DEPARTMENT OF MECHANICAL ENGINEERING
WILLIAM MAXWELL REED SEMINAR SERIES

Calibration-Based Inverse Method for Estimating Surface Heat Flux and Temperature in Aerospace Science Applications

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Abstract: Novel analytical research and experiments are underway at the University of Tennessee (UTK) for resolving inverse heat transfer problems associated with the prediction of the surface heat flux (net, W/cm2), total heat transfer (W) and temperature (oC) in highly hostile environments. Inverse heat conduction problems can be described by two categories: (1) parameter-required and (2) parameter-free methods. A transformative calibration approach (parameter-free method) has been proposed that is applicable to high-speed, aero-thermo applications using in-depth temperature sensors. In hypersonic flight, high temperatures and heat fluxes ensue on both the external portion of the flight vehicle and inside combustors. The thermally attacked surface often precludes the direct mounting of surface instrumentation. Reusable TPS's necessitate careful material evaluation and performance studies prior to integration into a flight vehicle. The inverse calibration method is applicable to coupon and plug geometries composed of multi-regions. Uncertainties associated with probe(s) location, thermophysical properties, and sensor properties are substantially reduced as they are not explicitly required or stated in the mathematical framework. Hence, a substantial reduction in systematic errors takes place. Both linear and nonlinear calibration methods are being developed for TPS applications. Experimental verification has been performed using two different UTK facilities (low-temperature, low-heat flux electrical heating sandwich facility and a high-temperature, high-heat flux Class 4, 500 Watt laser facility). A new small- sample, alternative ambient (air, light vacuum, inert gas) environment test facility is presently under development in which a high-heat flux, high-temperature electrical heating source will be well characterized through parameter estimation and sensitivity analysis. These electrical heaters are encased in Aluminum Nitride (AlN) and volumetrically instrumented. Additionally, we recently proposed that ultrasonic interferometry can be integrated into the present calibration framework where a backside surface mounted sensor is adhered. This could be highly useful as an alternative sensor for estimating surface heat flux and temperature; and, as an independent experimental relationship that can provide closure to inverse ablation problems of the type driven by chemical erosion. Accurate calibration is fundamental to the success of the approach and UTK continues to improve accuracy in this essential component. Additionally, the ill-posed resolution process is continuously under study as alternative predictive algorithms are also being developed based on parameter-required methods. New advances have been recently made in this arena as well as a new approach for extracting the optimal regularization or tuning parameter based on phase-plane and cross-correlation principles.

Bio: Professor J.I. Frankel received his BS from the University of Maryland, 1980 and his graduate degrees from Virginia Polytechnic Institute and State University (M.S., 1982, Ph.D., 1986). He previously worked in the DC metropolitan area at ORI and NBS (now NIST) (1982-84). His research involves numerous aspects of analytical and experimental heat transfer; and, applied/computational mathematics. He has more than 125 publications and 1 sensor patent on measuring dT/dt. Presently, his research involves inverse problems and calibration methods for heat conduction and chemical erosion. He was recently supported by US Air Force (WP), National Science Foundation and currently supported by MBDA (France). Professor Frankel has previously been supported by NASA, NSF, DOE (ORNL and Y-12) Sandia National Laboratory, DSWA, DNA, and the Aerospace Testing Alliance (AEDC). He recently consulted to the Air Force (WP) on high-speed flight TPS's (HTV-2 remediation) and in the past with AEDC on null-point calorimetry and sensor development.

Date: February 24, 2017

Time: 3:00pm

Place: CB 110

Contact: Dr. Alexandre Martin 257-4462

Meet the speaker and have refreshments
Attendance open to all interested persons

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