Preliminary finite element analysis of the folding mirror design with beam and solid elements
RAL 2007
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1. Introduction

This note looks at the possible arrangement of members for the folding mirror design.

The folding mirror structure has 24kg evenly distributed about the bottom six key points. The beam sections are 50 x 50 x 5mm box section. The general external dimensions of the rectangular box structure are 1100 x 710 x 1500mm. The face plates are not symmetrical about the centre of the 1500mm depth dimension, the middle ring is 640mm from the top, similar to the previous upper structure design for the quadruple suspension.

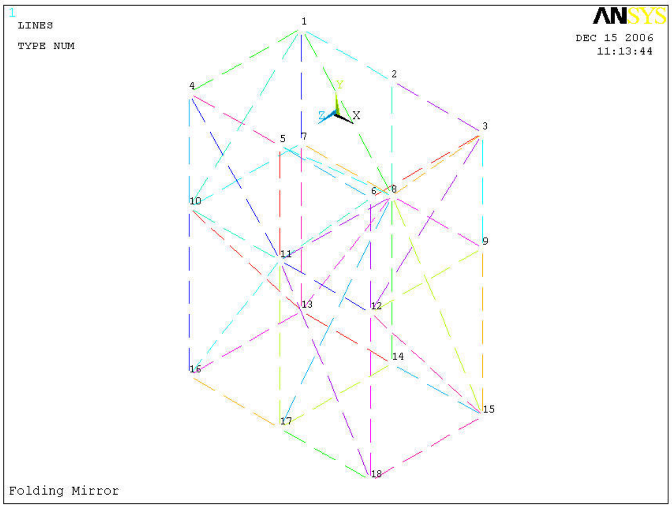

Fig 1. Beam model representation of folding mirror structure, with star arrangement, showing keypoint numbers.

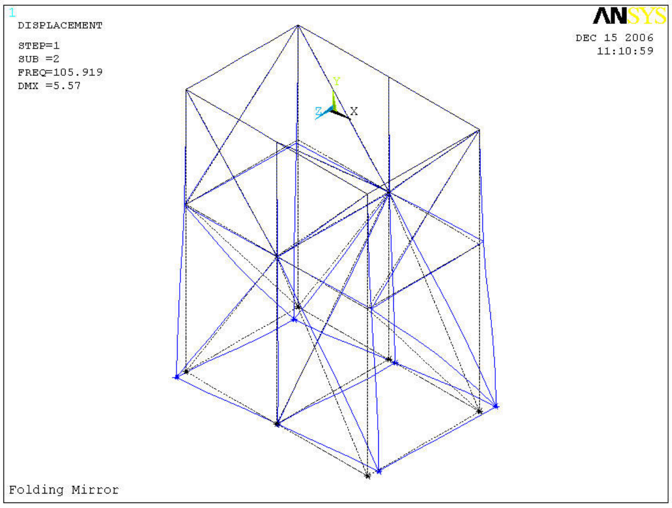

Fig 2. Star truss arrangement, second mode frequency at 105.9 Hz.

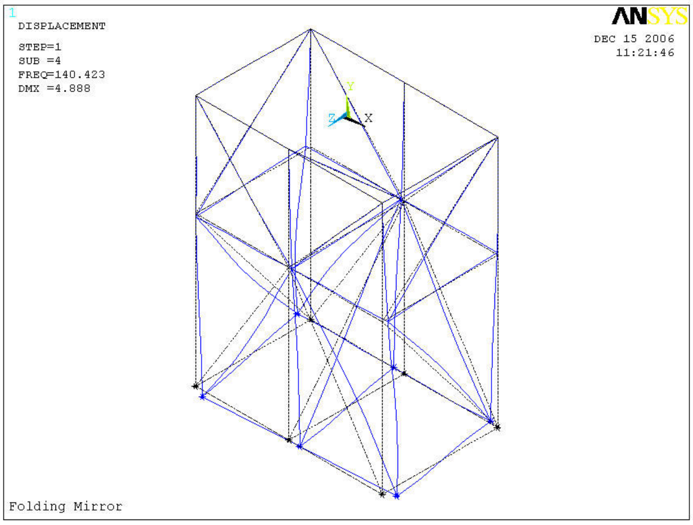

Fig 3. Star truss arrangement, fourth mode frequency at 140Hz.

Table 1. Star truss arrangement

Mode frequency	Frequency Hz	Mode shape
1	96.6	Longitudinal
2	105.9	Torsional pivot around keypoints 5,11,17 (bottom ring goes into parallelogram)
3	112.4	Traverse
4	140.4	Torsional pivot around vertical axis through 0,0,0 (bottom ring goes into parallelogram)
5	149.2	Panting longitudinal

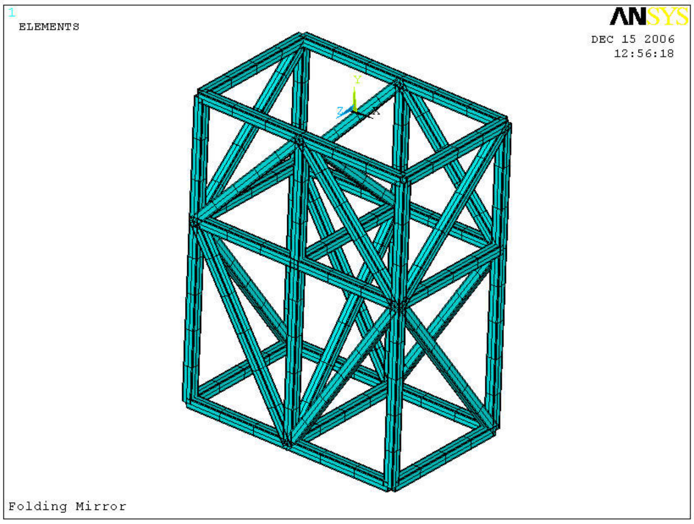

Fig 4. Folding mirror structure with diamond arrangement of members.

Table 2. Diamond truss arrangement

Mode frequency	Frequency Hz	Mode shape
1	94.9	Longitudinal
2	101.3	Traverse
3	111.9	Torsional pivot around keypoints 5,11,17 (bottom ring goes into parallelogram)
4	139.0	Torsional pivot around vertical axis through 0,0,0 (bottom ring goes into parallelogram)
5	145.26	Panting longitudinal

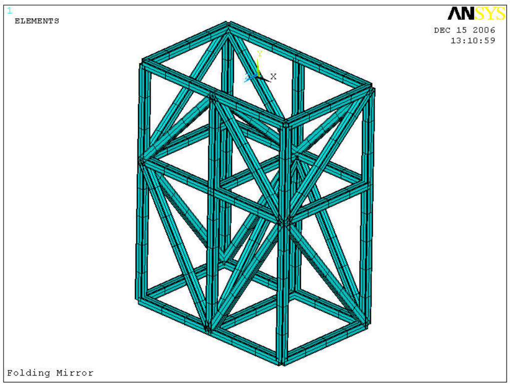

Fig 5. Combined diamond and star truss arrangement

Table 3. Diamond and star truss arrangement

Mode frequency	Frequency Hz	Mode shape
1	97.5	Longitudinal
2	104.68	Torsional pivot around keypoints 2,8,14

		(bottom ring goes into parallelogram)
3	110.5	Torsional pivot around keypoints 5,11,17 (bottom ring goes into parallelogram)
4	146.5	Torsional pivot around vertical axis through 0,0,0 (bottom ring goes into parallelogram)
5	153.0	Panting longitudinal

Summary

Table 4. Arrangement of members versus mode frequencies

Mode frequency	Star truss arrangement		Diamond truss arrangement		Diamond and star truss arrangement	
	Frequency Hz	Mode shape	Frequency Hz	Mode shape	Frequency Hz	Mode shape
1	96.6	Longitudinal	94.9	Longitudinal	97.5	Longitudinal
2	105.9	Torsion	101.3	Traverse	104.68	Torsion
3	112.4	Traverse	111.9	Torsion	110.5	Torsion
4	140.4	Torsion	139.0	Torsion	146.5	Torsion
5	149.2	Panting	145.26	Panting	153.0	panting

Conclusion

From a practical assembly stand point it's easier to arrange the stiff members to benefit the longitudinal and torsion modes of table 3. The weakest mode is in the longitudinal direction so it's best to have optimum stiffness in that direction, we can achieve this by using face plates, the face plates minimise the number of bolted joints in that direction. The solid rings help with the torsion modes by preventing the structure turning into a parallelogram; they are also very helpful in assembly. The top ring helps clamp the structure to the seismic table and both mid and bottom rings allow machining of features for supporting components.

2. Solid modelling of the structure

In order to reduce the number of individual face plate designs they are now symmetrical about the centre of the 1500mm depth dimension.

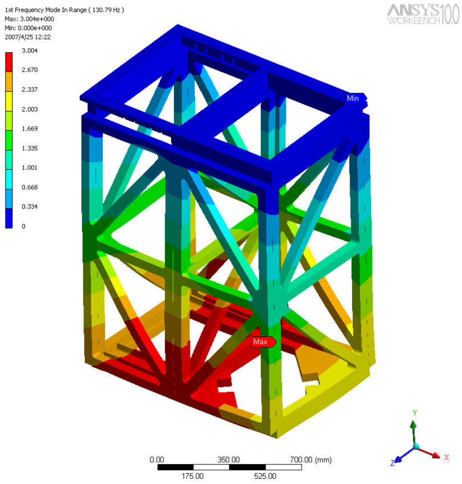

Fig 6. The original face plate design with solid face plates.

The First three frequencies from the arrangement in figure 6 are 130Hz, 136Hz and 183Hz, the mode shapes are longitudinal, traverse and torsion. The total mass of the structure is 366kg. The bottom plate, part td-1115-012, has cut out features for securing and assembling the lower structures for both chains, this part is a 5mm shell, with a mass of 10.2kg.

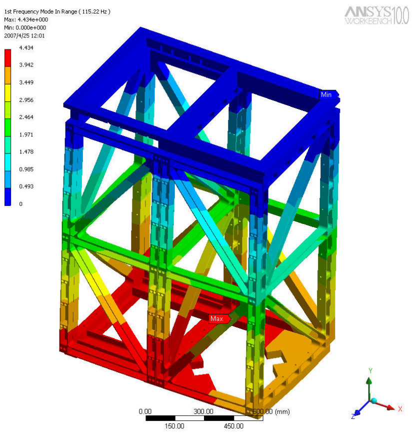

Fig 7. The face plates have gone through a light weighting exercise, turning them into channel sections with a 5mm wall thickness.

The first three frequencies from the arrangement in figure 7 are 115Hz, 125Hz and 161Hz the mode shapes are longitudinal, traverse and torsion. The total mass of the structure is 179kg.

By increasing the channel sections to have an 8mm wall thickness, the first three frequencies become 117.5Hz, 132.4Hz and 171Hz. The total mass of the structure is 212kg.

By increasing the wall thickness of the three channel sections in the plane of the first mode to 8mm and leaving the remaining channel sections at 5mm, the first three frequencies become 122.3Hz, 122.6Hz and 168Hz the mode shapes become, mostly traverse with some longitudinal, mostly longitudinal with some traverse and torsional respectively.

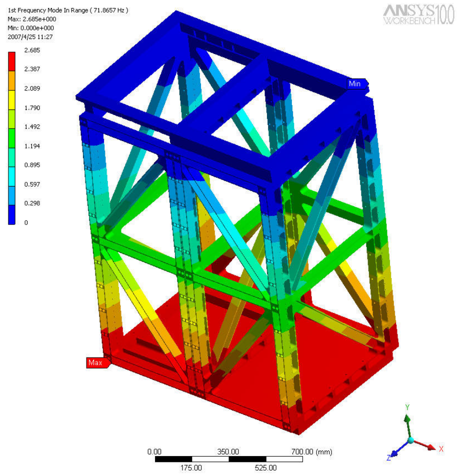

Fig 8. The channel sections all have a 5mm wall thickness. The bottom plate, part td-1115-012, has been de-featured and is now a solid rectangular plate, it's mass is now 101Kg an increase of 91kg.

The first three frequencies from the arrangement in figure 8 are 71Hz, 78Hz and 120Hz.

Conclusion

By optimising the faceplate designs it is possible to increase the frequency. However, a more detailed design of the folding mirror geometry, layout and size of masses is necessary before progressing to a final design.