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Applied Thermal Engineering 23 (2003) 1993–2008

APPLIED THERMAL ENGINEERING

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An Eulerian model for the simulation of an entrained flow coal gasifier

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Received 15 May 2002; accepted 25 April 2003

Abstract

A numerical model is used to simulate the gasification of coal inside an entrained flow gasifier. The model is based on the Eulerian–Eulerian concept. Both gas and particulate phases conservation Eulerian equations are solved. The model used includes the coal particle processes, such as drying, volatilization, heterogeneous reactions of combustion and gasification, particle drag and turbulent dispersion, as well as heat-up.

The model is applied to the investigation of the gasification of coal in a commercial entrained flow gasifier, from which experimental data is available. The results obtained show good agreement for both the main and minor species, and temperature.

Keywords: Coal; Eulerian model; Gasification; Combustion; Modeling; CFD

1. Introduction

Increasing energy efficiency in industries is a goal outlined by engineers and researchers all over the world. Related to this, the rising demand of energy, and the need for political strategies toward a sustainable development have made the development of new efficient technologies, like co-generation and combined cycles a priority.

Nowadays, solid fuels gasification technology has been getting more interest from the power generation Industry because of the greater versatility of fuels that can be used. For example,

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1359-4311/$ - see front matter
doi:10.1016/S1359-4311(03)00149-2

gasifiers can process coal, petroleum coke, biomass, or municipal residuals. Gasification technology allows us to process a solid or liquid carbon material into a gas fuel called syngas. This gas is mainly rich in carbon monoxide and hydrogen.

Several benefits may be gotten from gasification technology, like: (a) power generation with low pollutants emissions and high energy efficiency using residuals like pet coke; (b) the possibility to interact with some refinery activities, e.g., supplying hydrogen and energy to different processes; (c) a benign environmental disposition of residuals, and (d) use of biomass to generate power and mitigate the greenhouse effect (fuel consumption reduction).

As a corollary, a better use and implementation of an optimized gasification technology demands simulation tools, supplying a good knowledge of the aerodynamics, the chemical kinetics, as well as their interaction with the flow-field. In the case of coal gasification, the complexity of the physical processes and the disparity of scales present in the gasifier are compounded by the multiphase nature of flow, and by the complexity of the interphase processes. Lagrangian multiphase methods offer in this context a "natural" framework for the implementation of the physical models. However, the Eulerian model has some advantages over the Lagrangian model. These include the facility to use parallel codes, and fine-grid-embedding and grid restructuring techniques due to a more compact formulation. Also, the turbulent dispersion of particles is more readily accounted for by the Eulerian framework, if gradient-diffusion models are acceptable [6].

In this work, an Eulerian model is used to simulate an entrained flow coal gasifier. The model is based on the detailed modeling of all the coal particle processes, including particle drag and turbulent dispersion, heat-up, volatilization, drying, and heterogeneous combustion. The coal particle is characterized by its contents in raw coal, ash, water and char. All four components of the coal particles are accounted for by means of their mass fractions. Further equations need to be set up and solved for the particle velocity components, the particle specific enthalpy, the coal volume fraction of the particle phase, and a special variable from which the mean particle size can be computed [5].

The gas phase is modeled as a multicomponent mixture, including N_2, O_2, H_2O ,CO, CO_2, and CH_x (a general hydrocarbon that is the gaseous outcome of the particle pyrolisis). These components are accounted for by means of their mass fractions. Further equations are solved for each of the gas particle velocity components, for the gas specific enthalpy, for the gas-phase local volume-fraction, for the turbulent kinetic energy and its dissipation rate, and for the three net radiation fluxes of six-flux radiation model.

2. The gasifier considered

The case simulated is an entrained flow coal gasifier. This gasifier is operating in an Integrated Gasification Combined-Cycle (IGCC) configuration at Nakoso, Japan [1]. The system has a capacity to process 200 tons per day of coal, based on air blown operation. A schematic view of the gasifier is showed in Fig. 1. The gasifier is an up-flow reactor and has three sections: combustor, diffuser, and reducer. The burner chamber is located at the bottom section. In this section, air and pulverized coal are introduced through two sets of injection nozzles at 0.4 and 0.7 m above the bottom. Once the diffusion zone is reached, the pulverized coal is volatilized and reacts with oxygen to reach a high temperature, which is simultaneously used to produce the endothermic