

# Final Figuring of Optical Components Surfaces Considering Deformations Introduced by Support System

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**Abstract.** Membrane-pneumatic support systems for mirror mounting are often used at JSC LZOS during working surface tests while producing of large-dimensioned optical components of astronomical and space application. However, in some cases, it is necessary to support the mirror by glued interface elements. In such case, the difference in the surface shape between the standard and the technological support, which is considered during figuring, is calculated by means of modelling.

## 1 Introduction

In the process of figuring, the mirror is installed either on standard support, which is the best option, or, in some cases, if standard support is not available, on membrane-pneumatic support cell, which either supports the mirror uniformly, or imitates standard support cell. It allows both mirror figuring on grinding-and-polishing and finishing machine, and optical surface figure testing on vertical test bench, of which it is integral part. However, in certain cases, support system engineers design non-uniform efforts on interface elements of the mirror rear surface. In this case, the difference in the surface shape between the standard and the technological support, which is considered during figuring, is calculated by means of modelling.

## 2 Specific Features of Mirror Manufacturing Support

As an example, let us describe a number of projects on the production of large-dimensioned optical mirrors using membrane-pneumatic support.



**Fig.1.** Model interferogram of the required wavefront (left) and the one actually obtained in the process of machining (right).

Observational Sciences, India) [1]. The telescope was produced by AMOS. The primary mirror is a meniscus. The mirror diameter is 3700 mm, vertex radius is 14639 mm (F/1.96), asphericity is 111  $\mu\text{m}$ .

Under contract with Belgium company AMOS, JSC LZOS fulfilled work on the production of the set of optics for Devasthal Optical Telescope (DOT) ARIES (Aryabhata Research Institute of

The estimated manufacturing support was designed in such a way that the efforts on the points of mirror support are different. Both LZOS and AMOS specialists performed modelling of the supported state. The calculation results matched each other. Modelling results showed that locating of membranes in the points of standard support cell efforts induces errors on the surface, mainly, defocus and 3<sup>rd</sup> order spherical aberration. The rest of the errors, «traces» from support elements, are small and negligible, since they are included in the mirror deformation calculations both in the standard support cell and in the manufacturing support cell. Decision was taken to subtract in the process of mirror machining the error induced by the manufacturing support cell, together with AMOS specialists and thus obtain the surface figure compliant with the standard support cell. Defocus does not influence the mirror parameters, since it introduces error within radius of only 0.07 mm, and spherical aberration should be considered during mirror final polishing. In order to do this, it is necessary to obtain wavefront map with the required spherical aberration, which will be removed upon installation of the mirror on the standard support cell. Focus and 3 terms of Spherical aberration as given by the equation hereunder:

$$-207 \cdot (6\rho^4 - 6\rho^2 + 1) + 42.8 \cdot (20\rho^6 - 30\rho^4 + 12\rho^2 - 1) - 17.6 \cdot (70\rho^8 - 140\rho^6 + 90\rho^4 - 20\rho^2 + 1)$$

Interferogram of the required wavefront is showed in Fig.1, on the left. The parameters of such surface are:

$$\text{RMS (W)} = 0.133\lambda; \text{PV (W)} = 0.458;$$

$$\text{RMS SFE} = 42.0 \text{ nm}$$

By subtracting of this wavefront from the obtained one in the process of the mirror surface testing we remove the difference between support in the standard support cell and in the manufacturing membrane-pneumatic support cell and perform machining to meet the specification requirements. Possible errors in the mirror supports difference modelling in the process of

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machining and operation are compensated by the active system of impact on the primary mirror.

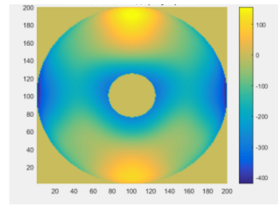
Another example – under Contract with AMOS, JSC LZOS is producing optics for DAG Telescope (Doğu Anadolu Gözlemevi) [2]. The primary concave hyperbolic mirror has diameter 4 m, vertex radius  $R_c = 14420 \text{ mm} \pm 12 \text{ mm}$  (F/1.80), conic constant  $K = -1.006574 \pm 0.0004$ , asphericity is  $153 \text{ }\mu\text{m}$  on the full diameter and  $139 \text{ }\mu\text{m}$  in the light zone.

Modelling results showed that locating of membranes in the points of standard support cell efforts induces errors on the surface, mainly, defocus, astigmatism, triangular coma and spherical aberration. The rest of the errors, «traces» from support elements, are small and will be removed in the process of figuring. Defocus is  $1.5 \text{ }\mu\text{m}$  and does not influence the mirror parameters, since it introduces error within radius of only  $0.12 \text{ mm}$ , however, such error can also be considered during figuring.

By subtracting of this wavefront from the obtained one in the process of the mirror surface testing we remove the difference between support in the standard support cell and in the manufacturing membrane-pneumatic support cell and perform machining to meet the specification requirements.

The view of wavefront and the corresponding interferogram, which should be obtained on membrane-pneumatic cell, are showed in Fig. 2-3, and the errors of wavefront are showed in Fig. 4.

The accuracy of positioning of the mirror support system interface elements is also important. In particular, positioning of the axial interface elements of DAG M1 mirror was performed with a higher accuracy,  $0.02\text{-}0.03 \text{ mm}$  instead of  $1.2 \text{ mm}$ . The purpose of this was to decrease considerably the errors induced by the manufacturing support cell influence on the mirror deformations in the process of its installation on the membrane-pneumatic support. Calculations of the mirror deformations in case of its shift with respect to the cell by  $0.5 \text{ mm}$ ,  $1 \text{ mm}$ , as well as in case of error in the axial interface element positioning by  $\pm 0.5 \text{ mm}$  and  $\pm 1 \text{ mm}$  were carried out. Influence of membrane shift with respect to the nominal position within  $1\text{-}2 \text{ mm}$  is negligible, since membrane mounting pad of diameter  $80 \text{ mm}$  has the same influence on the interface element as without the shift; at the same time, shift of the interface element causes the effort to be applied to the mirror in the shifted place, and this would have considerable influence on wavefront form. Within the telescope, this effect is compensated by active influence on the pad, while static membrane-pneumatic support lacks such compensation. Calculations showed that the axial interface elements should be glued with accuracy  $< 0.5 \text{ mm}$  from the nominal position, which is exactly the way it was done.



**Fig. 2.** Wavefront form in case of mirror support on manufacturing support cell.



**Fig. 3.** Model interferogram of the required wavefront and parameters of wavefront deviations.

	RMS	P - V
All	0,348	1,823
- Tilt	0,348	1,823
- Focus	0,348	1,823
- Astigmatism	0,168	0,770
- Coma3	0,348	1,823
- Coma5	0,348	1,823
- Triangular	0,345	1,749
- Quadratic	0,348	1,820
- Spherical	0,315	1,702
Local	0,068	0,344
Coefficient		
Focus	0,001	
Coefficient		
Angle		
Tilt	0,000	-0,060
Astigmatism	0,749	0,016
Coma3	0,002	-5,992
Coma5	0,003	169,632
Triangular	0,126	0,023
Quadratic	0,014	-44,987
Coefficient		
Spherical (0)	-0,790	
Spherical (2)	6,328	
Spherical (4)	-15,219	
Spherical (6)	15,784	
Spherical (8)	-6,475	

**Fig.4.** Parameters of the required wavefront.

In the course of figuring of such surface, it is possible either to subtract the required wavefront from the one obtained during testing, or to produce CGH, which considers the form of the required wavefront showed in Fig. 2-3. In this case, we would actually test aspherical mirror of arbitrary surface figure as spherical one. Only in such case, it is necessary to carry out fine alignment of the hologram with respect to the component by matching its angular position with respect to the tested component with the mirror vertex position.

## References

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