Technology Focus: Test & Measurement

Instrument for Measuring Thermal Conductivity of Materials at Low Temperatures

Applications include development of novel materials as well as quality control for materials and process requirements.

John F. Kennedy Space Center, Florida

With the advance of polymer and other non-metallic material sciences, whole new series of polymeric materials and composites are being created. These materials are being optimized for many different applications including cryogenic and low-temperature industrial processes. Engineers need these data to perform detailed system designs and enable new design possibilities for improved control, reliability, and efficiency in specific applications. One main area of interest is cryogenic structural elements and fluid handling components and other parts, films, and coatings for low-temperature application. An important thermal property of these new materials is the apparent thermal conductivity (k-value).

Thermal conductivity testing is needed as part of the physical characterization of these various new and innovative polymers and composites. The Cryogenics Test Laboratory (CTL) at Kennedy Space Center designed and built a cryostat test instrument to measure the thermal conductivity of these types of materials at low temperatures. The instrument, known as the Cup Cryostat, is a small-scale cryogenic boil-off calorimeter designed to determine the apparent thermal conductivity (k-value in milliwatt per meter-Kelvin) of materials for cryogenic temperatures and specifically at large temperature differences. Boundary temperatures are typically 300 K and 80 K, or any temperature difference in this range. The instrument's direct measure of the rate of thermal-energy transfer (power, in watts) provides relative thermal performance among materials (i.e., comparative k-value).

The Cup Cryostat method provides thermal conductivity data under representative-usage conditions, including a large temperature difference (delta-T) that is typical for most cryogenic applications. The materials are tested in a way that approximates the way such material would be implemented to solve engineering design problems. The new method is therefore complementary to the small temperature difference data generated by existing standard methods. The Cup Cryostat uses moderate size 75-mm-diameter round specimens, which is reasonable for the production of novel research materials. Thicknesses of up to 13 mm are permitted, but a 6.5-mm thick specimen is typical. The Cup Cryostat also provides mechanical compression loading capability so that thermal performance data can be obtained under representative mechanical loading. In addition to nitrogen, the Cup Cryostat can be operated with other fluids, such as Freon and other suitable liquid refrigerants. For porous materials, residual gases such as helium, air, nitrogen, argon, or carbon dioxide may be selected for the environmental condition. All tests are performed at ambient (room) pressure. The compact design of the Cup Cryostat allows for specimen installation, system preparation, and cryogenic testing to be completed in less than one day, which means that costly set-up within a vacuum chamber is avoided.

The Cup Cryostat is designed to determine the apparent thermal conductivity under representative-use conditions of large delta-T and also with appropriate compressive loading, as desired. The test is comparative in nature, so absolute values must be obtained by direct comparison with known materials.

This work was done by James Fesmire, Jared Sass, and Wesley Johnson of Kennedy Space Center. For more information, contact the Kennedy Space Center Innovative Partnerships Program Office at (321) 867-5033. KSC-13217

Multi-Axis Accelerometer Calibration System

Langley Research Center, Hampton, Virginia

A low-cost, portable, and simplified system has been developed that is suitable for *in-situ* calibration and/or evaluation of multi-axis inertial measurement instruments (e.g.,). This system overcomes facility restrictions and maintains or improves the calibration quality for users of accelerometer-based instruments with applications in avionics, experimental wind tunnel research, and force balance calibration applications. The apparatus quickly and easily positions a multi-axis accelerometer system into a precisely known orientation suitable for *in-situ* quality checks and calibration. In addition, the system incorporates powerful and sophisticated statistical methods, known as response surface methodology and statistical quality control. These methods improve calibration quality, reduce calibration time, and allow for increased calibration frequency, which enables the monitoring of instrument stability over time. This technology overcomes the limitations and restrictions on accelerometer calibration facilities by:

- Minimizing reliance on a fixed calibration system,
- Leveraging the user's data acquisition system,
- Allowing for increased calibration frequency due to improved accessibility, and
- Automatically compensating for local gravitational field.

The cuboidal positioning system can be used to calibrate or evaluate single, dual, or triaxial packages. The system employs a simplified, linear mathematical model that is a function of gravitational components.

At the time of this reporting, NASA has built six systems in support of program operations. Further development is expected to expand the system's capabilities to other instruments and to complete temperature characterization.

This work was done by Tom Finley and Peter Parker of Langley Research Center. For further information, contact the Langley Innovative Partnerships Office at (757) 864-8881. LAR-17163-1

Pupil Alignment Measuring Technique and Alignment Reference for Instruments or Optical Systems

This technique can be used in any instrumentation that requires measurement of pupil alignment, such as optical instruments and cameras.

Goddard Space Flight Center, Greenbelt, Maryland

A technique was created to measure the pupil alignment of instruments *in situ* by measuring calibrated pupil alignment references (PARs) in instruments. The PAR can also be measured using an alignment telescope or an imaging system. PAR allows the verification of the science instrument (SI) pupil alignment at the integrated science instrument module (ISIM) level of assembly at ambient and cryogenic operating temperature. This will allow verification of the ISIM+SI alignment, and provide feedback to realign the SI if necessary.

This innovation consists of a 10-mm reflective patch on the +V1 face of a filter or closed position of the SI pupil wheel. The PAR will have a centered alignment crosshair and a minimum of two concentric circular fiducials representing a reference for the SI pupil alignment. The fiducials need not be exactly centered to the nominal SI pupil position, but their alignment relative to the nominal pupil position must be known to 0.2-percent of the pupil diameter. A clocking reference point should also be included in one quadrant to provide a reference.

The SI teams will reference their pupil alignment to the PAR during their instrument alignment, and measure the PAR in the +V1 horizontal and +V1 down orientation at ambient temperature relative to the nominal V Coordinate system. The teams must demonstrate by test and analysis that the SI internal pupil alignment (from the kinematic feet up) is within the 0.5-percent placement allocation in 0-G. In addition, the SI team must demonstrate by test and analysis that the pupil alignment is within the 1-percent placement allocation in 1-G to a knowledge tolerance of 0.5 percent.

For ISIM, the PAR will be used at ambient temperature to verify that the SI has been installed to within allocated tolerances, and that its alignment does not shift due to vibration and other environmental test exposures. Ambient temperature measurements are performed using a PAR ISIM reference fixture to place alignment telescopes along the nominal chief center ray of each SI. The alignment telescopes will measure the offset of each SI PAR from nominal, and verify that the ISIM+SI alignment is within tolerance at ambient temperature. This also allows a non-invasive means of checking SI alignment to ISIM (without removing the ISIM enclosure) after shipping to observatory testing.

During the ISIM level verification, the OSIM will be aligned to ISIM and the optical telescope element (OTE) SIMulator (OSIM) pupil reference fiducials will be projected onto the SI PARs, and the pupil alignment will be mapped. A Global Nominal Pupil (GNP) position, optimizing all of the SIs, will be determined, and used to align the ISIM to the OTE to minimize common path pupil alignment error. The pupil alignment measurement will also verify that the ISIM+SI pupil alignment is within allocated tolerances for all SIs in the +V1 down orientation. Therefore, it is crucial that the SI pupil alignments are known in both orientations for each SI. The final opportunity to discover and correct ISIM+SI pupil alignment errors at cryogenic operating temperature is during ISIM level testing, so it is crucial that a standardized reference (SI PAR) be available. These references will be measured relative to Pupil Imaging Modes for NIRCam and MIRI to verify that the alignment has not changed downstream of the Pupil reference due to shifts of optics, and is the only way to deterministically demonstrate an unvignetted field at the observatory level of assembly.

This work was done by John G. Hagopian of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15783-1

Autonomous System for Monitoring the Integrity of Composite Fan Housings

John H. Glenn Research Center, Cleveland, Ohio

A low-cost and reliable system assesses the integrity of composite fan-containment structures. The system utilizes a network of miniature sensors integrated with the structure to scan the entire structural area for any impact events and resulting structural damage, and to monitor degradation due to usage. This system can be used to monitor all types of composite structures on aircraft and spacecraft, as well as automatically monitor in real time the location and extent of damage in the containment structures. This diagnostic information is passed to prognostic modeling that is