Lick

2.4 m Telescope

M1 Mirror Support

Finite Element Analysis

FEA-10526-1

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1 INTRODUCTION

This document describes the analysis performed to determine the structural component of the wavefront error for the M1 mirror of the Lick Telescope.

1.1 SCOPE

This document describes the wavefront error budget of the Lick telescope.

1.2 CONFIGURATION

This document has been configured as FEA-10526-1 and is a designated controlled document under the EOST Quality System.

1.3 REFERENCES

- None

1.4 DEFINITIONS AND ACRONYMS

- FEA – Finite Element Analysis
- FS – Factor of Safety
- M1 - Primary Mirror
- OSS: - Optical Support System
- WFE – Wavefront Error

1.5 LICK WAVEFRONT ERROR BUDGET

The wavefront budget allocations of the M1 mirror are listed in Table 1

Table 1 Wavefront budget allocations

Primary Mirror Support Allowance	
Zenith	32 nm
Horizon	152 nm

2 M1 MIRROR SUPPORT

2.1 PURPOSE

The purpose of the M1 mirror support FEA analysis is to determine the wavefront error induced by the structural support of the mirror at both Zenith and Horizon pointing. The model was also used to verify the structural integrity of the components.

2.2 ANALYSIS PROCEDURE

The M1 mirror support FEA model was used for wavefront error calculations. The model is composed of shell, tetrahedron, and beam elements along with point masses to model the small diameter rod flexures and counterweights.

Constraint equations were used to connect bonded components. Spring elements were used to represent the smaller flexures which include the “C-flex” type flexures in the lateral supports. Stiffnesses were input from the manufacturer data.

The counterweights were sized such that the mass of the counterweights multiplied by its moment arm to the ball joint flexure center equals the mass of the mirror multiplied by its moment arm from its CG to the ball joint flexure center.

The model had 1 G loading applied at zenith and horizon pointing orientations for both room temperature and at -20degC.

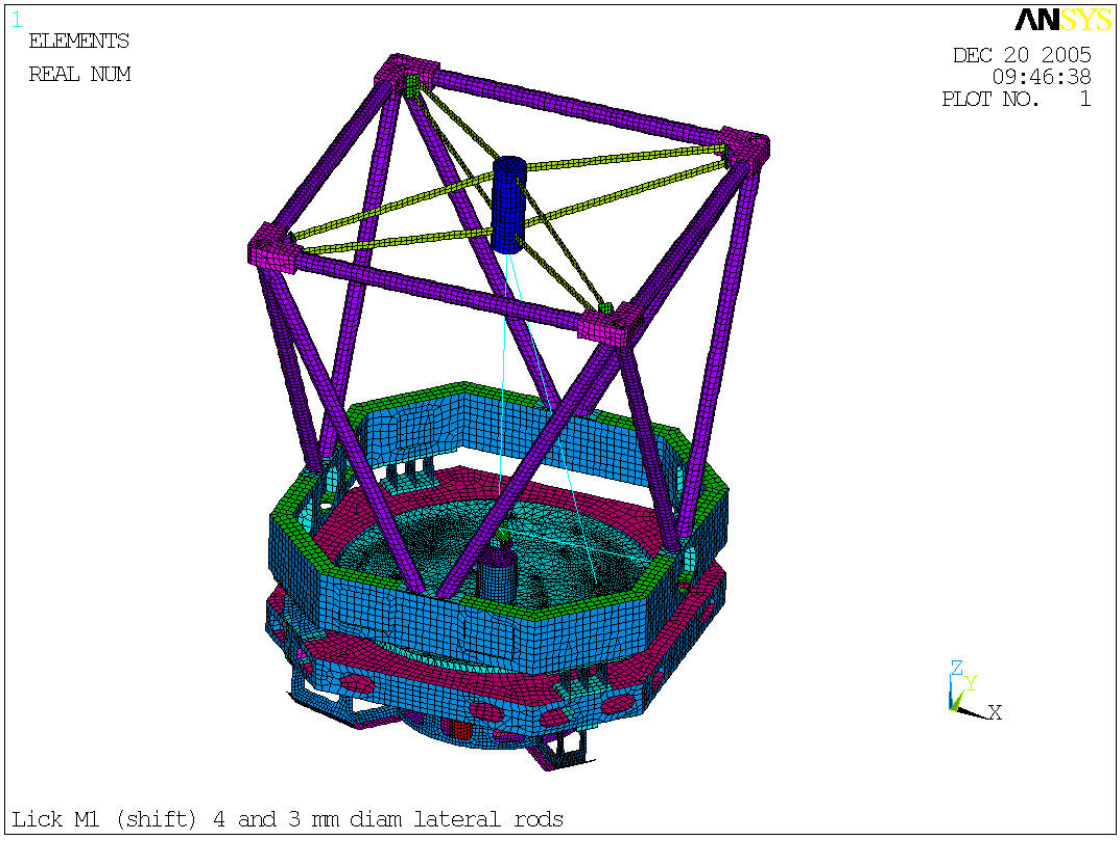

Figure 1 M1 mirror support and upper truss FEA model

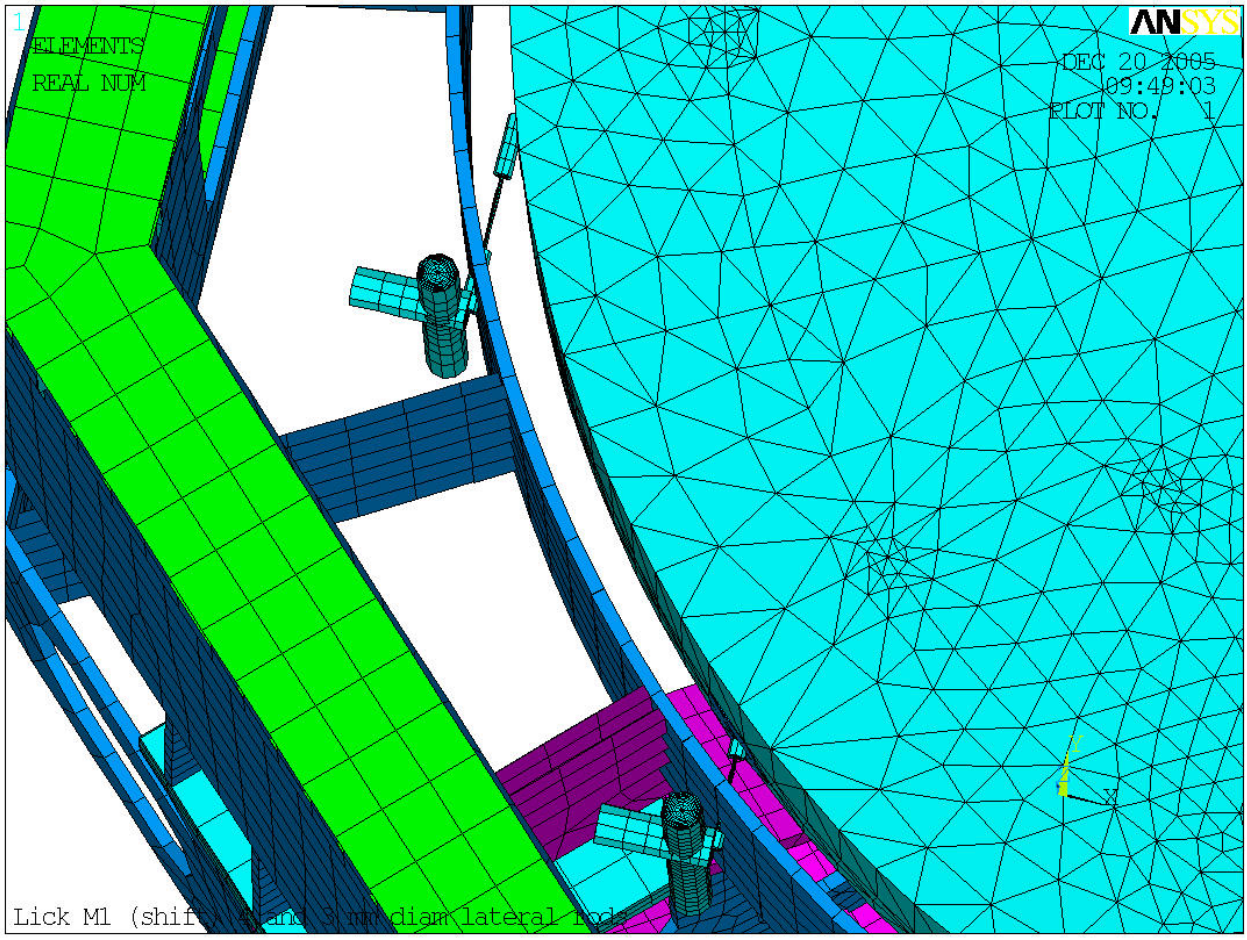

Figure 2 Zoom of lateral support details – mesh

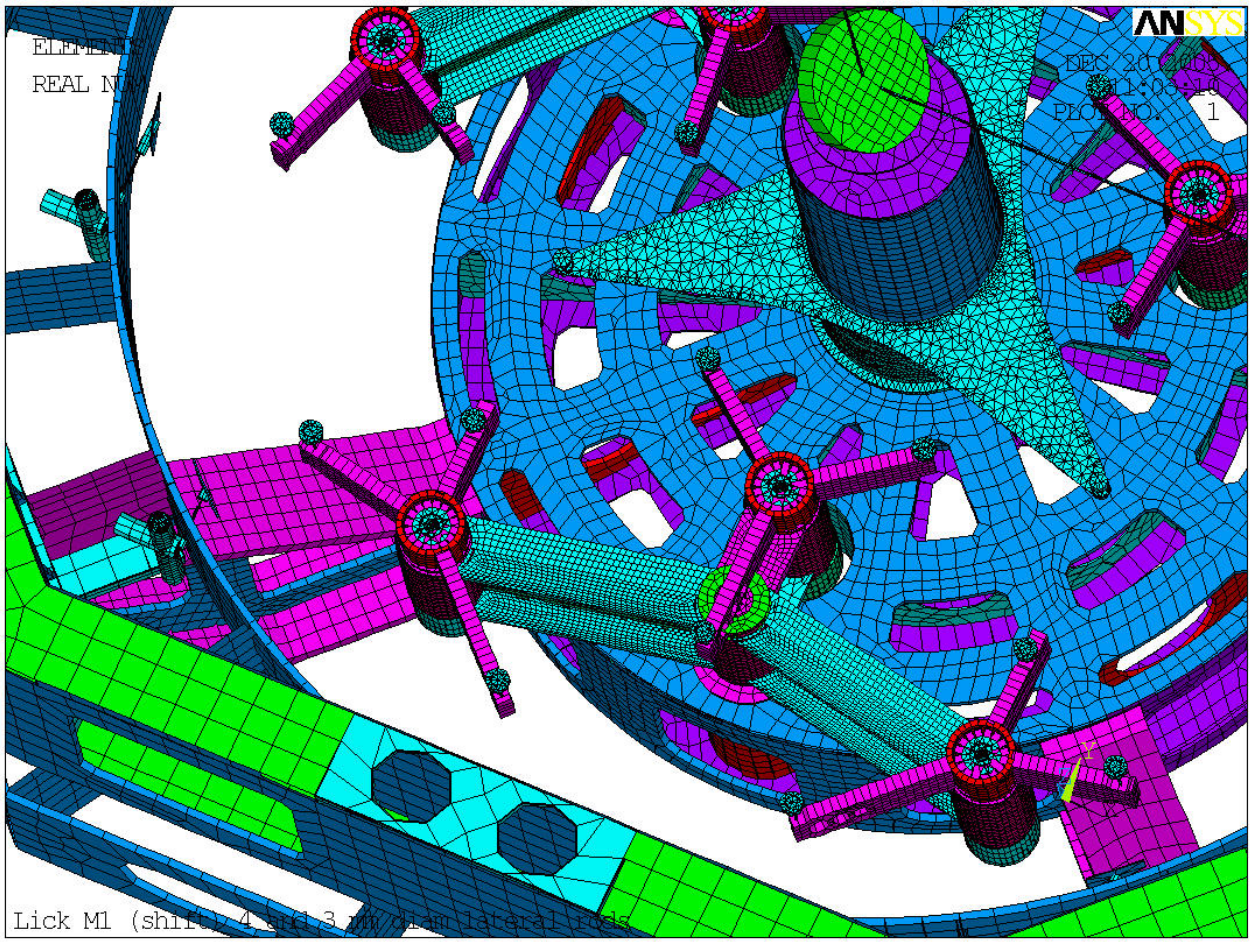

Figure 3 Zoom of vertical support details – mesh

2.3 MATERIALS

The M1 Mirror and mirror support materials are as follows:

- A36 Structural Steel: OSS, load spreader support beams, secondary lateral support ring
- Invar 36: Pucks
- LZOS Astrositall: M1 mirror
- 17-4 PH: all smiley and rod flexures

2.4 LOADS

The loads applied are summarized in Table 2. The entire FEA model is fixed at the elevation axis but is free to grow freely at these points so as to not constrain thermal expansion.

Table 2 M1 mirror support – wavefront error conditions run

Load conditions run for M1 mirror support		
Load step	1 G Acceleration direction	Applied Temperature ºC
1	1 G vertical	21
2	1 G horizontal	21
3	1 G vertical	-20
4	1 G horizontal	-20

2.5 REQUIREMENTS

The M1 mirror must meet the WFE requirements listed in Table 1.

2.6 RESULTS

2.6.1 Wavefront Error

The wavefront error (WFE) due to the M1 mirror support structure is summarized in Table 3. Figure 4 through Figure 9 display the plots of the wavefront error for the four conditions run.

Table 3 M1 mirror support wavefront error summary

Acceleration	Applied Temperature ºC	RMS Wavefront error (nm)	WFE budget (nm)
1 G vertical	21	36.8	32
1 G horizontal	21	98.7	152
1 G vertical	-20	54.3	32
1 G horizontal	-20	95.7	152

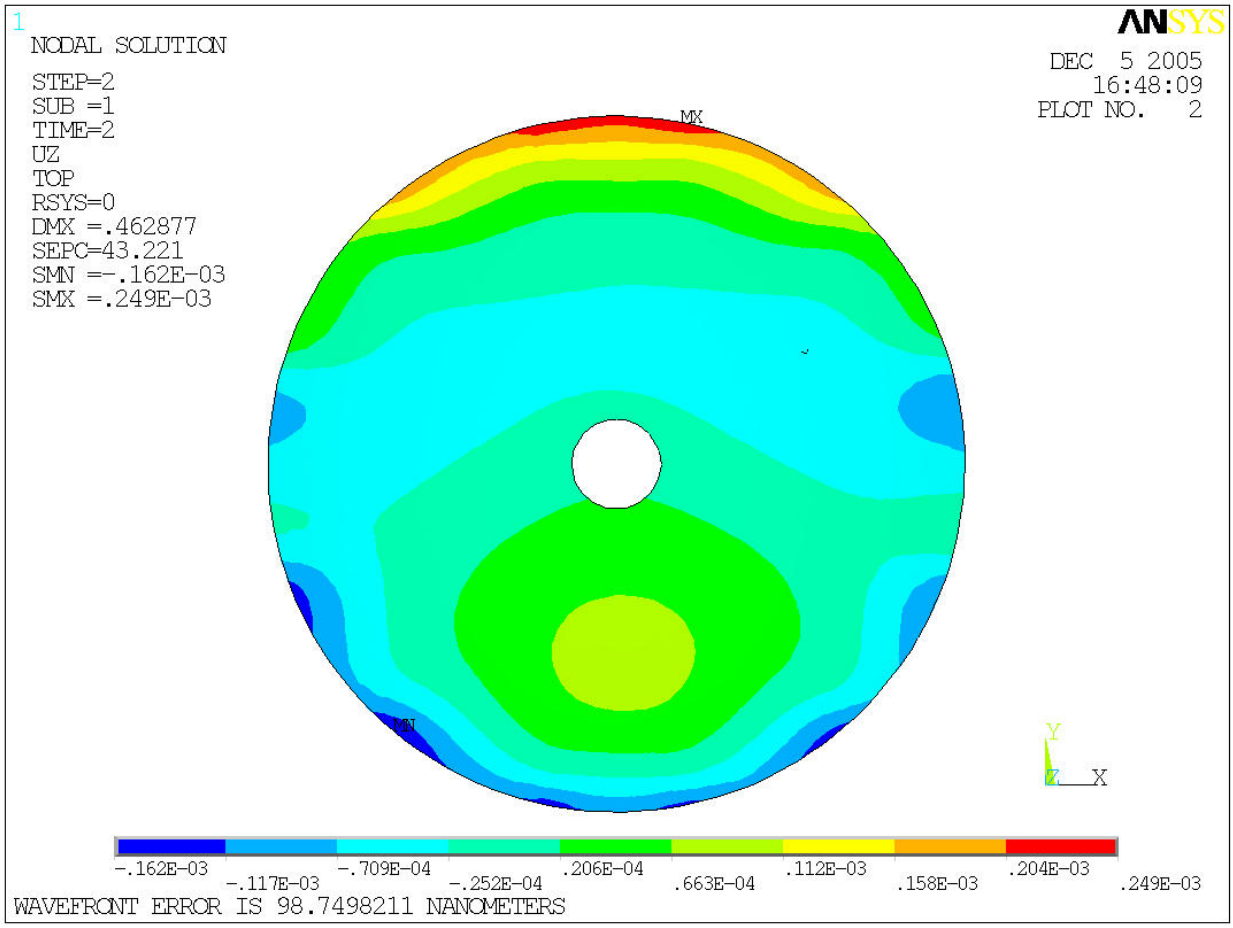

Figure 4 Surface error plot RMS WFE 1 G vertical @ +21 °C

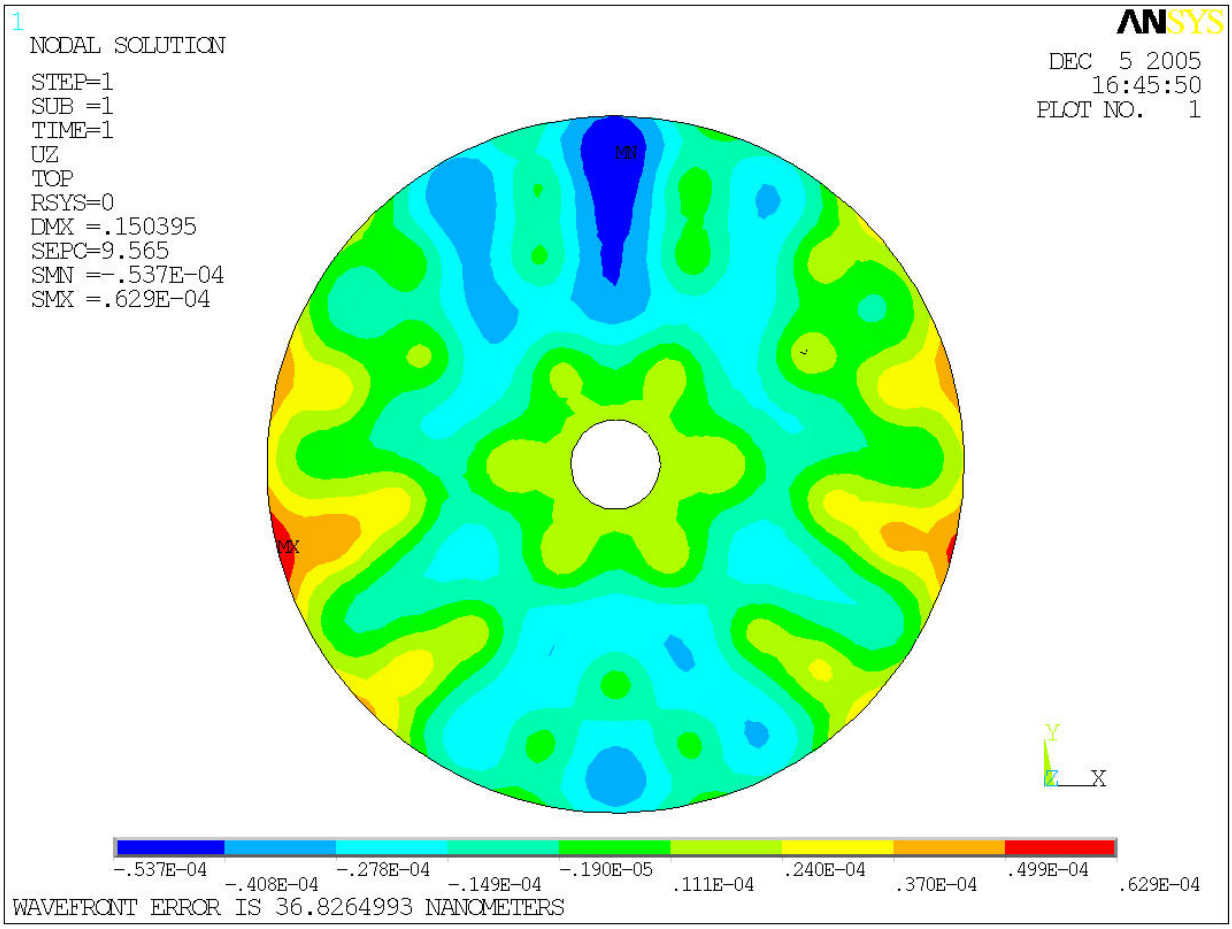

Figure 5 M1 surface error plot and RMS WFE 1 G Horizon @ +21 °C

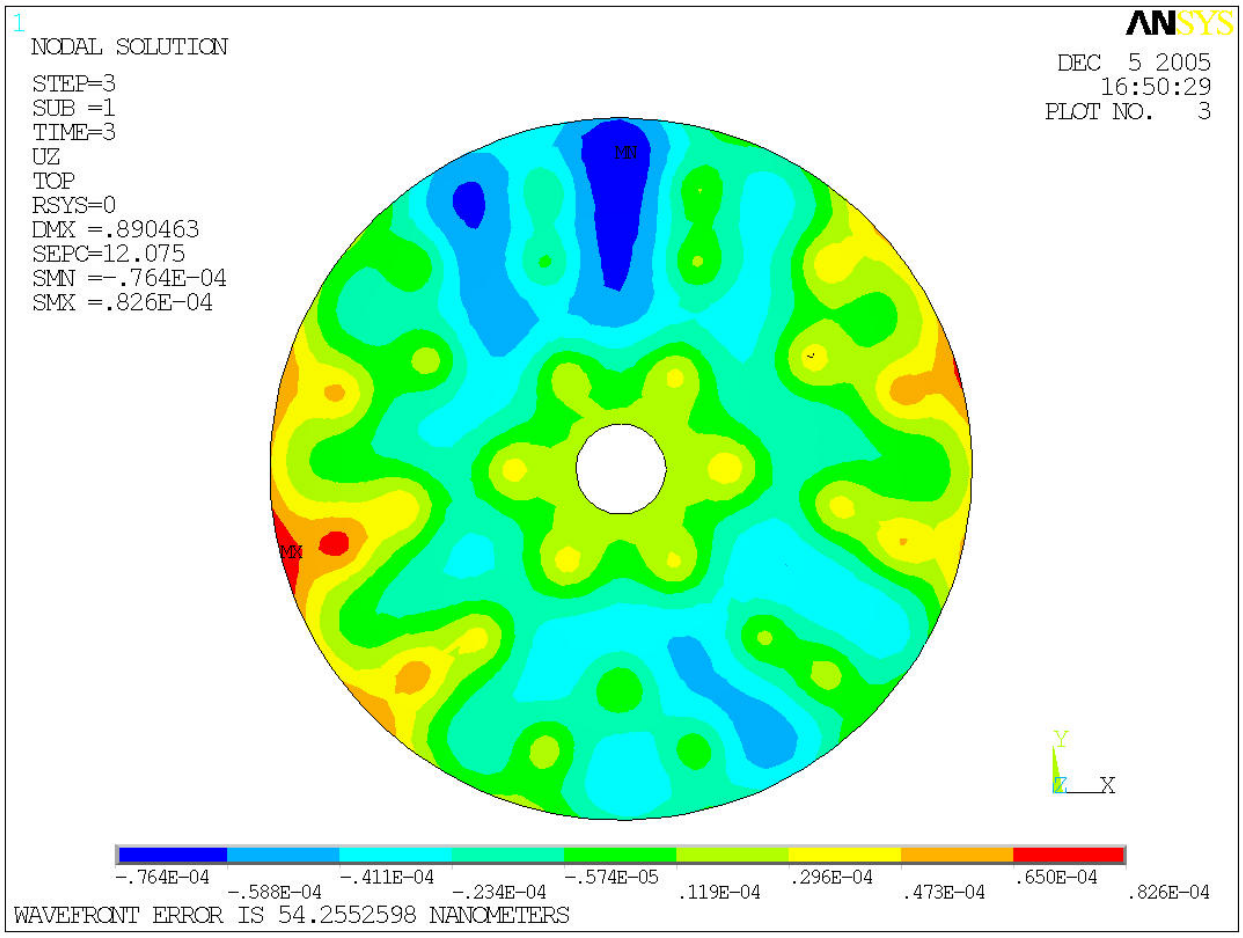

Figure 6 M1 surface error plot and RMS WFE 1 G vertical @ -20 °C

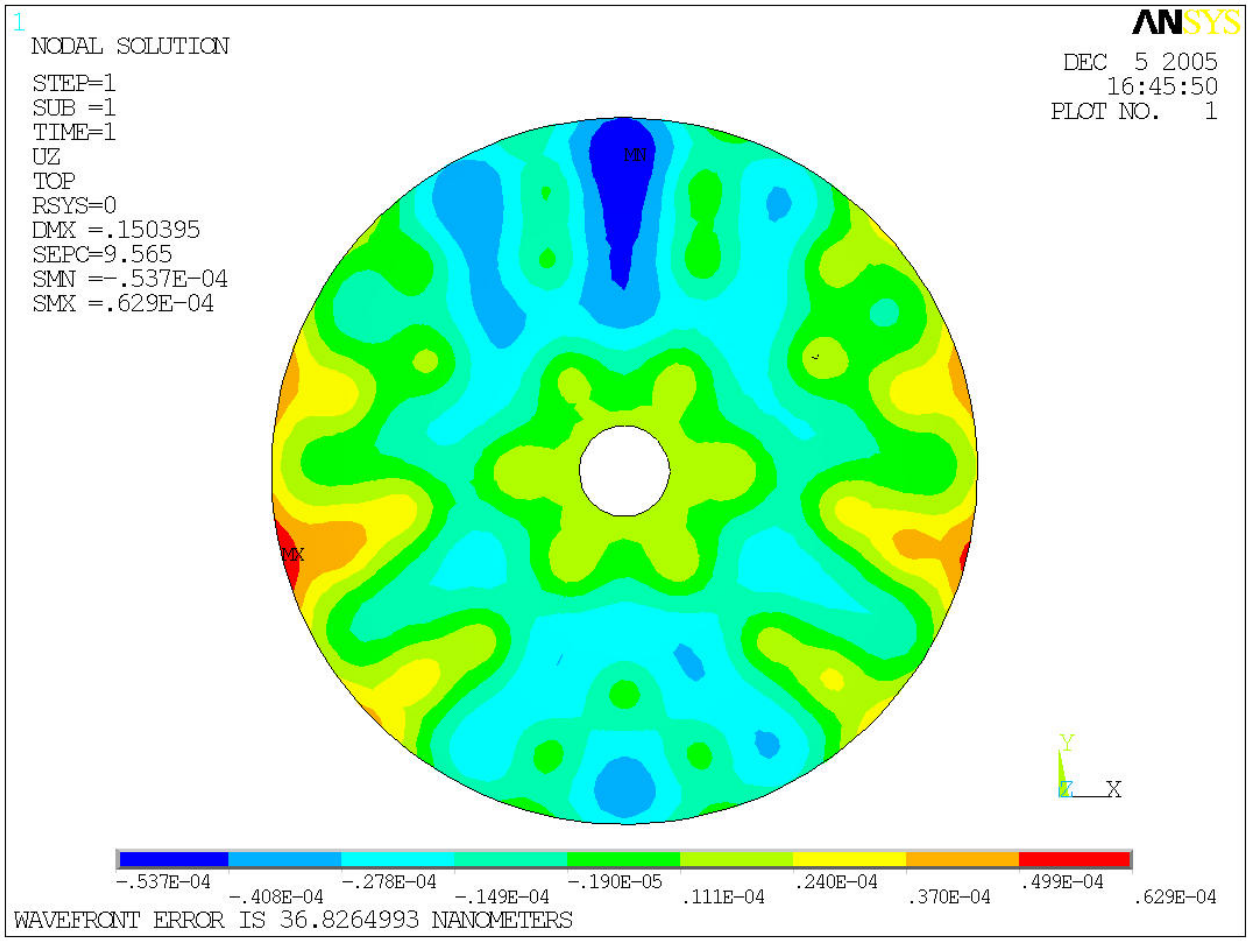

Figure 7 M1 surface error plot and RMS WFE 1 G horizon @ -20 °C

2.6.2 Flexure Stresses

Stresses in the flexures are low even for the worse case loading. Figure 8 and Figure 9 show the Von Mises stresses at the worst case loading condition at horizon pointing. All show a positive margin of safety based on no yielding.

2.6.2.1 Lateral Support Diaphragm Flexures

Figure 8 shows the lateral support diaphragm flexure stresses on the M1 mirror support.

Note:	The plot in Figure 8 shows stresses in MPa while the plot for the Smiley flexure (Figure 9) is in kPa. This is due to the use of different units in each run.

The lateral support diaphragm flexure stresses are as follows:

- Peak stress: 254 MPa
- Allowable: 17-4 PH H900
- σ_y = 1512 MPa
- FS=6.0

Buckling margin: Assuming the weight of the mirror is evenly distributed over the 12 lateral supports, the resulting axial load is 1398N. This gives as FS=29 in the 4mm section and a FS=9.2 in the 3mm section.

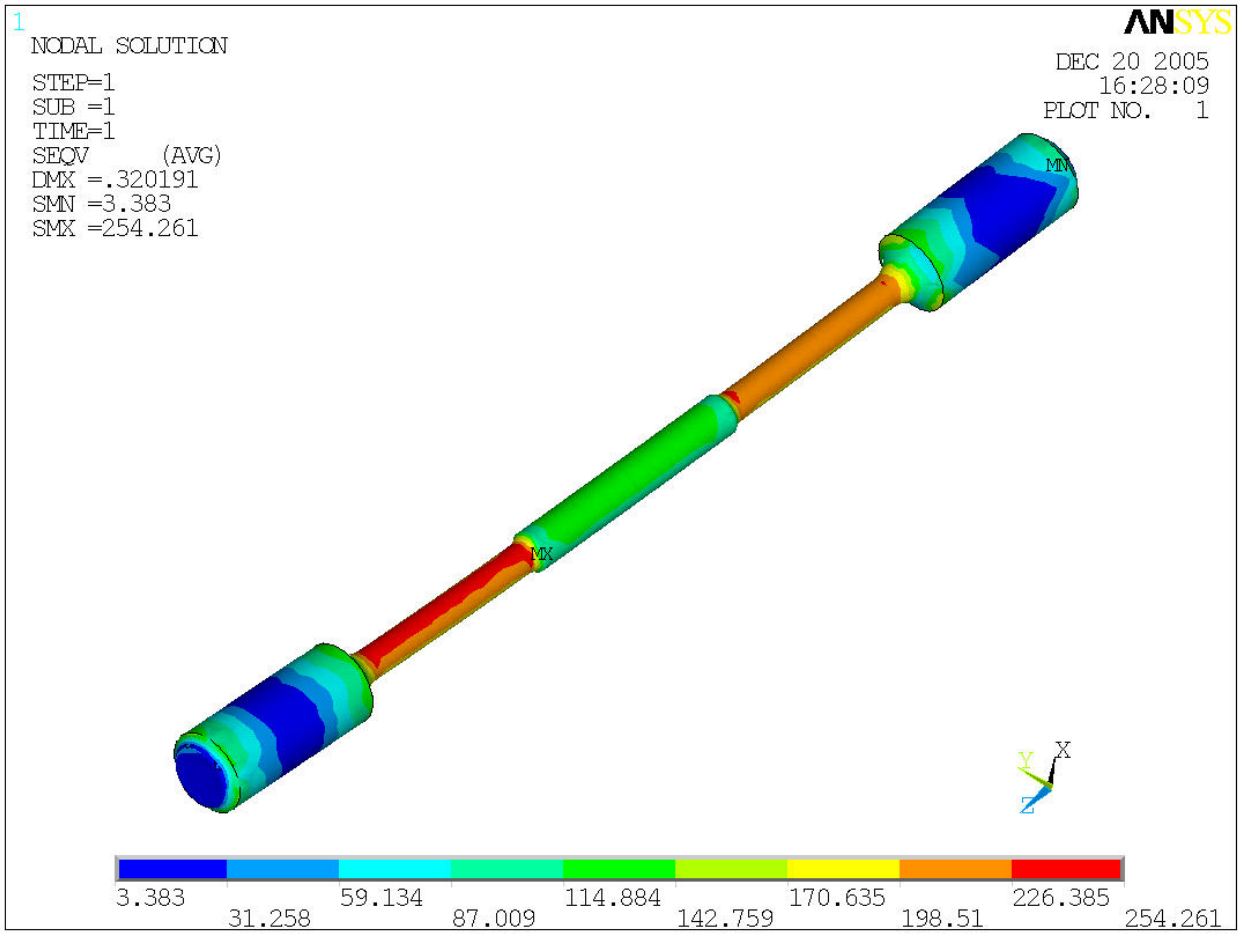

Figure 8 Mirror support – lateral support flexure stresses

2.6.2.2 Smiley Flexures

Figure 9 displays the Smiley flexure stresses on the M1 mirror support.

The Smiley flexure stresses are as follows:

- Peak stress: 126 MPa
- Allowable: 17-4 PH
- σ_y = 1172 MPa
- FS = 9.3

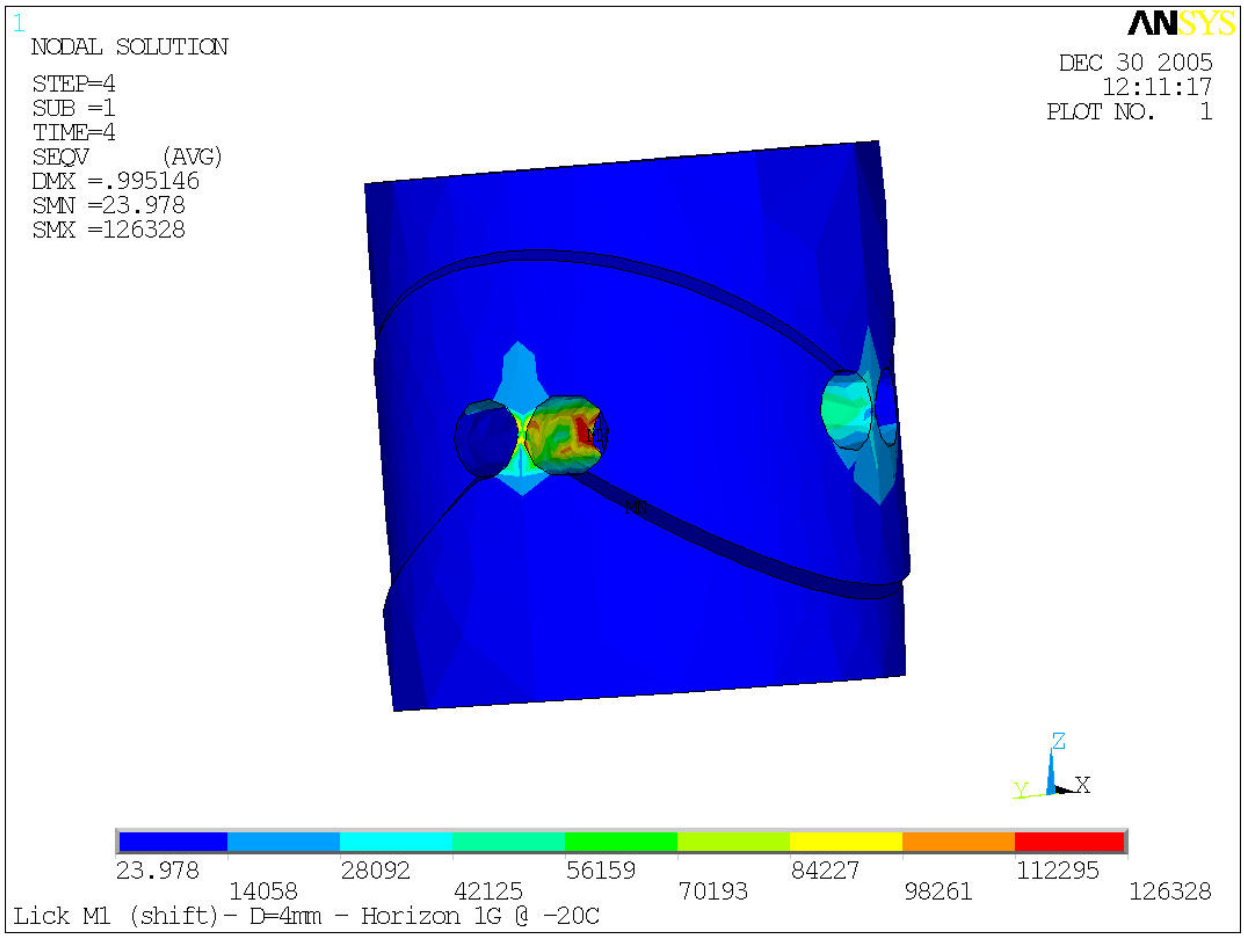

Figure 9 M1 mirror support – Smiley flexure stresses