***JGW-T1302090***

**Type-A SAS Mechanical Model Parameters**

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**1. Introduction**

**1.1. About This Document**

This document contains parameters for mechanical modeling of Type-A vibration isolation system.

**1.2. Version Information**

Version 1: MODEL20131220, Advanced Virgo-Like (RM suspended from IR)

**1.3. Note**

* The clamp position of a wire is different from its effective flexure point. The separation between the bending point and the clamp point can be calculated as *Δ*=√*EI*/*T*, where *E* is Young’s modulus, *I* is the moment of area, *T* is the tension on the wire.

**2. Mechanical Model**

**2.1. Room Temperature Part**



Fig: Overview of Type-A SAS

**2.1.1. Top Filter (F0)**



Fig: Closer look at F0

**Rigid Body Property**

* Mass: 474 [kg]
* Moment of inertia (X): 60 [kg m2]
* Moment of inertia (Y): 120 [kg m2]
* Moment of inertia (Z): 60 [kg m2]

**Linkage**

F0 is supported by three inverted pendulum (IP) legs from the ground.



Fig: Support of F0

**IP Property**

* Radial distance of the legs from center of mass (r\_IP): 600 [mm]
* Length of the IP leg: 500 [mm]
* Load on three IPs: 1085 [kg]
* Effective stiffness of each IP: 13 [N/m] (tuned at 30 [mHz] in the translation mode)
* Effective Q factor: 3
* Additional yaw stiffness due to torsional stiffness of the top flexures: 200 [Nm/rad]
* Center of percussion level: -80 [dB] (overcompensated)

**2.1.2. Magnetic Damper (MD)**



Fig: Closer look at MD and F1

**Rigid Body Property**

* Mass: 30 [kg]
* Moment of inertia (X): 1.3 [kg m2]
* Moment of inertia (Y): 2.5 [kg m2]
* Moment of inertia (Z): 1.3 [kg m2]

**Linkage**

MD is suspended by three wires from F0.

Eddy current damping is exerted between MD and F1.



Fig: Suspension of MD

**Wire Suspension Property**

* Radial distance of the wires from center of mass (r\_SP): 400 [mm]
* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: C-70 steel (*E* = 200 [GPa], *σ* = 0.3, *φ* = 3E-4)
* Natural length: 1795.5 [mm] (1800 [mm] in tension)
* Diameter: 0.5 [mm]
* Tension on each wire: 98.1 [N] (500 [N/mm2] stress)

**Eddy Current Damping Property**

* Damping point at MD in the local coordinate: (x, y, z) = (0, -10, 0) [mm]
* Damping point at F1 in the local coordinate: (x, y, z) = (0, 200, 0) [mm]
* Damping strength (X): 18 [N/(m/sec)]
* Damping strength (Y): 45 [N/(m/sec)]
* Damping strength (Z): 18 [N/(m/sec)]
* Damping strength (RX): 2.5 [N m/(rad/sec)]
* Damping strength (RY): 2.0 [N m/(rad/sec)]
* Damping strength (RZ): 2.5 [N m/(rad/sec)]

**2.1.3. Standard Filter 1 (F1)**



Fig: Closer look at MD and F1

**Rigid Body Property**

* Mass: 104 [kg]
* Moment of inertia (X): 1.3 [kg m2]
* Moment of inertia (Y): 2.5 [kg m2]
* Moment of inertia (Z): 1.3 [kg m2]

**Linkage**

F1 is suspended by a single wire from a GAS filter on F0.

(Eddy current damping is exerted between MD and F1.)



Fig: Suspension of F1

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): +120 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: Maraging steel (*E* = 195 [GPa], *σ* = 0.3, *φ* = 1E-3)
* Natural length: 2262.2 [mm] (2271 [mm] in tension)
* Diameter: 3.1 [mm]
* Tension on each wire: 5700 [N] (755 [N/mm2] stress)

**GAS Filter Property (on F0)**

* Spring constant: 516 [N/m] (tuned at 0.15 [Hz])
* Quality factor: 20
* Center of percussion level: -80 [dB]

**2.1.4. Standard Filter 2 (F2)**



Fig: Closer look at F2

**Rigid Body Property**

* Mass: 90 [kg]
* Moment of inertia (X): 4.0 [kg m2]
* Moment of inertia (Y): 6.4 [kg m2]
* Moment of inertia (Z): 4.0 [kg m2]

**Linkage**

F2 is suspended by a single wire from a GAS filter on F1.



Fig: Suspension of F2



Fig: Wire structure

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: Maraging steel (*E* = 195 [GPa], *σ* = 0.3, *φ* = 1E-3)
* Natural length: 2266.1 [mm] (2271 [mm] in tension)
* Main diameter (*d*): 3.8 [mm]
* Neck diameter (*d*\_neck): 2.8 [mm]
* Neck length (*L*\_neck): 20 [mm]
* Tension on each wire: 4680 [N] (760 [N/mm2] stress on the neck)

**GAS Filter Property (on F1)**

* Spring constant: 1177 [N/m] (tuned at 0.25 [Hz])
* Quality factor: 10
* Center of percussion level: -80 [dB]

**2.1.5. Standard Filter 3 (F3)**



Fig: Closer look at F3

**Rigid Body Property**

* Mass: 87 [kg]
* Moment of inertia (X): 4.0 [kg m2]
* Moment of inertia (Y): 6.4 [kg m2]
* Moment of inertia (Z): 4.0 [kg m2]

**Linkage**

F3 is suspended by a single wire from a GAS filter on F2.



Fig: Suspension of F3



Fig: Wire structure

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: Maraging steel (*E* = 195 [GPa], *σ* = 0.3, *φ* = 1E-3)
* Natural length: 2267.0 [mm] (2271 [mm] in tension)
* Main diameter (*d*): 3.8 [mm]
* Neck diameter (*d*\_neck): 2.5 [mm]
* Neck length (*L*\_neck): 20 [mm]
* Tension on each wire: 3800 [N] (774 [N/mm2] stress on the neck)

**GAS Filter Property (on F2)**

* Spring constant: 955 [N/m] (tuned at 0.25 [Hz])
* Quality factor: 10
* Center of percussion level: -80 [dB]

**2.1.6. Bottom Filter (F4)**



Fig: Closer look at F4

**Rigid Body Property**

* Mass: 84 [kg]
* Moment of inertia (X): 4.0 [kg m2]
* Moment of inertia (Y): 6.4 [kg m2]
* Moment of inertia (Z): 4.0 [kg m2]

**Linkage**

F4 is suspended by a single wire from a GAS filter on F3.



Fig: Suspension of F4



Fig: Wire structure

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: Maraging steel (*E* = 195 [GPa], *σ* = 0.3, *φ* = 1E-3)
* Natural length: 2369.7 [mm] (2373 [mm] in tension)
* Main diameter (*d*): 3.8 [mm]
* Neck diameter (*d*\_neck): 2.2 [mm]
* Neck length (*L*\_neck): 20 [mm]
* Tension on each wire: 2940 [N] (773 [N/mm2] stress on the neck)

**GAS Filter Property (on F3)**

* Spring constant: 740 [N/m] (tuned at 0.25 [Hz])
* Quality factor: 10
* Center of percussion level: -80 [dB]

**Load on F4**

* Total mass: 216 [kg]

**2.2. Cryogenic Payload**



Fig: Overview of Cryogenic Payload

**2.2.1. Platform (PF)**



Fig: Closer look at PF

**Rigid Body Property**

* Mass: 61.5 [kg]
* Moment of inertia (X): 2.4 [kg m2]
* Moment of inertia (Y): 3.8 [kg m2]
* Moment of inertia (Z): 2.4 [kg m2]

**Linkage**

PF is suspended by a single wire from a GAS filter on F4.



Fig: Suspension of PF



Fig: Wire structure

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): +5 [mm]
* Material: Copper beryllium (*E* = 134 [GPa], *σ* = 0.3, *φ* = 5E-6)
* Natural length: 3380.7 [mm] (3385 [mm] in tension)
* Main diameter (*d*): 4.1 [mm]
* Neck diameter (*d*\_neck): 2.0 [mm]
* Neck length (*L*\_neck): 20 [mm]
* Tension on each wire: 2120 [N] (675 [N/mm2] stress on the neck)

**GAS Filter Property (on F4)**

* Spring constant: 533 [N/m] (tuned at 0.25 [Hz])
* Quality factor: 10
* Center of percussion level: -80 [dB]

**2.2.2. Intermediate Recoil Mass (IR)**



Fig: Closer look at IR and IM

**Rigid Body Property**

* Mass: 44.9 [kg]
* Moment of inertia (X): 0.561 [kg m2]
* Moment of inertia (Y): 0.815 [kg m2]
* Moment of inertia (Z): 0.899 [kg m2]

**Linkage**

IR is suspended by three wires from PF.

Heat links are connected from the inner radiation shield.



Fig: Suspension of IR

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -50 [mm]
* Lower clamp y-position from the center of mass (y\_low): +50 [mm]
* Material: Copper beryllium (*E* = 134 [GPa], *σ* = 0.3, *φ* = 5E-6)
* Natural length: 299.2 [mm] (300 [mm] in tension)
* Diameter: 1.0 [mm]
* Tension on each wire: 257 [N] (327 [N/mm2] stress)

**Heat Link Property**



Fig: Heat link geometry

* Material: Pure aluminum (*E* = 70 [GPa], *σ* = 0.38, *φ* = 1E-2)
* Wire diameter: 0.15 [mm]
* Number of wires: 180 (4 fibers with 45 strands for each)
* Shape: Semi-circle with 150 mm radius (*r*\_HL) and 470 mm length
* Clamp position at IR in local coordinate: (x, y, z) = (145, 0, 0) [mm]
* Heat links are on XY plane.



Fig: A heat link model in COMSOL (coordinate system is different from that of the suspension model)

* DC spring constant (X in suspension model, X in COMSOL): 0.077 [N/m]
* DC spring constant (Y in suspension model, Z in COMSOL): 0.0146 [N/m]
* DC spring constant (Z in suspension model, Y in COMSOL): 0.0102 [N/m]
* First violin mode: 2.5 [Hz]
* Second violin mode: 6 [Hz]
* Details of calculation: **JGW-T1301996**



Fig: Simulated mechanical transfer functions of a heat link attached to a 50 [kg] mass
(results about a single fiber with 45 strands)

**2.2.3. Intermediate Mass (IM)**



Fig: Closer look at IR and IM

**Rigid Body Property**

* Mass: 53.2 [kg]
* Moment of inertia (X): 0.352 [kg m2]
* Moment of inertia (Y): 0.677 [kg m2]
* Moment of inertia (Z): 0.474 [kg m2]

**Linkage**

IM is suspended by a single wire from a GAS filter on PF.



Fig: Suspension of IM



Fig: Wire structure

**Wire Suspension Property**

* Upper clamp y-position from the center of mass (y\_up): -5 [mm]
* Lower clamp y-position from the center of mass (y\_low): -4 [mm]
* Material: Copper beryllium (*E* = 134 [GPa], *σ* = 0.3, *φ* = 5E-6)
* Natural length: 399.1 [mm] (400 [mm] in tension)
* Main diameter (*d*): 1.8 [mm]
* Neck diameter (*d*\_neck): 1.6 [mm]
* Neck length (*L*\_neck): 20 [mm]
* Tension on each wire: 745 [N] (371 [N/mm2] stress on the neck)

**GAS Filter Property (on PF)**

* Spring constant: 750 [N/m] (tuned at 0.5 [Hz])
* Quality factor: 1E3
* Center of percussion level: -80 [dB]

**2.2.4. Recoil Mass (RM)**



Fig: Closer look at RM and TM

**Rigid Body Property**

* Mass: 33.7 [kg]
* Moment of inertia (X): 0.433 [kg m2]
* Moment of inertia (Y): 0.433 [kg m2]
* Moment of inertia (Z): 0.642 [kg m2]

**Linkage**

RM is suspended by four wires from IR.



Fig: Suspension of RM

**Wire Suspension Property**

* X-distance between the wire and the center of mass (*dx*): 145 [mm]
* Z-distance between the wire and the center of mass (*dx*): 30 [mm]
* Upper clamp y-position from the center of mass (y\_up): 0 [mm]
* Lower clamp y-position from the center of mass (y\_low): 0 [mm]
* Material: Copper beryllium (*E* = 134 [GPa], *σ* = 0.3, *φ* = 5E-6)
* Natural length: 300.0 [mm] (300 [mm] in tension)
* Diameter: 0.6 [mm]
* Tension on each wire: 82.6 [N] (294 [N/mm2] stress)

**2.2.5. Test Mass (TM)**



Fig: Closer look at RM and TM

**Rigid Body Property**

* Mass: 22.7 [kg]
* Moment of inertia (X): 0.111 [kg m2]
* Moment of inertia (Y): 0.111 [kg m2]
* Moment of inertia (Z): 0.137 [kg m2]

**Linkage**

RM is suspended by four cantilever springs and wires from IR.



Fig: Suspension of TM

**Wire Suspension Property**

* X-distance between the wire and the center of mass (*dx*): 110 [mm]
* Z-distance between the wire and the center of mass (*dx*): 15 [mm]
* Upper clamp y-position from the center of mass (y\_up): 0 [mm]
* Lower clamp y-position from the center of mass (y\_low): 0 [mm]
* Material: Sapphire (*E* = 345 [GPa], *σ* = 0.3, *φ* = 2E-7)
* Natural length: 300.0 [mm] (300 [mm] in tension)
* Diameter: 1.6 [mm]
* Tension on each wire: 55.6 [N] (28 [N/mm2] stress)

**Cantilever Spring Property**

* Spring constant per blade: 22.4 [kN/m] (tuned at 10 Hz)
* Quality factor: 1E6