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The shape stability of thin mirrors for Cerenkov experiments.

Schovánek P. , Palatka M.

Abstract

Temperature and tilt dependence of shape stability of mirrors are analysed by FEM program computing. The deformation of ultra thin glass mirrors is presented on 11 mm thin and 500 mm diameter mirror example.

Introduction

A lots of high energy physicist are interested in study of gamma sources in the universe. A gamma quantum transits through the atmosphere and irradiates a pulse of Cerenkov light. Shape of these Cerenkov pulses is studied to find direction of the gamma quantum trajectory and then position of gamma sources in space from these trajectories.

The Cerenkov light pulse is necessary to collect by a large area mirror because its intensity level is very low. Telescope named CAT located in French Pyrenees has 5m diameter mirror for example (fig. 1.). Mirror area is completed with 90 smaller mirror pieces 500 mm in diameter.

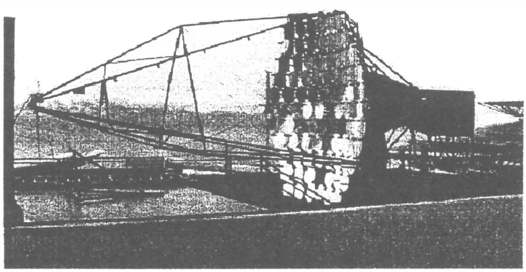

Fig. 1 : The CAT telescope in French Pyrenees

We cooperate with the international groups of physicist on two Cerenkov experiments projects named CAT and CELESTE . Our part is making and testing of glass Al mirrors. The stiffness of mechanical construction requires minimum thickness of mirror because the mass of glass is relatively heavy. Area of CAT telescope is about 19 m^2 . So large area is necessary to divided into smaller mirror pieces.

We have made glass mirrors with 500 mm diameter and 11 mm thickness. Four various curvature were required for CAT and CELESTE projects.

We have required to know shape stability so ultra thin mirror, specially deformation of mirror surfaces.

The shape stability of mirrors

The optical properties of any mirror depend on the accuracy of its reflection surface. The mirrors for Cherenkov CAT and CELESTE experiments have the spherical surface and the circular shape. Surface errors are caused by the quality of the manufacturing process and by the radius of curvature nonstability. The manufactured radius of curvature is deformed by a temperature fluctuation and by own weight of the mirror. The mirrors are held on the telescope construction of CAT project at three points on their circular edge (Fig. 2.) . They have a various position on the telescope dish and their tilts are different . See fig . 1 .

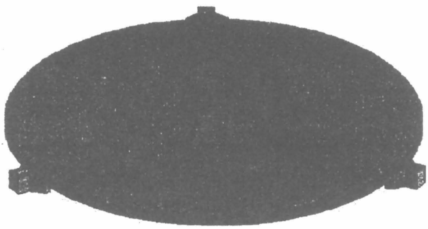

Fig. 2 : The mirror of CAT project with holders. Radius of curvature 12 000 mm thickness 11 mm and diameter 500 mm.

The temperature-dependence and tilt-dependence of curvature deformation of circular glass mirror were analysed by FEM computer simulation..

Tilt-dependence analysis

We present for example of analysis the mirror with diameter 500 mm and thickness 11 mm likes the mirror of CAT project and curvature R = 3600 mm (secondary optics of CELESTE project) here. The tilts were changed between the horizontal and the vertical position by step 30 degrees. We have chosen the temperatures -35° C , +20° C and +50° C .

The tilt-dependence analysis was made for a mirror rotation when one of the three holder was already on top edge of mirror . The extreme deformation of the curvature was found along the straight line which connects the mirror centre and the top holder . Some solution of this analysis is shown in Fig.3 and Fig.4. Face views of mirror in Fig.3. are rotated so that the top holder is on the right side. The reason of rotation is correct face view of mirror in Fig.3. regarding the graph in Fig.4.

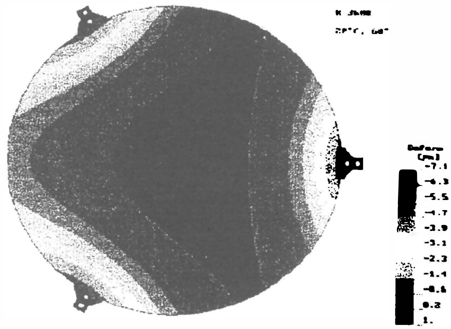

Fig . 3 : Face view of the mirror with radius of curvature 3 600 mm, thickness 11 mm and diameter 500 mm. The surface deformation for the mirror with tilt 60 degrees and temperature 20° C .

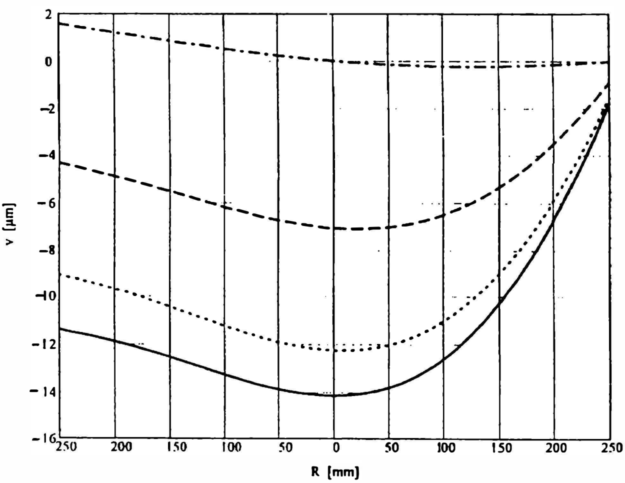

Fig . 4 : The surface deformation of the mirror with radius of curvature 3 600 mm thickness 11 mm and diameter 500 mm. The shift of surface in the normal direction vs. the diameter of mirror for various tilts and **temperature 20° C** .
Tilts are 0 degrees (solid line), 30 degrees (dotted line), 60 degrees (dashed line), 90 degrees (dash - dotted line).

The graph in Fig.4. shows the surface line deformation of radius of curvature for a surrounding temperature 20° C and four tilts. The extreme shift of the mirror surface exists in the centre of the mirror. The shift value is only about tens micrometers but for optical properties of any mirror the gradient of shift is more important. The extreme gradient of surface deformation is found in the horizontal position of mirrors near the edge of mirrors and their holders (Fig.3.).

Temperature-dependence analysis

Next step in analysis was the change of temperature. The graphs of the surface line deformation for -35°C and +50°C are shown in Fig.5. and Fig.6. When the mirror is cooled the concave surface becomes more concave in all tilts comparing with room temperature condition. On the contrary when the mirror is warming up the surface becomes light concave. We can see that the gradient of surface deformation has changed sign specially near hold elements.

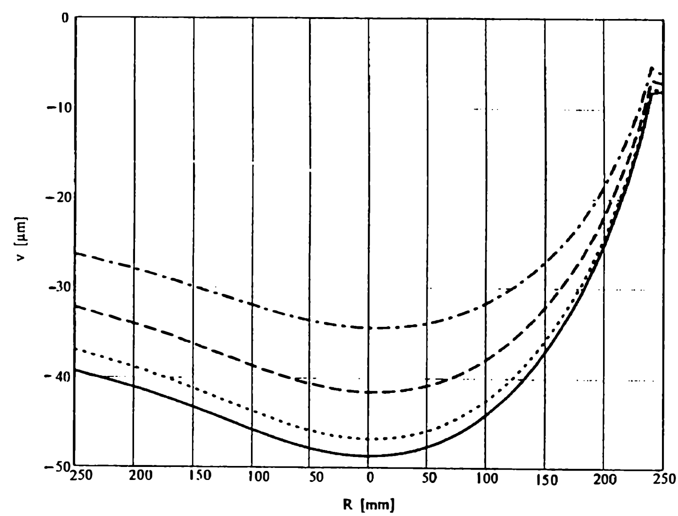

Fig . 5 : The surface deformation of the mirror with radius of curvature 3 600 mm , thickness 11 mm and diameter 500 mm. The shift of surface in the normal direction vs. the diameter of mirror for various tilts and **temperature - 35° C.**
Tilts are 0 degrees (solid line), 30 degrees (dotted line), 60 degrees (dashed line), 90 degrees (dash - dotted line).

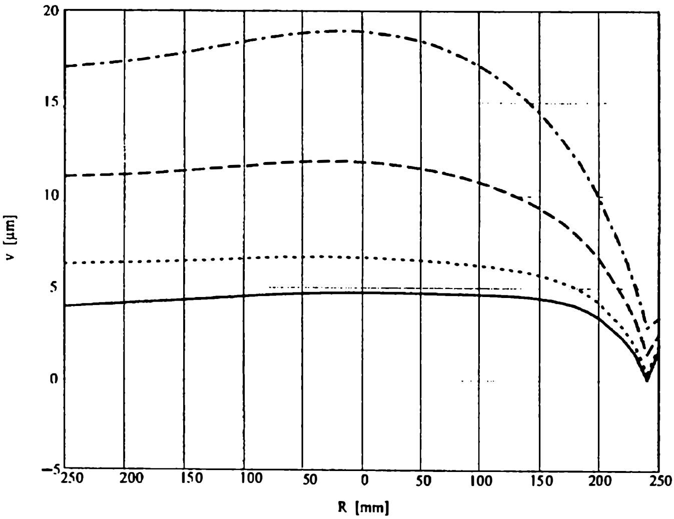

Fig . 6 : The surface deformation of the mirror with radius of curvature 3 600 mm thickness 11 mm and diameter 500 mm. The shift of surface in the normal direction vs. the diameter of mirror for various tilts and **temperature 50° C**.
Tilts are 0 degrees (solid line), 30 degrees (dotted line), 60 degrees (dashed line), 90 degrees (dash - dotted line).

How we can see from all figures the extreme gradient of the surface deformation is near holders of the mirrors on small areas. We are interesting in value of this gradient because this slope error leads to the change of a reflected ray direction and to spreading light spot of light source image in focal plane of the mirror.

Conclusion

The analysis shows that the maximal value of surface error is less than 0.5 mrad that is in agreement with desired optical properties of mirrors for CELESTE and CAT projects.
Similar analysis for mirrors with radius of curvature 2240 mm and 1450 mm was made too.

We would like to thank ing. Pavel Marcian and his firm Dystiff Olomouc for cooperation on shape analysis of mirrors. The computer program which was used for analysis is named ANSYS Ver. 5.3 . Its main function is computing problems related to elasticity and strength of constructional details.

References

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2. CELESTE , Experimental proposal , 1995,

Authors Addresses

Petr Schovánek, RNDr.
SLO UP a FzÚ AVČR Olomouc, tř. 17. listopadu 50, 772 07 Olomouc
tel. 068-563 1503, e-mail : schov@risc.upol.cz
Miroslav Palatka, RNDr.
SLO UP a FzÚ AVČR Olomouc, tř. 17. listopadu 50, 772 07 Olomouc
tel. 068-563 1516, e-mail : palatka@risc.upol.cz