BHQS workshop parameters

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1 Introduction

This is a compendium of the parameters and details shown in the talks at the March 2023 BHQS workshop. These parameters are represented in [1][2].

v2 updates the transverse separation parameters due to a transcription error from v1.

2 Mechanical parameters in QUAD model notation

The BHQS parameters are listed in Table 1 using the same convention as the QUAD model [3], which is summarized in Figure 1.

Symbols	**Description**	**Units**	**TOP**	**UIM**	**PUM**	**TST**
$m_n/m_1/m_2/m_3$	Mass	[kg]	117	83	100	100
$I_{n,x}/I_{1,x}/I_{2,x}/I_{3,x}$	Roll moment of inertia	[kg·m^2]	8.1	3.6	2.6	2.6
$I_{n,y}/I_{1,y}/I_{2,y}/I_{3,y}$	Pitch moment of inertia	[kg·m^2]	8.1	3.3	1.9	1.9
$I_{n,z}/I_{1,z}/I_{2,z}/I_{3,z}$	Yaw moment of inertia	[kg·m^2]	15.5	6.7	1.9	1.9
$I_{n,xy}/I_{1,xy}/I_{2,xy}/I_{3,xy}$	R-P cross moment of inertia	[kg·m^2]	0	0	0	0
$I_{n,yz}/I_{1,yz}/I_{2,yz}/I_{3,yz}$	P-Y cross moment of inertia	[kg·m^2]	0	0	0	0
$I_{n,zx}/I_{1,zx}/I_{2,zx}/I_{3,zx}$	Y-R cross moment of inertia	[kg·m^2]	0	0	0	0
$k_{cn}/k_{c1}/k_{c2}$	Vertical spring stiffness (per side)	[kN/m]	7.2	6.5	3.6	N/A
$k_{xn}/k_{x1}/k_{x2}$	Lateral spring stiffness (per side)	[kN/m]	∞	∞	∞	N/A
$Y_n/Y_1/Y_2/Y_3$	Young's moduli of wires	[GPa]	∞	∞	∞	72
$l_n/l_1/l_2/l_3$	Stretched wire length	[m]	0.34	0.34	0.34	0.60
$r_n/r_1/r_2/r_3$	radii of wires	[µm]	N/A	N/A	N/A	220
$d_{\text{top}}/d_n/d_1/d_3$	(upper) wire vertical attachment distance	[mm]	0	0	0	0
$d_m/d_0/d_2/d_4$	(lower) wire vertical attachment distance	[mm]	0	0	0	0
$s_n/s_u/s_i/s_l$	front-back wire attachment distance	[cm]	16	14	12.5	2.5
$n_{n0}/n_0/n_2/n_4$	(upper) wire transverse attachment distance	[cm]	18	13.5	23	23
$n_{n1}/n_1/n_3/n_5$	(lower) wire transverse attachment distance	[cm]	18	13.5	23	23

Table 1: BHQS parameters in QUAD notation [3].

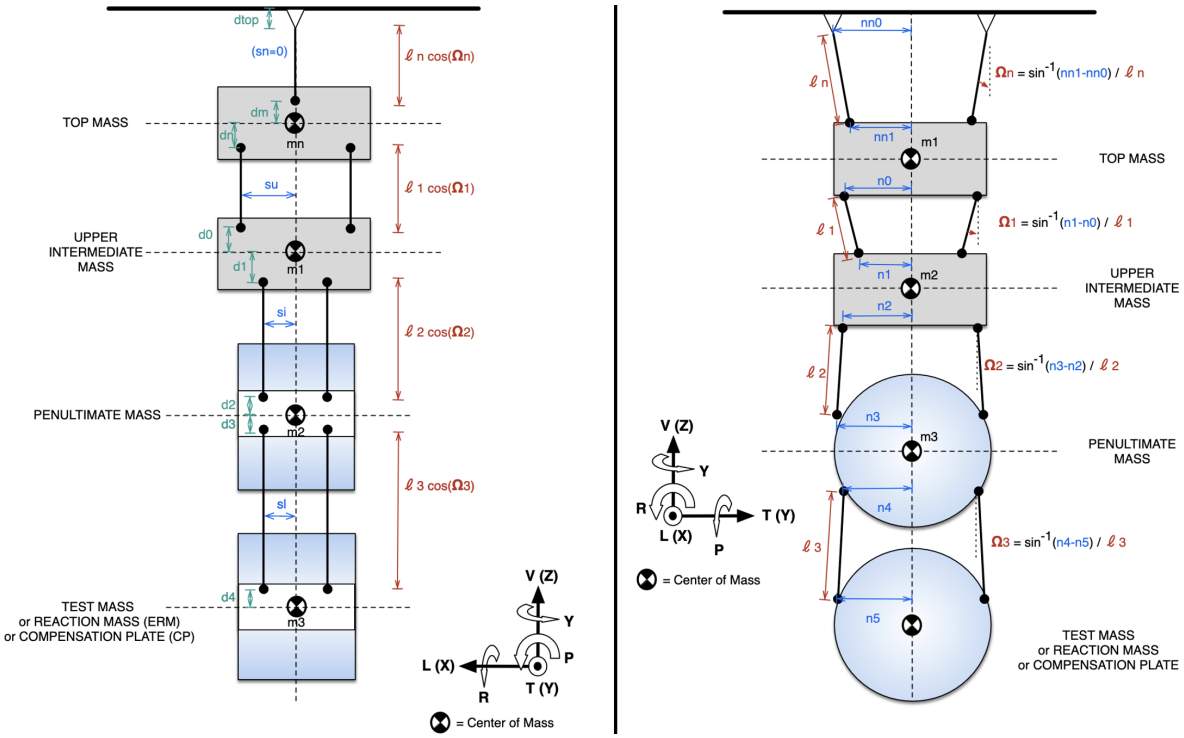

Figure 1: Quadruple suspension parameter definitions. Figure taken from [3]. The figure summarizes the notation used in Table 1

3 Simplified parameters for the BHQS

Since the 'd' parameters for the wire attachments in Table 1 are all zero, the wires are all vertical, and we consider the inertias of all masses to be diagonal; it is possible to decouple all degrees of freedom and simplify the modelling of each one as a spring-mass system with four masses and four springs. These parameters are summarized in Table 2. The six simplified models are decoupled and their resonant frequencies are summarized in Table 3 and Figure 2.

Finally, we include the parameters describing the blade springs for each stage of the BHQS in Table 4. The values for the deflection and internal modes are calculated following the guidelines of [4] and [5].

Symbols	Description	Units	TOP	UIM	PUM	TST
L	Distance to the previous stage	[cm]	34	34	34	60
m	Mass of the stage	[kg]	117	83	100	100
I_{RR}	Stage moment of inertia (Roll)	[kg·m^2]	8.1	3.6	2.6	2.6
I_{PP}	Stage moment of inertia (Pitch)	[kg·m^2]	8.1	3.3	1.9	1.9
I_{YY}	Stage moment of inertia (Yaw)	[kg·m^2]	15.5	6.7	1.9	1.9
k_L	Longitudinal stiffness above stage	[kN/m]	11.5	8.1	5.7	1.6
k_T	Transverse stiffness above stage	[kN/m]	11.5	8.1	5.7	1.6
k_V	Vertical stiffness above stage	[kN/m]	14.5	11.1	7.2	73.5
k_R	Roll rotational stiffness above stage	[N·m]	460	210	380	3880
k_P	Pitch rotational stiffness above stage	[N·m]	380	235	110	45
k_Y	Yaw rotational stiffness above stage	[N·m]	650	320	400	87

Table 2: Simplified parameters for quick (and approximate) computation.

Degree of freedom	Units	f_1	f_2	f_3	f_4
Longitudinal	[Hz]	0.45	0.96	1.7	2.6
Transverse	[Hz]	0.45	0.96	1.7	2.6
Vertical	[Hz]	0.6	1.8	2.9	6.2
Roll	[Hz]	0.59	1.45	2.4	8.7
Pitch	[Hz]	0.5	0.93	1.47	2.0
Yaw	[Hz]	0.6	1.1	1.5	2.8

Table 3: Resonant frequencies for BHQS

Description	Units	TOP	UIM	PUM
Length	[cm]	29.4	26.2	24.8
Width	[cm]	14.7	13.1	12.4
Thickness	[mm]	3.4	2.9	2.4
Stress	[MPa]	1018	990	1022
Deflection	[cm]	12.2	11.1	12.4
Radius of curvature	[cm]	33.2	24.1	22.4
Internal mode	[Hz]	148	159	147

Table 4: Blade Spring parameters

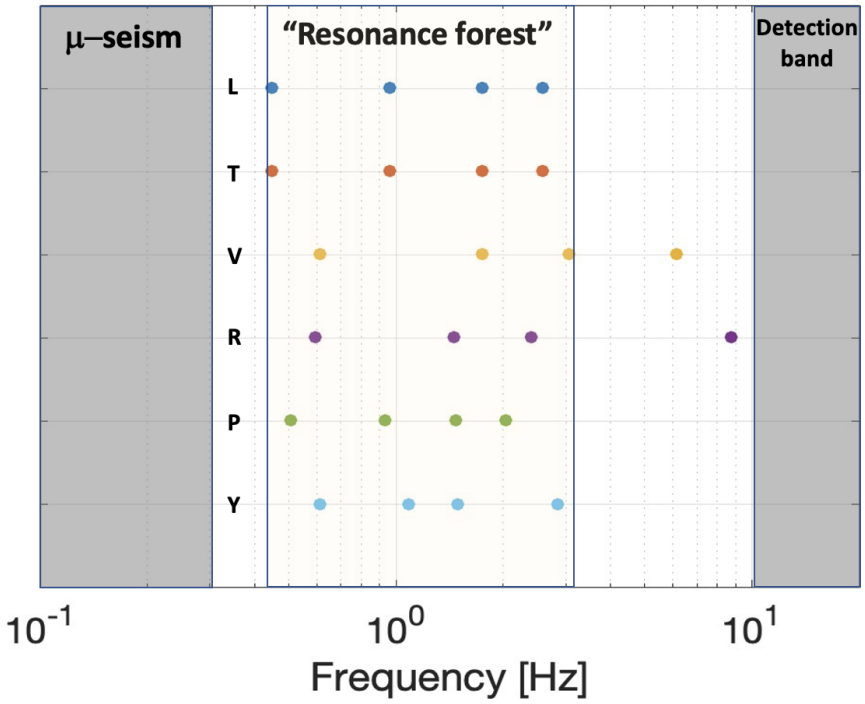

Figure 2: Resonant frequencies per degree of freedom of the BHQS according to the parameters in Table 1 (or Table 2). The exact values are represented in Table 3.

References

[1] E. Bonilla, "BHQS dynamics tradeoff notes," tech. rep., LIGO Internal Document G2300711, 2023.

[2] E. Sanchez, "BHQS, VE, BSC CHAMBER COLLAR (CONCEPTUAL)," tech. rep., LIGO Internal Document D2300150, 2023.

[3] J. Kissel and M. Barton, "QUAD Pendulum Parameter Descriptions and Naming Convention," tech. rep., LIGO Internal Document T1400447, 2014.

[4] N. Robertson, "Design Notes for Production Blades for HAM Suspensions," tech. rep., LIGO Internal Document T1000351, 2010.

[5] N. Robertson and C. Torrie, "EXCEL spreadsheet for design of HSTS Blades," tech. rep., LIGO Internal Document T1000352, 2010.