Low-NOx Gas Turbine Injectors Utilizing Hydrogen-Rich Opportunity Fuels

Increasing the Fuel Flexibility of Industrial Gas Turbine Combustion Systems

This project modified a gas turbine combustion system to operate on hydrogen-rich opportunity fuels. Increasing the usability of opportunity fuels will avoid greenhouse gas emissions from the combustion of natural gas and increase the diversity of fuel sources for U.S. industry.

Introduction

Gas turbines are commonly used in industry for onsite power and heating needs because of their high efficiency and clean environmental performance. Natural gas is the fuel most frequently used to power gas turbines because of its availability, historically low cost, and consistent composition.

However, a combination of recent factors, including unstable natural gas prices, actions toward carbon emissions regulation, and excess risk from reliance on a single fuel source, have made natural gas substitutes attractive from both environmental and economic standpoints.

These alternative fuels, commonly referred to as opportunity fuels, are unconventional fuels that have the potential to become economically viable sources for power generation. They are often derived from agricultural, industrial, and municipal waste streams or from byproducts of industrial processes. Common examples include synthesis gas derived from coal or biomass, anaerobic digester gas, and refinery gas from petroleum refineries.

Despite the prospects for increased opportunity fuel utilization, the inability of typical industrial gas turbines to operate effectively when powered by these fuels remains a challenge. Opportunity fuels are often rich in hydrogen, which combusts differently than methane, the primary component of natural gas.

This project aimed to address this barrier by developing and testing new fuel-flexible gas turbine injector concepts targeted at hydrogen-rich fuel applications. The project developed a detailed understanding of the kinetic mechanisms, combustion dynamics, and flame structure of opportunity fuel combustion.

Benefits for Our Industry and Our Nation

Implementing fuel-flexible gas turbines, which provide a high-efficiency, low-emissions source of electricity and process heat, will have major energy, economic, and environmental benefits, including the following:

- Utilization of an untapped energy source of significant potential

A fuel injector for the Solar Titan gas turbine.
Illustration courtesy of Solar Turbines Incorporated

- Increased diversity of eligible fuel sources for gas turbines used in U.S. industry, including many fuels that cost less than natural gas
- A decrease in greenhouse gas emissions from the combustion of natural gas by substituting renewable fuel sources or combining gasification with carbon capture and sequestration
- A reduction of solid hazardous waste through the use of gasifier technology
- Reduction or avoidance of waste disposal fees

Applications in Our Nation's Industry

This advanced combustion technology will particularly benefit industries that currently generate waste or byproducts consumable as opportunity fuels, including the chemical, petrochemical, refinery, food processing, pulp and paper, steel and metals, cement, and glass industries.

Project Description

This project redesigned a gas turbine combustion system to operate on hydrogen-rich opportunity fuels. This technology maximized efficiency and maintains satisfactory emissions performance while delivering reliability and durability to the customer.

Barriers

- Applying dry-low nitrogen oxide (NO_x) emissions technology to hydrogen-rich fuels
- Fuel injector capacity – the Wobbe index of the fuels are typically lower than Natural gas fuels due to inert content so design changes are required

- Overcoming the detrimental effect of the fuel composition variability of gasified waste streams to turbine performance and durability

Pathways

The University of Southern California (USC) tested the selected fuels and obtained fundamental combustion characteristics of these fuels.

The Pennsylvania State University (PSU) measured flame response and combustor pressure oscillations to characterize the effect of fuel composition.

Solar Turbines Incorporated redesigned and tested modified fuel injectors in their ambient and high-pressure test facilities by applying results from PSU and USC testing.

Concurrently, Solar performed a market study of gas turbines operating on renewable and opportunity fuels, leading to a full commercialization plan to address market introduction of the technology.

Milestones

- Fuel characterization
- Flame structure and combustion pressure oscillation characterization
- Definition of the concept based on fuel characterization, flame structure, injector performance testing results, and other relevant factors
- Development of the concept, including design, analysis, fabrication, and rig testing
- Single injector rig testing at simulated engine operating conditions
- Demonstration of the technology in a full-scale atmospheric rig at simulated engine inlet temperature

Accomplishments

- A combustion system was successfully developed for the Titan 130 SoLoNO$_x$™ product that met the 15 ppm NO_x goal with high-Hydrogen containing opportunity fuels.
- The combustion system demonstrated favorable results on meeting operability and durability goals of the product.
- The application of this product is for Coke Oven Gas (COG) utilization. The test program demonstrated that 15-ppm NO_x capability is feasible for COG application with a Hydrogen content up to 65%.

Commercialization

In commercializing the project technology, Solar Turbines will endeavor to ensure maximum durability, conversion efficiency, and thermal output with the lowest possible emissions through an engine qualification program.

Solar Turbines will collaborate in a commercial demonstration project to verify preliminary results in the field with an interested customer. The company also anticipates partnering with another firm to develop an appropriate gas cleanup system and to verify the technology as part of the field evaluation program. Funding for this phase of the project has not been defined.

The market for this product burning high Hydrogen renewable and opportunity fuels predominately covers two main areas. The first is for power producers looking to meet renewable portfolio standards of various States and utilities. The second main area is for commercial and industrial combined heat and power (CHP) applications.

Commercialization of this product requires validation of the combustion and detailed engine package systems including fuel delivery system design and safety and certification requirements. Based upon the successful rig test results, going forward with the engine qualification efforts will be the next recommended step.

Project Partners

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