CCS and Power Systems

ADVANCED ENERGY SYSTEMS - GASIFICATION SYSTEMS

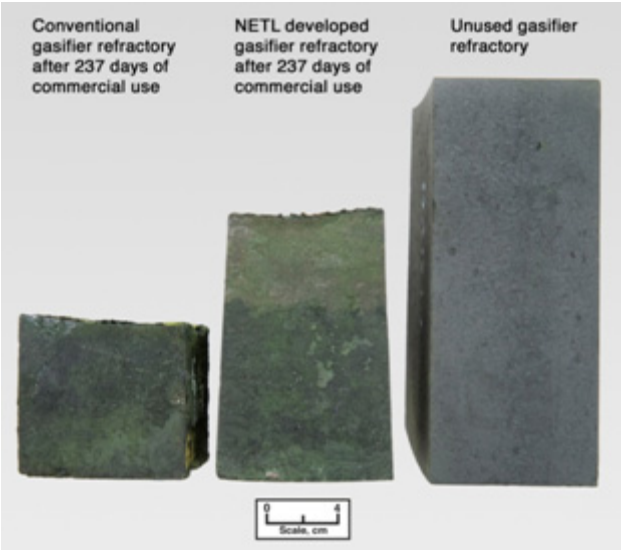
Refractory Improvement

Performer: NETL Office of Research and Development

Project No: FWP-2012.03.03 Task 2

Project Description

The gasification industry, in an NETL survey, indicates a desired on-line plant availability of 85-95% for utility applications and 95% for applications such as chemical production. Gasification facilities are currently unable to meet these requirements. This has created a potential roadblock to widespread acceptance and commercialization of gasification technologies. Refractory liners (and syngas coolers) are among key components of the gasification process identified as negatively impacting gasifier availability. Ash originating in the gasifier's carbon feedstock is the cause of many problems impacting gasifier reliability, availability, and maintainability (RAM). At the high temperatures of gasification, ash changes to liquid, gas, and solid phases which wear down refractory materials and can cause fouling, either of which can lead to unplanned shutdowns for system repair. This research will increase gasifier capacity factor and RAM for lower cost of electricity (COE) via refractory development. Gasifier service life will be improved through both refractory development and research on additives to carbon feedstock that affect ash behavior.



Comparison of NETL developed refractory lining, conventional lining, and unused lining

Program Background and Project Benefits

Gasification is used to convert a solid feedstock, such as coal, petcoke, or biomass, into a gaseous form, referred to as synthesis gas or syngas, which is primarily hydrogen and carbon monoxide. With gasification-based technologies, pollutants can be captured and disposed of or converted to useful products. Gasification can generate clean power by adding steam to the syngas in a water-gas-shift reactor to convert the carbon monoxide to carbon dioxide (CO_2) and to produce additional hydrogen. The hydrogen and CO_2 are separated—the hydrogen is used to make power and the CO_2 is sent to storage, converted to useful products or used for EOR. In addition to efficiently producing electric power, a wide range of transportation fuels and chemicals can be produced from the cleaned syngas, thereby providing the flexibility needed to capitalize on the changing economic market. As a result, gasification provides a flexible technology option for using domestically available resources while meeting future environmental emission standards. Polygeneration plants that produce multiple products are uniquely possible with gasification technologies. The Gasification Systems program is developing technologies in three key areas to reduce the cost and increase the efficiency of producing syngas: (1) Feed Systems, (2) Gasifier Optimization and Plant Supporting Systems, and (3) Syngas Processing Systems.

Gasifier Optimization and Plant Supporting System technologies under development are targeted at increasing gasifier availability and efficiency, improving performance, and reducing the capital and operating costs of advanced gasification plants. Ongoing R&D projects are developing more durable refractory materials, creating models to better understand the kinetics and particulate behavior of fuel inside a gasifier, and developing practical solutions to mitigate the plugging and fouling of syngas coolers. Future work will focus on the development of cutting edge gasifier technologies, which will start with multiple competing concepts and continue with support of the most aggressive and successful technologies being developed, both in the Gasification Systems program and other DOE programs, to reduce the cost of coal gasification. Future work will also aim to reduce the amount of water used in gasification plants and integrate technologies throughout the plant and beyond in a holistic approach to increase efficiency and reduce costs (e.g., the optimization of gasification plants to sell CO_2 for EOR applications).

This NETL Office of Research and Development (ORD) project involves development of a database of slag properties (chemistry, viscosity, etc.) to provide an understanding of refractory wear as well as potential wear mitigation methods by testing various ash and slag chemistries against commercial and newly developed refractory materials. The project includes work to design new refractory materials that can match or beat current refractory performance at a lower cost and with less environmental impact. The target is an affordable refractory material that will provide superior service life regardless of the feedstock used, offering the gasifier operator true fuel flexibility and the opportunity to achieve the industry's goal of 90 percent + on-line availability.

Project Scope and Technology Readiness Level

This task focuses on developing or improving the performance of existing gasifier refractory liner materials through control of the refractory microstructure or through ash/slag management. The goal is to improve gasifier RAM by reducing the amount of refractory material requiring repair/replacement and the frequency with which it is required.

This subtask targets ash/slag management as a means of improving the service life of gasifier liner materials, controlling slag viscosity to ranges desired by gasifier operators for good slag flow from the gasifier, and reducing fouling of the syngas coolers. The development of models predicting coal, petcoke, and coal/petcoke feedstock ash behavior at elevated temperatures will be used to control the gasification process for optimal system performance. Much of the focus will be on model development, and particularly the modeling of basic thermodynamic phase behavior.

The Technology Readiness Level (TRL) assessment identifies the current state of readiness of the key technologies being developed under the DOE's Clean Coal Research Program. In FY 12, this project was assessed a TRL of 3.

The TRL assessment process and its results including definition and description of the levels may be found in the "2012 Technology Readiness Assessment-Analysis of Active Research Portfolio".

Accomplishments

- The team completed an analysis of approximately 90 percent by weight high-chrome gasifier refractory samples with and without phosphate additions. The thickness of the samples with phosphate additions was approximately 33 percent greater after gasifier slag exposure than the samples without phosphate additions, a result that corresponds to an increase in refractory service life.
- Characterization of slag penetrated/non-penetrated areas in commercial high-chrome oxide refractory samples is being conducted to determine the causes of differences in structural spalling.
- Computed tomography imaging of refractory samples taken from gasifiers that use both coal and coal/petcoke blends indicate that cracks form in materials due to firing shrinkage, and that mismatches between structural materials occur at the hot face, creating pathways for slag penetration.
- Laboratory exposure of synthetic coal/petcoke slag compositions at 1425, 1500, and 1575 degrees Celsius under an oxygen partial pressure of 10-8 atm was completed, and phases in the samples analyzed. Nanophase vanadium oxide particles with specific sample chemistries have been found in the samples.
- Slag modeling to control refractory wear and slag viscosity and minimize downstream material effects continues, with current emphasis on entering published literature and laboratory data into the models, and on determining which software predictions using existing slag models are most accurate.

- It was found that phosphate additions migrate by the formation of a gas phase in the refractory, reducing porosity and further limiting slag penetration. This was determined by the high levels of phosphate found in brick pores that were either higher than originally introduced, or were in areas where phosphates were never added. This mechanism is being studied to determine how it may be used to further increase refractory service life.
- CanmetENERGY (Ottawa, Ontario, Canada) is conducting joint research with the NETL Refractory Improvement group on evaluating the creep of refractory materials under gasifier conditions, and evaluating the performance of select refractory material in their small-scale gasifier.
- As part of the vanadium phase study for coal/petcoke slag mixtures, synthetic slag samples were prepared and sent to Chiba Institute of Technology in Japan for evaluation in the double cell Knudsen mass spectrometer for vapor phase analysis.

Contacts, Duration, and Cost

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Duration
Award Date: 10/01/2011

Project Date: 09/30/2014

Cost
Total Award Value: $500,804

Presentations, Papers, and Publications

- Research Efforts at the National Energy Technology Laboratory to Improve Gasifier Performance, James Bennett, Gasification Technologies Conference, Colorado Springs, CO, Oct 13-16, 2013.
- Gasification Modeling Activities at the National Energy Technology Laboratory (Oct 2012)
  Presented by Chris Guenther, Gasification Technologies Conference, October 28-21, 2012, Washington DC.
- Improved Lining Material for Gasifiers Could Lead to Wider Commercialization of Clean and Efficient Energy Technology
  DOE - Fossil Energy Techline, Nov 2009.

Performer website: NETL Office of Research and Development