Structure transmissibility calculations - 1

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1. SUMMARY

We have been making measurements of the behaviour of various structures by fixing them to a solid mount (T07117, T07121), exciting with a vibrator, and observing the motion with accelerometers. In many cases it has been hard to correlate the observed results with the expectations from simple modal analyses (T060059; T050237; others). One particular cause for puzzlement was how to interpret the relative height of the peaks seen in the output from the accelerometers. In other words – when is a peak, not a peak?

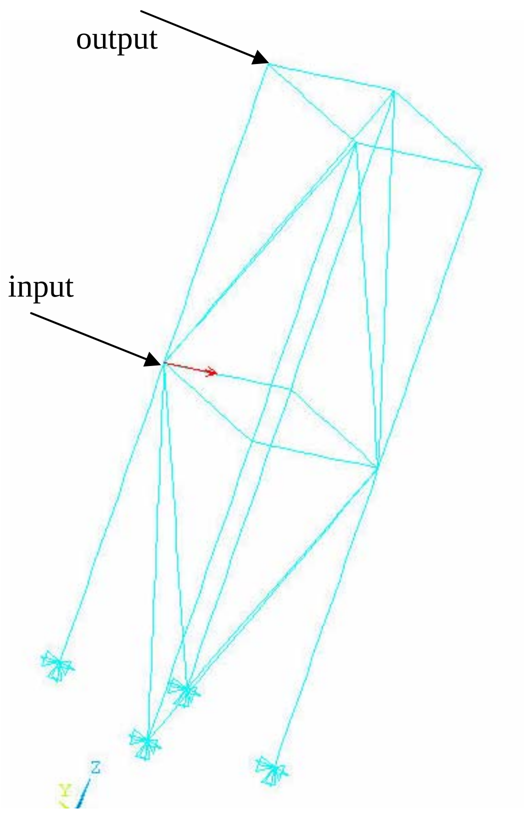
In trying to understand this, one suggestion is that instead of simply working out the modal frequencies and mode shapes, we should use the FE method to simulate what we are doing to the structure using a harmonic analysis. In this type of analysis the input force (or input displacement) can be specified, and the output displacement at any of the nodal positions can be predicted. If a unit in displacement is used as the input, then the output is by definition a transmissibility curve – this is what was done on the blades to work out their transmissibility. In the case of the blades, a structural damping coefficient was included. It has been suggested that we should measure transmissibility curves experimentally because it we do so then we eliminate any frequency-related variability in the input signal.

We have tried to measure a transmissibility curve directly, by positioning one accelerometer at the excitation point (where the “stinger” touches the structure, the “input” point), positioning a second accelerometer at some other point (the “output” point), and dividing the output motion by the input motion. In the FEA, we can simulate the same thing with an input force as the driver and by predicting the displacement at the input and output points. This has produced some interesting results for a simple trial structure, which we report here.

2. FE MODEL

The model was a subset of that which was used in T07117. It is a simple beam model of a structure similar to the beamsplitter structure, fixed at the base.

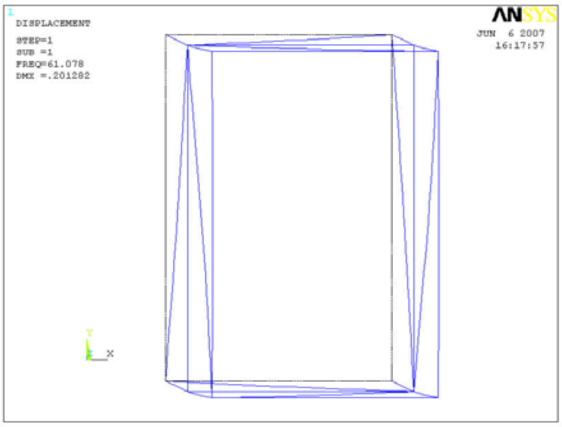
The input point and output point are indicated on the model. In both cases I considered movement in the “X” direction, indicated by the red arrow on the model.

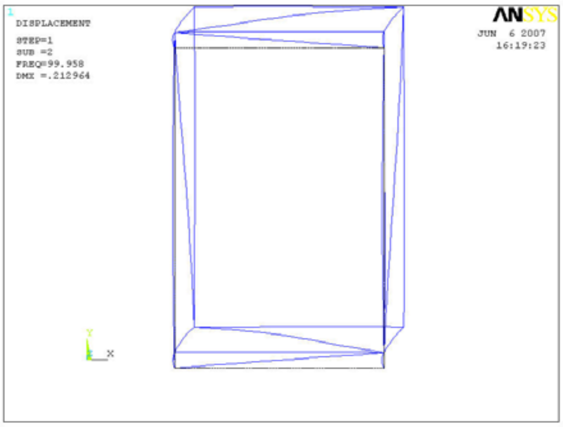


3. NATURAL FREQUENCIES

The first analysis was a simple model analysis just as we do with the suspension structures. The first few results were

1	61.078	1	1	1 (mostly X, some Y see below)
2	99.958	1	2	2 (mostly Y, some X above midplane)
3	133.07	1	3	3 (torsion)
4	197.52	1	4	4 (mostly X, second mode)



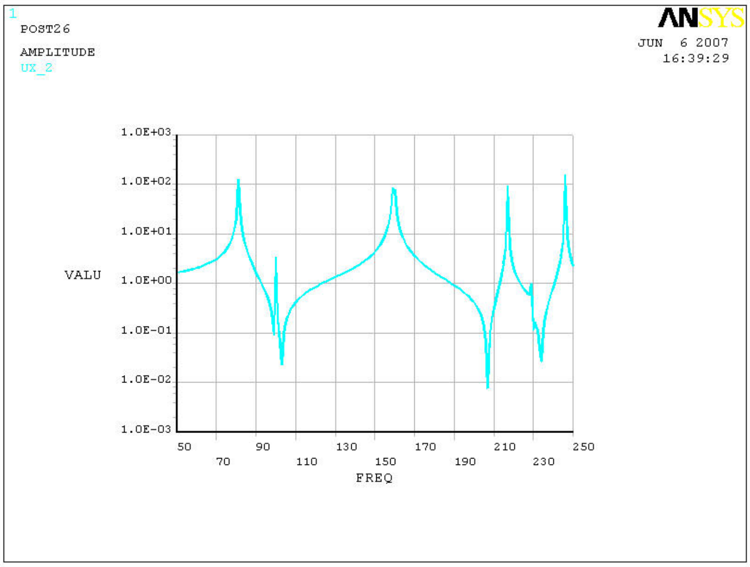


Here are the frequencies with the input point fixed in the X direction
(why I did this is noted below)

1	81.193	(middle ring twists, upper ring moves in X)
2	99.959	(as second mode above)
3	159.48	(torsion, middle ring twists asymmetrically)
4	216.94	(middle ring twists, lower members bend)

4. TRANSMISSIBILITY

For this calculation, I applied a unit displacement at the “input” point, and observed motion at the output point. I expected to see peaks at the natural frequencies of the structure: 61, 100, 133 and 197 Hz. Here is what I found:

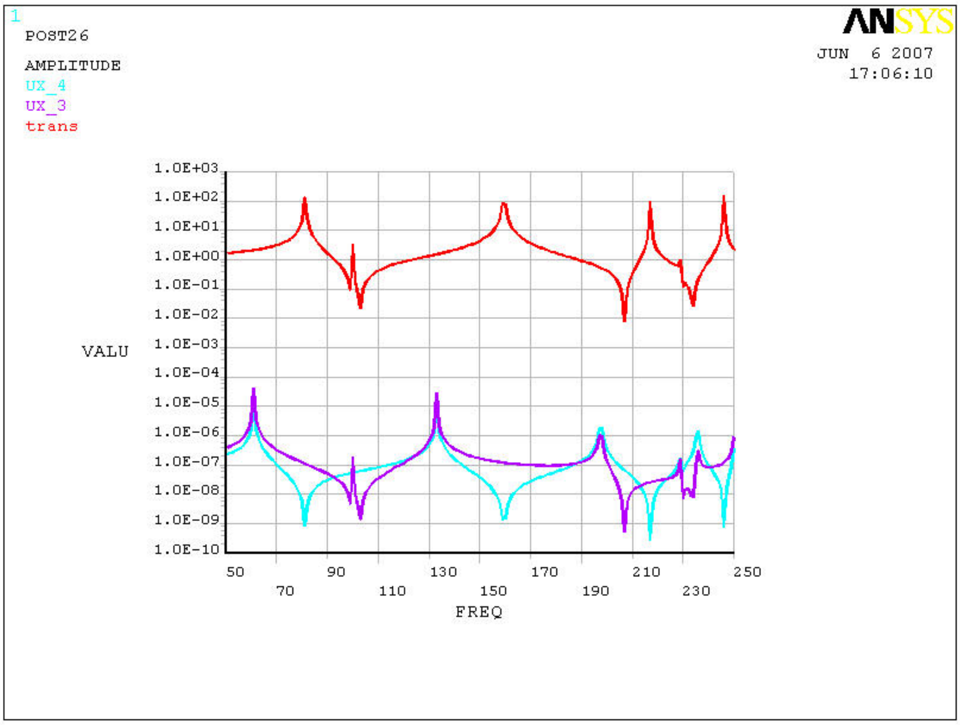


The identifiable features reflect the normal modes of the model with a constraint at the input point.

(Macro at appendix 1)

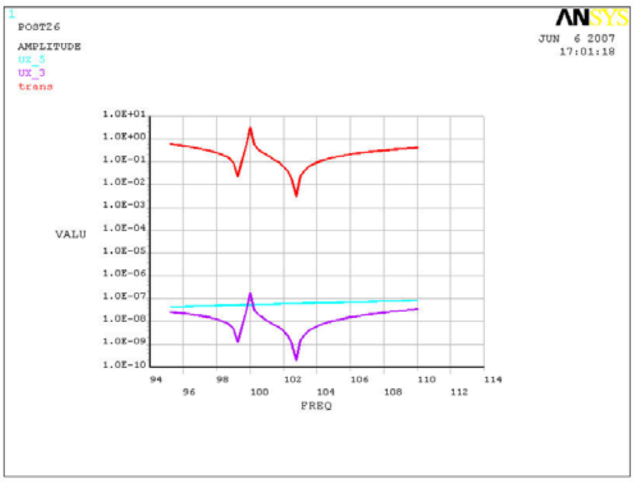
5. TRANSMISSIBILITY PART TWO

I decided to try exciting the model with a force (as we do in the real thing) and divide the output motion by the input motion. This produced a very interesting result show below:



The blue curve is the motion at the input point, the purple curve is motion at the output point, the red curve is transmissibility (which agrees with the previous result).

Expanding the results around 100 Hz:

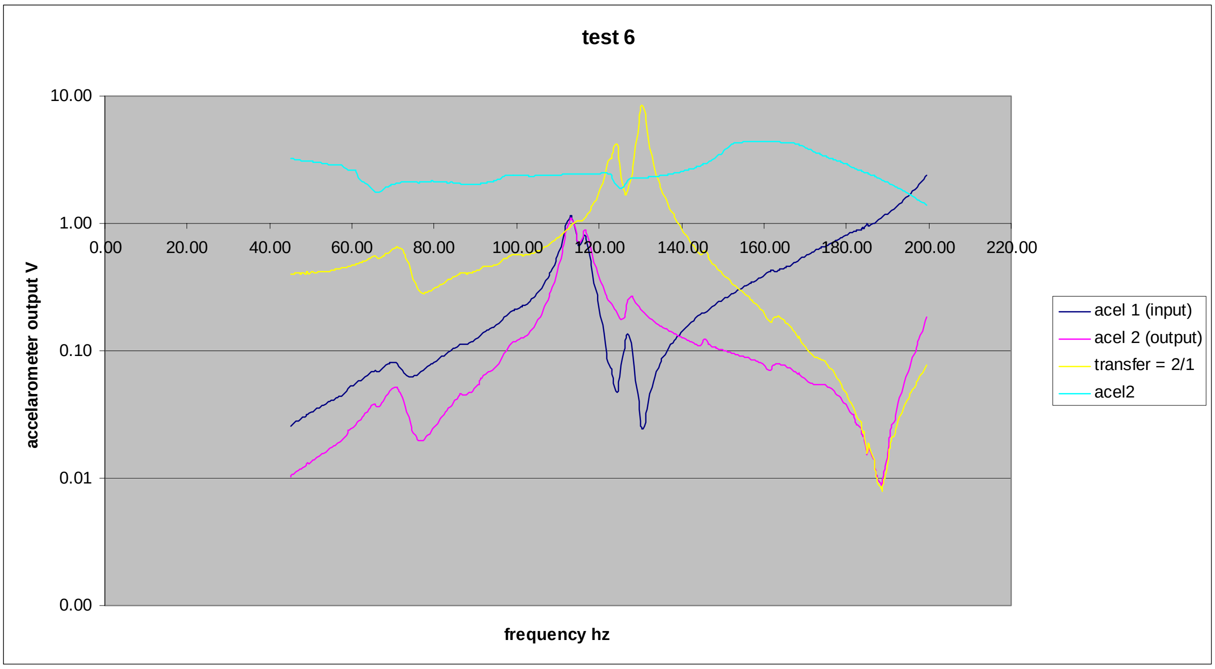


Summary of peaks and frequencies:

frequency	Present in model fixed/free at input point		Present in displacement curve		Present in transmissibility curve
	fixed	free	input	output	
61		Y	Y	Y	
81	Y		Y		Y
100	Y	Y		Y (complex)	Y (complex)
133		Y	Y	Y	
160	Y		Y		Y
197		Y	Y	Y	
~205				Y (trough)	Y (trough)
216	Y		Y		Y

6. CONCLUSION SO FAR

If we use a force to excite the structure, and look at the transmissibility between the excited point and some other point, the result will have frequency peaks (or troughs) at the modal frequencies of the structure **as if it were fixed at the excitation point** even though it is not. This is frustrating, because the only way to eliminate variability in the input signal is be looking at transmissibility. Here is a sample plot, to whet the appetite and show that the effects seen in the FEA are real:



The ink and blue curves are the accelerometer signals by the input" and "output" points on the ET structure – the yellow curve is transmissibility. The light blue curve is the frequency-response of the exciter taken with no load connected.

I have seen nothing in this FEA work to suggest that some peaks will be lower than others as we are seeing in the real tests. The next step is to reproduce the figure above for the FE model of a real structure and experimentally.

7. APPENDIX – MACRO TO GENERATE THE RESULTS SHOWN IN SECTION 4.

```
FINISH  ! Make sure we are at BEGIN level
/CLEAR
*abbr,doit,doit
*abbr,jreplo,/replot
/PREP7

! to build a simple beam model on steel blocks
!
!Element types
!*
ET,1,BEAM4
!*


!For the beams 1 = hollow; 2 = solid
!
R,1,0.0009,3.08E-07,3.08E-07,0.025,0.025
R,2,0.0025,5.21E-07,5.21E-07,0.025,0.025


!materials 1 = aluminium;
MPTEMP,,,,,,,,
MPTEMP,1,0
MPDATA,EX,1,,70E9
MPDATA,PRXY,1,,0.3
MPDATA,DENS,1,,2.7E3


! geometry

xoff = 0.23
yoff = 0.14
xstruct = 0.36
ystruct = 0.55
bsize = 0.610
bsizev = 0.1
gap = 0.010
zstruct1 = 0.8
zstruct2 = 1.6
fixoff = 0.05

X0 = 0
X1 = bsize - xoff
x2 = bsize
x3 = x2 + gap
x4 = x1 + xstruct
x5 = x3 + bsize
x6 = x1 - fixoff
x7 = x1 + fixoff
x8 = x4 - fixoff
x9 = x4 + fixoff

y0 = 0
y1 = bsize - yoff
y2 = bsize
y3 = y2 + gap
y4 = y1 + ystruct
y5 = y3 + bsize
y6 = y1 - fixoff
y7 = y1 + fixoff
y8 = y4 - fixoff
y9 = y4 + fixoff

z0 = 0
z1 = bsizev
z2 = z1 + zstruct1
z3 = z1 + zstruct2

!
keypoints

k, 1, x0,y0,z0
k, 2, x6,y0,z0
k, 3, x1,y0,z0
k, 4, x7,y0,z0
k, 5, x2,y0,z0
k, 6, x3,y0,z0
k, 7, x8,y0,z0
k, 8, x4,y0,z0
k, 9, x9,y0,z0
k,10, x5,y0,z0

!lines 1 to 4

l,1,2
,2,3
,3,4
,4,5
!lines 5 to 8
l,6,7
,7,8
,8,9
,9,10

k,11,x0,y6,z0
k,12,x0,y1,z0
k,13,x0,y7,z0
k,14,x0,y2,z0
k,15,x0,y3,z0
k,16,x0,y8,z0
k,17,x0,y4,z0
k,18,x0,y9,z0
k,19,x0,y5,z0

!lines 9 to 12
l,1,11
,11,12
,12,13
,13,14

!lines 13 to 16
l,15,16
,16,17
,17,18
,18,19

!z dimension
k,20,x0,y0,z1
k,21,x1,y1,z1+fixoff
k,22,x1,y1,z2
k,23,x1,y1,z3

!line 17
l,1,20

adrag,1,2,3,4,,,9,10,11,12
adrag,5,6,7,8,,,9,10,11,12

FLST,3,8,4,ORDE,8
FITEM,3,45
FITEM,3,48
FITEM,3,50
FITEM,3,52
FITEM,3,81
FITEM,3,84
FITEM,3,86
FITEM,3,88
LGEN,2,P51X, , , ,gap, , ,0

adrag,90,91,92,93,,,13,14,15,16
adrag,94,95,96,97,,,13,14,15,16

vdrag,all,,,,,,17
```

```
/VIEW,  1, -0.236620128544    , -0.782474382372    ,
0.575972877572
/ANG,   1,   10.5782042749
/REPLO

!restart line numbering from 500
NUMSTR,LINE,500,

!line 500 - 502
l,126,21
,21,22
,22,23

!vertical legs
ldrag,151,201,176,,,,500,501,502

!middle ring
l,22,219
,219,218
,218,217
,217,22

! diagonals
l,126,219
,219,201
,201,217
,217,126

l,23,219
,219,221
,221,217
,217,23

!top ring lines 524-527
l,23,222
,222,221
,221,220
,220,23

*go,:nolegs
!fixings
l,21,124
,21,131
,21,119
,21,127

,214,156
,214,152
,214,144
,214,149

,215,202
,215,206
,215,194
,215,199

,216,177
,216,169
,216,181
,216,174
:nolegs

!meshing
!set element size
lsel,s,line,,500,600
lesize,all,0.05

! structure except top ring
lsel,u,line,,524,527

mat, 1
real,1
type,1


lmesh,all

!top ring
lsel,s,line,,524,527
real,2
lmesh,all


!constraints


! fix leg ends
ksel,s,kp,,126
,a,kp,,176
,a,kp,,201
,a,kp,,151

dk,all,ux,0
,all,uy,0
,all,uz,0


allsel

dk,219,uX,1

sbctra

/solu
ANTYPE,3
!*
!*
HROPT,FULL
HROUT,OFF
LUMPM,0
!*
EQSLV, ,0,
PSTRES,0
!*
HARFRQ,50,250,
NSUBST,200,
KBC,1
!*
```