Blade Specification Document (Quad Controls Prototype)

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Rev 01: Includes some comments / additions / edits by CIT and MPL.

1. INTRODUCTION

The LIGO quad suspensions contain 3 sets of maraging steel blade springs. These springs are Top, Middle and Bottom springs, attached to the Top Stage, Top Mass and Upper Intermediate Mass respectively.

The Blade springs are all intended to be of similar design, with each set designed using the same guide lines. This note is intended to capture these design guide lines, and highlight the important areas of consideration in the blade design, as well as documenting the actual design used for the controls prototype (CP) suspension.

2. DESIGN REQUIREMENTS

Norna Robertson uses the MATLAB suspension simulation to produce a conceptual design for the full suspension, within this various blade properties are generated. During this process she selects dimensions for the blade which give the required spring constant whilst keeping the internal stress sufficiently low and the internal modes sufficiently high. Clearly the blades must physically fit into the suspension and so this is an iterative process with the rest of the suspension design. At the end of this initial stage, the MATLAB model includes length, thickness, root width, natural frequency, and maximum stress.

Basic beam theory has been used to develop a number of calculators to find the remaining essential blade parameter this is the bend radius which will allow the blade to adopt a flat shape under load in use.. At this stage it is usual to involve other blade experts to vet the basic design.

Once the basic mechanical dimensions have been decided, the blade must be extended to interface to both a blade and a wire clamp. This will require the addition of material and holes for various mountings. In addition to the blade clamps, provision must be made for eddy-current damping of the blade.

All of the above has to be incorporated in to the CP blades, the specifics of which are detailed below.

2.1 Suspension parameters

Norna provided the Excel spread sheet in Appendix A via email to the design group on Wed 21st April 2004.

The most relevant part of this is the last 3 lines, reproduced here:

i) top blades: length 48 cm width 9.5 cm, thickness 4.3 mm, f = 2.33 Hz, internal f = 70 Hz, stress 981 MPa
ii) middle blades: length 42 cm, width 5.9 cm thickness 4.6 mm f = 2.48 Hz, internal f = 98 Hz, stress = 990 MPa
iii) bottom blades: length 37 cm, width 4.9 cm, thickness 4.2 mm, f = 1.81 Hz, int f = 115.5Hz, stress = 983 MPa

2.2 Bend Radius

Taking the parameters from Norna the Bend radius was calculated via another Excel calculator, this is shown in appendix B, here an iterative solver is used for this calculation. This Excel workbook is included in Appendix B, where the 3 blades are worked through. The important numbers are highlighted in red, and are summarised here:

length mm	root width mm	thickness mm	E GPa	alpha	mt	m	f	fint	sigmax	Radius A	rad to surface	lambda
480	95	4.3	186	1.35	61	11	2.33	70.26	981.1	0.4007	398.53	0.2544
420	59	4.6	186	1.35	50	11	2.48	98.17	990.1	0.4451	442.81	0.1837
370	49	4.2	186	1.35	39	19	1.80	115.50	982.6	0.4127	410.56	0.1550

Mass kg
22
22
38.4
39.6

It should be noted that the numbers quoted for the mass refer to the main chain. The reaction chain is as follows: - 22
22
39.6
38.4 kg. This does not have an effect on the blade design.

Following tests on the blade test facility with blades near the size of the CP top blades, it was decided to use alpha = 1.36 and E=186GPa in the design of the blades, even though the blades are pseudo-triangular in shape. In fact alpha=1.35 had already been used to make provisional drawings and the differences are so small that we stuck with that figure.

2.3 Interfaces

The blades interface with clamps at their root and tip. Since neither of these have yet been developed it is quite hard to tie down the interface. Some provisional work has been done which gives a basic design of blade and wire clamp. In addition to this, past experience from the 2001 Quad, and ALIGO Mode-cleaner, was employed as a benchmark design.

A few important dimensions have been developed for the blade interfaces, these are listed below.

Wire break off: 5mm from end of blade (so that the blade is 5mm shorter than the "ideal" length of the triangle).

Blade tip width 10mm

Clamping length along the blade: ~~40mm~~ 30mm for blades on suspended masses, 50mm for blades on top stage

Blade clamp width: As blade

Wire clamp hole pattern: 2off 8-32 holes along the length of the blade.

Bolt sizes: sizes are defined by a simple moment calculation max allowable stresses are 66% of Yield of bolt core diameter.

Bolt clearances The bolt holes are 0.002" over the nominal bolt size with a +0.001/-0.000 tolerance

To ensure that the blade design is not going to be a problem the blade designs have been fitted to the conceptual masses and Top stage in SolidWorks.

Interface issues were reviewed by Mike Perreur-lloyd. He concurs that for revision C of the blades that they fit within the expected area in the top and upper intermediate masses.

2.4 Eddy-current damper

To damp the internal modes of each blade provision is made to install an eddy-current damper. FE analysis of the blade's internal modes gives the most effective position for this to be 21/32 from the root of the blade to the tip.

Although this was initially schemed the eddy-current damper was moved to ensure that the hole in the blade had minimal affect on the blades stiffness. Hence the hole for eddy-current damper was eventually placed halfway along the blade.

3. APPENDIX A

"Norna's CP Blade Info.xls"

4. APPENDIX B

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