the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

Low-Swirl Injectors for Hydrogen Gas Turbines in Near-Zero Emissions Coal Power Plants—Lawrence Berkeley National Laboratory

Background

The U.S. Department of Energy Hy(DOE) Lawrence Berkeley National Laboratory (LBNL) is leading a project in partnership with gas turbine manufacturers and universities to develop a robust ultra-low emission combustor for gas turbines that burn high hydrogen content (HHC) fuels derived from gasification of coal. A high efficiency and ultra-low emissions HHC fueled gas turbine is a key component of a near-zero emissions integrated gasification combined cycle (IGCC) clean coal power plant.

This project is managed by the DOE National Energy Technology Laboratory (NETL). NETL is researching advanced turbine technology with the goal of producing reliable, affordable, and environmentally friendly electric power in response to the nation's increasing energy challenges. With the Hydrogen Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from HHC fuels derived from coal that is clean, efficient, and cost-effective, minimizes carbon dioxide (CO_2) emissions, and will help maintain the nation's leadership in the export of gas turbine equipment.

Project Description

Low-swirl combustion technology was conceived at LBNL to help industrial natural gas turbines achieve ultra-low emission targets. This project is a logical extension to adapt a low-swirl injector (LSI) for HHC fuels and to scale up the sizes for large utility gas turbines. Most commercial gas turbines are developed for use with natural gas. Adapting these gas turbines to HHC fuels brings about complex combustion engineering issues and additional safety risks due to the higher reactivity and different combustion properties of the HHC flame compared to natural gas.

The LSI is a novel combustion technology that has the potential to meet the operational and emissions goals for HHC-fueled gas turbines. Its basic premise is to produce a detached and freely propagating flame. The idea is fundamentally different from the conventional approaches to trap or hold the flame by physical means or by strong vortices. Laboratory experiments have verified that the basic LSI concept is amenable to operate on natural gas, synthesis gas (syngas), and hydrogen while meeting the aggressive emission target of <2 ppm NO_x (less than two parts per million oxides of nitrogen). The current focus is on developing a conceptual LSI prototype for adaptation to utility-size gas turbine combustors. As an essential aspect of this effort, laboratory studies on premixed turbulent flames are also pursued.

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PARTNERS

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PERFORMANCE PERIOD

Start Date	End Date
10/01/2006	09/31/2013

(annual continuations)

COST

Total Project Value
$5,289,800

DOE/Non-DOE Share
$5,289,800 / $0

AWARD NUMBER

FWP7-678402

U.S. DEPARTMENT OF ENERGY

Goals and Objectives

The current goals of the project are to advance the core technology support research pertaining to fundamental hydrogen combustion issues while concurrently pursuing the development of a fuel-flexible LSI that operates on natural gas, syngas, and HHC fuels in a utility-size gas turbine of 100 to 250 megawatt (MW) power output. Project objectives are as follows:

- Develop a reduced-scale LSI combustor assembly for fuel-flexible operation and evaluate its performance at simulated gas turbine conditions.
- Define the size and configuration of the LSI for an industrial-size high-efficiency gas turbine operating on natural gas.
- Analyze lean premixed turbulent CH_4 and H_2 flame structures to support turbulent modeling development.
- Gain better understanding of turbulent H_2 flame structures and LSI flame acoustics.

Accomplishments

- Rig-tested a reduced-scale fuel-flexible LSI combustor at simulated gas turbine conditions and demonstrated the potential of the LSI technology to meet the aggressive emissions and operational program goals.
- Developed the basic layout of a multi-LSI combustor system for a high-efficiency ultra-low emissions 4 MW gas turbine.
- Characterized the instability behaviors of CH_4 and HHC flames and showed the influence of the outer shear layer on flame oscillations.

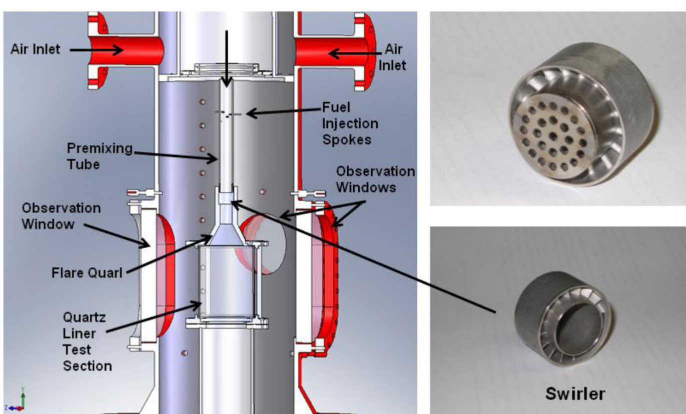

Figure 1. A high pressure chamber with a reduced scale LSI prototype simulating the combustor of a gas turbine.

- Previously conducted laboratory experiments at atmospheric conditions demonstrating that a LSI with a modified flared nozzle extends its operability with HHC fuel to an adiabatic flame temperature (Tad) of 1,700 K without inciting flame flashback.
- Demonstrated that the LSI performance is insensitive to variations in its geometric configurations and showed that the size of the swirl annulus can be increased to lower aerodynamic drag.
- Measured the local displacement flame speed for natural gas and hydrogen and gas turbine relevant conditions.
- Developed a unify method to define heat release density for lean premixed turbulent hydrogen and methane/hydrogen flames.

Benefits

The DOE's Hydrogen Turbine Program is striving to show that gas turbines can operate on coal-based hydrogen fuels, increase combined cycle efficiency by three to five percentage points over baseline, and reduce emissions. This project's ultra-low emission LSI combustion technology is paramount for producing a clean and efficient energy source with near-zero emissions using gas turbine technology. LSI technology operates on lean premixed combustion that is the foundation for the dry-low-NO_X (DLN) technologies for almost all advanced low-emissions gas turbines.

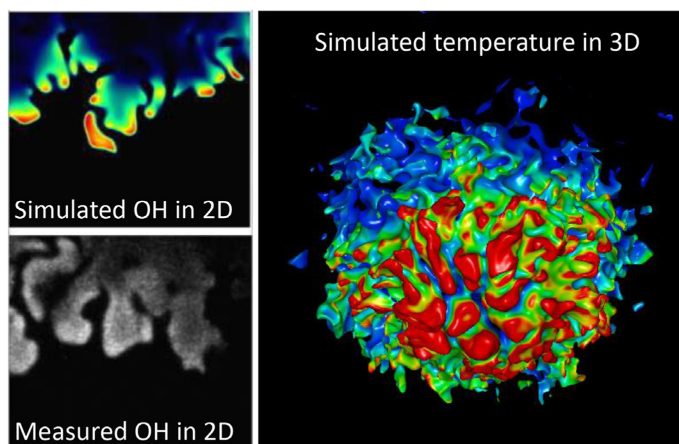

Figure 2. Due to high diffusivity of H_2, burning is non-uniform as shown in 2D by the gaps of the OH radicals for the numerical simulation of and measurement on a lean premixed turbulent hydrogen/air flame generated by a low-swirl injector. The local hot-spots, shown in red on the 3D numerical simulation results, also affects the emissions of pollutants such as oxides of nitrogen (NO_X). To capture the non-uniform burning process in a combustion model, a flowpath diagnostics has been developed to sample the time-dependent 3D simulation results. The sampling results also helped to interpret the experimental measurements and gain more insights into the heat release density of H_2 flames.

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