Title:
A Summary Report on Combustion and Gasification Processes

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Introduction

Six poster papers regarding combustion and gasification were reviewed. These six papers address various different technology subjects: (1) Underground coal gasification modeling, (2) wood gasification kinetics, (3) heat transfer surface pretreatment by iron implantation, (4) coal water slurry stabilization technology, (5) coal log pipeline technology, and (6) nuclear reactor decontamination. The following are summaries and comments of the above papers which will be presented at the Energy System Design and Analysis session of the 5th World Congress of Chemical Engineering.

Characterization of Flow and Chemical Processes in an Underground Gasifier at Great Depth -- (authored by J. P. Pirard, A. Coeme, M. Mostade, P. Pirlot and G. L'Homme)

Summary

Underground coal gasification (UCG) is the only economically acceptable way to exploit thin deep seams such as those situated in Western Europe. To prepare a coal seam for UCG, a horizontal channel was drilled in seam at 600 m depth. This horizontal channel is connected to an injection well at one side and to a production well at another side. A gasifying agent is introduced into the horizontal channel via the injection well, and the products of gasification leave via the production well. Coal is supplied from the wall of the horizontal channel and reacts with the gasifying agent. The coal layer surrounded on the channel wall is gradually depleted during gasification, and the diameter of the channel becomes larger. This creates the so-called cavity growth concept. The objective of this modeling work is to develop a cavity growth model based on the Wilks Model (U.S. DOE/METC/84-7, 1983) with improvements to characterization of flow and chemical processes.

Comments:

- The authors provided a very good description of the model concept and calculational procedure. However, equations used in the model (continuity, energy and species conservation, etc.) were based on the Wilks Model and were not listed in the paper. Also, the authors did not compare in detail the differences in computational results with previous work of Wilks to help readers appreciate the essence of the improved flow characteristics and chemical processes.

- In general, the model is a transient model (or quasi-steady state) with an axially symmetrical assumption. If the permeability of the underground coal seam is not uniform,

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the axially symmetrical results will not be possible. Nevertheless, this work shows a continuous improvement of process model leading to a better understanding of the underground coal gasification process.

Model for Reaction Kinetics in Pyrolysis of Wood -- (authored by P. Ahuja, P. C. Singh, S. N. Upadhyay, and S. Kumar)

Summary

A reaction model was proposed by the authors for the description of biomass pyrolysis reactions. This model assumes that the chemical processes taking place when biomass is pyrolyzed are devolatilization reactions (primary) and vapor-solid interaction (secondary). The primary reactions yield char and volatiles due to pyrolysis of biomass, while the secondary reactions produce secondary char after the volatiles interact with the primary char.

The authors conducted several laboratory tests of weight loss versus time using acacia wood and eucalyptus to verify their model. Samples were prepared in the forms of small particles (0.15-0.3 and 0.3-0.5 mm) and large cylindrical particles. The tests were conducted in open and sealed environments. The purpose for testing small particle samples in an open environment was to study primary reactions. The secondary reactions were tested using large particles assuming that large particles allow volatiles to have longer retention time to interact with the primary char. Tests seemed to verify the existence of primary and secondary reactions.

Comments:

- The kinetic rate constants (k_1, k_2, k_3, and k_4) for each reaction steps and the coefficient of deposition (delta) were obtained by least square optimization of experimental data to the proposed reaction mechanism. For isothermal analysis of small particle samples, a linear relationship of the resulting plot of ln k_1 and ln k_2 versus 1/T was not obtainable. This could imply that pyrolysis reactions were probably too complicated to be represented by a simple model or the pyrolysis data were not perfect.

- Four ordinary differential equations were used for the description of the overall kinetic model. Equation 3 is the rate of change of the secondary char C_{21}. It is represented by one term from the interaction of primary char (C_1) and the volatiles. The rate of disappearance of secondary char C_{21} to form C_{22} is not included. With the sophisticated

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computational capability available today, it seems
unnecessary to neglect the rate of disappearance term in
Equation 3.

- A similar conclusion was found by other authors (Antal and
  Varhegyi, 1995) that an irreversible, single-step, first-
  order-rate equation with a high activation energy can be
  used to describe a wide variety of cellulose pyrolysis under
  conditions with minimum vapor-solid interactions and heat
  transfer intrusions. These authors also pointed out the
  need to conduct methodical studies of the influence of
  particle size on pyrolysis chemistry and kinetics to address
  the secondary vapor-solid reactions. The present paper did
  reveal some of the test data.

**Development of a Stainless Steel Heat Transfer Surface with Low
Scaling Tendency -- (Authored by H. Mueller-Steinhagen and Q.
Zhao)**

Summary

The purpose of the paper was to present a new method of preparing
low fouling metal surfaces by using modern surface modification
techniques. The fundamental concept of the method is essentially
to prepare alloys which possess low surface energy, in a metallic
surface layer of 1-3 micron meter by ion implantation. Ion
implantation is the introduction of atoms or ions into the
surface layer of a solid substrate by bombarding it with high
velocity ions at the keV or the MeV energy dose range. Result of
ion implantation will reduce the surface free energy. Less
deposit formation should occur on materials that have lower
surface energies. While the ion implantation technique has been
applied in many fields, it has not been widely considered in
reducing fouling of heat transfer surfaces. Consequently, at the
University of Surrey (UK), the Department of Electronic and
Electrical Engineering tested this method using silicon fluoride
ions bombarded on the surface of stainless steel heater rods and
compared the fouling behavior of implanted surfaces and bare
surfaces for a certain $CaSO_4$ concentration and at a certain heat
flux. The results indicate that, as expected, implanting energy
at the keV or MeV dose have significant impact on the surface
energy of the modified surface, and implanted surface show less
$CaSO_4$ scale formation. Given the outcome of their results, the
university filled a patent on Modification of Metal Surfaces
(Ref. P31807GB).

Comments:

- Q. Zhao also carried out similar research in China since
  1984 and reported on surface treatment techniques to

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demonstrate that the ion implantation concept is applicable to metals.

- The authors talked about stainless steel heat transfer surface with low scaling tendency. The experiments were performed at 1 bar, and at 100° C. Superheater and evaporator tubes R&D are now being developed to operate at about 630° C. For commercial application to various energy systems, it is highly desirable to conduct future experiments at high temperature and pressure for an extended period of time.

Storage and Transportation of Coal Water Mixtures -- (authored by Hiromoto Usui and Takashi Saeki)

Summary

A coal water mixture (CWM) may be an economically attractive liquid fuel alternative when transported to the customer directly from the coal mine via ship or pipeline. However, when CWM is stored in tanks, notably ship tanks, coal particle sedimentation can become a severe problem. The subject paper describes the performance of two different sedimentation-preventing, stabilizing additives: (1) Coaboxymethyl cellulose (CMC); and (2) rhamsan gum. The CWM's were prepared from the Yoazhou and the Prima coals and were treated with a dispersing additive, polymethacrylate before adding a stabilizing additive. The dispersing additive allows water to be highly loaded with pulverized coal particles.

The effect of "shear rates" on CWM sedimentation was determined experimentally. Shear rates typical in tank storage were applied to a CWM by placing it in the annulus between two rotating, coaxial cylinders. After the CWM was exposed to a shear rate for a period of time, sedimentation was characterized by measuring the thicknesses of two layers, a "soft pack" layer and a "hard pack" layer.

Without a stabilizing additive, the hard pack layer became unacceptably large when the applied shear rate was 0.2 to 1.0 s^{-1}. (The hard pack layer disappeared at high shear rates, but the soft pack layer persisted.) At a concentration of 0.02% by weight, a rhamsan gum stabilizing prevented the formation of a hard pack layer. Another stabilizing additive, CMC, failed to prevent significant sedimentation under applied shear rates of 0.2 to 0.8 s^{-1}. Therefore, the rhamsan gum stabilizing additive was recommended for the prevention of CWM sedimentation.

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Comments:

- This research was intended to solve the problem of CWM sedimentation during transportation and storage. The success of this research will make CWM technology an attractive alternative for coal transportation and eventually contributes to the cost reduction of coal transportation.

- Both the soft pack and hard pack layers were measured by a rod manually. The authors should have addressed the reproducibility issue.

Coal Log Pipeline: Development Status of the First Commercial System -- (authored by T. R. Marrier)

Summary

The paper presented an overview design description of a coal log pipeline (CLP) system as a substitution to coal transport by train and truck. Coal is pressed into a cylindrical log with 120-140 mm diameter and length to diameter ratio of 1.8, propelled by high pressure water through a 200 mm diameter underground pipeline. Coal logs travel butted together in train with coal to water ratio of 4:1. Coal logs are separated at destination via screen and conveyed to a crusher. Transported water is treated and reused at a power generation station. The economic analysis done by the authors indicate that CLP transportation is cost competitive with coal slurry, railroads and trucks in certain situations.

Comments:

- The author provided a good general description of the CLP system. However, very little technical information was revealed. Coal logs have a specific gravity of 1.3. Therefore, one can expect that they will not float in still water and there are possible problems due to attrition of the logs during transit. More tests on the durability of coal logs and flow of coal logs in a pipe elbow and U-bend should be worthwhile to ensure technical viability of the process before building an expensive demonstration unit.

- A detailed technical comparison between CLP and coal slurry transportation will be beneficial to identify strength and weakness of each process.

- Economic Analysis of the CLP transportation was conducted by the same developer. It is suggested to have an independent cost assessment of the CLP and the coal slurry transportation processes.

Decontamination of Nuclear Systems at the Grand Gulf Nuclear Station -- (authored by Ronald D. Weed and Kenneth R. Baker).

Summary

The paper discussed the decontamination plan for Recirculation System and Reactor Water Cleanup System at Grand Gulf Nuclear Station located at Gibson, Mississippi. The goal of the plan was to achieve cleanup to meet the As Low As Reasonably Achievable level. Two processes were used for decontamination. The LOMI process was used for the recirculation system and the CANDEREM process was used for the reactor water cleanup system.

Comments:

-   Both the LOMI and CANDEREM decontamination processes were used to remove the target components of decontamination (i.e., chrome metal and radionuclide Cr-51). However, the chemical solutions used in these two processes for removal were not specifically identified. Only the alkaline-permanganate chemical solution was revealed in one of the CANDEREM process steps. It is difficult to understand the chemistry of the decontamination processes. The readers have to find out at the poster exhibition.

-   There are two recirculation loops in LOMI, and one circulation loop under CANDEREM, based on the text. However, it is hard to visualize how the decontamination systems work without cross contamination, as pointed out by the authors. A simple process flow diagram should greatly help clarify the issue.