PHYSICS-BASED COMPRESSIBLE FLOW AND NETWORK MODELING FOR DESIGN APPLICATIONS

April 13th, 2019
Westin Las Vegas Hotel & Spa, Las Vegas, NV, USA

www.astfe.org/courses/pbcf2019/

Bijay K. Sultanian, Takaniki Communications, LLC

Nonisentropic compressible flows are ubiquitous in many mechanical, chemical, and aerospace engineering applications, including gas turbines in their inlet systems, compressors, combustors, turbines, and exhaust systems. One-dimensional treatment of these flows forms the basis for most preliminary/conceptual designs. They are, however, generally counter-intuitive. For example, it defies common sense that the wall friction accelerates a subsonic compressible flow in a constant-area duct with or without heating. This workshop will provide a comprehensive review and reinforcement of the key concepts of one-dimensional compressible flows with simultaneous area change, friction, heat transfer, and rotation, which is seldom found in a textbook. In addition to the key concepts of thermofluids such as stream thrust, impulse pressure, rothalpy, mass flow functions, impulse functions, and normal shock function, this workshop will present an easy method to compute pressure and temperature changes in a generalized vortex in both rotor and stator reference frames. The workshop will conclude with a design-friendly overview of a compressible flow network featuring internal choking and normal shocks along with robust solution methods. A number of design-relevant examples will also be solved in the workshop. It behooves CFD engineers to use the unique foundation developed in this workshop as a prerequisite for all their 3-D CFD analyses, including physics-based interpretation of boundary conditions and computed results for design applications.

KEY BENEFITS TO PARTICIPANTS

1. Will develop a unique intuitive understanding of isentropic and nonisentropic compressible flows, including the coupled effects of area change, friction, heat transfer, and rotation
2. Will develop a strong foundation in the physics-based thermofluids design of various engineered components
3. Will be more knowledgeable in developing physics-based compressible flow models and applying accurate boundary conditions
4. Will be more knowledgeable in correctly interpreting results of their compressible flow design analyses
5. Will develop skills to hand-calculate compressible flow results to perform sanity-checks of predictions by design tools as well as validate these tools during their development
6. Will improve participant's engineering productivity with reduced design cycle time

WHO SHOULD ATTEND

This workshop will be of interest to graduate students, research workers in universities and research institutes, and research and design engineers in industry who are involved in the physics-based thermofluids design and technology development of various components and systems, including high-performance gas turbine components such as inlet systems, compressors, combustors, turbines, diffusers, exhaust systems, internal air systems, and turbine airfoil internal and film cooling.

REGISTRATION

- **Fee: $300**
- **Registration will be limited to 30 participants**
- **Five complimentary, autographed copies of Fluid Mechanics: An Intermediate Approach (2015) will be distributed among workshop attendees using a random draw**

WORKSHOP OUTLINE

Module 1: Key Concepts of Thermofluids

- What is a physics-based modeling?
- What are 1-D, 2-D, and 3-D CFD analyses?
- Fundamental difference between a compressible flow and an incompressible flow (beyond constant density!)
- A new interpretation of total pressure in an incompressible flow
- Stream thrust and impulse pressure
- Physics of Mach number of a compressible flow
- Physics of choking and normal shock phenomena
- Concept of rothalpy
- Converting total properties between rotor and stator reference frames
- Concept of entropy
- Computation of entropy change between two points
- Generating entropy map from 3-D CFD results

Module 2: Compressible Flow Functions

- Total-pressure mass flow function
- Static-pressure mass flow function
- Loss coefficient versus discharge coefficient
- Total-pressure impulse function
- Static-pressure impulse function
- Normal shock function

Module 3: Isentropic Flows

- Isentropic compressible flows
- Isentropic flow with area change
- Operation of a converging nozzle
- Operation of a converging-diverging nozzle

Module 4: Flows with Gradual Changes in Entropy – Fanno and Rayleigh Flows

- Conservation equations
- Fanno flows
- Property changes in a Fanno flow
- Use of Fanno flow tables
- Rayleigh flows
- Property changes in a Rayleigh flow
- Use of Rayleigh flow tables

LUNCH

Module 5: Flows with Abrupt Changes in Entropy – Normal Shocks

- Normal shocks
- Normal shock using Fanno and Rayleigh lines
- Characteristic Mach number
- Normal shock relations
- Normal shock tables
- Locating a normal shock in a converging-diverging nozzle

Module 6: Pressure and Temperature Changes in a Generalized Vortex

- Vortex versus vorticity
- Free vortex, forced vortex, and Rankine vortex
- Generalized vortex
- Pressure and temperature changes in isentropic free and forced vortices
- Pressure and temperature changes in a nonisentropic generalized vortex

Module 7: Compressible Flow Network Modeling

- Element modeling
- Total-pressure-based formulation (not physics-based!)
- Static-pressure-based formulation
- Junction modeling
- Handling internal choking and normal shocks
- Determining element flow direction under area-change, friction, heat transfer, and rotation
- Generating initial (starting) solution
- Robust iterative solution methods

Module 8: Design Examples and Discussions

- Coupled heat transfer and work transfer in a rotating duct flow
- Calculation of pressure-rise coefficient of a real exhaust diffuser
- Aerodynamic mixing loss calculation
- Turbine airfoil internal cooling flow modeling with area change, friction, heat transfer, and rotation
- General discussion and additional questions/answers

WORKSHOP INSTRUCTOR

BIJAY K. SULTANIAN

Takaniki Communications, LLC

Dr. Bijay Sultanian is an international authority in gas turbine heat transfer, secondary air systems, and Computational Fluid Dynamics (CFD). Dr. Sultanian is Founder & Managing Member of Takaniki Communications, LLC, a provider of high-impact, web-based, and live technical training programs for corporate engineering teams. Dr. Sultanian is also an Adjunct Professor at the University of Central Florida, where he has been teaching graduate-level courses in Turbomachinery and Fluid Mechanics since 2006. He has instructed several workshops at ASME Turbo Expo since 2009. During his 30+ years in the gas turbine industry, Dr. Sultanian has worked in and led technical teams at a number of organizations, including Allison Gas Turbines (now Rolls-Royce), GE Aircraft Engines (now GE Aviation), GE Power Generation (now GE Power & Water), and Siemens Energy (now Siemens Power & Gas). He has developed several physics-based improvements to legacy heat transfer and fluid systems design methods, including new tools to analyze critical high-temperature components with and without rotation.

During 1971-81, Dr. Sultanian made landmark contributions toward the design and development of India's first liquid rocket engine for a surface-to-air missile (Prithvi) and the first numerical heat transfer model of steel ingots for optimal operations of soaking pits in India's steel plants.

Dr. Sultanian is a Life Fellow of the American Society of Mechanical Engineers, a registered Professional Engineer in the State of Ohio (1995), a GE-certified Six Sigma Green Belt (1998), and an Emeritus Member of Sigma Xi, The Scientific Research Society. He is the author of **Fluid Mechanics: An Intermediate Approach** (2015); **Gas Turbines: Internal Flow Systems Modeling, in Cambridge Aerospace Series** (2018); **Logan's Turbomachinery: Flowpath Design and Performance Fundamentals, 3rd edition** (2018).

Dr. Sultanian received his B.Tech. and MS in Mechanical Engineering from Indian Institute of Technology, Kanpur (1971) and Indian Institute of Technology, Madras (1978), respectively. He received his PhD in Mechanical Engineering from Arizona State University, Tempe (1984) and MBA from the Lally School of Management and Technology at Rensselaer Polytechnic Institute (1999).

ASTFE
American Society of Thermal and Fluids Engineers

167 Madison Ave, Suite 501, New York, NY 10016, USA
Telephone: +1 212 288 9200, Fax: +1 212 427 0300

info@astfe.org
www.astfe.org, www.astfe.org/courses/pbcf2019/