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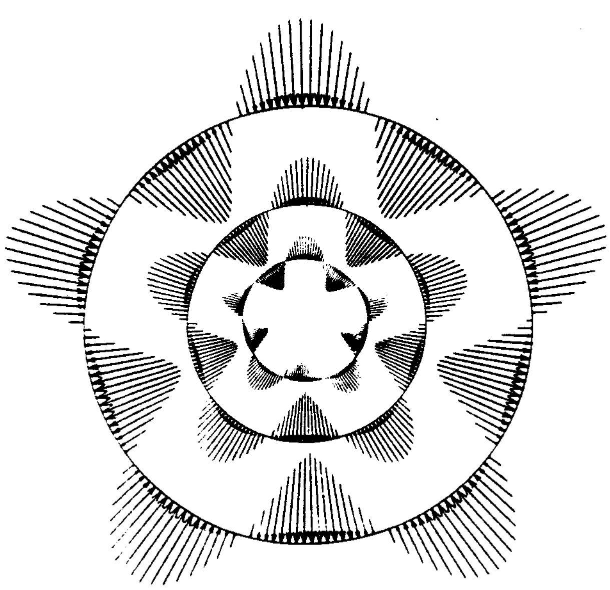
COLUMBUS PROJECT

MIRROR BLANK 8.4 mt diam F/1.14

SUMMARY OF THE NUMERICAL ANALYSIS DEALING WITH THE CONCEPTUAL DESIGN OF PRIMARY MIRRORS HANDLING



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BCV progetti performed stress analysis of primary mirrors of Columbus telescope during handling operations, in operative conditions and in telescope cell in non operative conditions (earthquake pads).

In the following pages we summarize, from the conceptual point of view, the main results obtained with these analysies. For quantitative results or for a complete description of our analysisies we refer directely to the reports N° 117 - 118 - 123 (rev.0,1) - 124 - 126 - 127 - 128 - 129 - 130.

The stress analysies of primary mirror can be subdivided in the following items:

- **Mirror in telescope cell in operative conditions** (axial - lateral supporting system is active)
  - Mirror zenith pointing (rep. N° 117)
  - Mirror horizon pointing (rep. N° 123 Rev.0,1)

- **Mirror in telescope cell in non operative conditions**
  - Mirror zenith pointing (rep. N° 126)
  - Mirror horizon pointing (rep. N° 124)

- **Handling**
  - Mirror zenith pointing (rep. N° 126)
  - Mirror nadir pointing (rep. N° 129)
  - Mirror horizon pointing (rep. N° 128)

In all the cases considered global analysies and local analysies have been performed. Global analysies give us average stress values and big scale stress patterns. Local analysies give us stress peaks and stress patterns produced by singularities in the geometry (for example crosspin holes, ventilation holes) or by singularities in the applied loads (for example concentrated loads, force offsets and so on).

We want point out that global and local analysies have been performed syde by syde. So sometimes a report doesn't exhaust the analysies relative to a particular load condition since, for example, local checks have been performed in a succesive step.

In this report there aren't new results, the main task of this summary is to point out the thread connecting the results obtained during the old analisies.

At this purpose we want point out the importance of the results in report N° 130: the estimation of the effects produced by crosspin holes in the ribs require changes in the handling schemes considered in reports N° 126-128-129.

For what it concernes the load acting on the mirror, the following load patterns have been considered:

- Axial forces applied on the back plate
  - placed at the external and internal rings (rep. N° 126 - 130)
  - placed at the rib intersections (rep. N° 117)
- Axial forces applied on the upper plate
  - at the external and internal rings (rep. N° 129 - 130)
- Lateral forces on the back plate
  - Due to operative lateral supports (rep. N° 123 - 126* - 127)
  - At the back plate external edge due to "earthquake pads" (rep. N° 124 - 126* - 127).
- Lateral forces on the external edge of both upper and lower plate (rep. N° 126* - 127 - 128 - 130)

  (* for ventilation hole local effects).

Before to analyze the results obtained it is usefull to point out some general concepts:

- In all the analysies performed we neglected the elasticity of the cell: it has been considered having infinite stiffness.

  Elastic strains of the cell, inelastic ones (due for example to manifacturing) and tolerances could alterate the force distribution on the mirror, producing forces and stresses concentration. So it is necessary to design an opportune system in order to compensate elastic and inelastic cell displacements.
- All stress checks have been performed for stated load conditions acting on the mirror. Such load distributions came from hypotesis and/or analysies performed by means of simplified models. Obviously in order to respect stress values and patterns so estimated it is necessary to guarantee these load distributions. So in our opinion it is necessary to have the possibility to controle the applied loads. This could be obtained for example by means of hydraulic devices exerting well known pressures or by leverages. By means of these devices it is also possible to compensate geometry tolerances that otherwise could produce partial contacts and stress concentrations.

- All contacts between mirror and devices that exert forces must be realised by means of material having opportune stiffness and low friction coefficient in order to avoid concentrated contacts and friction forces.

We can now point out the main results obtained in our analisies.

MIRROR IN TELESCOPE CELL - OPERATIVE CONDITIONS - ZENITH POINTING (rep. N° 117)

The big number of supporting points makes useless a global stress analysis.
Local stress analysies in rep. N° 117 showed that the maximum axial forces foreseen (1500-2000 N on a whole spreader) are compatible with tensile allowable stress assumed equal to $0.7 \frac{N}{mm^2}$.

MIRROR IN TELESCOPE CELL - OPERATIVE CONDITIONS - HORIZON POINTING (rep. N° 123 rev. 0-1; rep. N° 126-127)

The analisies performed showed that, since the lateral force offset, it is very unfavourable to apply lateral forces at single supports. So we suggested to apply lateral forces only by means of spreaders and to reduce maximum lateral load applied by spreaders.
Prudentially we suggested to fix this maximum load as 2500 N for the whole spreader.

MIRROR IN TELESCOPE CELL - NON OPERATIVE CONDITIONS (EARTHQUAKE PADS OLD CONCEPT) - ZENITH POINTING (rep. N° 118 - 126 - 130)

and

HANDLING - MIRROR ZENITH POINTING (rep. N° 118 - 126 - 130)

Results in report N° 118, confirmed by results in report N° 126, showed that it is unsafe to sustain the mirror only at external ring.
In report N° 126 we checked the case with 25% of dead weight at inner ring and 75% at the external one. In such a way maximum tensile stress in back plate is $0.68 < 0.7 \frac{N}{mm^2}$ (rep. N° 126 pag. 42).
Tensile stress peak produced by crosspin holes in the ribs near internal ring is estimated as $1.55 > 0.7 \frac{N}{mm^2}$ (see rep N° 130 pag. 13), so it is necessary to modify support pattern used in report N° 126, for example shifting the internal pad ring increasing its radius. In this way,

since the number of loaded ribs increases, the stresses decrease. (N.B. none stress check has been performed for this condition)

It could be interesting to note that if we balance 20% of dead weight at internal ring and 80% at the external one, tensile stress in back plate don't increase to much (from 0.68 to 0.72 greater but $\cong 0.7 \frac{N}{mm^2}$). These load shares are those relative to the case of mirror nadir pointing, so probably the same device can be used for both the cases.

Obviously also in the case 20%-80% we have the overstresses produced by crosspin holes in the ribs near internal hole, so it is still necessary to increase the pad ring radius, in this way probably also tensile stresses in the back plate decrease a little.

MIRROR IN TELESCOPE CELL - NON OPERATIVE CONDITIONS (EARTHQUAKE PADS OLD CONCEPT) - HORIZON POINTING (rep. N° 124 - 126 - 127)

In this case we considered lateral pads distributed at the lower half of the external edge of the back plate (overturning moment is balanced by axial forces). The analysis showed that:

- if the elastomer layer is too soft maximum value of lateral force increases. So local stress peaks due to ventilation holes increase.

  On the other hand, if the elastomer layer is too stiff and the applied forces are not controlled, mirror casting and mirror cell tolerances, if not compensated, produce force and stress concentrations.
- To apply lateral forces only at the external edge of the back plate produces not negligible (but allowable) tensile stresses in the upper plate.
- Friction between elastomer pads and mirror produces unsafe tensile stresses in the back plate.

As conclusion this handling scheme seems us unfavourable.

HANDLING - MIRROR NADIR POINTING (rep. N° 126 - 129 - 130)

Also in this case it is unsafe to apply forces only at the external ring. For the stresses in the upper and lower plate the best dead weight subdivision is 20% at the internal ring and 80% at the external one (25% + 75% is unsafe).

Overstresses due to crosspin holes in the ribs near internal ring (rep. N° 130 pag 15) require to modify the force pattern used in rep. N° 129, for example increasing the radius of the internal pad ring in order to distribute the load on a greater rib number.

If the axial load is distributed (in radial direction) along a sufficient width, without concentrations along the external circumference, it does not produce unsafe effects (rep. N° 130 pag. 3-6).

HANDLING - MIRROR HORIZON POINTING (rep. N° 118 - 124 - 126 - 127 - 128 - 130)

We considered only the case with mirror + mold + water since in this case the mirror dead weight is considerably greater than in other cases.
It is surely a delicate handling condition. The numerous analysies performed showed that:

- It is unsafe to apply lateral forces on all the external ring wall (rep. N° 118 pag. 19). So we decided to apply lateral forces at the upper and lower plate edges.
- It is unsafe to have friction between mirror and handling device (rep. N° 124). By means of PTFE it is possible to reduce but not to eliminate friction.
- Since the ventilation holes near external edge of the back plate, it is unsafe to apply excessive radial load at the external back plate edge (rep. N° 127). So we proposed to reduce as little as possible the diameter of the ventilation holes near external and internal edges.

For the reasons explained in rep. N° 128 we think that it is dangerous to use tension band as handling device, so we proposed to use a steel frame composed by different sectors, assembled by bolts around the mirror resting on the platform. This frame will have box shaped cross section.
Other analysies showed that:

- Concentrated lateral loads are unfavourable as regards distributed one (rep. N° 127 pag. 8).
- Pull lateral loads are unsafe (rep. N° 128 pag. 10).
- The elastomer material layer placed between mirror and handling device must be quite stiff in order to distribute contact avoiding force concentration (if none other precautions are used in order to controle force values, but in our opinion the force controle is very recommended).
- It is necessary to foresee a supporting device regulation in order to compensate mirror casting and steel frame tolerances.
  In fact, if these tolerances would be compensated by means of the elastomer strains, big changes in lateral force distribution would be produced (rep. 128 pag. 32).
  Otherwise it is necessary to reduce considerably tolerance values.

- Ovalization of the internal hole is very dangerous since it produces tensile stresses ampliflied by back plate ventilation holes (rep. N° 128 pag. 53).
  So "lateral containment" forces are necessary.
- Mirror overturning must be balanced by axial forces (placed for example at the external ring).
- Some changes in the upper plate overhang shape the respect of lateral load location are necessary in order to avoid overstresses (rep. N° 130 fig. 11).
- In order to avoid overstresses produced by crosspin holes due to lateral force diffusion in the mirror thickness, it is necessary to preload in axial direction the mirror blank external edge by means of axial self balanced compressive forces applied to upper and lower mirror plates (rep. 130 pag.16).