LIGO-T970243-00-D

HYTEC-TN-LIGO-20
06/26/97

BSC Seismic Isolation with Damped Coil Springs - Performance Update

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July 26, 1997

Abstract

This note summarizes new simulation results for the isolation performance and resonance characteristics of the BSC seismic isolation system, using a damped coil spring isolation stack. Spring stiffness and loss models are semi-empirical curve fits and extrapolations based on a combination of experimental data and analytical spring models. Results are presented for mode shapes, natural frequencies, and quality factors of the stack, as well as transmissibility curves and power spectral density of residual seismic motion at the mirror surface.

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1. Model Updates

1.1 Support System

The support system is modeled using 2 rigid bodies and 8 springs for a total of 12 degrees of freedom (see Fig. 1). The model parameters are exactly as described in [1]. This simplified model predicts 11 out of 12 natural modes with good fidelity as compared to detailed finite element solutions (see [1]). Quality factors in these structures are arbitrarily assumed equal to 20 for the pier/actuator assembly and 200 for the support structures. Recent design changes (new Z-stage design and elimination of STACIS) have not yet been accounted for so that this support model is likely to be conservatively soft.

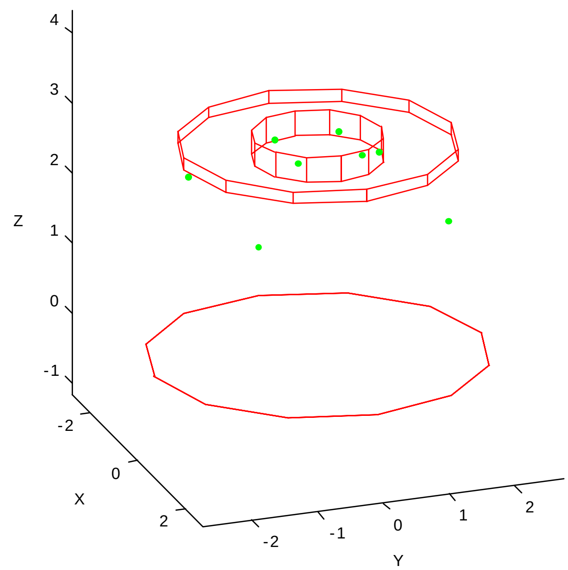

Figure 1: twelve degree of freedom model of the BSC support system. The red cylinders represent rigid bodies and the green dots identify 3-dimensional spring locations.

1.2 Springs

As of this report, damped coil springs have gone through complete design qualification testing. In particular, good experimental data is now available for dynamic stiffness and damping of damped coil springs in solid Fluorel seats in both axial and shear directions at frequencies between 0.6 and 2.5 Hz. This experimental data has made it possible to compile semi-empirical models, fitting experimental values with high fidelity at low frequency and following analytically predicted trends at higher frequencies. Refer to [2] for a detailed description of those models.

1.3 Isolation Stack & Downtube

The models of the stack and downtube have been updated to reflect final mass and inertia properties per fabrication drawings. In particular, the downtube design has been lengthened by 10 cm to achieve the correct vertical separation between optical surface and beam line. Other changes in the optics table stiffening pattern also led to changes in the mass properties of the downtube. Leg element mass properties were also updated to account for alignment pins and holes and the dynamic mass of the springs. The model is shown in Fig. 2.

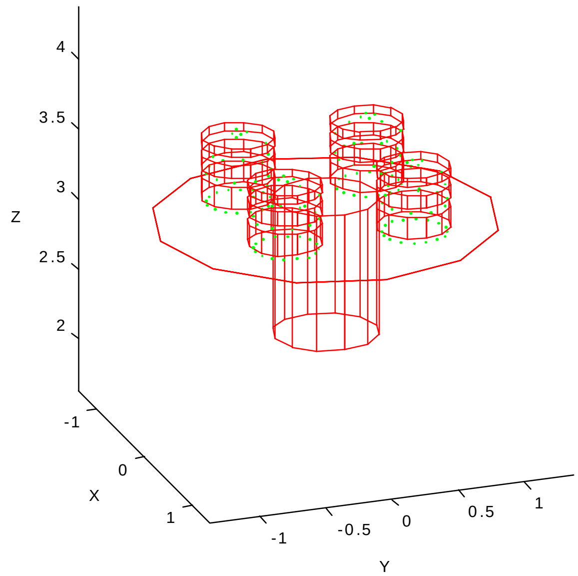

Figure 2: 78 degree of freedom model of the BSC isolation stack. The red cylinders represent rigid bodies and the green dots identify 3-dimensional spring locations.

Dynamic models of the support system and the stack can be combined to create a floor-up representation of the SEI sub-system as shown in Fig. 3.

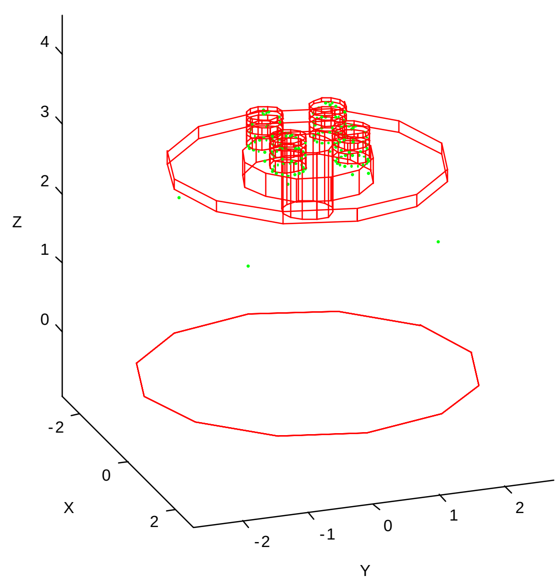

Figure 3: 90 degree of freedom model of the BSC SEI. The red cylinders represent rigid bodies and the green dots identify 3-dimensional spring locations.

2. Stack Resonances and Quality Factors

These simulations are intended primarily to provide accurate data on the lowest frequency stack resonances and their quality factors. The support system was not included in the model since its lowest resonances occur around 15 Hz. Mode shapes, natural frequencies and quality factors are shown in Fig. 3.

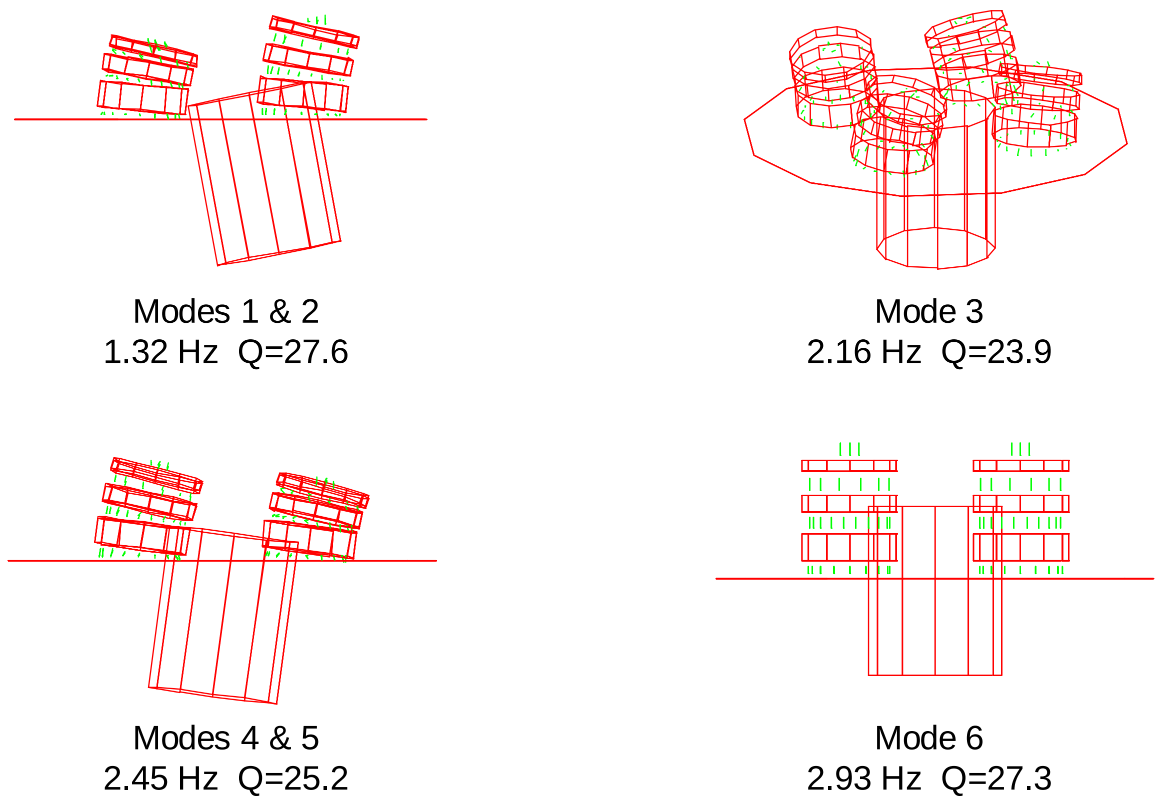

Figure 4: First six mode shapes, natural frequencies, loss factors, and Q's of the BSC coil spring stack (from non-linear modal analysis, accounting for frequency dependent spring properties).

3. Floor to SUS Attachment Transfer Functions - Stack with Support

Horizontal and vertical transfer functions of the complete seismic isolation system (piers, actuators and support structures included) are given below (Fig. 4). These transfer functions are calculated from pure horizontal or vertical motion of the facility floor to horizontal or vertical motion of a "nominal" pendulum suspension attachment point. That point is assumed to be offset from the center of the optics table mounting surface by 20 cm in the Y (transverse to beam) direction and -15 cm (vertical down) in the Z direction[1]. For comparison, transfer functions of the same stack on an infinitely rigid support system are also shown in the Figure.

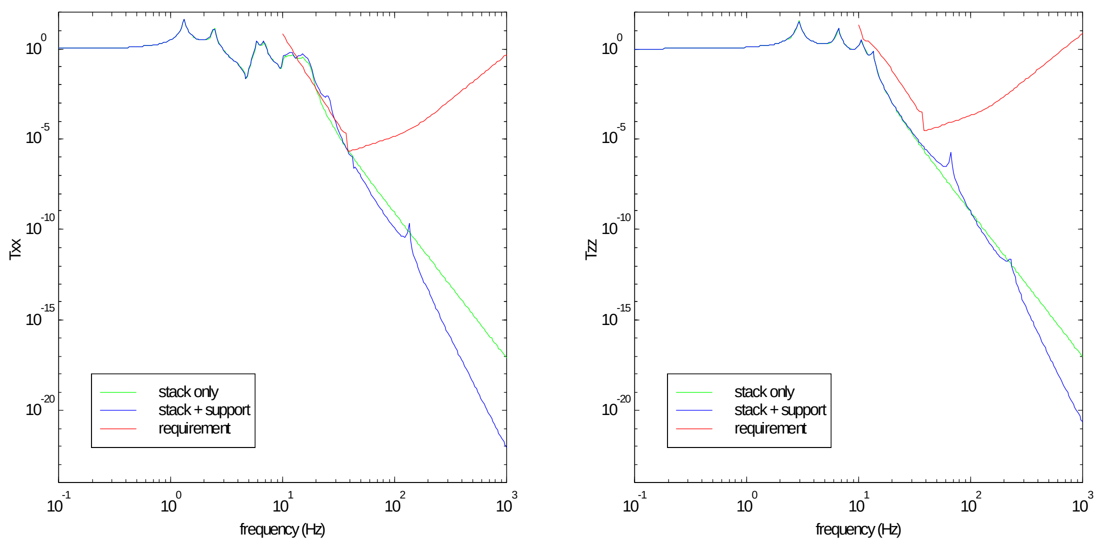

Figure 5: Nominal isolation of BSC stack with coil springs compared to requirements (axial and shear spring models form experimental data).

4. Residual Seismic Noise Spectrum at Mirror Surface

The floor-up stack model is combined with transfer functions of the SUS system to evaluate residual motion normal to the mirror surface, in response to a combination of X and Z floor motion. See [1] for details.

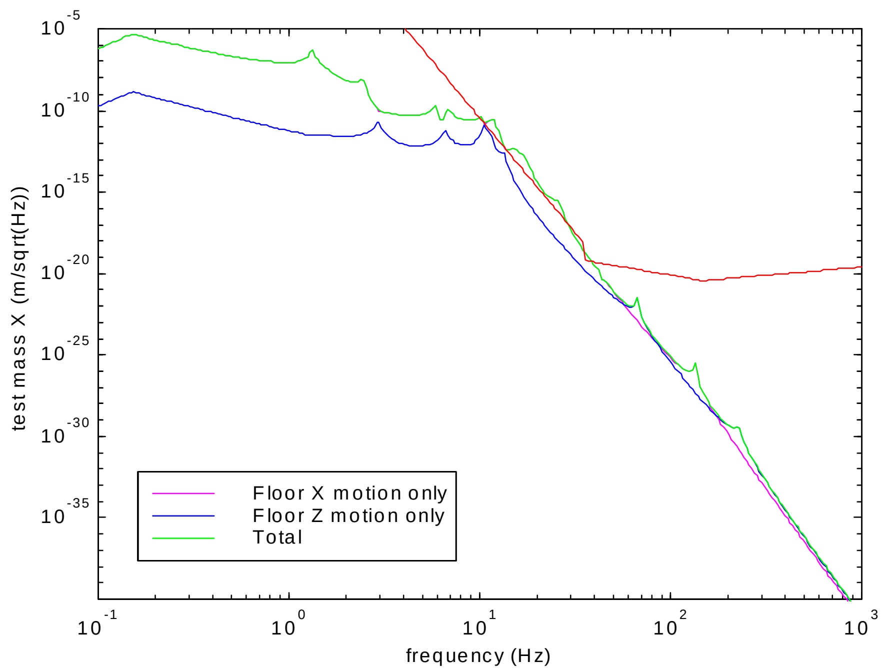

Figure 6: Spectrum of residual test mass X motion for BSC coil spring stack with flexible support; the green curve shows total residual motion in response to X and Z floor noise, while the purple and blue curves show contributions from horizontal and vertical floor noise, respectively.

5. References

1. E. Ponslet, *BSC Seismic Isolation - Projected Performance Update*, HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-07a (revision *a*), January 1997.
2. F. Biehl, *Analytical Expressions and Interpolations for Coil Spring Experimental Data*, HYTEC Inc., Los Alamos, NM, document HYTEC-TN-LIGO-19, June 1997.

Note 1, Linda Turner, 09/03/99 02:11:51 PM
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