Discrete Element Roughness Modeling for Design Optimization of Additively and Conventionally Manufactured Internal Turbine Cooling Passages

Robert F. Kunz[1], Michael P. Kinzel[2], David R. Hanson[3], Edward W. Reutzel[3], Jason E. Town[3], Karen A. Thole[1]
The Pennsylvania State University
[1]Department of Mechanical Engineering, [2]Department of Aerospace Engineering, [3]Applied Research Laboratory

PENNSTATE
DEPARTMENT OF MECHANICAL AND NUCLEAR ENGINEERING

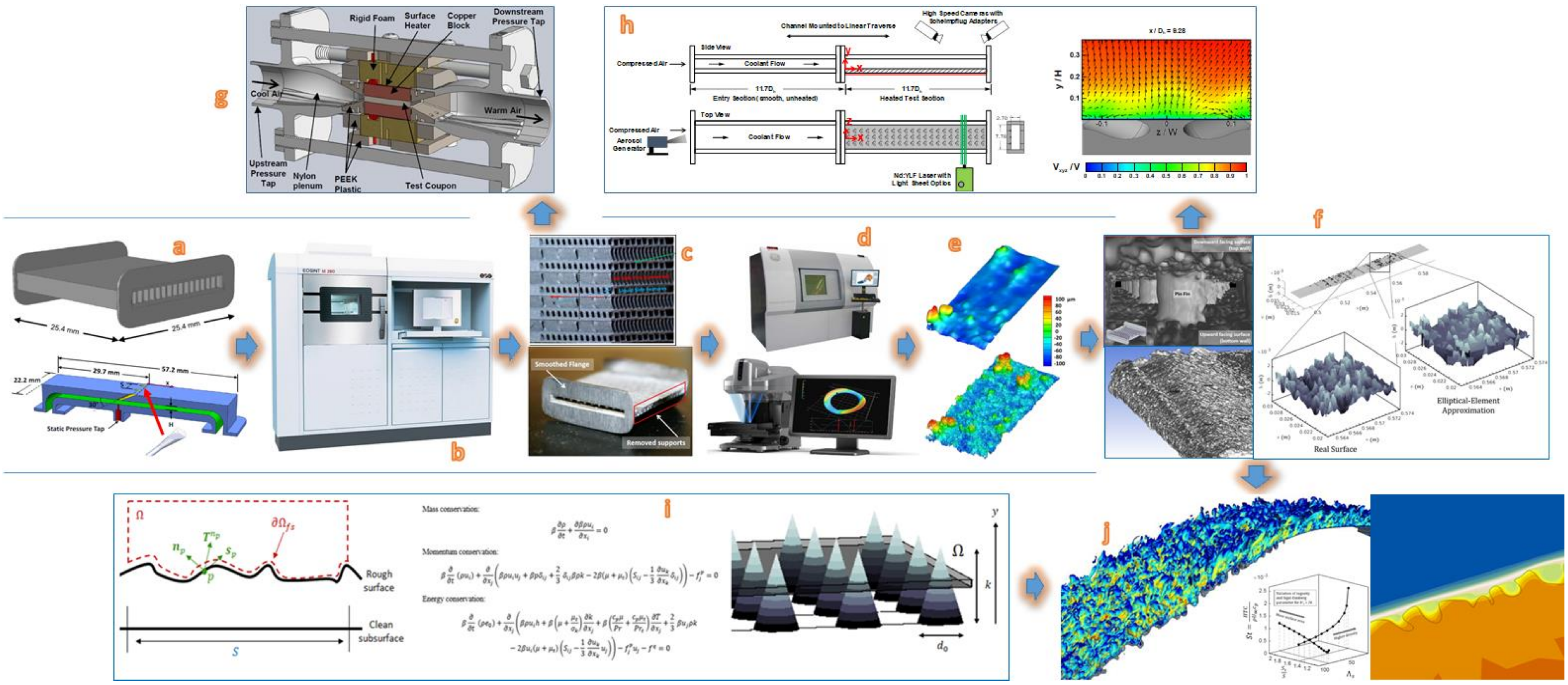
Stephen T. McClain, Lesley M. Wright
Baylor University
Mechanical Engineering Department

CORPORATE PARTNER
General Electric

Background

- Metal additive manufacturing is enabling gas turbine designers to explore internal turbine passage cooling schemes not manufacturable using current methods
  - Potential significant gains in turbine operating temperature and durability ➔ transformational
  - Harnessing opportunity requires maturing design tools
- Accommodate very complex “roughness field” that characterizes these engineered flow passages
- Conventional CFD roughness modeling for field/convective heat transfer are inadequate
- Accordingly, this project develops **Discrete Element Roughness Modeling (DERM)**, in the context of Large Eddy Simulation (LES) and Reynolds Averaged Navier-Stokes (RANS)
  - Necessary and sufficient for mechanistic predictions of additively manufactured turbine cooling scheme configurations
  - DERM also represents a viable design approach for conventionally manufactured internal blade cooling features

Technical Approach



a) Design for AM, b) EOSINT M 280 PBF system , c) Engine Scale Parts, d) CT and OP scanning, e) CT and OP roughness fields, f) Synthesized multi-scale geometries for CFD modeling and geometric up-scale, g) Engine scale heat transfer and pressure drop testing, h) Up-scale local conditions flow and heat transfer testing, i) DERM model development/calibration, j) DNS, LES, RANS validation, application, design optimization.

Objectives

- Advance CFD methods for accuracy and run time requirements for design and optimization relevant to additively and conventionally manufactured turbine cooling scheme configurations
- Synthesis of state-of-the technology: CFD modeling and optimization, Powdered metal additive manufacturing (AM), Multiscale 3D scanning and attendant roughness field characterization, Heat transfer and flow measurements
- Deliver to OEM turbine blade design community a sufficiently physics rich and validated model set for design of blade cooling passages and cooling holes that are subject to the roughness and tolerancing field inherent to Powder Bed Fusion (PBF) manufacturing of these blades

Tasks

- Task 1 - Engine Scale Turbine Cooling Passage Manufacture, Scan, and Bulk Testing
- Task 2 - Advancement, Validation, Application of DERM
- Task 3 - Local Conditions Up-Scale Flow/Heat Transfer Experimental Measurements
- Task 4 - Optimization