the ENERGY lab

PROJECT FACTS

Gasification Technologies and Advanced Research

Single-Crystal Sapphire Optical Fiber Sensor Instrumentation for Coal Gasifiers

Description

Accurate temperature measurement inside a coal gasifier is essential for safe, efficient, and cost-effective operation. However, current sensors are prone to inaccurate readings and premature failure due to harsh operating conditions like high temperature (1,200–1,600 °C), high pressure (up to 500 pounds per square inch gauge [psig]), chemical corrosiveness, and high flow rates, all of which lead to the corrosion, erosion, embrittlement, and cracking of the gasifier components. Temperature measurement is a critical gasifier control parameter, because premature failure of temperature sensors impacts the efficiency and reliability of the entire system.

Sponsored by the U.S. Department of Energy's Office of Fossil Energy (DOE/FE) through the National Energy Technology Laboratory (NETL), the Center for Photoics Technology at the Virginia Polytechnic Institute and State University (Virginia Tech) has developed a new, robust, accurate temperature measurement system that can withstand the extreme conditions found in commercial gasifiers for an extended period, allowing for improved reliability and advanced process control. This system utilizes a sapphire-based fiber and sapphire wafer to form a point sensor (Figure 1), also referred to as an extrinsic Fabry-Perot interferometric (EFPI) sensor, which provides temperature data from inside the gasifier at temperatures up to 1,600 °C.

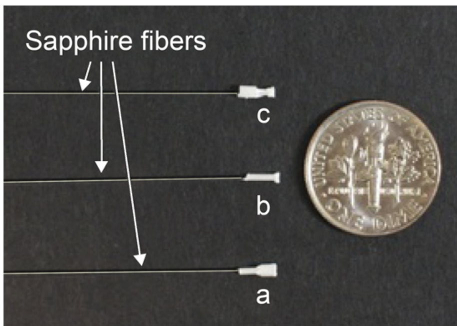

Figure 1. Single-crystal sapphire sensor heads with sapphire fiber waveguides achieve greater precision through miniaturization.

The approach is based on the measurement of the optical path difference (OPD) between two light beams reflected from sapphire wafer surfaces. Reflections from the two surfaces will interfere with each other, producing a modulated spectrum, whose pattern is determined by the optical thickness (OT) of the wafer. The OT is the product of the refractive index and the thickness of the wafer, both of which have thermal dependence, resulting in a temperature-sensitive OT and spectrum. Therefore, the temperature can be determined from the change in the reflected spectrum.

Primary Project Goal

The primary goal of this project is to develop an accurate temperature measuring system that is capable of withstanding extreme conditions for use in commercial full-scale gasification systems.

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PROJECT COST

Total Project Value:

$1,711,221

DOE/Non-DOE Share:

$1,363,507 / $347,714

Accomplishments

This effort succeeded in developing and testing a prototype temperature measurement system under full-scale operating conditions, resulting in the potential for process improvement, cost reduction, and greater efficiency. Specific accomplishments include:

- Evaluated various sensor designs and selected a Fabry-Perot interferometry-based design for its self-calibrating capability, simplicity, and accuracy. This design was used in the development of sensor prototype for full scale testing.
- Demonstrated in a laboratory setting that the sensor was capable of accurately measuring temperature from room temperature up to 1,600 °C with a close resolution of approximately 0.26 °C. Sensor consistency was also demonstrated in multiple laboratory tests, which conformed closely to B-type thermocouple data.
- Demonstrated improved sapphire corrosion resistance compared to other ceramic materials, such as polycrystalline alumina.
- Tested the prototype sensor at Tampa Electric Company's Polk Power Station under actual operating conditions; sensor was evaluated and optimized at temperatures up to 1,400 °C.
- The prototype sensor survived and measured temperature seven months in the gasifier (Figure 2). This surpassed the performance of resistance based temperature sensors which survive on average of only 45 days. Continuous operation for one year of the sensor is a goal now that basic performance and survivability have been shown to be improvements over current technology.
- Examined the sensor after an additional full-scale test failure revealed that the protective housing had broken and a crack allowed slag to reach the fiber; however, the sensor itself remained intact, proving that the sensor design and sensor are robust.

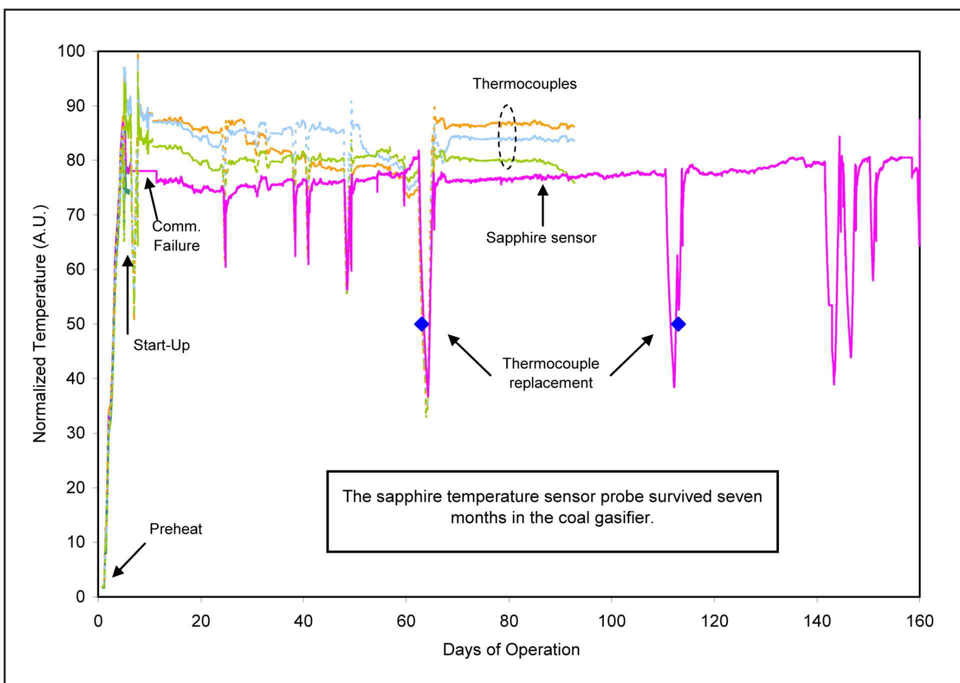

Figure 2. Comparison of sapphire fiber sensor temperature data to conventional thermocouple data. Both sets of thermocouples have now been replaced, as indicated by the blue diamonds on the graph. Differences in port sizes and sensor positions resulted in lower temperature readings from the fiber sensors.

Benefits

The development of a single-crystal sapphire temperature sensor that can accurately measure gasification conditions in extreme conditions will increase the reliability and efficiency of gasifier systems. Since gasifiers are central to many advanced high-temperature power systems, tomorrow's advanced power generation systems, such as Integrated Gasification Combined Cycle (IGCC), will benefit from this development. Other high-temperature applications, such as a combustion turbine, may benefit as well.

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