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Small Optics Suspension Prototype Test Results

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1 OBJECTIVES AND SCOPE

The prototype for the Small Optic Suspension (SOS) was built and tested per the Suspension Test Plan, LIGO-T960086-02-D to evaluate its feasibility and performance in preparation for the final design. Difficulties encountered during assembly and testing were corrected and documented for the final design. The mechanical portions of the SOS were tested along with only the conceptual features of the control system.

2 TEST RESULTS

2.1. MECHANICAL FEATURES

2.1.1. Magnet-to-Standoff Fixture

A fixture was designed to aid in gluing the magnet to the standoff. In testing this gluing fixture and the fixtures below, it became apparent that these glued magnet/standoff assemblies are quite fragile. In response to this, an adhesive testing program has been implemented according to the steps outlined in “Adhesive Testing”, LIGO-T970006-00-D. The goal of this testing is to increase the reliability and repeatability of the present adhesive, the preparation, cleaning and baking of the components and how that effects the glue joints integrity and the possibility of an alternative adhesive.

Parallel to this testing, an alternative design of the standoff was tested. It is “dumbbell” shaped and has 3.4 times the surface area of the original standoff. It provides a more robust joint and is easier to handle than the conventional cylindrical standoff. It was found not to degrade mechanical losses of the LIGO large test mass around 100 Hz. Testing and results for this type of standoff are detailed in “Dumbbell-type Standoff for Magnet/Standoff Assembly”, LIGO-T970096-00-D. The original magnet-to-standoff fixture was modified to accept the dumbbell shaped standoff. This modified fixture has been used twice, with two different adhesives; Vac Seal and Torr Seal, and has worked well.

2.1.2. Magnet/Standoff Assembly Fixture and Guide Rod Fixture

Fixtures were designed to position and epoxy the magnet/standoff assemblies to the face and sides of the optic and to position and epoxy the guide rods to the side of the optics. Each of these fixtures is compatible to use with dumbbell type standoffs. The fixtures were tested with an aluminum model, the 40 meter beamsplitter and recycling optics. The following tasks and tests were completed.

- The fixtures were built.
- The model optic, beamsplitter and recycling mirror were installed.
- Attachments were glued in place.

- The ease of assembly, alignment and gluing were checked.

During the time that the SOSs were being assembled and tested, a number of suspension fixtures were redesigned to increase reliability, protection of the optic, and ease-of-use. Most notably the magnet/standoff assembly fixture and the guide rod fixture were redesigned to make gluing of the magnet/standoff assemblies easier and to make the glue joints more robust. Adoption of the dumbbell standoff, as validated by high Q measurements, decreases the chances of the magnet/standoffs failing by making it easier to grasp and handle the standoffs.

Also, because the optic is so thin, the magnet/standoff assembly fixture and the guide rod fixture cannot be used simultaneously. It was noticed during the balancing of the beamsplitter suspension that since these two fixtures are autonomous, the position of the face magnet/standoff array may be rotated relative to the components glued on with the guide rod fixture. To address this problem, the assembly procedures, detailed in the Small Optics Suspension Assembly Specification, LIGO-E970037-00-D, details a fixture plan that has the optic sitting on the base plate of the guide rod fixture while using the magnet/standoff fixture. Screws are used to attach the magnet/standoff fixture to the base plate of the guide rod fixture.

2.1.3. Construction and Alignment/Fit Checks

Two SOS structures were built. The optical table was leveled for alignment tests. The Vacuum Assembly Room in the 40-Meter lab So. Annex building was used for these tasks. An aluminum model optic, and then later the 40 meter beamsplitter and recycling optics, were suspended and a coarse alignment was performed by tapping on the wire standoffs. It was verified using a microscope and bushing that the magnet assemblies were coarsely aligned with the sensor/actuator plates. This alignment was verified by the proper operation of the sensor/actuator head assemblies once installed in the plate. A fine optical alignment was performed on the beamsplitter and the recycling mirror by micropositioning one of the wire standoffs.

The wire standoffs were glued in place. The optics and the aluminum model, at two separate times, were removed from the suspension, cleaned and baked, and remounted into proper optical alignment, within design tolerances. The pitch frequency was measured at 0.79 Hz with a design parameter of 0.75 Hz. The yaw frequency was measured at 0.85 Hz with a design parameter of 0.85 Hz. The pendulum frequency was measured at 1.04 Hz with a design parameter of 1.0 Hz.

During the time that the SOSs were being assembled and tested, a number of suspension components were redesigned to increase reliability, protection of the optic, ease-of-cleaning and ease-of-use. These components include the bracket on top of the optic that has the safety stops in it. It was redesigned to allow for drag wipe cleaning of the optic.

2.1.4. Installation Tests

Following the fine alignment of the beamsplitter, the optic was locked in its safety cage. The suspension structure was transported to the beamsplitter chamber and clamped in place. The optic was unlocked from the safety cage and checked for optical alignment. Electrostatic discharge on the Teflon safety cage screws can change the alignment. We put some Teflon screws under a flow hood for a week or so to try to induce an electrostatic charge on the screws from the flowing air. During a vent of the 40 meter interferometer, we removed one of the stainless, spring-tipped screws from the face of the beamsplitter suspension and replaced it with the charged up Teflon screw. We then incrementally moved the screw tip closer to the optic face and noted the reflected beam's movement. We tried to remove this charge by brushing a grounded copper broom across the safety cage screw. After brushing, we reinstalled the Teflon screw and moved it incrementally closer to the optic. It moved the optic the same displacements per increment as before brushing with the grounded broom.

As a replacement to the electrostatically-challenged Teflon screws, we have researched conductive plastics from which to make the safety cage screws. A graphite filled Teflon made by Furon Dixon in Briston, R.I. has passed an initial bake and RGA scan. Safety stop screws were made from the sample material and were used in an electrostatic test as described above. The conductive Teflon screws did not deflect the optic as the charged Teflon screws had. The SOS Assembly drawing has been changed to include safety stops made from this conductive Teflon compound.

Also, to reduce the electrostatic charge-up potential between the optic and the Macor (a Corning machinable ceramic) sensor/actuator head, we have researched coating the head with gold. We had a ceramics company coat a sample of Macor with ceramic-quality gold glaze and fire the sample at 1450 degrees F for 2-3 hours to remove the organic media. We baked the sample for 48 hours at 120 degrees C and it passed an RGA scan. The LIGO sensor/actuator heads will be coated with a thin layer of gold to reduce the electrostatic charge-up potential.

2.2. Performance

2.2.1. Frequency and Q Measurements

These measurements were performed after the beamsplitter suspension was installed in the 40 meter interferometer. Substrate vibrational-mode Q's for the lowest five modes were measured after gluing on all attachments. The requirement for these Q's is 1×10^5. We plan to measure the Qs of the recycling mirror, after it is installed in the 40 meter interferometer, to verify that the substrate's Qs do not degrade due to the dumbbell standoffs. The results are below and are compliant with the requirements.

The violin mode frequencies and Qs were measured and are listed below in Table 2. The requirement for the violin mode Qs is 5e4. So the measured result of 2.2e5 meets the requirement.

Table 1: Internal Modes

f0 (kHz)	*Q*
20.15194	4.9e5
20.18583	2.7e5
28.40520	3.1e5
37.97721	2.4e5
37.99493	2.4e5

Table 2: Violin Modes

f0 (kHz)	*Q*
0.7083040	2.2e5
1.4165378	6.7e5

The first mode for the magnet/dumbbell standoff assembly is 9.7 kHz with a Q of ~130. This Q value is dependent on the amount of glue used between the magnet and standoff and between the standoff and optic.

2.2.2. Mode Measurements of the Suspension Structure

Measurements of the mechanical resonances of the suspension structures were made to compare with the resonances of the PNI upon which its design is based. The structure was clamped to the optical table to mimic the situation in LIGO since some modes may couple vibrational energy through the suspension support structure to the proof mass. These modes form a two body system and the system's reduced mass should resemble the situation in LIGO. Otherwise these modal frequencies will shift when placed on a LIGO optical platform. The following task/tests were performed.

- The SOS was bolted to the top of an optical table.
- Structural resonances were excited by tapping on the structure at various spots. A laser was directed toward a split photodiode. In between the photodiode and the laser, the SOS was positioned such that an edge of the suspension structure just clipped a portion of the beam. An oscilloscope was used to measure the resonances as evidenced by the frequency of the light hitting the photodiode.
- Verification was made that there are no modes below the gravest mode specified in the design requirements, which is 150 Hz. The lowest mode is 156 Hz.

2.2.3. Sensor/Actuator Head Tests

The sensor/actuator heads damped the mass to their performance requirements. Tests were also performed to measure the maximum DC current of a coil. The test procedures and results are documented in the report titled "Maximum Current of the Suspension Actuator Coil" by Shinji Miyoki and Seiji Kawamura, LIGO-T960148.

2.2.4. Demonstration of Local Damping

Reasonable damping was achieved under local control making use of the servo electronics which were made for the beam splitter for the Mark II interferometer. An aluminum model was used in place of optical components. The model optic was given an electrical kick and the displacement as a function of time was measured using the output of the sensor in the sensor/actuator head.

3 CONCLUSION

The mechanical test results for the Small Optic Suspension validated the design. The construction, fixture usage and installation tests allowed us opportunities for improving the design, which were completed. Most redesigns were prototyped and tested successfully. Some were adopted without testing due to the small risk associated with the change. The fixture redesign concept was prototyped and proofed for the large optics suspension. Some redesigns, such as the dumbbell standoffs for the recycling mirror, will be qualified in the coming months.