TWO-DIMENSIONAL MATHEMATICAL MODEL OF LIQUID FUEL COMBUSTION IN BUBBLING FLUIDIZED BED APPLIED FOR A FLUIDIZED FURNACE NUMERICAL SIMULATION

by

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Original scientific paper
https://doi.org/10.2298/TSCI170922307N

Lately, experimental methods and numerical simulations are equally employed for the purpose of developing incineration bubbling fluidized bed (BFB) facilities. The paper presents the results of the 2-D CFD model of liquid fuel combustion in BFB, applied for numerical simulation of a fluidized bed furnace. The numerical procedure is based on the two-fluid Euler-Euler approach, where the velocity field of the gas and particles are modeled in analogy to the kinetic gas theory. The proposed numerical model comprises energy equations for all three phases (gas, inert fluidized particles, and liquid fuel), as well as the transport equations of chemical components that are participating in the reactions of combustion and devolatilization. The model equations are solved applying a commercial CFD package, whereby the user submodels were developed for heterogenic fluidized bed combustion of liquid fuels and for interphase drag forces for all three phases. The results of temperature field calculation were compared with the experiments, carried out in-house, on a BFB pilot facility. The numerical experiments, based on the proposed mathematical model, have been used for the purposes of analyzing the impacts of various fuel flow rates, and fluidization numbers, on the combustion efficiency and on the temperature fields in the combustion zone.

Key words: *CFD model, combustion, liquid fuel, bubbling fluidized bed, Euler-Euler approach, three phase flow*

Introduction

Fluidized bed (FB) incineration, *i. e.* combustion and co-combustion, is a very efficient technology for removing the redundant industrial byproducts. In the case that the combustion of the waste substances has positive energy effects, the FB technology has a great importance not only in terms of preserving the environment but also for the purpose of energy efficiency and utilization of renewable energy sources.

Benefits of combusting unconventional fuels in a BFB are numerous. The unconventional fuels are substances that can be combusted in conventional furnaces, but with great difficulty, due to its high viscosities, low heating value, and content of ballast substances (water and other incombustible materials). Advantages of the FB combustion are primarily the high heat capacity and thermal conductivity of the bed, and intense heat transfer between particles

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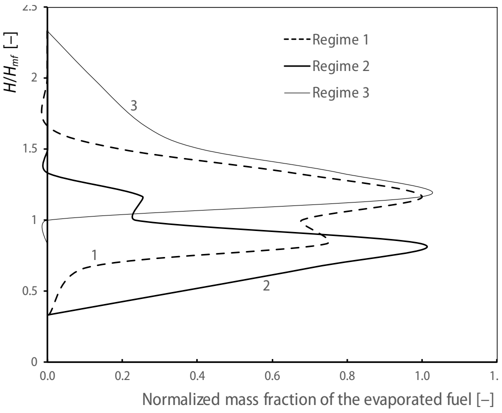

Figure 5. Calculated averaged evaporated fuel mass fractions along the reactor height

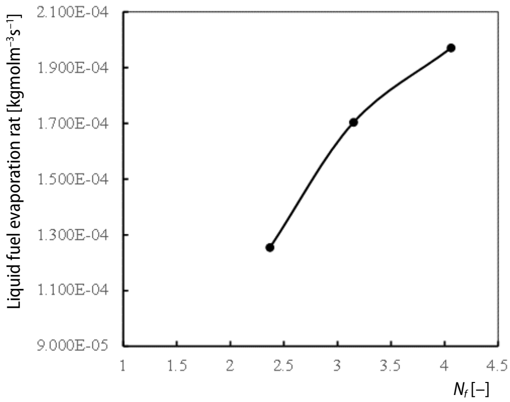

Figure 6. Liquid fuel evaporation rate in the function of the fluidization number

in the fluidization reactor and is a limiting factor in the entire chain of reactions. As seen from the table, the intensity of the reaction rate of fuel evaporation continually increases with fluidization number, which is contrary to the effect of the complete combustion zone volume dependence of N_f were this functional relation have a minimum.

Conclusions

A numerical CFD model of the liquid fuels combustion in a 2-D BFB has been proposed. The model is based on the EE granular flow simulation method including the KTGF for the particles motion modeling. The basic KTGF model is upgraded by the inclusion the liquid-phase due to fuel and also by the including evaporation and combustion models.

Because of the way of fuel dosing the processes in an experimental combustion chamber have a 3-D character. However, due to the complexity of the numerical simulation of FB with the chemical reactions here were applied the model equations in 2-D form, and fuel dosage is set symmetrically at 5 cm from the distribution plate. All other parameters: geometric, temperature, flow rates, chemical composition, *etc.*, correspond to the experimental conditions.

The developed numerical simulation procedure has been applied to the analysis of the different fluidization regime impacts on the efficiency of liquid fuels combustion in FB furnaces. For this purpose, the calculations of test fuel combustion with three different fluidization numbers were carried out. The results of temperature field calculation were compared with the experiments in-house provided on a BFB pilot facility. The general conclusion that can be obtained on the basis of the performed numerical simulations is that temperature profiles along the central vertical line of the FB combustor obtained by measurements as well as by calculation show that very high temperatures can be achieved on relatively low heights of the reactor. This leads to the conclusion that efficient and complete combustion is accomplished within a relatively small volume, what could be of importance for the FB incinerators design. The dimensionless temperature profiles along the reactor central vertical line obtained by numerical simulation with combustion conditions corresponding to Regime 2 and profiles obtained from the experiments are in good agreement.

Analyzing the calculated dimensionless temperature profiles, as well as diagrams of the averaged vaporized fuel mass fraction for all three simulated regimes, it can be concluded that there is an optimal fluidization regime from the point of view of the zone size in which