The AAE Spring 2017 Colloquium Series

Presents

“Imaging Guiding the Way to Improved Heat Transfer Predictions for Internal Combustion Engines”

Volker Sick
Arthur F. Thurnau Professor
Department of Mechanical Engineering
University of Michigan

Thursday, March 23, 2017
ARMS 1109
3:00 pm

Abstract
Research and engineering developments continue to contribute to advances in the performance and emissions control of internal combustion engines. In particular, there is a strong focus on advancing 3D simulation capabilities to a point where truly predictive design work can be performed. In concert with detailed in-cylinder measurements the fidelity of 3D CFD has improved over the years but is still far from satisfactory in terms of predictive power and speed of execution. At first glance, it might appear that the key physical and chemical processes in internal combustion engines are bulk-phenomena, such as overall charge preparation, combustion, and exhaust emission. However, as this talk will emphasize and detail, the role of processes at interfaces have pronounced impact on the performance of engines, including combustion stability, efficiency, and pollutant formation. Examples of important processes at interfaces in engines range from the atomization of liquid fuel sprays, the interaction of plasma discharge and flame kernel with the spark plug electrodes, liquid fuel deposits on piston and cylinder walls, and the interaction of flames with walls. After identifying shortcomings in our understanding of interfacial processes in internal combustion engines this talk will mostly focus on how optical diagnostics are developed, applied, and what is learned to advance science and engineering of engines. While including examples for all processes listed above, the focus here will be on near-wall layer flows and how results from high frame rate measurements are used to advance heat transfer models that can be integrated into 3D simulations of internal combustion engines. Boundary layers in internal combustion engines differ from those in other flow situations because external flow, pressure, temperature, and composition change on short time and length scales. Steady-state conditions are not reached and non-equilibrium effects therefore might become important in the description of mass and momentum transfer in near-wall regions. Basic assumptions made to traditionally describe boundary layer flows fail in engines and as a result substantial errors in heat transfer predictions are observed. High-resolution and high frame rate measurements are therefore needed to quantitatively measure the dynamics of near-wall layers in operating internal combustion engines. Ideally, flow and thermal state are characterized at the same time, though even sequentially obtained information is useful. Micro-Particle Image Velocimetry could be adapted
to measure velocity fields in operating optical engines. However, there is a variety of challenges to overcome to enable reliable and useable data for model development. These include imaging aberrations, flow seeding problems, window fouling, and post processing to obtain vector fields. Similarly, quantifying the thermal stratification using laser-induced fluorescence imaging in near-wall layers poses a range of challenges that include poor signal strength, image distortion due to index of refraction gradients, amongst others. We will demonstrate how the results of high frame rate measurements were used to guide the development and validation of improved models for near-wall layer modeling and show where improvements were made.

Bio
Volker Sick holds appointments at the University of Michigan as Arthur F. Thurnau Professor of Mechanical Engineering and as Associate Vice President for Research. He earned degrees in Chemistry and Physical Chemistry from the University of Heidelberg in 1988 (Diplom), 1992 (Dr. rer. nat), and 1997 (Habilitation). At the University of Michigan, Ann Arbor, he built an internationally recognized program in laser-based imaging diagnostics and engine research. The Combustion Institute recognized his work with the Silver Medal and ASME honored him with the 2015 Internal Combustion Engine Award. He is a Fellow of SAE International. His awards include a number of teaching awards and citations for international engagement. He serves as the Editor of the Proceedings of the Combustion Institute and on the editorial boards of Experiments in Fluids and Progress in Energy and Combustion Science.