Transmissibility of a revised set of blades

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1. BACKGROUND

Norna has been working to get some increased vertical isolation for the control prototype and asked for a modified set of blades to be run through the FEA analysis. This note reports the results. Refer to T040024 and –25 for context.

2. BLADE DIMENSIONS ETC

Norna report that she has used an alpha of 1.35 and gives sizes and frequencies in her email (reproduced at the back of this note). With an E of 186Gpa I was able to reproduce her uncoupled frequencies, internal modes, and maximum stress numbers using the spreadsheet of blade equations. We need the alpha to work out the tip widths for the FEA, as follows

Alpha = 1.35

Implies beta = 0.15051

So,

Tip width = root width * 0.15051

The blade dimensions for the FEA macros are thus

length	thickness	root	tip	tipmass	testmass
0.480	0.0043	0.095	0.0143	0.01	11
0.420	0.0046	0.059	0.0089	0.01	11
0.370	0.0042	0.049	0.0074	0.01	19.2

3. FREQUENCIES BY FEA

The parameters in the model macro bf1 were

```
blength=ARG1
bthick=ARG2
rootwidth=ARG3
tipwidth=ARG4
hroot=rootwidth/2
htip=tipwidth/2
maryoung=1.86e11
```

```
marpoiss=0.3
mardens=7800
wireyoung=2e11
wirepoiss=0.3
wiredens=7800
!dampratio=1e-4
tipmass=ARG8
wiredia=7e-4*2
wirelen=0.54
testmass=ARG9
```

Referring to T040025, I ran bfmany as follows:

```
bf1,.48,.0043,.095,.0143,20,1,1000,.010,11
bf1,.42,.0046,.059,.0089,20,1,1000,.010,11
bf1,.37,.0042,.049,.0074,20,1,1000,.010,19.2
```

results were

```
 ****  VALUES OF ARGx  *****

  NAME         VALUE                     TYPE

  ARG1    0.480000000                    SCALAR
  ARG2    4.300000000E-03                SCALAR
  ARG3    9.500000000E-02                SCALAR
  ARG4    1.430000000E-02                SCALAR
  ARG5     20.0000000                    SCALAR
  ARG6     1.00000000                    SCALAR
  ARG7     1000.00000                    SCALAR
  ARG8    1.000000000E-02                SCALAR
  ARG9     11.0000000                    SCALAR


  *****  INDEX OF DATA SETS ON RESULTS FILE  *****

   SET   TIME/FREQ    LOAD STEP   SUBSTEP  CUMULATIVE
     1  2.3222            1          1         1
     2  69.444            1          2         1
     3  209.93            1          3         1
     4  396.23            1          4         1
     5  419.91            1          5         1
     6  664.44            1          6         1
     7  821.47            1          7         1
     8  914.31            1          8         1
     9  922.79            1          9         1

 ****  VALUES OF ARGx  *****

  NAME         VALUE                     TYPE

  ARG1    0.420000000                    SCALAR
  ARG2    4.600000000E-03                SCALAR
  ARG3    5.900000000E-02                SCALAR
  ARG4    8.900000000E-03                SCALAR
  ARG5     20.0000000                    SCALAR
  ARG6     1.00000000                    SCALAR
  ARG7     1000.00000                    SCALAR
  ARG8    1.000000000E-02                SCALAR
  ARG9     11.0000000                    SCALAR


  *****  INDEX OF DATA SETS ON RESULTS FILE  *****
```

```
  SET   TIME/FREQ    LOAD STEP   SUBSTEP  CUMULATIVE
    1  2.4748           1          1         1
    2  96.596           1          2         1
    3  291.22           1          3         1
    4  573.21           1          4         1
    5  680.68           1          5         1
    6  750.77           1          6         1
    7  856.11           1          7         1

 ****  VALUES OF ARGx  *****

 NAME         VALUE                    TYPE

 ARG1    0.370000000                   SCALAR
 ARG2    4.200000000E-03               SCALAR
 ARG3    4.900000000E-02               SCALAR
 ARG4    7.400000000E-03               SCALAR
 ARG5     20.0000000                   SCALAR
 ARG6     1.00000000                   SCALAR
 ARG7     1000.00000                   SCALAR
 ARG8    1.000000000E-02               SCALAR
 ARG9     19.2000000                   SCALAR


 *****  INDEX OF DATA SETS ON RESULTS FILE  *****

  SET   TIME/FREQ    LOAD STEP   SUBSTEP  CUMULATIVE
    1  1.8046           1          1         1
    2  113.59           1          2         1
    3  342.89           1          3         1
    4  669.77           1          4         1
    5  730.32           1          5         1
    6  930.42           1          6         1
    7  958.36           1          7         1
```

The internal modes of 69.444, 96.596 and 113.59 are close to those found with the blade equations (70, 98, 115.5).

How do the modes at 2.32, 2.47 and 1.8 compare with Norna's results?

4. TRANSMISSIBILITY

Next I had to find frequency ranges that would capture the peaks for the three blades. I took this chance to modify the damping ratio from previous work (ref email from Norna Sat 28/02/2004 00:32) I settled on:

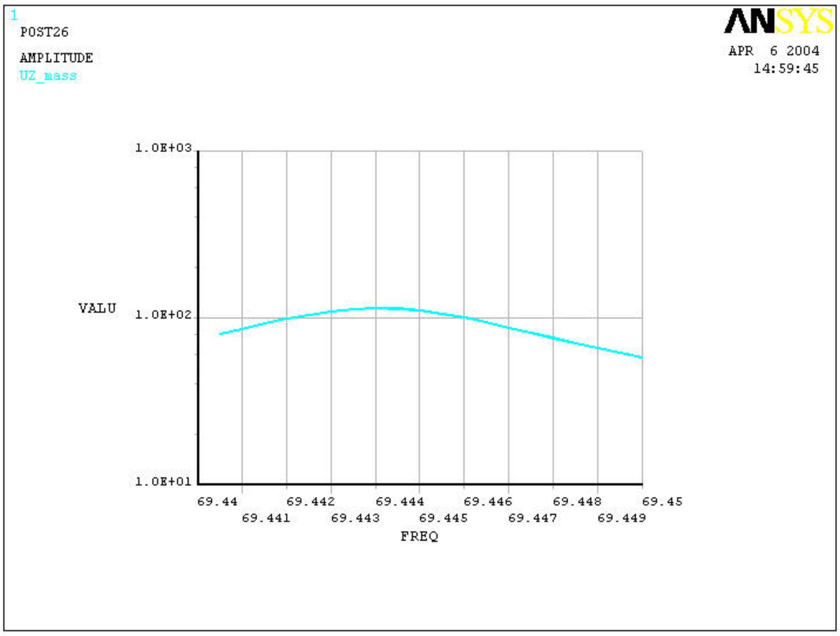
```
! macroname blength,bthick,rootwidth,tipwidth,nsteps,fstart,fend,tipmass,testmass,dmprat

bt1,.48,.0043,.095,.0143 , 20,69.44,69.45,.010,11,5e-5
```

Noting the other variables in the bt1 macro:

```
blength=ARG1
bthick=ARG2
rootwidth=ARG3
tipwidth=ARG4
hroot=rootwidth/2
htip=tipwidth/2
maryoung=1.86e11
marpoiss=0.3
mardens=7800
```

```
wireyoung=2e11
wirepoiss=0.3
wiredens=7800
dampratio=ar10
tipmass=ARG8
wiredia=7e-4*2
wirelen=0.54
testmass=ARG9
```

Which gave this:



and

```
bt1,.42,.0046,.059,.0089, 20,96.59,96.60,.010,11,5e-5
```

and

```
bt1,.37,.0042,.049,.0074, 20, 113.58,113.60,.010,19.2,5e-5
```

btmany becomes

```
bt1,.48,.0043,.095,.0143 , arg1,arg2,arg3,.010,11,5e-5
bt1,.42,.0046,.059,.0089, arg1,arg2,arg3,.010,11,5e-5
bt1,.37,.0042,.049,.0074, arg1,arg2,arg3,.010,19.2,5e-5
```

and btlots is

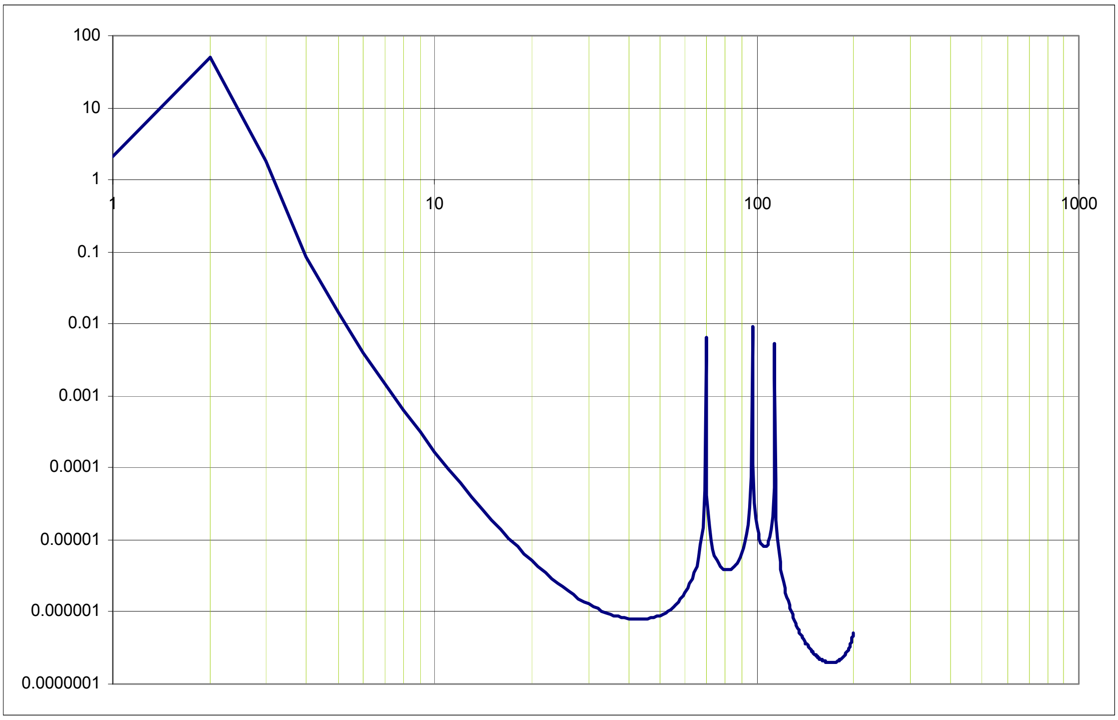
```
btmany,200,0,200
btmany, 20,69.44,69.45
btmany, 20,96.59,96.60
btmany, 20,113.58,113.60
```

The curves are given in the spreadsheet with this note, and reproduced below. Peak heights of the three peaks are

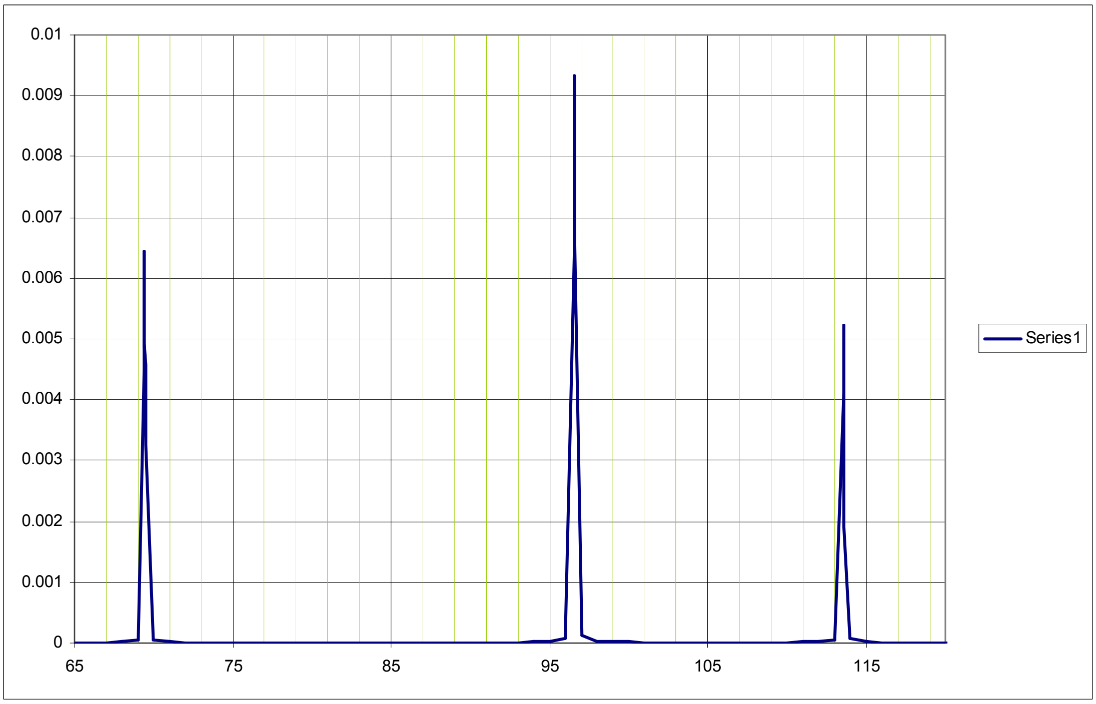
0.006453 at 69.444 Hz

0.009319 at 96.596 Hz
0.00523 at 113.59 Hz

here are two versions of the graph, first log-log



and locally around the peaks (linear plot)



From the fact that the middle peak is higher than the first one (and from the shape of the overall curve) I infer that there is some interaction going on.

5. EFFECT OF VARYING TIP MASS

This is a convenient set of data of which to try the effect of varying the mass of the wire clamps. Try 100g (a high limit):

Bfmany becomes

```
bf1,.48,.0043,.095,.0143,20,1,1000,.100,11
bf1,.42,.0046,.059,.0089,20,1,1000,.100,11
bf1,.37,.0042,.049,.0074,20,1,1000,.100,19.2
```

And the internal modes are then

69.433, 96.545 and 113.49

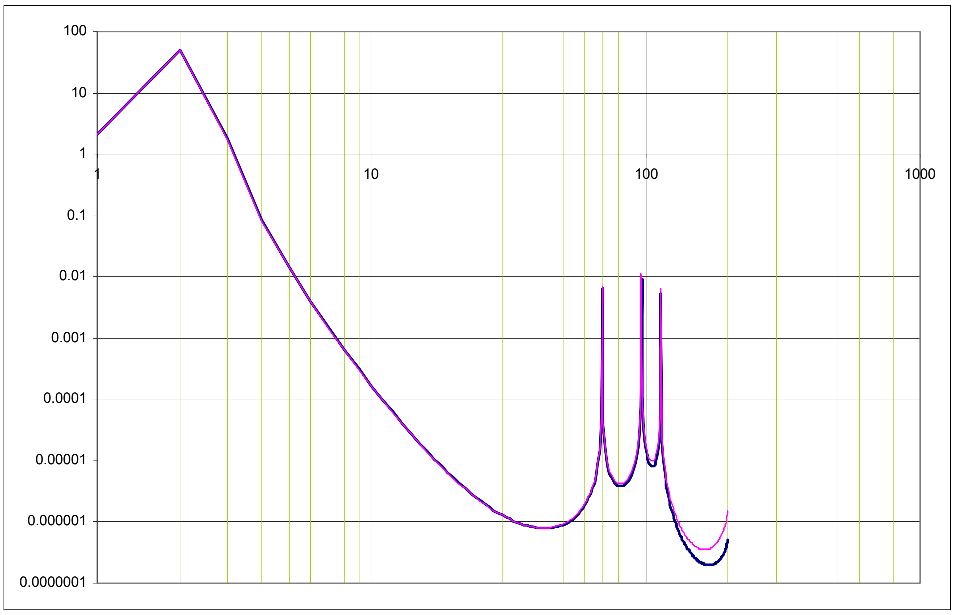
Btmany becomes

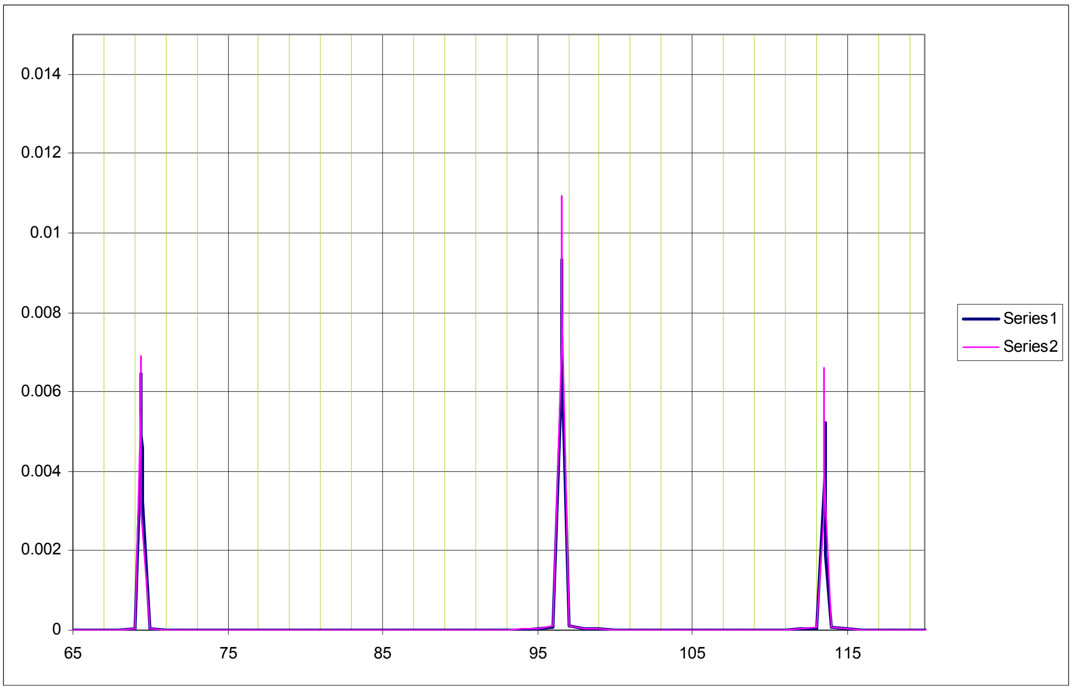
```
bt1,.48,.0043,.095,.0143 , arg1,arg2,arg3,.100,11,5e-5
bt1,.42,.0046,.059,.0089, arg1,arg2,arg3,.100,11,5e-5
bt1,.37,.0042,.049,.0074, arg1,arg2,arg3,.100,19.2,5e-5
```

```
And Btlots is
```

```
btmany,200,0,200
btmany, 20,69.43,69.44
btmany, 20,96.54,96.55
btmany, 20,113.48,113.50
```

The graphs are similar (thin pink = 100g tip mass, thick blue = 10g mass)





And the three peak heights have increased to

0.0069, 0.011, 0.0066

5.1.1.1.1.1 Justin

Please see below an e-mail i sent to Calum and the two Mikes re suggested revised blades for the controls prototype. Calum and Mike P-L will look at layout implications of my slightly longer lowest set of blades. In the meantime I was wondering if you could enter these parameters into your transmissibility model to produce a curve as on page 32 of your LSC presentation G040058 so that we can see if my revised choice has any bad implications re the fact that the internal modes are closer together.

Note - qun a) should read "The middle blades.."

Thanks very much

Norna

p.s. these designs are not meant to be prescriptive for the noise prototypes - we can and should continue to look at possibilities of further increasing stress etc and changing lengths. However to keep moving on the controls prototypes i wanted to get a "strawman" design going.

>Date: Sun, 04 Apr 2004 15:24:22 -0700
>To: ctorrie <ctorrie@ligo.caltech.edu>, m.perreurlloyd@physics.gla.ac.uk,
>m.plissi@physics.gla.ac.uk
>From: Norna Robertson <nornar@stanford.edu>
>Subject: revised blade sizes
>
>Hi Calum, Mike, Mike
>
>I have now taken a look again at sizes of blades to get a little more
>vertical isolation for controls prototype. My ground rules were the
following.
>1) Assume alpha = 1.35 as a working value , as per discussion Calum and I
>had with Mike Plissi last week.
>2) Assume we can use a slightly higher stress - set upper value at 1000
MPa
>Justify for two reasons. a) Longer heat treatment can improve strength
>and b) we might move to maraging 300 in later prototypes which has higher
>yield strength than 250 (~ 2000 MPa).
>3) Put in realistic masses (sapphire with flats and ears 39.6kg, SF2 as
>penultimate mass also with flats and ears, 38.4kg), with top two masses at
>22kg each.
>3) Keep the length and width of upper two sets approx. as in conceptual
>design, and aim to gain some improvement in isolation by increasing length
>of lowest set.
>4) Keep the internal frequencies reasonably separate (at least by 15 Hz)
>to avoid chance of overlap.
>
>With all these criteria I came up with the following:
>
>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 cm, f = 1.81
>Hz, int f = 115.5Hz, stress = 983 MPa
>
>Questions
>

>a) The top blades are one mm larger in width than before - is that OK for
>the design of the top mass? Going to 5.8cm takes the stress over 1000 MPa
>but only to 1007 - so could fall back to original width if necessary.
>
>b) Can we accommodate the new length of bottom blades - 2cm longer than in
>Mike PL's current drawings? I have checked that it is acceptable to
>increase the tip separation - using pend.n2 = 0.14; (it is 0.12 in
>conceptual design) which should allow more overlap of the blades.
>
>Comments, queries?
>
>Maybe we could bring this up at design meeting tomorrow Calum. i can
>briefly summarise what i have been doing and why.
>
>Cheers
>Norna

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