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Deflection Requirements for HAM Support Beam Bellows

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Abstract

Worst case HAM support beam bellows deflections in axial and shear directions are evaluated by combining actuation ranges and manufacturing and positioning tolerances of the chamber and support structure. The shear and axial bellows deformations are large and define critical selection/design requirements for the support beam bellows.

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Table of Contents

1. Problem Description

The purpose of this calculation is to evaluate the axial and shear deflection requirements on the HAM support beam bellows. These bellows connect the internal support beams of the SEI to the corresponding ports on the HAM vacuum chambers. Their large diameter and the limited axial space makes shear deflection capacity a very critical requirement for the selection and/or design of these bellows.

Figure 1 shows a layout of the support system and defines the axis system used throughout this note.

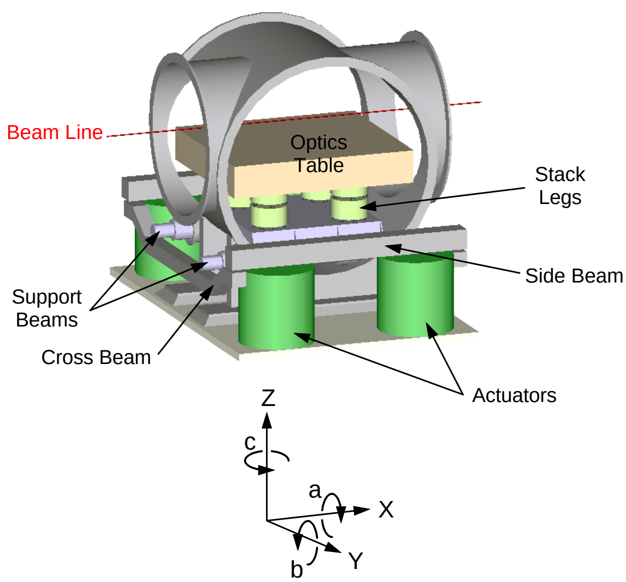

Figure 1: BSC SEI layout, axis system definition.

Various factors contribute to the total shear and axial deflections in the bellows:

- Coarse actuation requirements: The actuation systems move the support beams relative to the vacuum chambers, deforming the support beam bellows.
- Manufacturing and alignment tolerances: both the vacuum chambers and the support structure have manufacturing imperfections; in addition, the vacuum chambers are aligned with the theoretical optical axis of the detector with finite accuracy. Because in operation the support system will be brought into alignment with the optical axis, these imperfections will again be absorbed by the support beam bellows.

Note that because of the proximity of the HAM support beam ports to the floor and the feet of the vacuum chambers, the effect of vacuum chamber deflections under atmospheric pressure loads is neglected.

2. Actuation Ranges

The required ranges of actuation[1] are ±5 mm in the *X*, *Y*, and *Z* directions and ±4 mrad in rotation around *Z* for the coarse actuation (drift compensator). Any parasitic roll (*a*, around *X*) is limited to a maximum of 0.05 mrad (reduced from 0.5 mrad in [1]). There is no fine actuation system for the HAM support structures. With the lever arms shown in Fig. 2, the ±4 mrad coarse yaw range leads to additional linear ranges of ±4.27 mm in the *Y* direction and ±2.74 mm in the *X* direction. The ±0.05 mrad roll tolerance gives an additional ±0.03 mm range in the *Z* direction.

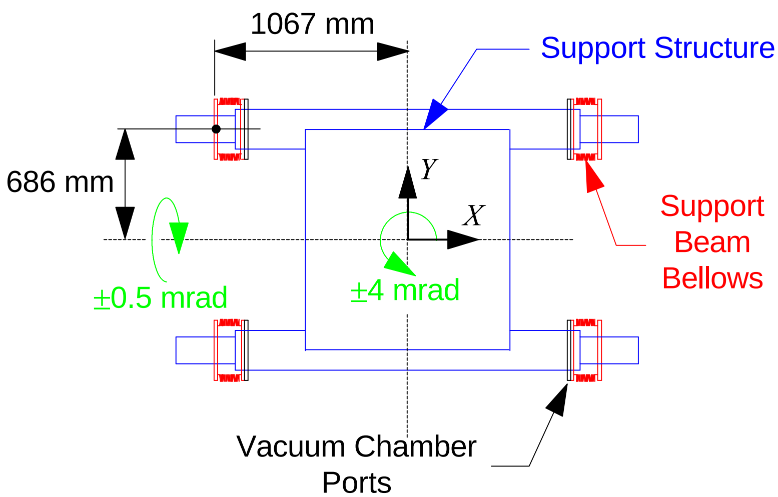

Figure 2: BSC support beam bellows.

3. Manufacturing and Alignment Tolerances

3.1 Vacuum Chamber Alignment Tolerances

The main ports of the HAM vacuum chambers will be positioned and aligned in the facility with reference to the theoretical beam line. Tolerances on this alignment are ±2 mm [6].

3.2 Vacuum Chamber Manufacturing Tolerances

Manufacturing tolerances on the position of the support beam port flanges with respect to reference (centerline of main 60" beam ports) were listed on PSI drawings[5] as ±0.38 mm (0.015 in). The LIGO vacuum equipment specifications[7] gives upper limits on those tolerances of ±2.54 mm (0.1 in). Recent measurements performed by PSI on a first article of the BSC chamber reveal imperfections up to 1.52 mm (0.060 in)[6]. A tolerance of ±2.54 mm (0.1 in) is adopted here.

3.3 Support Structure Manufacturing and Alignment Tolerances

Manufacturing tolerances on the support structure must also be taken into account. For axial deformation of the bellows, the critical dimension is the axial distance between the mating surfaces for the bellows flanges that are machined into the support beams. A tolerance of ±1.52 mm (0.060 in) was adopted on this dimension. In addition, assuming no shimming, the separation between the two support beams is fixed by the machining of the support beams/platform interfaces; a tolerance of ±1.52 mm (0.060 in) was adopted on this dimension.

4. HAM Support Beam Bellows - Requirement Summary

Table 1 summarizes and combines bellows deflections from all effects considered. It shows that - with the present requirements and tolerances - the support beam bellows must be able to sustain about ±11.3 mm axial deflection and ±15.5 mm shear deflection. These requirements are **extremely severe**, even for welded diaphragm bellows.

Source	Twist	Axial	Shear	
	a	*X*	*Y*	*Z*
	(mrad)	(mm)	(mm)	(mm)
actuation systems Coarse: drift compensator, ± 5 mm X,Y,Z & ± 4 mrad Yaw 0.05 mrad Roll tolerance	± 0.05	± 7.74	± 9.27	± 5.04
Vacuum chamber positioning tolerance (wrt beam reference)	*-*	*– 2.00*	*– 2.00*	*– 2.00*
Vacuum chamber manufacturing tolerances (distance from 60 port to support beam ports and support beam ports separation)	*-*	*– 2.54 (100 mil)*	*– 2.54 (100 mil)*	*– 2.54 (100 mil)*
Support structure manufacturing tolerance (axial distance between bellows flanges)	*-*	*– 1.52*	*– 1.52*	*– 1.52*
Total deflections from tolerances (RMS)	**-**	± 3.57	± 3.57	± 3.57
			< ± 12.84	**< ± 8.61**
TOTAL	**< ± 0.05**	**< ± 11.31**	**< ± 15.46**	

Table 1: Deflection requirements for HAM support beam bellows.

5. References

1. F. Raab and N. Solomonson, *Seismic Isolation Design Requirements Document* (draft and early corrections), LIGO draft document LIGO-T960065-02-D, California Institute of Technology and Massachusetts Institute of Technology, April 15, 1996.
2. *Beam Splitter Chamber Deflections*, PSI International, Inc., V049-1-029, December 6, 1995.
3. *Vacuum Load Static Analysis*, the Ralph M. Parsons Co., contract #PP150969, CDRL 11, DRD # 05, LIGO-C961598-00-D, Feb. 6, 1996.
4. Equipment Layout Drawings for Washington Corner Station, PSI international, Inc., LIGO-D960800-00-D and LIGO-D960799-00-D, June 1996.
5. *LIGO Vacuum Equipment Final Design Report: Volume V, Drawings - Mechanical*, contract # PC175730, CDRL 03, May 1996.
6. Dennis Coyne, E-mail communication, August 15, 1996.
7. *Specification for the LIGO Vacuum Equipment,* California Institute of Technology, LIGO-E940002-02-V, Revision 2, August 18, 1995.

Note 1, Linda Turner, 09/03/99 11:35:22 AM
LIGO-T960217-A-D