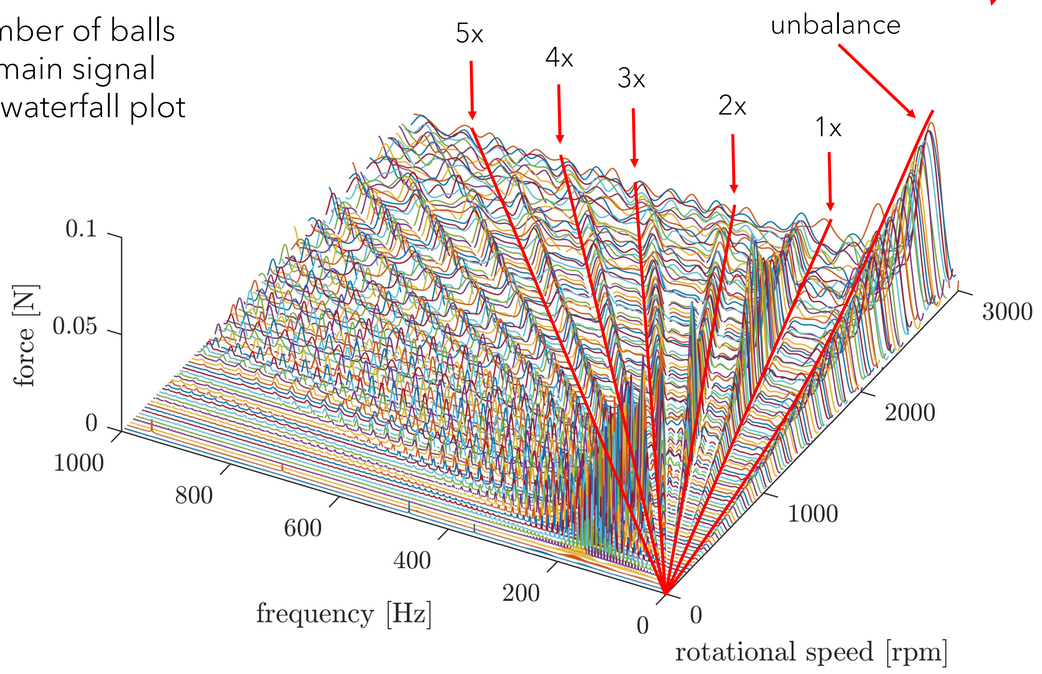


Figure 7: Simulated microvibration waterfall plot corresponding to outer race ball bearing imperfection

References:
[1] ECSS-E-HB-32-26A, Spacecraft mechanical loads analysis handbook. ESA Requirements and Standards Division, 19 February 2013.
[2] K. Sathyan, H.Y. Hsu, S.H. Lee, K. Gopinath, Long-term lubrication of momentum wheels used in spacecrafts-An overview, Tribology International, Volume 43, Issues 1-2, 2010, Pages 259-267