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Mechanical design and deflection analysis of TACTIC gamma-ray telescope

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Abstract. The high sensitivity gamma-ray telescope TACTIC to be set up at Gurushikar is presently being manufactured at the Central Workshop, BARC. Deflection analysis of the mirror basket assembly, which holds 34 spherical mirror facets weighing about 1 tonne, has been performed to arrive at the deflection in the position of the focal point of the mirror combination at various zenithal positions. The results of this analysis and the mechanical design aspects of the telescope are discussed.

Key words : mirror basket—mechanical design—deflection analysis

1. Introduction

One unit of the TACTIC gamma-ray telescope (see Koul *et al.* 1993) is presently being manufactured at the Central workshop, BARC. The 34 spherical mirror facets of 0.6 m diameter are mounted on a mirror basket of size 4 m × 4 m to generate common quasi-parabolic surface of 4.1 m focal length. This surface reflects the light parallel to its principal axis to the focal plane instrumentation of the telescope. During tracking the mirror basket orientation changes with time resulting in the deflection of the individual mirror axes which changes the spot size of the mirror from one position to another. The telescope comprises a number of distinct mechanical subsystems.

2. Mechanical design details

One assembly of the telescope comprises the following sub-assemblies (figure 1) :

2.1. *Mirror basket*

It is a tubular 3 dimensional truss type structure weighing about 1 tonne. It supports 34 mirror facets, each one of which is mounted on a three point support structure fixed to the mirror basket. Upper members of the trusses form an approximate spherical surface of 8566 mm radius. Lower members of the trusses form a plane surface welded to the mirror basket structure. Mirror basket assembly is actually made in three parts and bolted together, for ease of manufacture and transport. Heavier central part of mirror basket has provision for

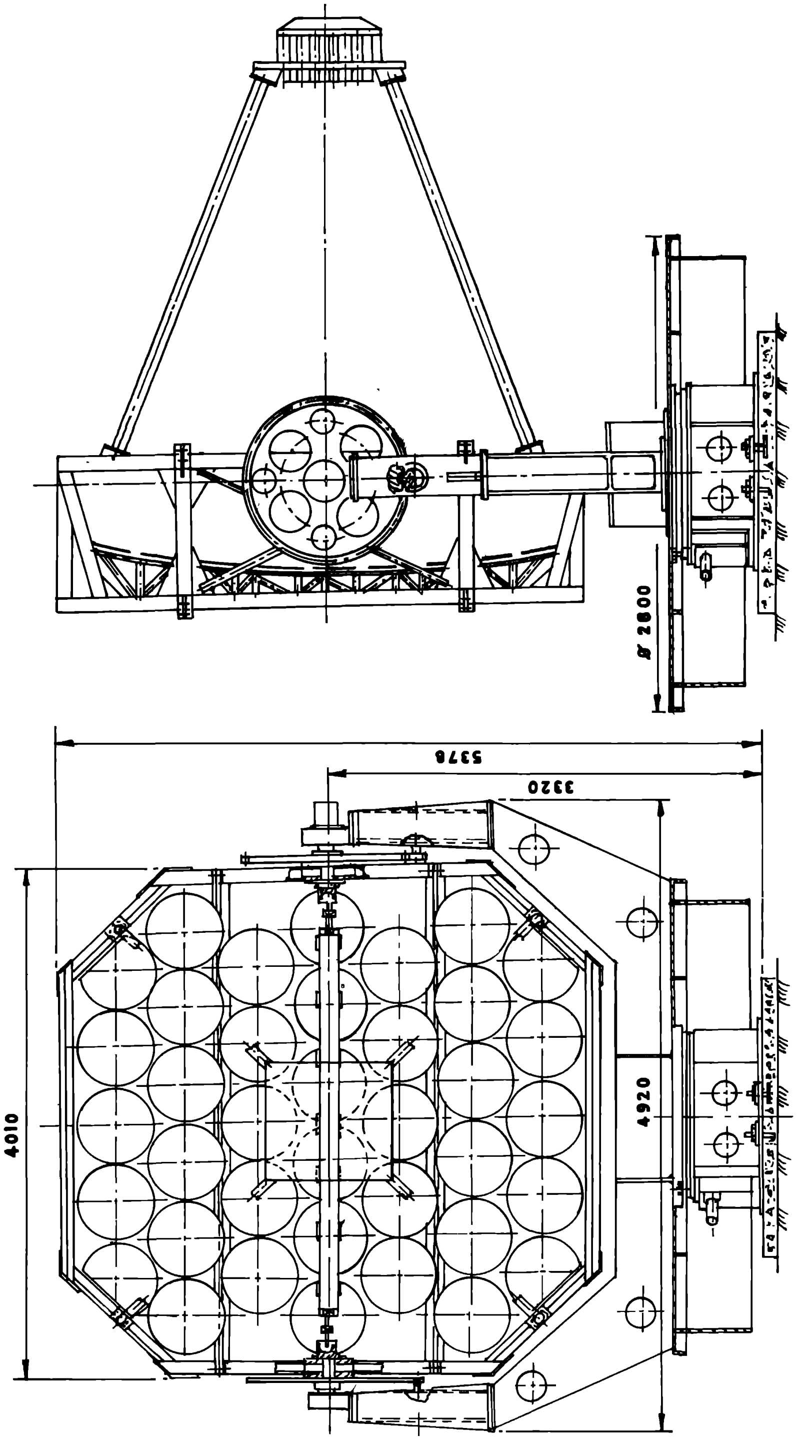

Figure 1. The front and the side elevation view of the TACTIC Imaging Unit.

fixing it to 2 large (1200 pcd) gears, weighing 184 kg each. A common shaft assembly (4.8 M long) fixed in self aligning ball bearings has these large gears fixed on it. Rotation of these gears provide the zenithal rotation of the mirror basket.

2.2. *Mirror fixing/adjusting frames*

600 mm dia. mirror facets are fixed in such a way as to obtain desired inclination for each of the mirrors w.r.t. the mirror basket axis. The mirrors thus can form a common parabolic surface of 4 m focal length. After obtaining the desired inclination, the supporting studs can be locked in position to maintain the desired orientation.

2.3. *Fork frames structure*

Mirror basket is supported and held in the middle of a 5 m $\times$ 3 m $\times$ 0.4 m thick fork type frame structure. It also contains the mirror basket (zenithal) drive system in its arm. Base, of the frame is clamped on the large gear of the azimuthal drive rotary table of the telescope.

2.4. *Rotary table and its special thrust bearing*

Rotary table of the telescope has a specially made 900 mean dia. roller thrust bearing consisting of hardened & ground top and bottom races and 100, 18 mm dia $\times$ 18 mm long hardened rollers. It supports the 7 tonnes weight of the moveable upper part of the telescope.

2.5. *Mirror basket (zenithal) drive assembly*

Two sets of 5 stage gear boxes (all precision ground gears) with a total speed reduction of 6631 are used to drive the mirror basket at the required speed of 5 degrees/hr (min.) to 1600 degrees/hr (max.).

2.6. *Rotary table (azimuthal) drive assembly*

Here also two sets of 4 stage gear boxes on opposite faces of the rotary table with total speed reduction of 6349 are used to drive the telescope about the azimuthal axis at the required speed of 5 degrees/hr (min) to 1600 degrees/hr (max).

2.7. *Encoders and motors for the drives*

Evershed UK makes hybrid stepper motors type FEL 23, having a torque capability of 100 Nt-cm. power the two drive axes of the telescope. Due to the large reduction gear ratio, these motors have to operate at high stepping rates of about 1.5 KHz. CCC US make synchro based absolute encoders are used to read the absolute position of the two axes. (refer Koul *et al.* 1993 for more drive details).

2.8. *PMT support boom*

Four nos. of 3.45 meters long members connect the PMT (photomultiplier tube) assembly to the mirror basket.

2.9. *Focal plane instrumentation*

The TACTIC Cerenkov Light Imaging Camera (CLIC) comprises 400 photomultiplier tubes arranged in a 20 $\times$ 20 square grid assembly covering a field of view of 7.2° $\times$ 7.2°. The CLIC has a light tight motorized lid to prevent any accidental leakage of light which might damage its photomultipliers.

3. Angular accuracy

The 14 bit shaft encoders provide a position resolution of 1.3 arcmin and a position accuracy of 6 arcmin. However with tracking scheme being implemented, a tracking accuracy of 0.2 degrees is expected. Mirrors will be aligned to a common focal point with an accuracy of about 0.1°.

4. Deflection analysis

The structural deflections of the (i) mirror basket frame, (ii) mirror holding attachment and (iii) PMT support booms due to their self weight and dead weight of 34 mirror facets were determined at different angular positions of the telescope using FEM software package. New co-ordinates of the nodes after deflection were calculated. Here we made an assumption that each mirror after attachment, lies in a plane which is parallel to the plane of the three nodes to which that particular mirror is attached. The direction-ratios of the plane containing three nodes before deflection, for each mirror is determined. Then considering the new plane for the same three deflected nodes, direction-ratios are calculated. With the help of direction-ratios, angle between the two normals or planes are determined. Using angular deflection, lateral shift of the PMTs with respect to the position of axis of a specific mirror is calculated. Deflection due to mirror holding attachment and PMT support booms is calculated separately. This helps us to check the adequacy of the structural design as each mirror's alignment is to be retained during all the positions assumed by the telescope.

5. Results of analysis

Maximum value of the shift of some mirrors w.r.t. its PMT axis are as follows :

(1) 4.71 mm for mirror no. M13 of central frame at zenithal angle '0 degree'

2.60	+	0.90	+	2.75	–	1.54
(a)		(b)		(c)		(d)

(2) 4.27 mm for mirror no. L3 of left frame at zenithal '0 degree'

2.05	+	0.90	+	2.75	–	1.54
(a)		(b)		(c)		(d)

(3) 2.26 mm for mirror no. M13 of central frame at zenithal '90 degree'

2.26 (a)

where (a) = deviation due to deflection at the nodal attachment of mirror, (b) = deviation due to deflection at the nodal attachment of mirror, (c) = deviation due to bending in vertical frame member, (d) = deviation due to deflection in support-booms. The results of deflection analysis show that PMT's would be out of focus of mirrors approximately by 5 mm, which is within the acceptable limits.

Reference

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