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Modifications to the f/9 Secondary Mirror Hardpoints

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Abstract

From Oct. 2001 to Jan. 2002, the f/9 secondary mirror hardpoints were modified in order to stabilize elevation-dependence of the mirror position within the cell. The modifications consisted of simplifying the tangent arms, replacing rod ends with flexures, improving the tangent arm connection to the mirror, and stiffening the axial hardpoint column members. These modifications have vastly improved the robustness of the defining points against wind buffeting and have eliminated the large elevation-dependent mirror position discontinuities. To this date, the mirror positioning system has remained reliable and stable both in terms of elevation behavior and resistance to wind buffeting. This information is largely historical, but we feel it is important to document the early problems with the f/9 secondary system and the modifications we performed to the hardpoints.

I. Introduction

The f/9 secondary mirror was generated and polished at the Steward Observatory Mirror Laboratory from a Hextek substrate. The mirror support system was designed and manufactured at Steward Observatory with minor input from the MMTO. The mirror system was delivered to the MMTO for final assembly in April 2000. For completeness, we reference much of the f/9 secondary design and analysis work at the end of this memo.[1-10] This memo supplements the f/9 installation procedures and details previously reported[11].

Once installed on the telescope, it was soon realized that mirror had a rather large position discontinuity near 75-degrees elevation (Figure 1). After the installation of the light baffle in 2001, the position of the secondary mirror relative to the primary became erratic causing large non-repeatabilities in the collimation (Figure 2) and high frequency image oscillations in the presence of wind. Taken together (and after some tests verifying the integrity of the OSS top end), this implied that the hardpoint system that defined the position of the secondary mirror within the cell had become unreliable. Presumably, the baffle significantly increased the wind vibration on the f/9 support system causing a degradation of its performance.

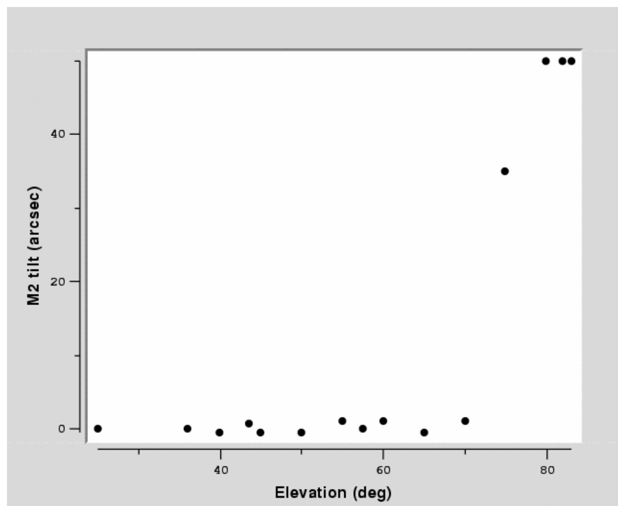

Figure 1: The first indication of a problem with the f/9 mirror system manifested itself (in June 2000) as a collimation discontinuity for high elevation. This graph was obtained before the telescope wavefront sensor was implemented by using an out-of-focus star image and tilting the secondary vertex until the secondary shadow was centered as a function of elevation (nulling coma visually).

II. Hardpoint modifications

During the primary mirror realuminization in the latter half of 2001, the MMTO undertook minor redesigns in both the tangent arms and axial hardpoints which we hoped would make them: 1) immune to loosening in the presence of wind buffeting and 2) remove the large position discontinuity at high elevations.

The tangent arm modifications (Figure 3) concentrated on simplifying the arm struts by removing the jam-nut connections and replacing the rod-ends with flexures. The axial hardpoints modifications (Figure 4) consisted of removing jam-nut connections, replacing the rod-end with a flexure, and stiffening the hardpoint spacing columns and upper tower.

The f/9 mirror system was placed upon the handling fixture which allowed the cell to be rotated in elevation. A high-precision Mitutoyo gauge was mounted to contact the inner central perforation in the f/9 mirror backplate (Figure 5) so that the

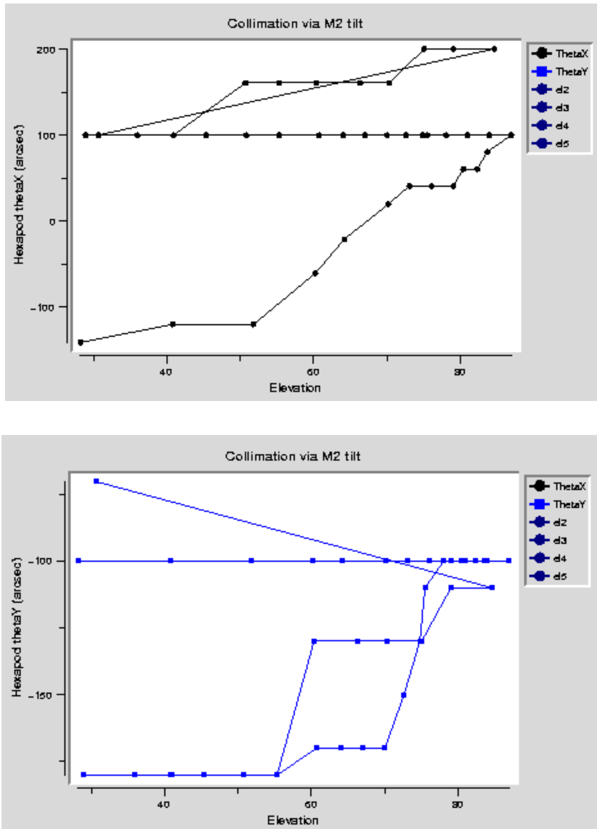

Figure 2: Examples of the erratic collimation behavior vs. elevation that occurred after the f/9 secondary baffle was installed. An out-of-focus star image was used to null coma by tilting the secondary vertex in thetaX (top) and thetaY until the secondary shadow was centered in the pupil.

Figure 3: Original (top) and modified f/9 tangent arm assemblies. The MMTO modifications consisted of removing several jam-nut connections in the shafts and replacing the rod-ends with flexures. Additionally, minor maintenance was performed on the breakaway mechanisms.

mirror decenter error [relative to the cell] vs. elevation could be reliably measured.

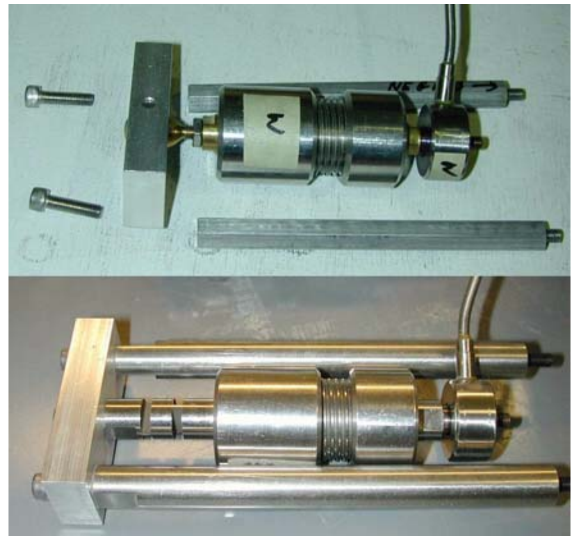

Figure 4: The original (top) and modified axial hardpoint assemblies. The jam-nut connections were eliminated, the rod-end was replaced with a flexure, and the column spacers were stiffened.

Figure 5: Setup for measuring the decenter of the mirror with respect to cell using a Mitutoyo gauge contacting the inside edge of the central perforation in the mirror backplate.

Although the newly modified hardware would surely increase the robustness of the mirror defining points in the presence of wind buffeting, the modifications did not eliminate the high-elevation collimation discontinuity shown in Figure 1. Additionally, we noticed that the lateral support servo became unstable in the region of the discontinuity. Extensive testing of the electronics failed to show an electronic problem.

After close inspection, we discovered a single-point contact of an axial earthquake pad with the mirror backplate. After eliminating this contact, the lateral support servo was still unstable in the region of the discontinuity suggesting compliance in the load path from the tangent arm load cells to the mirror.

The cause of the compliance turned out to be the three linear bearings that are in the direct load path between the tangent arms and the edge of the mirror frontplate. A blade-flexure was designed to be placed in parallel with each linear bearing (Figure 6). The thin membrane flexure significantly reduces

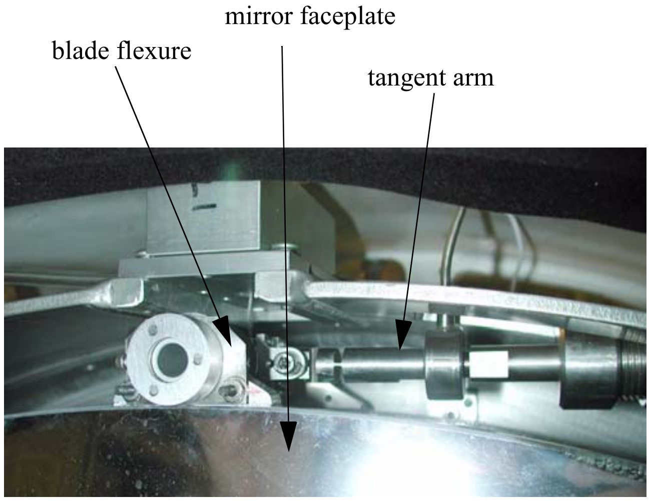

Figure 6: Blade flexure solution that ultimately eliminated the high-elevation collimation discontinuity and lateral servo instabilities.

the radial compliance of the linear bearing while still allowing axial compliance [parallel to the mirror's optic axis] for the CTE mismatch between the glass and lateral support columns.

Figure 7 shows the elevation dependence of mirror position for the various steps in the modifications described above. Note that the simple beam flexure of the aluminium post that connects the tangent arm to the bearing flexes by 30 microns, so that the displacement shown in the graph for the "clamped bearing" case is near the theoretical flexure for the geometry.

III. Conclusions

In late 2001 and early 2002, we implemented modifications to the f/9 mirror support system aimed at: 1) increased robustness of the hardpoints against wind vibration, and 2) elimination of the observed collimation discontinuity and elevation servo instability. The modifications were successful, and as recent observations show[12], the f/9 mirror system has since remained reliable, stable, and repeatable.

IV. Appendix

Two miscellaneous items are included in this appendix that help complete the documentation for the f/9 secondary system.

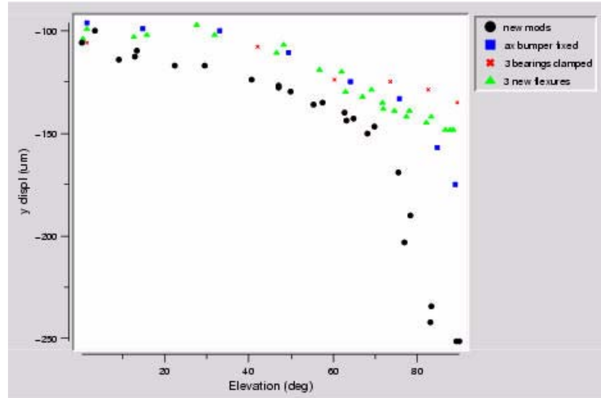

Figure 7: Graph showing the progress in reducing the elevation dependence of mirror position within its cell. After the hardpoint modifications (black), the collimation discontinuity was still present. Removal of the axial earthquake interference reduced its magnitude (blue), but the elevation servo was still unstable in this region. Clamping the 3 linear bearings in the direct load path between the tangent arms and the mirror eliminated the discontinuity and elevation instabilities (red). The final blade flexure solution (green) is not as stiff as clamping the linear bearings, but allows for axial compliance for the CTE mismatch between the mirror and lateral support connection columns.

A. Air regulators

Because of the difficulty in accessing the air servo control boxes, Figure 8 provides identification of the air regulators

Figure 8: Photo identification of one of the 4 air regulators currently used in f/9 mirror support system.

currently used in the mirror support system.

B. Remote force monitoring

It is important to provide remote verification that the mirror support system is working properly. The mirror support load cell forces may be viewed remotely by accessing the serial data stream of the on-board Microchip PIC16C773. Currently, the serial cable is connected to camera.mmto.arizona.edu (although the connection needs to be moved to the Cyclades serial network box for more general access). A short script was written in TCL to provide the load cell forces (called f9monitor.tcl):

```
#! /usr/bin/tclsh

# scw and dc: 1-28-02

# script to read the f/9 secondary force monitor PIC board that Dusty designed. This serial board return lines of 8 numbers.  The first 6 contain the force data (0-5).

# channelID

#0 SE axial fmon1

#1 SE lateral fmon3

# 2 SW lateral fmon4

#3 SW axial fmon5

#4 NE axial fmon7

#5 N lateral fmon9

set port [open "/dev/ttyS0" RDWR]

#no blocking is required the way Dusty has this set up. His version required

#"-translation {lf cr}" to follow his c-code.

fconfigure $port -mode 38400,n,8,1 -buffering line -blocking 0  -translation cr

set IDs "SE_axial SE_lateral SW_lateral SW_axial NE_axial N_lateral"

puts $port 0; # turn data stream off

after 100

set tmp [read $port]

puts $port 1

after 100

set data [read $port]

close $port

puts $data

#convert from volts to lbs (80mv/lbf)

set cntr 0

foreach voltage $data {

puts "[lindex $IDs $cntr] : (mv) = [expr $voltage * 1000], (lbf) = [expr $voltage * 1000/80]"

incr cntr

}
```

V. References

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[12] S.C. West, "Fall 2002 f/9 optical performance fo the 6.5m MMT analyzed with the top box Shack-Hartmann wavefront sensor," *MMTO Tech. Memo* #**03-1**, Jan. 2003.