the ENERGY lab

R&D FACTS

Advanced Energy Systems

Turbine Thermal Management

The gas turbine is the workhorse of power generation, and technology advances to current land-based turbines are directly linked to our country's economic and energy security. Technical advancement for any type of gas turbine generally implies better performance, greater efficiency, and extended component life. From the standpoint of cycle efficiency and durability, this suggests that a continual goal for higher gas turbine-inlet-temperatures with reduced coolant levels is desirable.

The realization of future high-efficiency, near-zero emission turbine power systems depends on the advancement of thermal protection of hot sections, such as first-stage vanes and blades, and control of secondary flows. Current technology for protecting such airfoils relies primarily on the combined effects of a thermal barrier coating (TBC) and convective cooling. However, state-of-the-art development in both TBC materials and cooling technologies is insufficient to meet the thermal-mechanical demands imposed by hot gas with elevated turbine-inlet-temperatures. This suggests that significant advances in turbine cooling effectiveness, as well as TBC performance and durability, are required. This research effort aims to significantly advance TBC material and aerothermal cooling technologies.

In addition to addressing technology advancements that improve gas turbine airfoil performance, pressure gain combustion has been identified as a possible means to contribute to improved plant operating efficiency. Unlike the Brayton Cycle of a conventional gas turbine engine that experiences a pressure drop across the combustor, the combustion process in a Humphrey (or Atkinson) Cycle produces a pressure gain that even under conservative estimates could result in a 4 – 6% gain in overall system efficiency. Rotating Detonation Combustion (RDC) capitalizes on this cycle and offers potential as a drop in replacement for conventional gas turbine combustors. In addition to the potential gain in efficiency, due to minimal time spent at peak combustion temperatures NO_X may also be reduced. The work conducted in the Turbine Thermal Management project explores the potential of RDC and is addressing its technical challenges.

Turbine Thermal Management Research at NETL

The NETL-Regional University Alliance (NETL-RUA) Turbine Thermal Management team is taking an integrated, systematic approach to addressing advanced turbine needs. The primary objective of this research is to support the hydrogen turbine technology area in meeting the DOE advanced turbine development goal, which calls for a 3–5 percent increase in power island efficiency and a 30 percent power increase above the hydrogen-fueled combined cycle baseline.

Research projects utilize the extensive expertise and facilities readily available at NETL and participating universities. The research approach includes explorative studies based on scaled models and prototype coupon tests conducted under realistic pressurized, high-temperature turbine operating conditions.

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Technical goals for NETL-RUA Turbine Thermal Management research include:

- Development of novel, manufacturable internal airfoil cooling technology concepts that achieve a cooling enhancement factor of approximately five times that of smooth state-of-the-art cooling channel surfaces.
- Development of advanced, manufacturable airfoil film cooling concepts that achieve a 50 percent reduction in required cooling flow.
- Design, construction, and operation of a world-class facility for testing new cooling improvement strategies for the turbine rotating blade platform.
- Development of advanced material system architectures that permit operation of turbine airfoils at temperatures approximately 50–100 °C higher than current state-of-the-art components.
- Manufacture of commercially cast test coupons containing the advanced NETL-RUA cooling concepts (i.e., fully bridged or partially detached pin-fins, tripod film cooling holes, trailing edge configurations, and near surface embedded micro-channels) with subsequent integration into airfoil geometries for prototype, sub-pilot-scale testing under representative gas turbine engine conditions.

Technical goals for the pressure gain combustion research effort include:

- Demonstrating reliable deflagration-to-detonation transition and detonation initiation with natural gas and natural gas/hydrogen fuel blends.
- Achieving sustained rotating detonation combustion in an annular combustor operating on natural gas and natural gas/hydrogen fuel blends.
- Exploring optimal operating conditions to reduce non-detonative combustion that adversely impacts potential efficiency improvements.
- Examining combustor configurations to achieve quasi-steady exit flow.
- Considering influence of mixing strategy and operating conditions on NO_X emissions.
- Producing high-fidelity experimental data intended for validation of continuous detonation numerical models.

Impact and Benefits

Research results obtained through this project can directly benefit the U.S. power and utility turbine industry by improving product development that specifically meets DOE advanced turbine program goals. Turbine technology benefited by this research will lead to products with higher efficiency and reduced emissions. Higher efficiency implies alleviating dependence on foreign oil and improving preservation of domestic natural resources. Reduced emissions will not only yield better environmental conditions but will also decrease costs for pollution controls, including carbon capture and sequestration. These factors combined will eventually lead to greater energy security and economy.