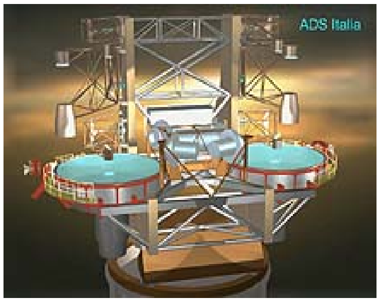
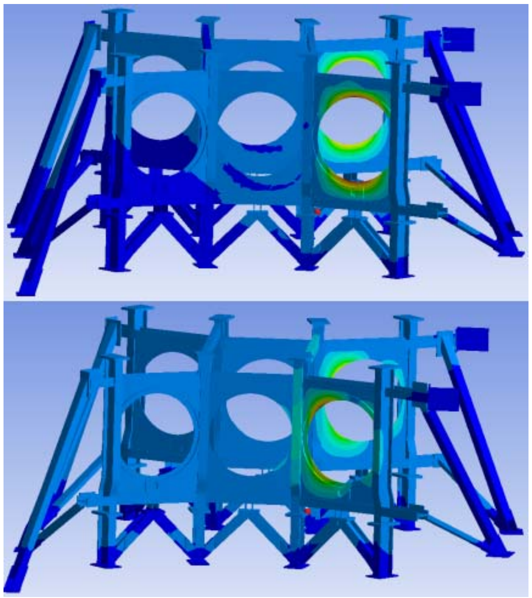


LBT PROJECT 2x8.4m TELESCOPE
Doc.No. : 671s010 Issue : a Date : 5 March 2007

LBT PROJECT

2 X 8.4m OPTICAL TELESCOPE



Instrument Rotator and Cable Chain Bent

Rotator Gallery Analysis

	Signature	Date
Prepared	Thomas Hair	03/05/2007
Reviewed	Robert Meeks	
Approved		

1 Revision History

Issue	Date	Changes	Responsible
a	05 March 07	First issue	T.Hair, R.Meeks

2 Table of Contents

3 About this document

3.1 Purpose

This document is to describe the analysis results from ANSYS about the deflection and stiffness of the Rotator Gallery.

The results from the ANSYS analysis are to verify the stiffness of the front bent Gregorian rotator with the load from LUCIFER.

3.2 Analysis Results Summary

The resultant maximum deformation of the entire model is 2.54mm at Zenith and 1.31mm at Horizon. This corresponds to a stiffness of 13.8 N/micron and 26.7 N/micron respectively.

The resultant maximum deformation of the instrument mount plates are 2.54 microns (DX Side) and 1.91 microns (SX Side) at Zenith, and 1.31 microns (DX Side), and 0.91 microns (SX Side) at Horizon. This corresponds to a stiffness of 13.8 N/micron (DX Side) and 18.3 N/micron (SX Side) for Zenith, and 26.7 N/micron (DX Side) and 38.5 N/micron (SX Side) for Horizon.

The resultant maximum deformation of the interior mount “Ring” specific regions are the same as the instrument mount plate results stated above.

The following analysis is the average deformation of the 9638 nodes that make up the “Ring” region on the DX side and 9614 nodes for the SX side.

The calculated average deformation of the interior mount “Ring” region for the DX side is 1.35 microns at Zenith and 0.61 microns at Horizon. The calculated average stiffness is 25.9 N/micron and 57.3 N/micron respectively.

The calculated average deformation of the interior mount “Ring” region for the SX side is 1.05 microns at Zenith and 0.45 microns at Horizon. The calculated average stiffness is 33.4 N/micron and 78.6 N/micron respectively.

The average deformation of the individual nodes in the “Ring” region has higher accuracy of the instrument mount plate stiffness than the prior results. This is due to the localization of the node displacements allowing a more accurate analysis of the plate deformation.

The difference in stiffness between the DX and SX sides is due to the many variations that occur in the construction of the mesh. The stiffness is also varied by the number of elements and nodes in each mesh.

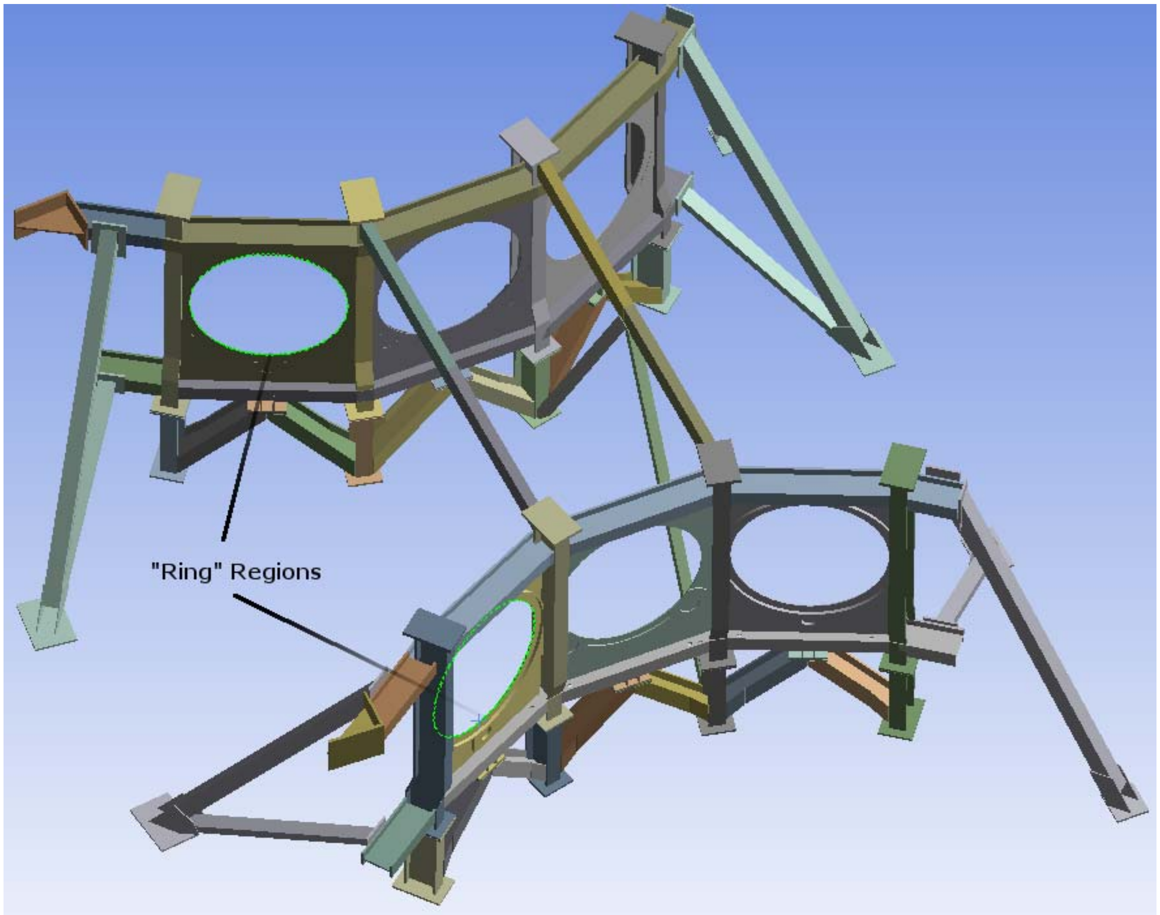


Figure 1 - Selected "Ring" Regions

3.3 Acronyms and Definitions

LBTO: Large Binocular Telescope Observatory

LUCIFER: LBT NIR-Spectroscopic Utility with Camera and Integral-Field Unit for Extragalactic Research

Units are expressed in their standard abbreviations.

3.4 Reference Documents

[RD1] 604s001c – Lucifer FDR Review Items
[RD2] 670s004a – Instrument Rotator and Cable Chain Conceptual Design Description

4 Model Description

4.1 Analysis Model Versus Actual Built

There are some differences in the model used for analysis in comparison to what exists on the telescope. The plate that the instruments mount to is actually offset slightly in the analysis model. The offset makes the plate less stiff than the location where it is actually located on the telescope. This means that the stiffness values in this document are lower than the stiffness of what is actually built on the telescope.

4.2 Mesh

Construction of an appropriate mesh accommodates applicable loads and supports giving results conducive of the actual assembly deformation.

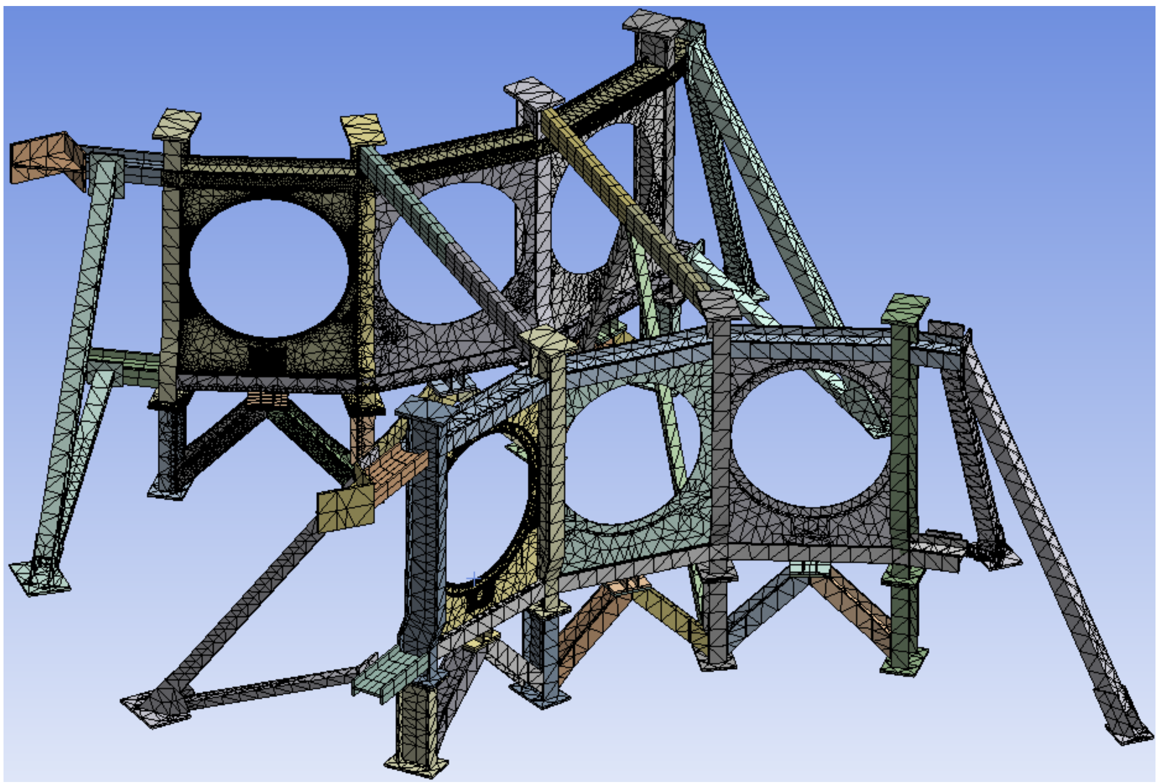


Figure 2 – Rotator Gallery Mesh

There are 167205 elements, and 354743 nodes in the mesh seen in Figure 2. The solid elements are primarily quadratic tetrahedrons and secondarily quadratic wedges. All parts in the assembly are "Structural Steel". Definitions of "Structural Steel" are in section 6.5.1.

4.3 Loads and Support

"Remote Force" loads were applied to the assembly model according to a configuration that they would most likely occur on the rotator gallery.

The loads are 35000 N pointing in the direction of gravity, displaced a distance approximately 1.5 m from the optical axis of the instrument mount plate in the assembly as seen in Figure 3.

Any load could have been used instead of 35000 N. This is due to the linear relationship between load and deformation shown in Equation 1.

$$k = \frac{F}{\delta}$$

Equation 1 - Stiffness Calculation (stiffness is k, load is F, and deformation is δ)

The displacement of the loads is located approximate to the center of gravity of LUCIFER when mounted on the plate.

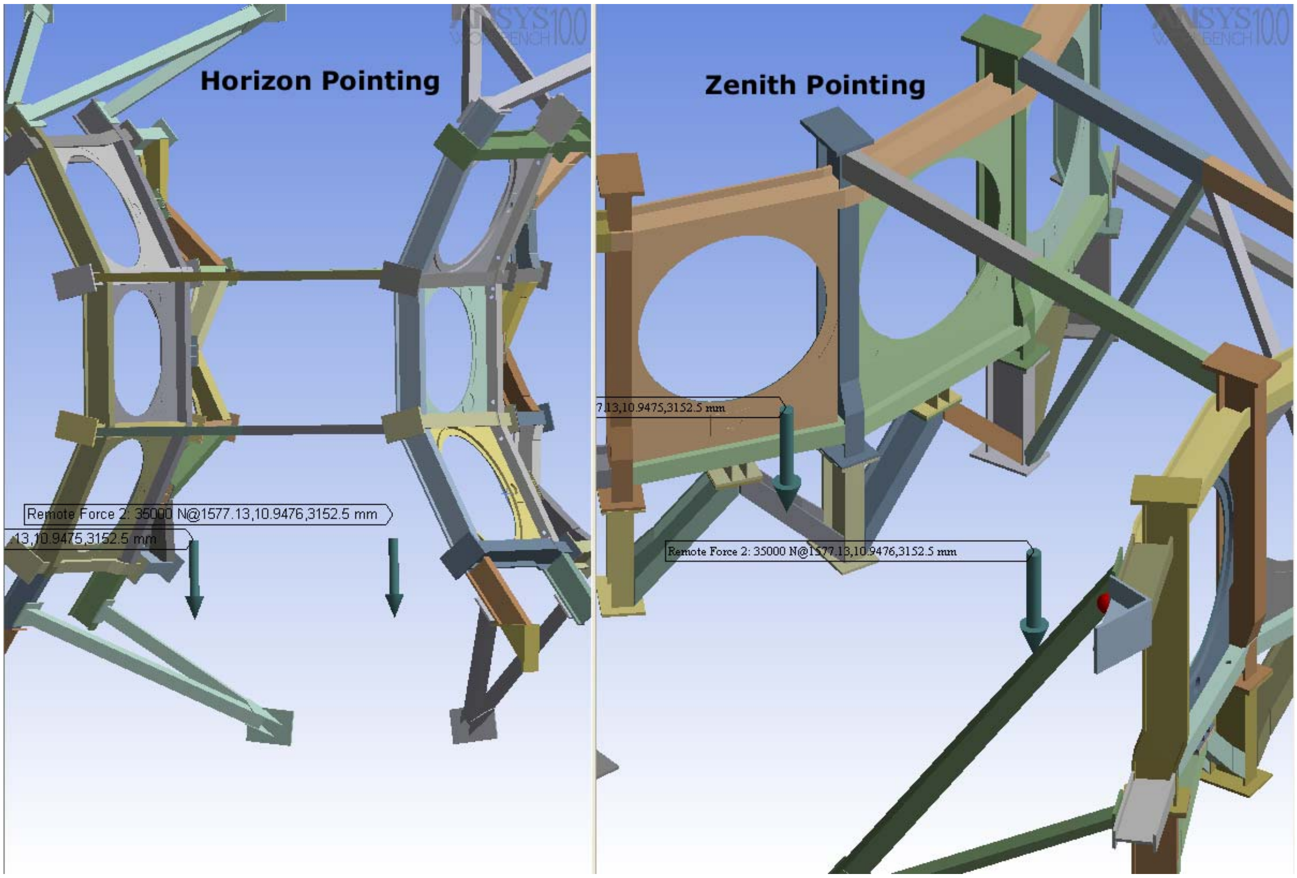


Figure 3 – Rotator Gallery Applied Loads

The Rotator Gallery has 16 fixed supports as seen in Figure 4 as the green highlighted selections. These are the mounts for the Rotator Gallery.

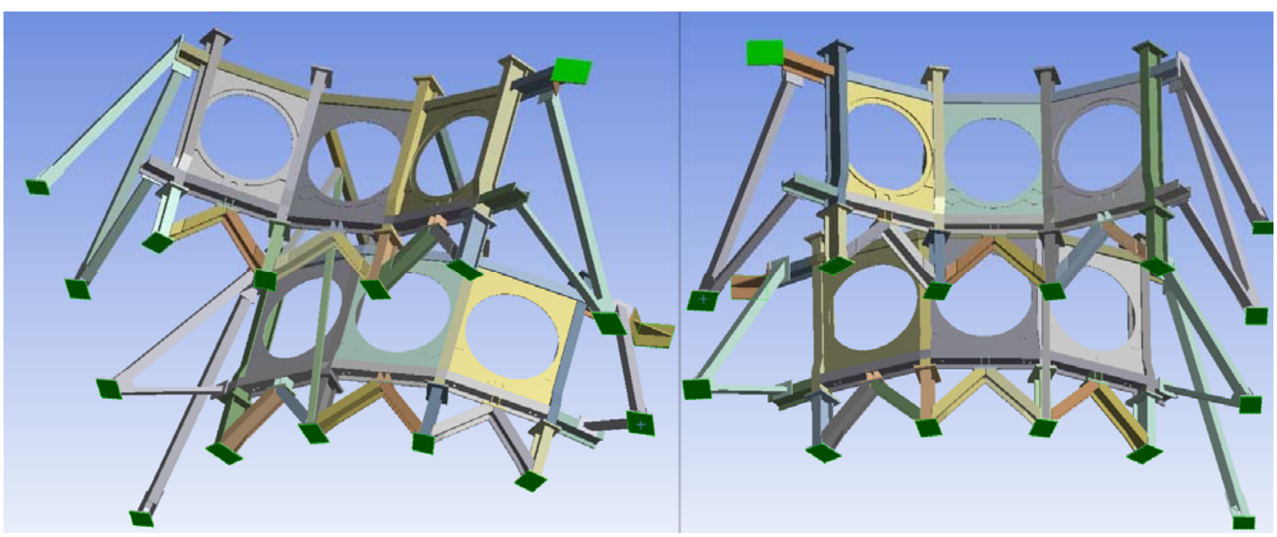


Figure 4 - Fixed Support Selections

5 Results

The results obtained are from the calculations and analyses of the stiffness of the entire model, the plates that LUCIFER is mounted, the "Ring" of each plate, and the nodes of each "Ring". The "Ring" region is where the instruments, gears, and bearings are mounted.

The completed analysis returns information on the deformation of the specified model, part or region. Stiffness is calculated by using Equation 1, the maximum deformation acquired from the completed analysis, and knowing that the Load applied is 35000 N. This is shown in as an example Equation 2 using the results of the analysis of the entire model.

$$k = \frac{F}{\delta} = \frac{35000N}{2.536mm} = 13.8\frac{N}{\mu m}$$

Equation 2 - Stiffness of Rotator Gallery plates Pointing Horizon

5.1 Entire Model Deformation Results

Deformation of the entire model indicates a maximum deformation of 2.54mm at Zenith and 1.31mm at Horizon as seen in Figures 5 and 6. This corresponds to a stiffness of 13.8 N/micron and 26.7 N/micron respectively.

The increase in stiffness from Zenith to Horizon is partially due to the change in angle that the resultant load is applied from the center of gravity of LUCIFER. The other causes are due to the load distribution change over the Rotator Gallery geometry applied from the change in elevation.

The deformations shown in Figures 5 and 6 are highly localized results. These results are maximum deflections that are possible for only the small regions that the maximum deformations occur. However, this is not specifically pertaining to the deflection of the entire model, LUCIFER, or the plate.

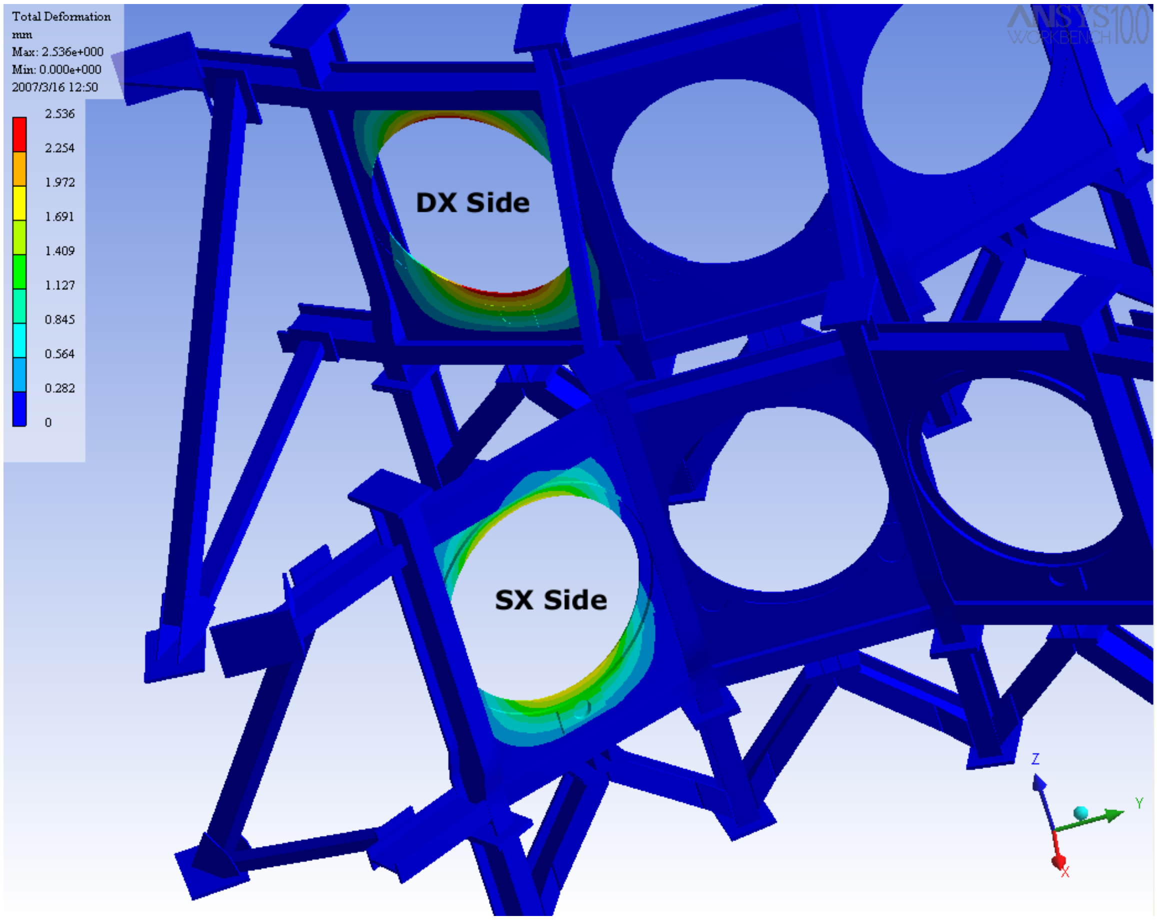


Figure 5 – Total Deformation of Rotator Gallery LUCIFER mount plates pointing Zenith

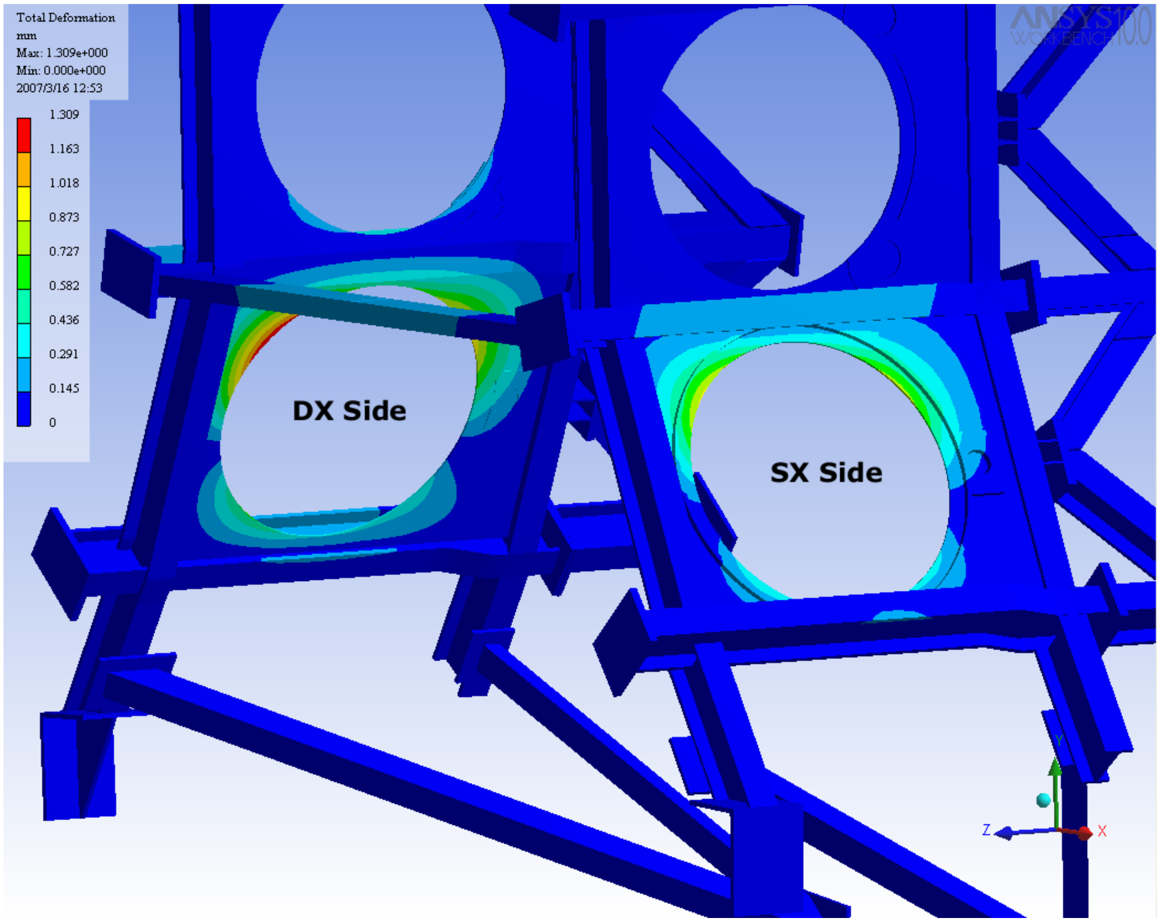


Figure 6 – Total Deformation of Rotator Gallery LUCIFER mount plates pointing Horizon

5.2 LUCIFER Mount Plate and "Ring" Deformation Results

The deformation of the instrument mount plates, seen in Figures 6 and 7, indicate maximum deformations of 2.54 microns (DX Side) and 1.91 microns (SX Side) at Zenith and 1.31 microns (DX Side) and 0.91 microns (SX Side) at Horizon.

This corresponds to a stiffness of 13.8 N/micron (DX Side) and 18.3 N/micron (SX Side) for Zenith, and 26.7 N/micron (DX Side) and 38.5 N/micron (SX Side) for Horizon.

Figures 8 and 9 indicate the same results in deformation and stiffness for the "Ring" regions as the results indicated in the previous paragraphs for the plates.

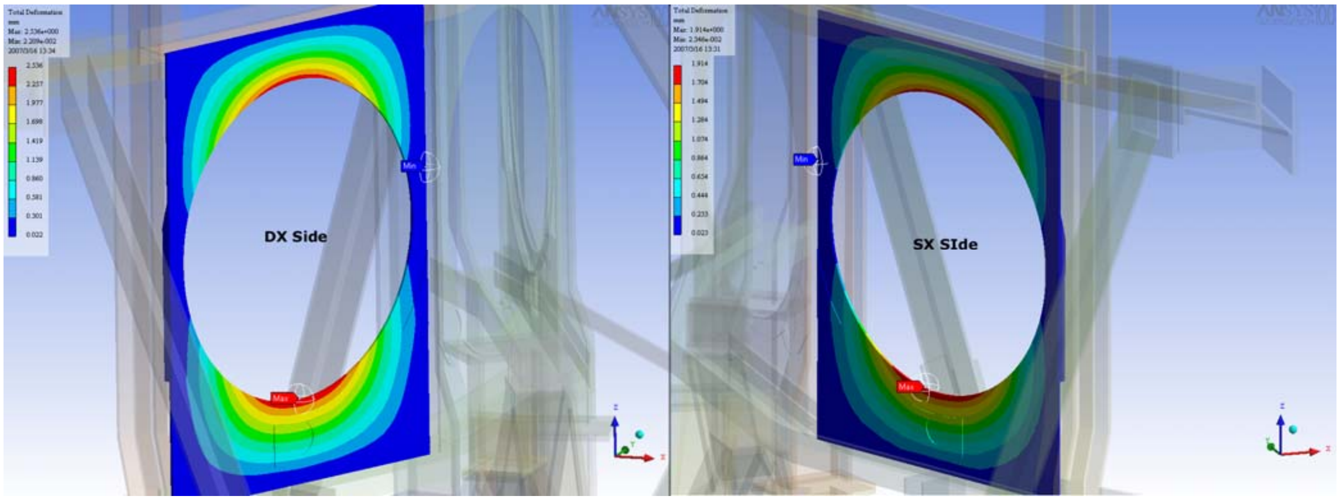


Figure 7 – Mount Plate Zenith Pointing Deformation

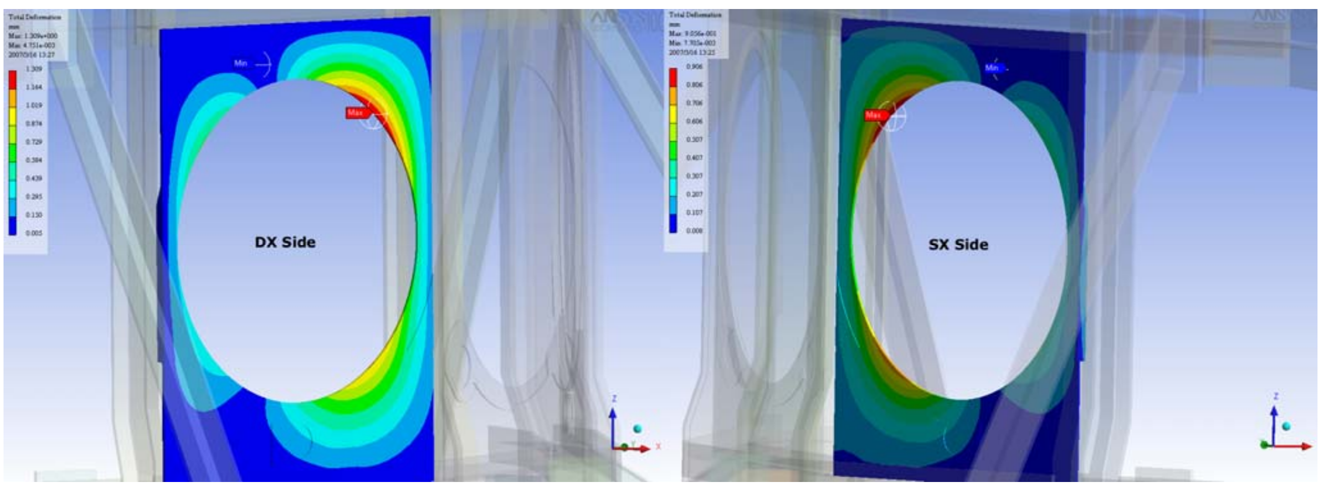


Figure 8 - Mount Plate Horizon Pointing Deformation

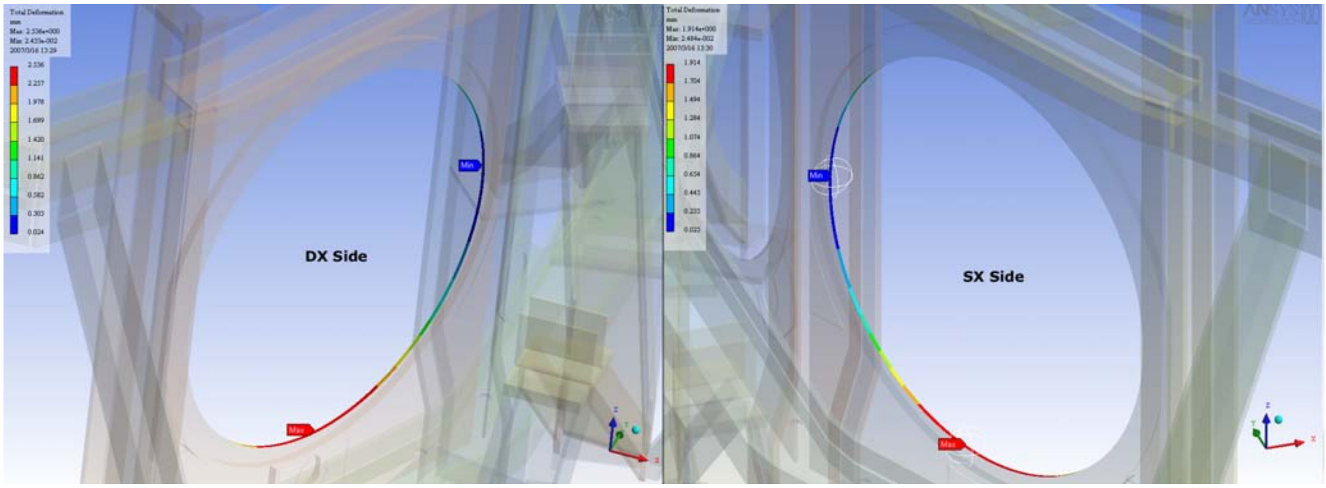


Figure 9 – Plate "Ring" Region Zenith Pointing Deformation

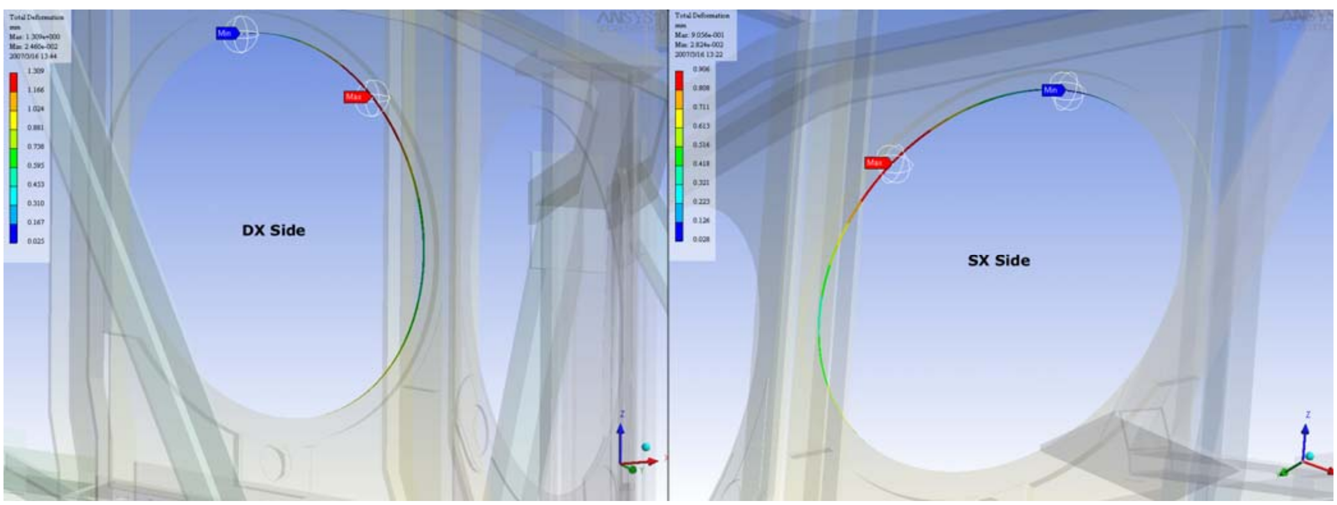


Figure 10 - Plate "Ring" Region Horizon Pointing Deformation

5.3 *Average Results of “Ring” Region*

A better deformation and stiffness is available by exporting the amount of deformation by each node within the “Ring” region and taking the average of that sum total.

The calculated average deformation is 1.35 microns (DX Side) at Zenith and 0.61 microns (DX Side) at Horizon for 9638 nodes. The calculated stiffness is 25.9 N/micron and 57.3 N/micron respectively.

The calculated average deformation is 1.05 microns (SX Side) at Zenith and 0.45 microns (SX Side) at Horizon for 9614 nodes. The calculated stiffness is 33.4 N/micron and 78.6 N/micron respectively.

The results obtained from averaging the deformations of the individual nodes in the "Ring" region are more relevant to the deflection of the LUCIFER instrument. This is because the "Ring" region will deform (deflect) in a similar manner to the optical axis of LUCIFER.

The average nodal deformation is more relevant than the maximum deformation of the plate and "Ring", because the maximum deformation of the plate and "Ring" is another localized result similar to the localized result of the deformation of the entire model.

6 Generated ANSYS Report

Large Binocular Telescope Observatory

ANSYS Report

Author

Thomas Hair

Subject

Instrument Rotator and Cable Chain Bent Rotatotor Gallery Analysis

Project Created

Monday, February 12, 2007 at 12:05:38 PM

Project Last Modified

Thursday, March 15, 2007 at 4:31:53 PM

Report Created

Friday, March 16, 2007 at 10:00:24 AM

Software Used

ANSYS 10.0

6.1 Summary

This report documents design and analysis information created and maintained using the ANSYS® engineering software program. Each scenario listed below represents one complete engineering simulation.

Scenario 1

- Based on the Inventor assembly *"\\Lbtdw102\LBTO Home\thair\My Documents\Vault Working Folder\Projects\671 Nasmyth Rotator\Rotator Structure Assembly.iam"*.
- Considered the effect of body-to-body contact, structural loads and structural supports.
- Calculated structural results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 1 below for supporting details and Appendix A1 for corresponding figures.

Scenario 2

- Based on the Inventor assembly *"\\Lbtdw102\LBTO Home\thair\My Documents\Vault Working Folder\Projects\671 Nasmyth Rotator\Rotator Structure Assembly.iam"*.
- Considered the effect of body-to-body contact, structural loads and structural supports.
- Calculated structural results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 2 below for supporting details and Appendix A2 for corresponding figures.

6.2 Introduction

The ANSYS CAE (Computer-Aided Engineering) software program was used in conjunction with 3D CAD (Computer-Aided Design) solid geometry to simulate the behavior of mechanical bodies under thermal/structural loading conditions. ANSYS automated FEA (Finite Element Analysis) technologies from ANSYS, Inc. to generate the results listed in this report.

Each scenario presented below represents one complete engineering simulation. The definition of a simulation includes known factors about a design such as material properties per body, contact behavior between bodies (in an assembly), and types and magnitudes of loading conditions. The results of a simulation provide insight into how the bodies may perform and how the design might be improved. Multiple scenarios allow comparison of results given different loading conditions, materials or geometric configurations.

Convergence and alert criteria may be defined for any of the results and can serve as guides for evaluating the quality of calculated results and the acceptability of values in the context of known design requirements.

- *Solution history* provides a means of assessing the quality of results by examining how values change during successive iterations of solution refinement. *Convergence criteria* sets a specific limit on the allowable change in a result between iterations. A result meeting this criteria is said to be "converged".
- *Alert criteria* define "allowable" ranges for result values. Alert ranges typically represent known aspects of the design specification.

All values are presented in the *"Metric (mm, kg, N, °C, s, mV, mA)"* unit system.

Notice

Do not accept or reject a design based solely on the data presented in this report. Evaluate designs by considering this information in conjunction with experimental test data and the practical experience of design engineers and analysts. A quality approach to engineering design usually mandates physical testing as the final means of validating structural integrity to a measured precision.

6.3 *Scenario 1*

6.3.1 Entire Gallery Horizon Pointing

"Entire Gallery Horizon Pointing" obtains geometry from the Inventor assembly *"\\Lbtdw102\LBTO Home\thair\My Documents\Vault Working Folder\Projects\671 Nasmyth Rotator\Rotator Structure Assembly.iam"*.

- *"Rod:1"* and *"Rod:1 (2)"* were suppressed. Suppressed parts do not affect the results in this scenario in any way.
- The bounding box for all positioned bodies in the model measures 11,180.85 by 10,750.14 by 4,920.0 mm along the global x, y and z axes, respectively.
- The model has a total mass of 22,142.22 kg.
- The model has a total volume of 2.82×10^{9} mm³.

6.3.2 Contact

- *"Contact"* uses a tolerance of 5.0×10^{-3} mm for automatic detection.

6.3.3 Mesh

- *"Mesh"*, associated with *"Entire Gallery Horizon Pointing"* has a curvature/proximity value of -100.
- *"Mesh"*, has an element size of 250.0 mm.
- *"Mesh"* uses standard shape checking.
- *"Mesh"* uses a program controlled method for selecting high or low order elements for solids.
- *"Mesh"* uses active assembly for initial size seed.
- *"Mesh"* contains 354743 nodes and 167205 elements.

6.3.4 Environment

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment" contains all loading conditions defined for *"Entire Gallery Horizon Pointing"* in this scenario.

6.3.5 Structural Loading

Name	Coordinate System	Type	Magnitude	Associated Bodies
"Remote Force"	Global Coordinate System	Remote Force	35,000.0 N	*"StructureCenterInstrumentPlates-Front:1"*
"Remote Force 2"	Global Coordinate System	Remote Force	35,000.0 N	*"StructureCenterInstrumentPlates-Front1:1"*

6.3.6 Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Associated Bodies
"Fixed	Fixed	69,999.93 N	[$6.67\times10^{-}$	1.66×10^{8} N·mm	*"StructureBase:1"*,

Support"	Surface		^{4} N x, 69,999.93 N y, -1.38×10^{-3} N z]		*"StructureMidCrossbeamTopFlange:1"*, *"StructureBaseIBeamColumn:1"*, *"StructureBaseIBeamColumn:2"*, *"StructureBaseIBeamColumn:3"*, *"StructureBaseIBeamColumn:4"*, *"StructureBase2:1"*, *"StructureBase1:1"*, *"StructureBaseIBeamColumn1:1"*, *"StructureBaseIBeamColumn1:2"*, *"StructureBaseIBeamColumn1:3"*, *"StructureBaseIBeamColumn1:4"*, *"StructureMidCrossbeamTopFlange1:1"* and *"StructureBase21:1"*

6.3.7 Solution

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for *"Entire Gallery Horizon Pointing"* given loading conditions defined in *"Environment"*.

Structural Results

Name	**Scope**	**Minimum**	**Maximum**	**Minimum Occurs On**	**Maximum Occurs On**
"Total Deformation"	All Bodies In *"Entire Gallery Horizon Pointing"*	0.0 mm	1.31 mm	StructureBase:1	StructureCenterInstrumentPlates-Front:1
"Inner Ring Face Total Deformation-DX Side"	Face(s) on *"StructureCenterInstrumentPlates-Front:1"*	2.46×10^{-2} mm	1.31 mm	StructureCenterInstrumentPlates-Front:1	StructureCenterInstrumentPlates-Front:1
"Inner Ring Face Total Deformation-SX Side"	Face(s) on *"StructureCenterInstrumentPlates-Front1:1"*	2.82×10^{-2} mm	0.91 mm	StructureCenterInstrumentPlates-Front1:1	StructureCenterInstrumentPlates-Front1:1
"Plate Total Deformation-SX Side"	*"StructureCenterInstrumentPlates-Front1:1"*	7.7×10^{-3} mm	0.91 mm	StructureCenterInstrumentPlates-Front1:1	StructureCenterInstrumentPlates-Front1:1
"Plate Total Deformation-DX Side"	*"StructureCenterInstrumentPlates-Front:1"*	4.75×10^{-3} mm	1.31 mm	StructureCenterInstrumentPlates-Front:1	StructureCenterInstrumentPlates-Front:1

- Convergence tracking not enabled.

6.4 *Scenario 2*

6.4.1 Entire Gallery Zenith Pointing

- *"Rod:1"* and *"Rod:1 (2)"* were suppressed. Suppressed parts do not affect the results in this scenario in any way.
- The bounding box for all positioned bodies in the model measures 11,180.85 by 10,750.14 by 4,920.0 mm along the global x, y and z axes, respectively.
- The model has a total mass of 22,142.22 kg.
- The model has a total volume of 2.82×10^{9} mm³.

6.4.2 Contact

- *"Contact"* uses a tolerance of 5.0×10^{-3} mm for automatic detection.

6.4.3 Mesh

- *"Mesh"*, associated with *"Entire GalleryZenith Pointing "* has a curvature/proximity value of -100.
- *"Mesh"*, has an element size of 250.0 mm.
- *"Mesh"* uses standard shape checking.
- *"Mesh"* uses a program controlled method for selecting high or low order elements for solids.
- *"Mesh"* uses active assembly for initial size seed.
- *"Mesh"* contains 354743 nodes and 167205 elements.

6.4.4 Environment

Simulation Type is set to Static

Analysis Type is set to Static Structural

"Environment" contains all loading conditions defined for *"Entire GalleryZenith Pointing "* in this scenario.

6.4.5 Structural Loading

Name	Coordinate System	Type	Magnitude	Vector	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Location
"Remote Force"	Global Coordinate System	Remote Force	35,000.0 N	[0.0 N x, 0.0 N y,-35,000.0 N z]	N/A	N/A	N/A	N/A	[-1,577.13 mm x,10.9 mm y,3,152.5 mm z
"Remote Force 2"	Global Coordinate System	Remote Force	35,000.0 N	[0.0 N x, 0.0 N y,-35,000.0 N z]	N/A	N/A	N/A	N/A	[1,577.13 mm x,10 mm y,3,152.5 mm z

6.4.6 Structural Supports

Structural Supports						
Name	**Type**	**Reaction Force**	**Reaction Force Vector**	**Reaction Moment**	**Reaction Moment Vector**	**Associated Bodies**
"Fixed	Fixed	69,999.91 N	[2.71×10⁻	1.9×10^{8} N·m	[-1.9×10^{8} N·mm x,	*"StructureBase:1"*,

Support"	Surface		^{3} N x, - 2.25×10^{-2} N y, 69,999.91 N z]	m	- 3.03×10^{6} N·mm y, - 53,844.99 N·mm z]	*"StructureMidCrossbeamTopFlange:1"*, *"StructureBaseIBeamColumn:1"*, *"StructureBaseIBeamColumn:2"*, *"StructureBaseIBeamColumn:3"*, *"StructureBaseIBeamColumn:4"*, *"StructureBase2:1"*, *"StructureBase1:1"*, *"StructureBaseIBeamColumn1:1"*, *"StructureBaseIBeamColumn1:2"*, *"StructureBaseIBeamColumn1:3"*, *"StructureBaseIBeamColumn1:4"*, *"StructureMidCrossbeamTopFlange1:1"* and *"StructureBase21:1"*

6.4.7 Solution

Solver Type is set to Program Controlled

Weak Springs is set to Program Controlled

Large Deflection is set to Off

"Solution" contains the calculated response for *"Entire GalleryZenith Pointing "* given loading conditions defined in *"Environment"*.

- Convergence tracking not enabled.

6.5 *Appendices*

6.5.1 Definition of "Structural Steel"

"Structural Steel" **Constant Properties**	
Name	**Value**
Compressive Ultimate Strength	0.0 MPa
Compressive Yield Strength	250.0 MPa
Density	7.85×10^{-6} kg/mm³
Poisson's Ratio	0.3
Tensile Yield Strength	250.0 MPa
Tensile Ultimate Strength	460.0 MPa
Young's Modulus	200,000.0 MPa
Thermal Expansion	1.2×10^{-5} 1/°C
Specific Heat	434.0 J/kg·°C
Thermal Conductivity	0.06 W/mm·°C
Relative Permeability	10,000.0
Resistivity	1.7×10^{-4} Ohm·mm

7 Doc_info_start

Title: *Instrument Rotator and Cable Chain Bent Rotator Gallery Analysis*
Document Type: Report
Source: Steward Observatory
Issued by: Thomas Hair
Date_of_Issue: *28 Feb 2007*
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Sub-Assembly:
Part Name:
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