Opto-mechanical design and fabrication of a highly reliable and light weight stray light baffle

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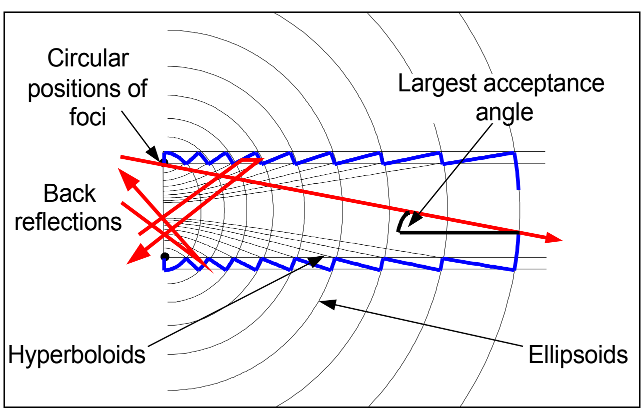
ABSTRACT

Optical instruments for remote sensing applications frequently require measures for reducing the amount of external, unwanted stray light in the optical instrument path. The reflective planet baffle design and manufacturing process for the thermal infrared imaging spectrometer MERTIS onboard of ESA's cornerstone mission BepiColombo to Mercury is presented. The baffle has to reflect the unwanted solar flux and scattered IR radiation, and minimize the heat load on the instrument. The baffle employs a Stavroudis geometry where alternating elliptical and hyperbolic vanes reflect radiation at incidence angles outside the instrument field of view. Due to the demanding requirements regarding surface quality, low mass and high mechanical stability, electroforming fabrication was selected for the baffle. During manufacturing, a layer of high strength nickel alloy, NiColoy® is electrodeposited onto a diamond turned aluminum mandrel. The mandrel is subsequently chemically dissolved. Not only the baffle, but also the baffle support structure and other mating components are electroformed. Finally, the baffle and support structure are assembled and joined by an inert gas soldering process.

BAFFLE GEOMETRY

Baffles are placed on the front of optical instruments like telescopes, cameras or spectrometers to shade the interior from solar and planetary radiation. A good survey can be found in Ref. 1. Based on optical stray light simulations and analyses of different baffle concepts the Stavroudis principle shows the best performance and the smallest number of internal reflections. The setup makes use of the optical properties of specific conic sections of revolution. These are the oblate spheroid, generated by rotating an ellipse about its minor axis, and the hyperboloid of one sheet, obtained by the rotation of a hyperbola around its conjugate axis. In both cases, the foci are also rotated about the axis of the conic, generating a circle in a plane perpendicular to that axis[2]. The working principle is shown in Figure 1: The majority of rays is leaving the baffle with one single internal reflection (i.e. minimum absorbed power), only some rays with two.



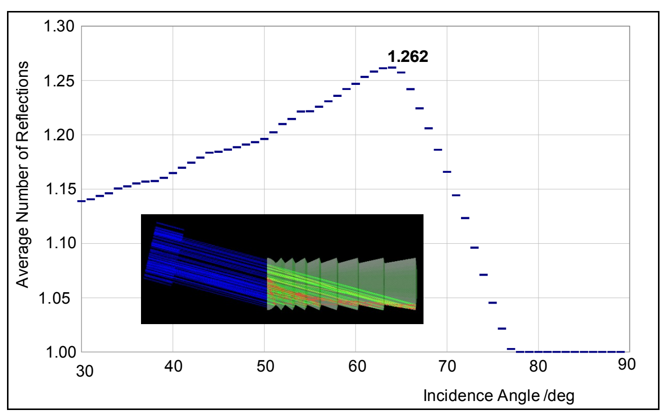


Figure 1: Consecutive ellipsoids and hyperboloids are leading to a minimum number of reflections.

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MANUFACTURING PROCESS

The design of the stray light baffle requires pristine surface quality with a roughness of 20 nm RMS or better, low mass of 0.25 kg or better and high mechanical stability and stiffness due to the extreme mechanical loads during launch. The first mechanical eigen mode of the baffle structure shall be above 150 Hz.

The net-shape electroforming fabrication process in combination with the mechanical properties of NiColoy® and the design of the electroformed baffle support structure provide the best solutions to meet the demanding requirements of the assembly.

Electroforming begun with a diamond machined mandrel that has the exact surface finish, dimensions and geometry desired of the inside of the finished part, cf. Figure 2. The mandrel was cleaned and a layer of NiColoy® - a proprietary Nickel-Cobalt alloy, was electrolytically deposited onto it. The plated layer was then laser cut on the ends to make the required orifices which define the instrument's FOV.

Finally, the aluminum mandrel was chemically dissolved in a caustic solution that does not attack NiColoy®. The result is shown in Figure 3: An 0.2 mm thick NiColoy® shell that has the desired net-shape of the baffle. Since plating is an atomic level process, exact replication of the optical surfaces was achieved. Additionally, internal stress of the deposit was kept close to zero, which eliminated geometric distortions of the optics.

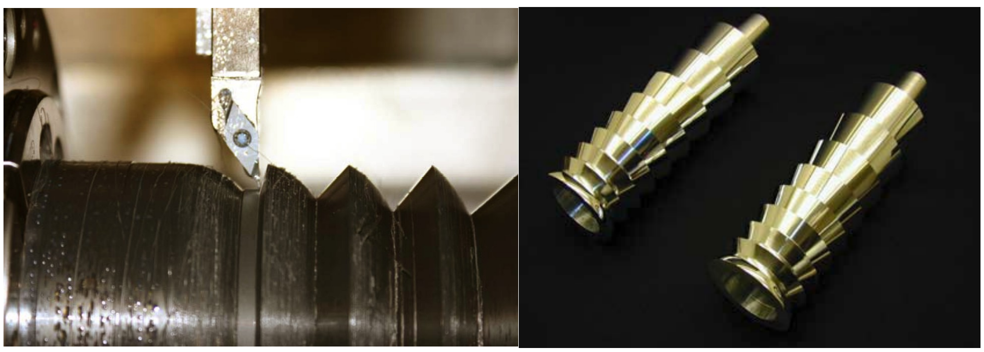

Figure 2: Diamond turning of mandrel.

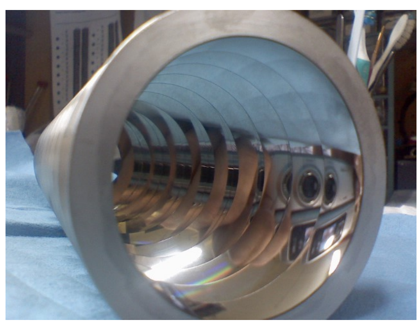

Figure 3:.Replication of the diamond turned mandrel on the inside of the electroformed baffle.

MATERIAL SELECTION

The baffle, being a flight component, requires a low mass and high strength material. NiColoy® has a density of 8.88 g/cm^3, which is relatively high compared to traditional aerospace materials, like Titanium Alloys[3] (~4.5 g/cm^3).

The electroforming process gives the ability to deposit a thin but uniform wall of material which allows for fabrication of a low mass component. Examining the material options that are available through electroforming, NiColoy® proved to have a higher strength than pure electroformed Nickel[4]. Moreover, compared to Titanium Alloys, NiColoy® has similar Yield Strength, Ultimate Tensile Strength and Modulus of Elasticity. Based on these values and detailed structural analysis for the component, it was determined that NiColoy is a suitable material for baffle fabrication. See the comparison in Table 1 below.

Table 1: Comparison of Mechanical Properties

Material	Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	Modulus of Elasticity (ksi)	Elongation at Break (%)
NiColoy®	96-120	125-150	20000-22000	2.5-7.5
Titanium Alloys[3]	110-205	120-229	15200-17800	4-18
Electroformed Nickel[4]	60-80	90-120	21000	10-20

MATING COMPONENTS AND ASSEMBLY

The extreme loads and intense vibrations that the planetary baffle will experience during launch required the additional design of a support structure for the baffle. The use of electroforming enabled the design of a single, thin walled sleeve- type support structure as opposed to an eight piece “rib-like” structure which was originally proposed. This single component structure simplified the assembly process and further reduced the overall weight of the component as compared to alternative designs. Assembly of the baffle, support structure, aperture and flange was completed in an inert gas soldering process. Since all mating components were fabricated with the same material, the coefficient of thermal expansion is the same from component to component, making for a more stable assembly.

Figure 4: Planetary baffle assembly (length is 220 mm and diameter is 70 mm).

SUMMARY AND CONCLUSIONS

Electroforming of NiColoy® has been implemented in manufacturing the planetary baffle that takes advantage of the Stavroudis geometry to reflect radiation at incidence angles outside the MERTIS instrument field of view. The high strength of NiColoy® and the replication capabilities of electroforming enabled the manufacturing of this baffle which cannot be made by any other method. By manufacturing the mating components from NiColoy®, a strong and rigid component with a first eigenfrequency at 323 Hz, a low mass of 0.232 kg and uniform thermal properties has been achieved.

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