UNIQUE APPLICATION OF PLASTICS AND COMPOSITE MATERIALS IN THE DESIGN OF THE MAGNETOMETER INSTRUMENTS FOR THE ULYSSES AND CASSINI SPACECRAFT

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ABSTRACT

T"he JPL magnetometer design for the Ulysses solar polar mission is the first to explore the structure and characteristics of the magnetic field out of the ecliptic plane. A dual technique combination vector/scalar that modified second generation sensor is currently being manufactured for the Cassini mission. The experience gained from JPL's successful magnetometer designs flown on Pioneer and ICE spacecraft establish a goal for performance and specific requirements governing the new vector helium design. Three major considerations incorporated in the design were greater use of lightweight composite and plastics, interchangeability of the sensor components, and self-alignment of optical components. The nonmagnetic characteristics of plastics and their lightweight to strength properties worked together to meet the 900 gram limit for the boom-mounted sensor. A wide range of nonmetallic materials were candidates in the selection for use in the magnetometer components. The primary requirements beyond environmental and structural were stringent criteria that all materials and processes for parts be nonmagnetic and free from the thermocouple effect that causes the slightest thermal electric noise from the interaction of dissimilar materials. To accomplish this, the manufacturing and assembly must be free of contamination from particle inclusion in the material manufacturing, forming, process and finishing operations. The further requirement that no part of the sensor could have permeable properties in the plastics or adhesives. The dimensional stability of the instruments' optical axis was a critical consideration in the CTE properties of the materials selected.

HISTORY

This paper presents the unique function of composites and plastics over a two decade period in the development of Helium magnetometers for deep space exploration . Currently two magnetometers are in production for the **1997** Cassini Spacecraft mission to Saturn. These magnetometers function either in a vector mode, where the 3 mutually orthogonal components of the magnetic field are measured or in a scalar mode where the field is measured. [n the vector mode accuracy is better than .1% where as the Scalar mode absolute accuracy is on the order of 1 % in 105 1 he range of field detection sensitivity is from a few nano Teslar to 4400 n T (nano Teslar). To achieve magnetometers of this Precision and still weather the rigors of space flight require materials having unique properties. figure-1 T-he experience gained from JPL

successful Magnetometer design flown on pioneer-1O and 11 and ICE E-3 Space craft establish goal for performance and specific requirements governing the new VHM design. The three major considerations incorporated in the design concepts were 1) greater uses of light weight composites and plastics. 2) interchangability of the sensor components and 3)selfalinginment of internal optical components .4) long projected stable life of the material in deep space environment. The design for packaging the JPL vector helium magnetometer started with magnetometer science instrument selection to fly the out of the ecliptic solar polar mission on the Ulysses spacecraft The Magnetometer
unique application of plastic and composite materials for the design of manufacturing the Ulysses space craft V/MS magnetometer and the CASSINI spacecraft V/SHM magnetometer

[PHOTO ULYSSES]/f (MAG ASSEMBLY)

Why plastics were selected

Plastic and composite materials application in the design of a Vector Helium Magnetometer was the only range of materials that could both met the structural strength mass weight requirements and transparency to magnetic fields, but shield from electric fields and provide shielding requirements to record the magnetic fields of outer planets. the use of adhesives and bonding resins to eliminate mechanical fasteners and secure elements of the sensor into a monolithic system.

Primary goals of the design effort:

- Transparent to incoming magnetometer waves
-EMI shielding for sensor
- Light weight
-Thermal stability and capability with other elements of the sensor for optical alignment
-Non-by metal effects of the material in the sensor assemblies

Successful use of plastic and composite materials for the Ulysses space craft Magnetometer

Sensor design requirements

Operational and within calibration after three axis 100 G'S centrifuge test

1 hermal environment of +30 deg. and - 130 deg. C

Total weight of 900 grams

Magnetically quiet at Pico Teslar levels.

Sensor configuration

I-he sensor elements are configured in a cylindrical stacked assembly with parts internally stacked in a flashlight and battery like system where the basic five elements that require alignment for the detector system are staged in side a graphite epoxy tube that serves as the primary structure all the sensor elements. the magnetometer field coils are supported from the external surface of the graphite tube. the other elements of the sensor head are shown in figure-2

[PHOTO EXPLODED VIEW OF SENSOR]2

Material selection

A wide range of non metallic materials wore candidates for use in the Magnetometer design. they have been screened in an empirical fashion over the three decades of the sensor development to find the optimum match between the structural value and the specific function in the sensor realize the highest sensitivity by not generating magnetic noise due to by metal erni generation or dimension instability due to temperature change. the signal drift in the sensor performance due to thermal or special changes of the composites due to that temperature gradients has been the focus of component dersign and development. the industrial supplier of these materials have over the years up graded. the manufacturing process to meet higher quality controls and the natural improvements to the product to meet the high tech purity requirements of the electronic industries . these improvements have allowed us the reconsideration of a material that had special properties to be re-introduce for use in the instruments ; such as vespel for the field coil structure.

The primary requirements beyond the material adequacy to meet the structural requirement of a 100 g three axis launch environment and the ability to perform in a thermal environment of + 130 to - 30°c;is the properties free from interactions with other materials that would generate thermal electric noise to the sensor detection system. The most stringent requirement that no part of the sensor could have permeability properties in the materials used in the instrument or contaminated with particulate inclusions of materials that had in the forming process of manufacturing contaminated element used in the sensor. The slightest amount of permeable material as a "smudge" or micro chip of material would be detected as "hot" condition by a process detector system using a flux tank chamber made of mu-metal to null the earth geomagnetic field and a flux gate Magnetometer to detect residual magnetic charge. The parts are assayed on a regular basis while in the fabrication to identify the process step that is contaminating the part or contamination from permininability materials during the process or handling operation. The second level of sensor performance degeneration is from by-material effect with in the thermal performance window that ranged from +130°c to -30°c. the material mix can create a nonlinear performing response of the sensor . careful selection was made of compatible material CTE to maintain pre-load on the stack of internal components for performance stability.

The early development testing of proto sensor sub assemblies units and with the proto sensor assembly revealed the problem areas to be design around to assure a quite sensor un affected from thermal changes. Thermal electric noise generated from thermal gradients in by-metal parts assembled make up the magnetometer sensor the mission were compatible with other material selection. CTE's and free of permeability as material supplied for manufacturing components.

Magnetometer composites and plastic compotes identification and functional:

- Lamp housing LEXAN
- Cell housing LE XAN
- Detector GLASS/EPOXY BOARD
- High voltage starter transformer GLASS/EPOXY BOARD
- Field coil housing LEXAN
- Secondary field coil housing LEXAN
- SEnsor case GRAPHITE EPOXY
- . Thermal isolation support tube KEVELAR 49
- Pre-load and alignment yoke LEXAN
- Secondary boxing coils VESPEL POLYIMIDE
- Coaxial cable guides KEVLAR
- Non-generating emi heater EPOXY GLASS AND RESIN

Material	Tensila psi(MPa)	Elongation %	Modulus × 10EE PSI (MPa)	Shear psi(MPa)	CTE / c
KEVELAR	157000 (1150)	16	1.0 (6895)	6300 (44)	4.1
Thornel T-300 Fbertwrite HMF 341 /34	109900		10.74 ( )? ~ 70000	7900 (55)	-4 +2
Lexan 1500	9900	110	.0345 (240)	6000 (42)	37.6

Special manufacturing techniques and adhesive bonding

The manufacturing process for a highly sensitive detection system for magnetic planetary magnetic field require special c controls on all phases of production to safe guard against contamination. micro partial of permeable materials will be detected as back ground noise or a hot condition in the instrument calibration against the earth's ambient magnetic field. therefore all elements production for the sensor are assayed to be free of magnetic response from permeability material inclusion in forming processes or surface particulate transferred to the parts surface. materials were screened during all phases of production to assure quality .

A number of special fixturing devices were required for the machining operation and many annealing process steps to achieve the high tolerance parts. mandrill for the composit elements were carefully designed 10 control inter-changeability and part alignment in assembly.

[PHOTO OF FIELD COILS]4 [PHOTO OF VESPEL FIELD COILS]5

The lamp cell optical reflector surface was a special process where a vapor source of methalyne cloride was used to blend a pre-polished optical reflector surface to generate a highly specular substrate in the lexan. The surface was then vacuum coated with a flash of copper(350 å) and 1800 a of vapor deposited Gold. The Gold film is then conductivley bonded with optics to a thin grounding ring and secured in assembly with 2216 Epoxy

[PHOTO OF LAMP HOUSING]6-

Future mission applications requiring a set of field large field coils approximently 6.00 in, diameter have been designed for the sensor using vespel rings that nest together to form a supporting structure and three axis coil groves positing around the censor cell. the strength to weight and thermal stability of vespel material meet the design requirements

[PHOTO VESPEL COILS] 7-

In conclusion the versatility of plastics and composit materials have over the last twenty years facilitated the development of highly sensitive sensor for deep space magnetic field definition and mapping of variations around the members in our planet system.

The magnetometer has for the first time observed while traveling out of the ecliptic plane around the solar poles the sun's heliospheric magnetic field originating in the sun's surface field. While field lines are drawn out into intertplanetary space in the high electric photosphereas investigation using the magnetometer will look at the heloispheric magnetic field as related to studiy of the solar magnetism.