MODELING OF MASS AND HEAT FLOW THROUGH REACTING POROUS BED

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Introduction

The aim of the study was to simulate and analyze the flow characteristics through the heated packed bed of coal particles. The flow is strongly influenced by the pyrolysis occurring due to temperature increase. This kind of phenomena is a fundament of a coal coking and biomass gasification, and is of crucial importance in predicting pressure increase inside the coal bed during its thermochemical conversion, particularly in industrial scale coking process. The proposed description of physico-chemical processes typical for coking is based on the one-dimensional transient two-component model.

Model description and calculation results

The model consists of balance equations for mass and energy for solid phase, as follows:

$$\frac{\partial\left(\epsilon_s\rho_s\right)}{\partial t} = -W_{sg}, \tag{1}$$

$$\rho_s c_{v,s}\frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\lambda\frac{\partial T}{\partial x}\right) + W_{sg}h_{sg} \tag{2}$$

and mass and momentum for gases, respectively:

$$\frac{\partial\left(\epsilon_g\rho_g\right)}{\partial t} + \frac{\partial\left(\epsilon_g\rho_g v_g\right)}{\partial x} = W_{sg}, \tag{3}$$

$$\frac{\partial\left(\epsilon_g\rho_g v_g\right)}{\partial t} + \frac{\partial\left(\epsilon_g\rho_g v_g v_g\right)}{\partial x} = -\frac{\partial\left(\epsilon_g p_g\right)}{\partial x} - \frac{\mu_g\epsilon_g v_g}{k}, \tag{4}$$

where ϵ means porosity, ρ density, W_{sg} interphase mass flux, c_v specific heat, T temperature, h_{sg} enthalpy of pyrolysis, v_g velocity, p_g pressure. The numerical scheme for gases is based on the balance equations on the staggered grid for mass and momentum. To solve the energy balance equation for solid phase the semi-implicit algorithm is used. The mass source/sink of gases in balance equations comes from the experimental data regarding thermogravimetric analysis of coal sample. The system of equation is completed with the ideal gas state equation for mixture of gases. It is known that speed of heat transfer during coal carbonization in fixed bed is of order of 10^{-6} m/s whereas the mass flow of gases is about 10^{-3} m/s. The multi-scale character of flow processes in packed bed during thermo-chemical conversion of solid particles makes the calculation procedure difficult. The gas velocity, being considerably larger than the speed of heat propagation, requires very small time-step in numerical scheme and thus leads to time-costly calculations. The interaction between phases can be essentially two-sided, but in the analyzed case it is assumed that the solid phase has impact only on the gas flow. Initially, right boundary of the bed is heated; the temperature evolution is described by

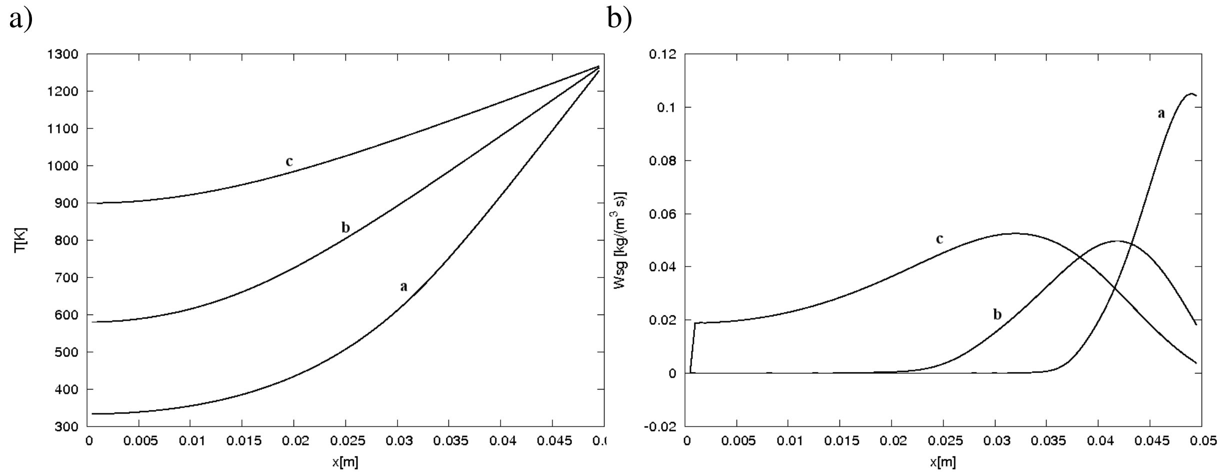

Figure 1: Calculation results for fixed coal bed – evolution of: a) temperature, b) mass source; **a** – $t = 635$s, **b** – $t = 1905$s, **c** – $t = 3175$s.

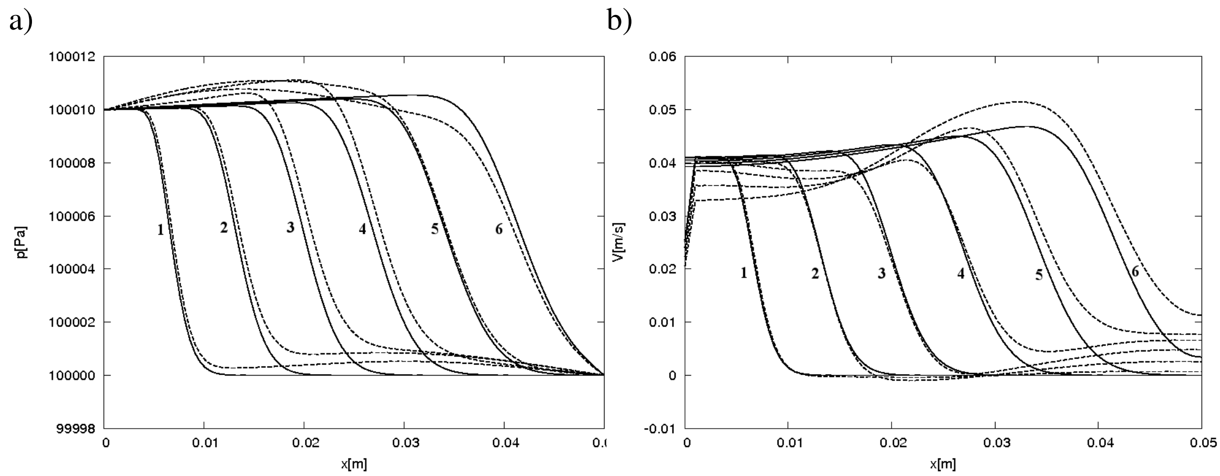

Figure 2: Pressure (a) and gas velocity change (b) inside the coal bed; with devolatilization assumed (dashed lines) and without (solid lines); **1** – $t = 1.67 \cdot 10^{-5}$s, **6** – $t = 9.6 \cdot 10^{-5}$s.

the curves in Figure 1a. Temperature increase causes pyrolysis, mass flux between solid and gaseous phase W_{sg} is presented in Figure 1b. The calculation of the gas mass and momentum equation starts when left and right side of the reactor are opened, temperature is described by curve *c* in Figure 1a. The results of calculations for the gas flow in a reactive bed are denoted by continuous lines and compared with gas flow in the inert bed (dashed lines) – Figures 2a and 2b show the distribution of pressure and velocity in the reactor as a function of x for six instants of time. For a reactive bed, the source of the mass W_{sg} increases gas pressure in every point of the reactor overlapping with the wave induced by pressure boundary pulse.

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