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Propulsion and Energy

Advances made toward rotating detonation

engines

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

With the promise of performance gains of 10-15 percent, researchers are advancing the technologies required to make unsteady detonation-based engines a reality for aerospace propulsion and stationary power-generation applications. The rotating detonation engine, or RDE — a device that exploits continuous detonative combustion in a thin annular channel — is the main focus of research, and several critical advances were made in 2017.

Russia's NPO Energomash and Lavrent'ev Institute of Hydrodynamics conducted a long-duration firing of a large-diameter oxygen/kerosene liquid rocket engine with RDE combustion.

The U.S. Air Force Research Laboratory in April demonstrated thermally steady operation of an air-breathing RDE with a ceramic matrix composite outer body. In February, AFRL also tested an RDE integrated into a T63 gas turbine as the combustor; results show low nitrogen oxide production and good combustion efficiency, indicating promise for the technology.

The U.S. Department of Energy's National Energy Technology Laboratory continued leading the implementation of RDE technology into stationary power-generation systems. Aerojet Rocketdyne planned to conduct hot-fire testing of an air-breathing, natural gas-fueled RDE in November under a $6 million contract awarded in 2016. And efforts at Purdue University, the universities of Michigan, Alabama and Central Florida, and the Southwest Research Institute complemented the NETL program with advanced measurements and fundamental studies.

Detonation-based engine research expanded internationally. Japan has a large number of efforts in both RDE and pulse detonation engine technology. In August, a team from Nagoya and Keio universities, the Japan Aerospace Exploration Agency and Muroran Institute of Technology conducted a 330-second specific-impulse, near-vacuum and 895-newton high-thrust experiment with an ethylene/oxygen RDE with combustion efficiency exceeding 95 percent.

In China, several university groups are working to advance RDE technology. Peking University studied ignition delay time and re-initiation phenomenon. National University of Defense Technology conducted air-breathing RDE experiments and established operability limits. Nanjing Institute of Technology achieved detonative performance in a gasoline-oxygen RDE. Tsinghua University conducted experimental research on RDE combustion instability.

Russia's Semenov Institute of Chemical Physics and Institute of Theoretical and Applied Mechanics focused on a hydrogen-fueled scramjet of significant scale (1.05-meter long and 0.31 m in diameter) demonstrating specific impulse as high as 3,600 seconds in wind tunnel tests over a Mach 4-8 range. Both rotating detonation and longitudinal pulsation modes were observed.

In France, national research center CNRS and the University of Poitiers tested different inner cylinder sizes, while MBDA developed a full-scale RDE for ground tests. ONERA's numerical simulations focused on optimization of injector performance. Warsaw University of Technology studied gaseous methane-oxygen RDE combustors of 150 millimeters and 200 mm outer diameters. The first International Constant Volume and Detonation Combustion Workshop was held in June at ENSMA near Poitiers.

In the U.S., military researchers advanced both rocket and air-breathing RDE technology. The Naval Research Lab studied inlet/combustor interactions in a ramjet RDE operating at 42,000 feet and Mach 2.5. NRL also developed detonation models for fuel blends, quantifying the effect of blending hydrogen with methane through propane on induction times and detonation stability.

The Naval Postgraduate School explored the impact of engine inlet characteristics on the performance of an air-breathing RDE. The investigation involved hot-fire testing with detonation zone imaging, optical diagnostics and collaborative computational efforts with NRL. Purdue

tested a high-pressure rocket RDE fed by gas from a liquid oxygen preburner using both natural gas and methane fuels. Operation was demonstrated at pressures exceeding 400 psi.