THE WILLIAM E. BOEING DEPARTMENT OF

AERONAUTICS & ASTRONAUTICS

... welcomes ...

DR. TOM I-P. SHIH

PURDUE UNIVERSITY

Gas-Turbine Heat Transfer – Challenges and Opportunities

Gas turbines are widely used for propulsion and for electrical and mechanical power generation. Though tremendous advances have been made since its invention in the 1930's with Frank Whittle's and Hans von Ohain's patents, there are still huge opportunities for further advances in efficiency, performance, service life, environmental friendliness, and affordability.

One of the most important opportunities that has been exploited for decades and still available today is to improve the thermal efficiency of gas turbines by developing technologies to enable higher gas temperatures at the inlet of the turbine component because efficiency increases with the turbine's inlet temperature and that temperature could be as high as the adiabatic flame temperature from the combustion of fuel and air in the gas turbine's combustor. Though the turbine's inlet temperatures have steadily increased over the past few decades, they are still far below the maximum possible and hence the opportunity. The challenge is that the current inlet temperatures (up to 2,000 oC) already far exceed, by hundreds of degrees Celsius, the maximum temperature at which even the best turbine materials (e.g., Ni-based super alloys and CMCs) lose strength and durability. Thus, all turbine material that come in contact with the hot gases must be cooled. Currently, 15 to 30% of the air entering the gas turbine's compressor are used to cool the turbine – air that could be used to generate thrust or power. Thus, reducing the amount of cooling flow to enable a given turbine's inlet temperature is another opportunity to improve efficiency.

To further increase turbine's inlet temperature and/or reduce coolant flow needed to achieve a given inlet temperature require a leap beyond existing materials and/or cooling science and engineering. This talk provides an overview on turbine cooling, how geometry has been used to create the fluid mechanics that enhance cooling, and addresses challenges and opportunities that could enable a leap forward on cooling. Since this is not a low hanging fruit, details and inaccuracies at the most fundamental levels matter? Some fundamental questions to be discussed include: How universal is Newton's law of cooling in quantifying heat transfer in extreme environments? How does one define or measure the bulk temperature in complicated configurations with U-bends and separated flows? Since heat-transfer enhancement features in turbine cooling are so small and so numerous with hundreds of them in each turbine vane and blade, what are the effects of providing an "averaged" heat-transfer coefficient (HTC) for a feature instead of the detailed distribution to characterize the heat transfer as is commonly done? Could transient methods be used to measure the HTC for complicated configurations as is commonly done? How does one scale measurements made under laboratory condition to engine conditions? What is the most important parameter that must be matched in scaling experimental studies if the goal is to understand the temperature distribution in the materials being protected by cooling? What are the uncertainties on verification and validation for RANS and LES simulations of turbine cooling? Since it only takes one hot spot where material temperature exceeds the maximum permitted for a turbine vane or blade to fail and cooling efficiency requires the turbine material to be operating at close its maximum permitted temperature, achieving the next leap on cooling requires greatly improved understanding on how design and operating parameters affect the detailed fluid-mechanics and conjugate heat-transfer mechanisms in harsh environments and complicated geometries and how that understanding is used in design.

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WILLIAM E. BOEING
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS
UNIVERSITY *of* WASHINGTON

Monday, October 24, 2016 @ 4:00pm
Johnson 075, UW Seattle

Visitor RSVP: contact@aa.washington.edu

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AERONAUTICS & ASTRONAUTICS

... Distinguished Guest Speaker ...

DR. TOM I-P. SHIH
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Tom I-P. Shih is Professor and Head of the School of Aeronautics and Astronautics at Purdue University, a position held since 2009. Previously, he was a faculty member at Iowa State University (2003-09), Michigan State University (1998-2003), Carnegie Mellon University (1988-98), and the University of Florida (1983-88). Also, he was a mechanical engineer at NASA Lewis (now Glenn) Research (1981-82). He started his undergraduate education at West Virginia University, but completed his BS degree at the National Cheng Kung University in Taiwan. His MS and PhD degrees are from The University of Michigan in Ann Arbor. He is a Fellow of ASME and AIAA. His research interests are in CFD/HT, turbine cooling, aircraft icing, and control of shock-wave/boundary-layer interactions.

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