Review of "Gravity Deflections of Lightweighted Mirrors"

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Introduction

As a mirror becomes larger in size, its mass scales linearly. Lightweighting a mirror involves removing mass without altering the shape of the mirror through bending. If material is removed specifically, deflection due to gravity can be reduced as the weight is reduced. Gravity deflection will affect the shape of the mirror, increasing the wavefront error. Some mirrors can be cast with a rib or honeycomb structure, but for other types the material must be removed after the the mirror is cast. There are a few different possible designs for the removal, with two choices being the single arch and double arch patterns.

Knowledge of how mirror shapes distort the wavefronts is important for the manufacture and

Paper

Two such 20" spherical mirrors were tested for their deformations due to gravity. Each mirror was made out of 4" thick Fused Silica because of its uniform thermal expansion at cryogenic temperatures, important for space operation.

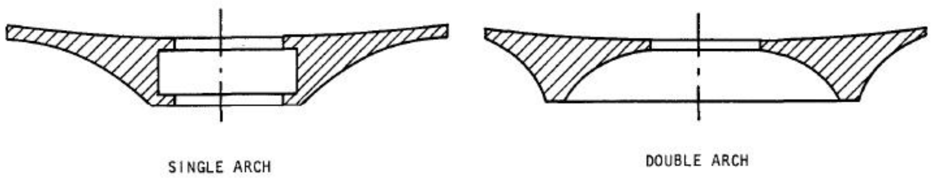


Figure 1: Mirror Cross Sections(From *Anderson*)

The mirrors were sloped into their arches on a polishing machining using a cam template designed for the shape. If the slopes are very steep, the production of such curves can take longer to make, as with the double arch system. After this step is finished, holes for supports are made.

Each mirror was tested horizontally in two ways. First, the mirror was tested on the ground resting on a three point support. Then, the mirror is mounted on a structure so that it can be tested hanging upside down from a three ball spider attached to the inner diameter of the central hole. The purpose of this is to remove any errors in shape due to the support structure. To accurately see these effects, ideally an image would be taken from above and below to see how it deforms. Since the arch support prevents images taken from below, the mirror can be inverted in the air so that the front surface can be viewed with the opposite gravity effect. By subtracting the interferometer data taken from each of the two tests with one another, the forces from each of the supports can be negated appropriately leaving twice the gravity error.

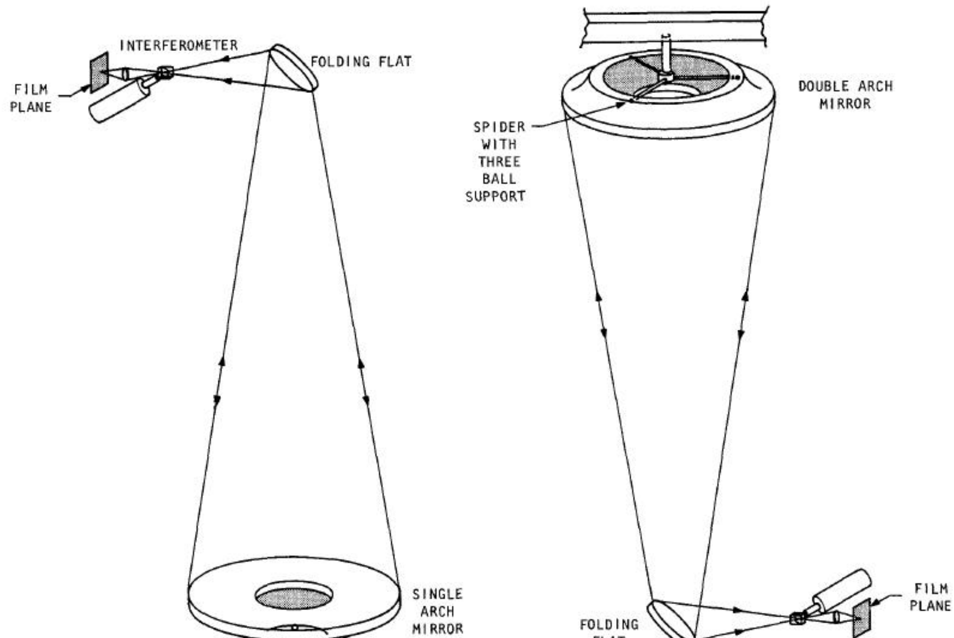
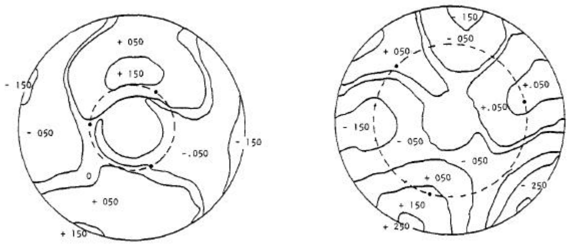


Figure 2: Test Setup(From *Anderson*)

The interferograms were broken apart into the first 36 Zernike Fringe Polynomial terms. The Zernikie Polynomials can then be used to find the OPD of the wavefront, providing system noise like air turbulence is ignored.

The end result of the tests showed that the single arch design was stiffer than the double arch by a factor of two. The authors attributed this to the mirror having greater azumithal stiffness. This is because of the larger moment in the wider ring of the double arch as shown from the high order Zernike terms.



(a) Single Arch (b) Double Arch

Figure 3: Wavefront Contour Maps(from Anderson)

Interferogram analysis of the double arch does show that it has a factor of 4 greater radial stiffness. The paper suggests that more uniform support along the support ring can increase the aszumithal stiffness making the design potentially better in the long run.

	Mirror #1 Single arch		Mirror #2 Double arch	
	P-V (waves at 6328 Å)	Rms	P-V (waves at 6328 Å)	Rms
Total deflection	0.286	0.054	0.599	0.094
1θ terms	0.146	0.027	0.136	0.025
2θ terms	0.211	0.042	0.193	0.043
3θ terms	0.019	0.003	0.395	0.078
Radial	0.083	0.020	0.022	0.005

Figure 4: Subtracted Deflections(from Anderson)

The testing of the errors is also important for this system. Using Zernike Fringes does a great job for determining each of the individual wavefront contributions. However, the technique does not work for noisy systems(*Wyant*). Finite element analysis was used to assess the affects of noise in the system. They showed an error of 0.205λ, agreeing with the final data. Noise from air turbulence was shown to be 0.107λ from the RMS error of the individual tests.

Conclusions

Mirror lightweighting is an important part of producing functional mirrors. In space-based optics it reduces the payload costs for launching. Ground-based it can be used to reduce deflection or for micromachined parts to allow faster motion with less error.

The paper clearly shows that gravity can have a significant effect on the surface for two designs in larger mirrors. The induced wavefront errors are brought above the P-V diffraction limit(0.25λ). These optics would eventually go into space, where gravity is less of an issue, but for other ground based mirrors, gravity can be a significant detriment. Knowing how much the mirrors shift is important for the support designer. The structure can be built for ground based optics that reduce the overall deflections.

Other works out of the University of Arizona suggests that other designs also see elastic deformations due to gravity, which is reasonable to assume since gravity will affect any ground based mirror.

References

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