LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T030068-00-D *ADVANCED LIGO* 15th April 2003

LIGO Winch Analysis and Testing

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Distribution of this document:
LIGO Science Collaboration

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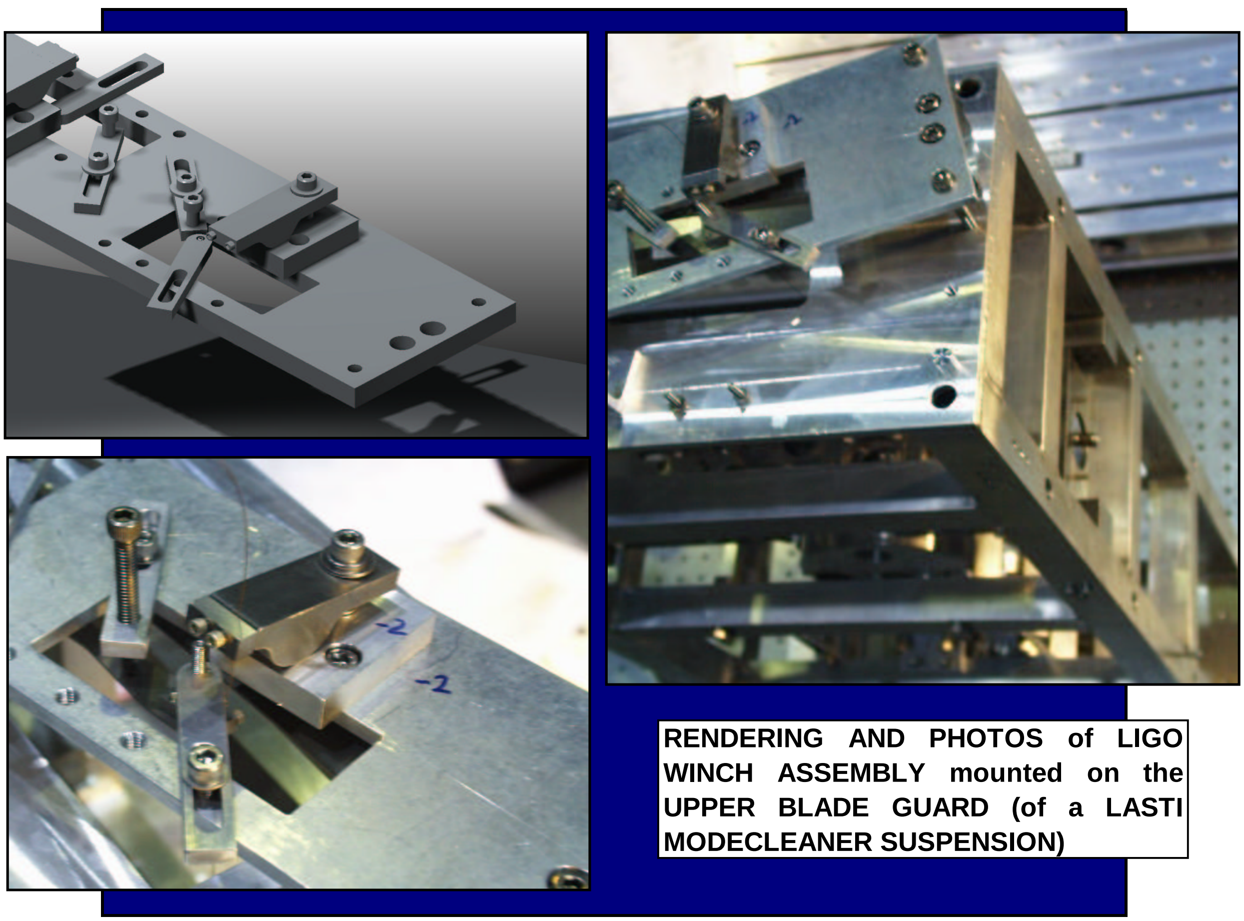
Introduction

The LIGO Winch is a component part from the original LIGO project brought forward for use in the LASTI and Advanced LIGO Projects.

The component is used to lift a suspension in the vertical (z-direction) when it is found to be hanging below the calculated height and hence below the optimum height to align with the optics. This is an unlikely occurrence that can nevertheless happen as a result of the blades over-deflecting or where mass has been added to help balance the upper, intermediate or test masses.

In the circumstance where this does occur we need to be able to accurately move the suspension to the correct height. To understand this and the full range of vertical movement allowed by the winch a series of experimental tests were completed and calculations were made to backup the results.



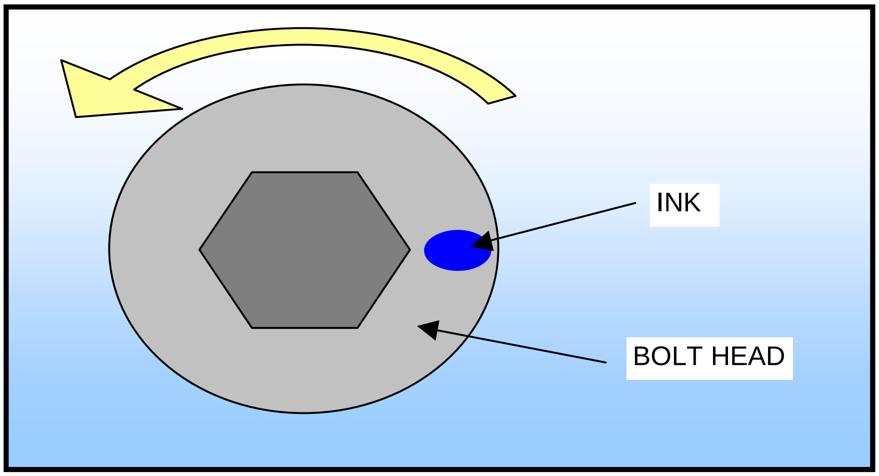
RENDERING AND PHOTOS of LIGO WINCH ASSEMBLY mounted on the UPPER BLADE GUARD (of a LASTI MODECLEANER SUSPENSION)

Contents

Experimental Setup

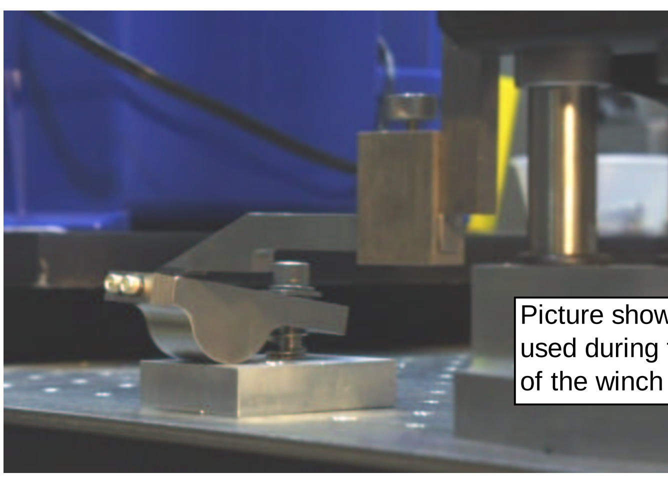
The experiment was completed four times (see results on following page), the first two of these were done without the winch being put under load. The steps completed in setup were as follows:

* The winch was bolted onto the test bench and with the winch in the neutral, horizontal position, the height difference between the base and top of the winch was measured.
* The bolt, marked with ink on its face, was then turned one full rotation - judgement of this rotation was by eye.



* Following the completion of one rotation a measurement was then taken at the tip of the winch using the height gauge.
* This procedure was then repeated until the bolt could travel no further - approximately 5.5 turns. For results, see tables overleaf.

After repeating the initial experiment for a second time with no loading it was then repeated with a suspended mass of 4.5kg (half the mass of a Mode cleaner suspension). The results gained from the loaded tests gave similar results to those taken earlier demonstrating that the height at the tip is related directly to the number of turns and is not affected by the load.
The load, however, does affect the amount of torque required to turn the bolt. And the load was to prove critical in the final test as the standard thickness stainless steel washer failed under the loads present and tells us thain practice it would be advisable to use a thicker washer.

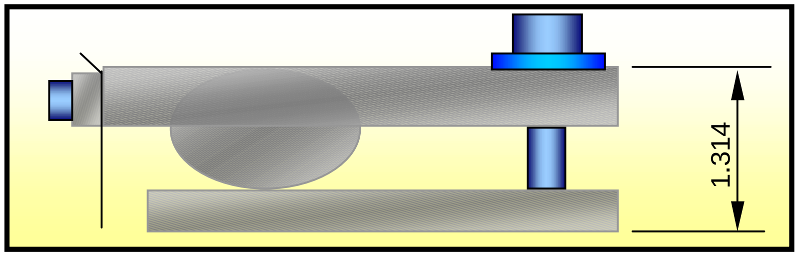


Picture shows the equipment used during the measurement of the winch break-off height .

The results from testing are shown overleaf.

LIGO Winch Measurement Results

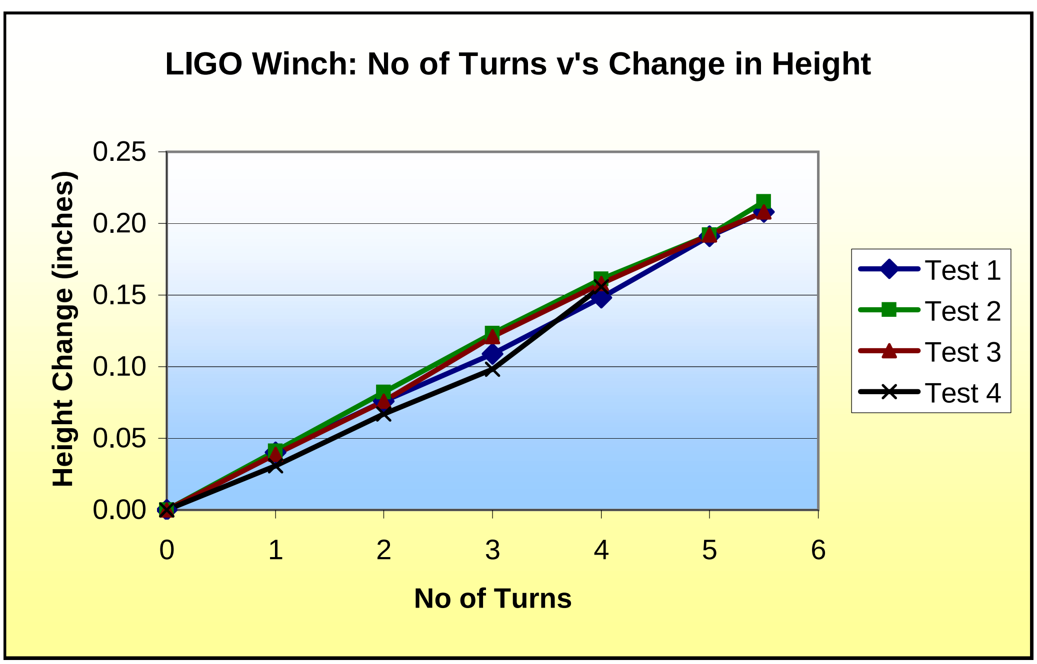
All measurements in the following document are in inches.



	Test 1 No loading		Test 2 No Loading		Test 3 With loading		Test 4 With loading	
No. of Turns	Height of break of point	Deflection on each turn	Height of break of point	Deflection on each turn	Height of break of point	Deflection on each turn	Height of break of point	Deflection on each turn
0	1.314		1.314		1.314		1.314	
1	1.354	0.04	1.355	0.041	1.353	0.039	1.345	0.031
2	1.39	0.036	1.396	0.041	1.39	0.037	1.381	0.036
3	1.423	0.033	1.437	0.041	1.435	0.045	1.412	0.031
4	1.462	0.039	1.475	0.038	1.472	0.037	1.47	0.058
5	1.505	0.043	1.506	0.031	1.506	0.034	* Washer Damaged	
5.5	1.522	0.017	1.529	0.023	1.522	0.016		

* in practice it is advisable that a thicker washer be used.

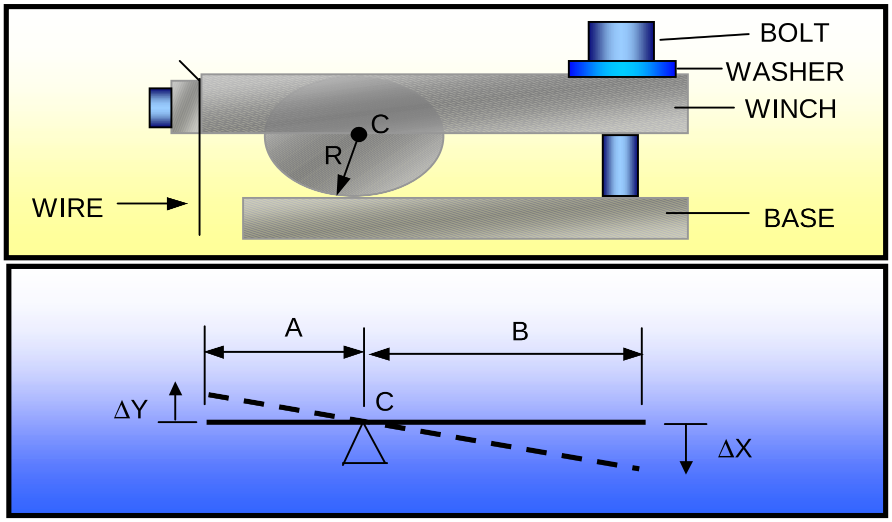
No. of Turns	Height of break of point	Overall Deflection	Height of break of point	Overall Deflection	Height of break of point	Overall Deflection	Height of break of point	Overall Deflection
0	1.314	0	1.314	0	1.314	0	1.314	0
1	1.354	0.04	1.355	0.041	1.353	0.039	1.345	0.031
2	1.39	0.076	1.396	0.082	1.39	0.076	1.381	0.067
3	1.423	0.109	1.437	0.123	1.435	0.121	1.412	0.098
4	1.462	0.148	1.475	0.161	1.472	0.158	1.47	0.156
5	1.505	0.191	1.506	0.192	1.506	0.192	* Washer Damaged	
5.5	1.522	0.208	1.529	0.215	1.522	0.208		



Calculation of Wire break off height per turn of the bolt.

By measurement we find that when a 1/4-20 UNC bolt is turned by one whole rotation the change in height vertically [ΔX] is 0.059" (1.5mm).
By assuming that the winch pivots around the centre [C] of the Radius [R] we can approximate that the ratio between the change in height vertically at the bolt [ΔX] and the change in height at the break off point [ΔY] is equal to the ratio between the distance from the end of the winch (where the wire breaks off) [A], to the centre of the radius [C] and the distance from the centre of the radius to the centre of the bolt [B].

Diagrammatically this can be shown as:



From the Engineering Drawing we can see that:

Distance A = 0.707" and Distance B = 1.043".

$A/B=\Delta Y/\ \Delta X$

$\Delta Y=\Delta X*(A/B)$

$\Delta Y=0.0059 * (0.707/1.043)$

<u>$\Delta Y=0.04$" per turn</u>

Conclusions

The above calculation is not strictly accurate because as the bolt is turned, the winch becomes angled and hence the point of contact between the bolt and the winch is at the edge of the washer below the bolt rather than at the bolt centre.
However, as the measured results are close to that which was calculated and the relationship between number of turns and height travelled is approximately linear, it is unneccesary to go to any greater complexity with the calculations. Using the data recorded and the associated graph (see page 3 of 5) we can now adjust the suspension to the required height.
It is important to note that should a similar mechanism be used in the Recycling Mirror, where the mass suspended from each winch is 18kgs, the winch may require a substantial re-design.
In the final experiment with the winch tested under load the washer was damaged due to the force involved. It would be advisable to use a thicker washer in practice.

Engineering Drawing of LIGO Winch showing Accurate Dimensions