New and existing systems show progress

BY SCOTT CLAFLIN | DECEMBER 2016

The Pressure Gain Combustion Program Committee advances the investigation, development and application of pressure-gain technologies for improving propulsion and power generation systems and achieving new mission capabilities.

The state of the art in pressure gain combustion advanced significantly this year as numerous government, industry and academic institutions continued to develop new

experimental engines and mature analytical models.

In the U.S., both the Defense Department and the Department of Energy are supporting PGC development. Under an Office of Naval Research grant, the Naval Postgraduate School in Monterey, California, explored the impact of engine inlet characteristics on the delivered performance of a rotating detonation engine, or RDE. The investigation involved hot-fire testing with detonation zone imaging, optical diagnostics and collaborative computation efforts with the Naval Research Laboratory, NRL, in Washington, D.C. The Naval Postgraduate School also supported a DARPA-funded team comprising HyPerComp Inc. of California, the University of Connecticut and Aerojet Rocketdyne of California in developing a continuous detonation turbine engine. The program measured turbine efficiency when driven by the unsteady flow of an RDE.

Under National Energy Technology Laboratory, or NETL, sponsorship, the University of Michigan, Penn State University and Purdue University have begun RDE development on the University Turbine Systems Research Initiative. In September, NETL awarded a three-year phase 2 program to Aerojet Rocketdyne to advance air and natural gas RDE technology.

NETL continued its own internal research that includes fundamental bench-scale experiments, lab-scale experiments and computational studies. The bench-scale rig is evaluating RDE fuel and air inlet geometries. The 6-inch lab-scale RDE with ducted exhaust has been tested with variable back pressure control permitting operation at elevated pressures. The rig is currently being modified to permit oxides of nitrogen emissions measurements.

The Air Force Research Laboratory is collaborating with NETL on the testing of an RDE combustor coupled to a T63 gas turbine engine. These tests are evaluating RDE-to-turbine interface conditions and potential impact on turbine performance as well as oxides of nitrogen emissions. At NRL, recent numerical simulations of an air/hydrogen RDE using detailed chemistry show that those emissions can be kept to an acceptable level by suitably choosing the equivalence ratio and engine geometry.

The NASA Glenn Research Center in Cleveland continued PGC investigations by demonstrating performance improvements through simulation of a resonant pulse combustor concept. Also, RDE modeling, validation and optimization capability expanded via collaboration with the Air Force Research Laboratory.

Academia made significant progress in PGC development this year. A team from the University of Washington demonstrated success in controlling the spin direction of an RDE detonation wave using a system that emits circumferentially phased sequential sparking. Purdue is working on an effort sponsored by the Air Force Office on Scientific Research that focuses on combustion characteristics in high-pressure rocket RDE devices. Three successful test series have been undertaken: two with gaseous hydrogen and one with natural gas fuels. A NASA and Purdue-sponsored effort in pulse detonation engines, PDEs, completed the final round of testing in which natural valveless detonative performance was achieved using high concentration hydrogen peroxide with hypergolic fuels in a nozzleless combustor.

Research on both RDE and PDE technology is robust outside of the U.S. A Japanese research group from Nagoya University, Keio University, JAXA and Muroran Institute of Technology conducted a successful sled test of an RDE, and the group has started development of an RDE-powered sounding rocket. In Russia, the Semenov Institute of Chemical Physics successfully operated an RDE with air and liquid propane by augmenting the detonation process with hydrogen. In Saudi Arabia, the King Abdullah

University of Science and Technology has developed and characterized a novel, actively valved and acoustically resonant pulse combustor with pulsed fuel injection. The pulsed combustor is designed to produce meaningful pressure gain with low pollutant emission in a gas turbine engine. ★