the ENERGY lab

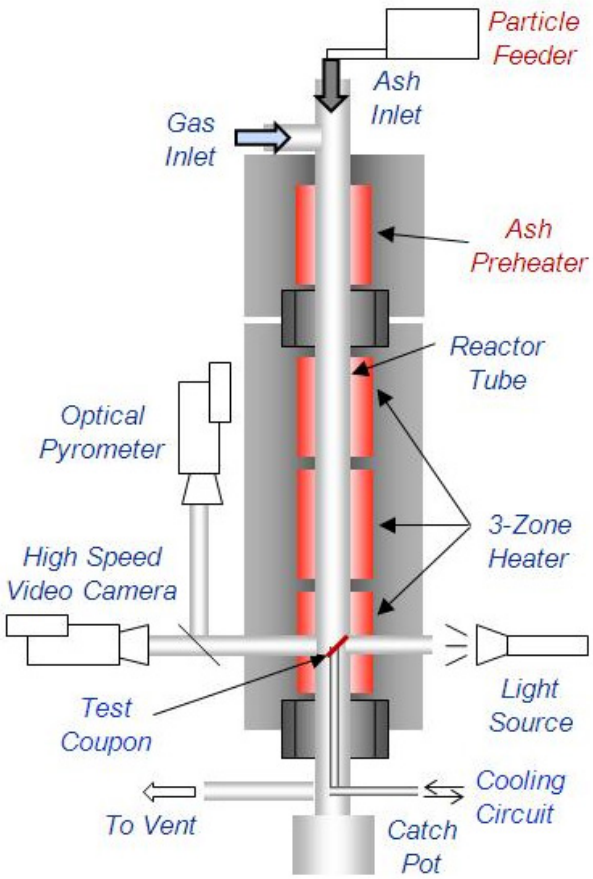
PROJECT FACTS

Project No: FWP-2012.03.03 Task 3
Performer: NETL Office of Research and Development

Project Description

Accurate physical models are needed to predict the rates of slag buildup in a gasifier or ash deposition in a syngas convective cooler. Gasification plants can experience lower carbon conversion and plugging of syngas coolers with fly ash, reducing the thermal efficiency of a gasifier and its overall reliability. Molten ash chemistry and viscosity are crucial aspects of carbon feedstock ash impact on slag properties and refractory corrosion in a gasifier.

In this project researchers will develop reduced order models (ROMs) with higher fidelity computational fluid dynamics models coupled to the ROMs to enable more accurate prediction of gasifier performance. Proposed devolatization and char kinetics work will attempt to identify the factors responsible for the formation of fly ash particles by using the traditional mineral processing approach of particle partitioning and by superimposing kinetics of char and mineral transformations. Slag viscosity will be investigated using a high-temperature rotating-bob viscometer and a temperature gradient furnace in which slag infiltration in a controlled atmosphere can be studied. Particle deposition testing will initially be conducted at temperatures relevant to the convective syngas coolers in order to generate ash particle chemistry; ash adhesion probabilities as a function of particle size, temperature, and velocity; surface temperature; and contact angle. Ash particles from the High Pressure Entrained Flow Reactor (HPEFR) at Pennsylvania State University (Penn State) will be generated from coal and petcoke feedstocks that are separated into multiple size and density fractions, each containing various amounts of mineral matter, which will be used to determine the characteristics of the fly ash particles. The effect of iron sulfides and other coatings on particle deposition will also be investigated in the latter stages of the project, and a comprehensive model for ash deposition at convective syngas cooler (CSC) conditions will be generated.



Particle deposition experimental schematic

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 reduced-order models as well as high-fidelity engineering models based on tests they are performing to measure pyrolysis and gasification kinetics of relevant coal types used in power generation. The models constitute tools that can be used to evaluate the impact that fuel properties have on slag and refractory interaction and will guide efforts to reduce plugging and fouling throughout the syngas cooling system. The result of reduction of plugging and fouling will be improvement of the reliability, availability and maintainability of gasification plants and accompanying reduced costs.

Project Scope and Technology Readiness Level

This project will improve the reliability, availability, and maintainability of gasification plants by developing tools to evaluate the impact of fuel properties on slag and refractory interactions. Plugging and fouling throughout the syngas cooling system can be reduced by evaluating ash deposition from carbon feedstock. To achieve this goal, four major areas of research are being pursued concurrently:

- Model Development: The modeling effort involves developing a heuristic spreadsheet-based reduced ROM with the capability to predict the effects of the distributive properties of fuels used in entrained-flow gasifiers on key gasifier performance indicators, so that the ROM may be used as a tool to investigate syngas cooler fouling and the amount of unconverted carbon.
- Devolatization and Char Kinetics: The objective of the devolatization and char kinetics effort is to measure pyrolysis kinetics for various density and size fractions of Pittsburgh #8 coal and, at high temperature and pressure, characterize the changes to char particles during pyrolysis (early stages)—including particle size, density, char reactivity in carbon dioxide (CO_2), and mineral matter transformations—and identify the critical conversion(s).
- Slag Viscosity and Unburnt Carbon: The slag viscosity and unburnt carbon effort is focused on measuring slag viscosities as a function of temperature and carbon monoxide (CO)/CO_2 ratio for laboratory manufactured synthetic ash to determine how slag infiltrates into a refractory material subjected to a temperature gradient.
- Particle Deposition: The particle deposition effort is focused on conducting ash particle deposition experiments at conditions relevant to existing convective syngas coolers and using the data to generate a comprehensive model of ash deposition probability as a function of feedstock size and density fractions, ash particle size, particle temperature, particle velocity, surface temperature, and contact angle.

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

- Researchers at West Virginia University (WVU) have developed a rules-based partitioning spreadsheet ROM to predict gasifier performance. The ROM can be used to predict the solids mass fraction that adheres to the slag and the fraction that leaves the gasifier in the fly ash.

- A High Pressure Entrained Flow Reactor has been commissioned at Penn State and the fuel feeder has been tested with coal particles of various sizes. A very consistent flow was observed for both atmospheric and pressurized (100 pounds per square inch) flow. The reaction tube was fitted and the collection probe inserted in the gasifier being assembled. The unit was than evaluated for carbon feedstock feed rates in preparation for initial evaluation of the gasifier at high temperatures.
- Researchers at Carnegie Mellon University (CMU) have completed viscosity measurements of coal/petcoke slag mixtures with good experimental reproducibility. The resultant slags are being analyzed by researchers. The ash deposition ROM developed for the industrial convective syngas cooler is being used to help determine how the High Pressure Tubular Reactor deposition studies at atmospheric pressure will relate to the actual particle deposition process at higher pressures relevant to domestic integrated gasification combined cycle (IGCC) plants.
- A model to predict slag film thickness flowing in a gasifier was developed that accounts for the distributed flux of ash into the slag film over the entire slag-syngas interface. Predictions were obtained for gasifier axial temperature distributions from 2000 K at the top of the gasifier to 1750 K at the bottom of the gasifier.
- The high-speed video pyrometer was developed at NETL and will be used to track particles and their temperature in hot fluid bed reactors, for monitoring turbine blade particle deposition in the aerothermal rig, and to determine char/ash particle rebound/sticking in a slag layer during gasification.
- The design aspects of the new HPTR reactor at NETL Morgantown were finalized and the modification of the existing HPTR reactor to those designs began.

Contacts, Duration, and Cost

Contacts

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Duration
Start Date: 10/01/2011
End Date: 09/30/2014

Cost
Total 2013 Project Value: $529,759

Presentations, Papers, and Publications

- Research Efforts at the National Energy Technology Laboratory to Improve Gasifier Performance
  Presented by James Bennett, U.S. Department of Energy, National Energy Technology Laboratory, Gasification Technologies Conference, October 13-16, 2013, Colorado Springs, CO.
- Gasification Modeling Activities at the National Energy Technology Laboratory (Oct 2012)
  Presented by Chris Guenther, Gasification Technologies Conference, October 28-21, 2012, Washington DC.
- Recent Developments in Carbonaceous Chemistry for Computational Modeling (C3M) with Uncertainty Quantifications (UQ) (Oct 2012)
  Presented by Kiran Chaudhari, AICHE 2012, October 31, 2012, Pittsburgh, PA.

Performer website: NETL Office of Research and Development