LIGO Laboratory / LIGO Scientific Collaboration

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Optics Table Hole Size and Spacing based on Suspension Attachment Frequencies

(Advanced LIGO)

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Distribution of this document:
SEI, SUS subsystem group

This is an internal working note
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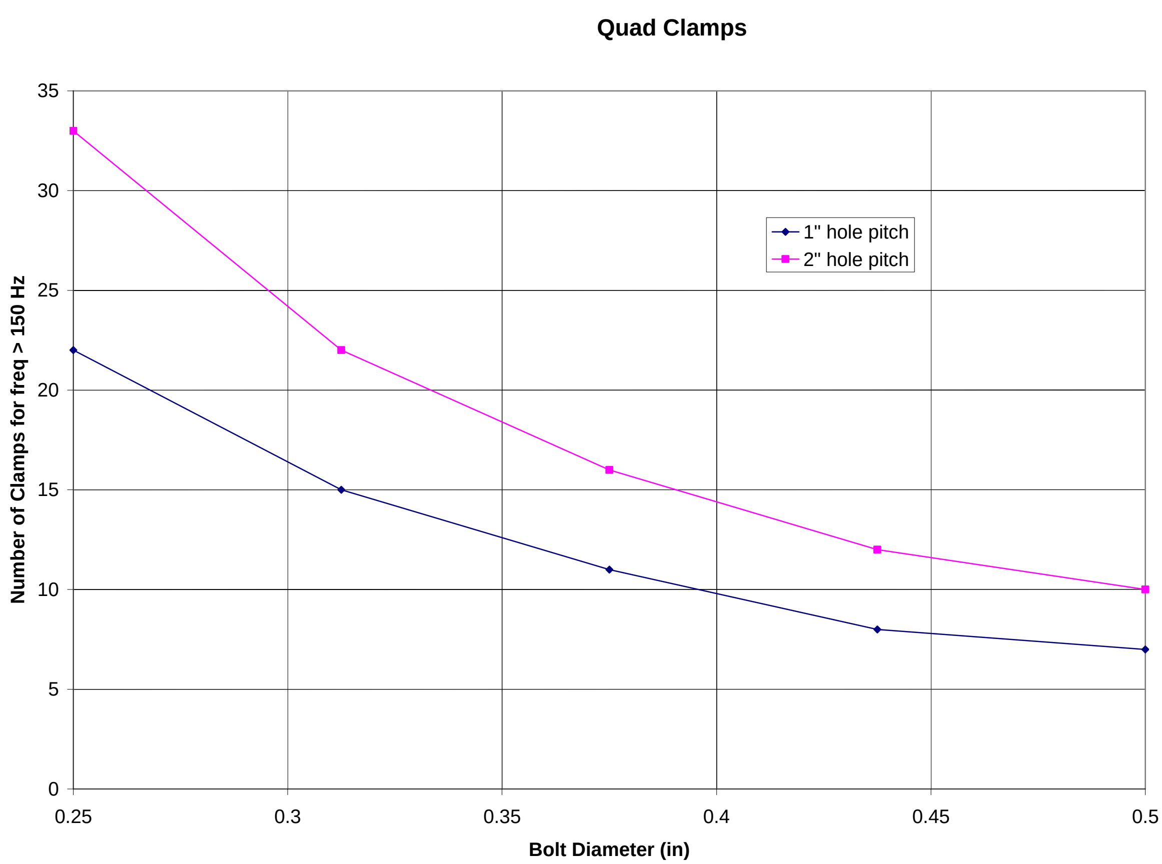
The following are some notes justifying the choice of 3/8-16 UNC-2B threaded holes on 1 inch centers for the BSC optics table.

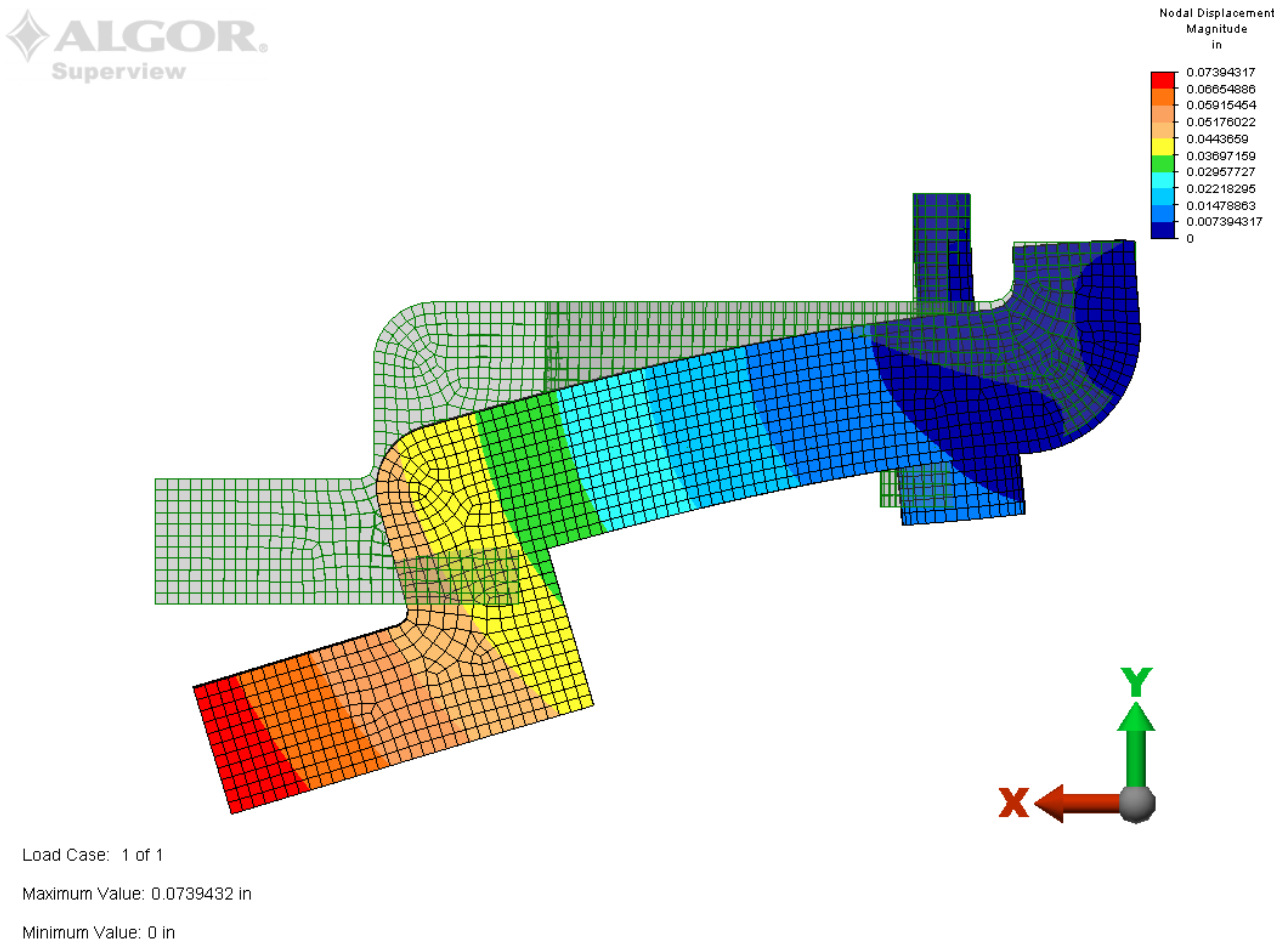
I've modeled the clamp stiffness in the attached spreadsheet using the joint stiffness analysis in A. Slocum's "Precision Machine Design" (see Appendix A for an excerpt on bolted joints from Slocum's text). I've also modeled the clamp with the geometric parameters for D050150-02 using Algor. The closed form analysis gives a clamp stiffness of 2.0e4 lbf/in whereas the Algor analysis gives 1.7e4 (20% lower). An "optimal" clamp design has bending and shear stiffness of the clamp equal to the bolt extension stiffness. Using the model, I've varied the optics table hole pitch and the bolt diameter, optimizing the clamp stiffness, to determine the number of clamps required as show in the plot below. I conclude that we need a 1 inch hole spacing and 3/8 inch diameter bolts at least.

Figure 1: Number of Clamps Required to Achieve a Quad Suspension Structure, Vertical Bounce Mode Frequency of 150 Hz



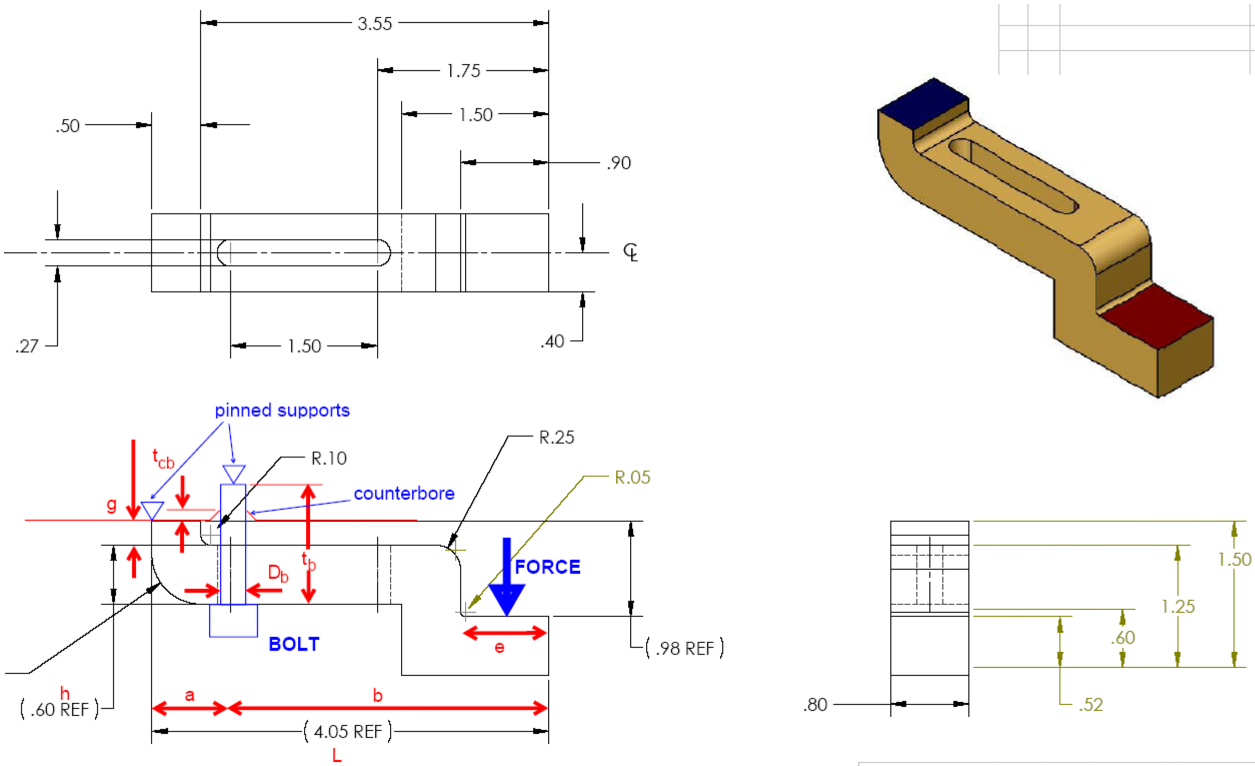
Algor model: Pinned nodes at the far edge of the clamp at it's interface with the optics table, pinned nodes at the end of the effective length of the bolt (using Slocum's definition of effective length) and the force (weight) from the suspension represented as a point load centered on the flat surface of the clamp which interfaces to the suspension structure. Note that this is for the worse case extension of the clamp (i.e. placement of the bolt).

Figure 2: Algor Deflection Analysis
0.074 in peak deflection for 1000 lbf load centered in the flat area which interfaces to the suspension frame.



In the analysis I kept the same width to depth ratio. I optimized the stiffness of the clamp so that it is comparable to the extensional stiffness of the bolt. So the 3/8-16 SHCS version of D050150 would have a width of 1.27 in, a section thickness of 0.95 in and a "dog" leg height (at the optics table end) of 0.05 in. This stiffer design takes advantage of the stiffer 3/8" dia. bolt.

Figure 3: Clamp Suspension Structure Dog Clamp Dimensions/Variables



LIGO I style clamp which was ~ 5" long and around the bolting section it was .47" thick with a 2.5" long slot. Reference LIGO-D980184.

LIGO-D050150. The unusual shape comes from the fact that it has to interface with a 1" high ledge around the top of the suspension structure. The thickness around the bolt has been increased from .47" to .6" (or ~ 3.5mm thicker) and the length has been reduced to ~ 4" with only a 1.5" long slot. This last choice is based on the assumption that the seismic table will have a set of 1/4-20 tapped holes on 1" pitch or at least a 1" pitch around the probable areas that you will clamp a structure.

As an aside, I had mentioned at the LSC meeting that in Slocum's text one could find the preload (torque) required to achieve a desired joint stiffness. This is true for compressive stiffness, but only for joints with considerably higher stiffness than the quad clamps that we are considering, i.e. the effect is negligible.