MATHEMATICAL SIMULATION OF THE COMBUSTION OF A PEAT BED. INFLUENCE OF STEAM CONDENSATION

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A model of the pyrolysis and combustion of a porous medium in the absence of forced convection is suggested. Substantial differences between this statement of the problem and filtration combustion of gases in inert porous media are considered. The influence of the condensation of steam contained in the products of pyrolysis on gas filtration and the temperature field close by the combustion site is shown.

Keywords: filtration, combustion, heterophase medium, peat.

Introduction. There are two essential features that distinguish combustion of porous media under the conditions of natural convection from filtration combustion of gases in inert porous media: 1) there is no forced filtration of a gas, with the main driving force of filtration being the transition of a solid phase into a gaseous one, which requires the reformulation of the equation of gas momentum conservation; 2) heterogeneous chemical reactions occur that require a change in the equations of substance conservation and enthalpy for the gas and solid phases.

Statement of the Problem. The object of simulation is a peat deposit subjected to thermal effect from the side of an external heat source (Fig. 1). This effect leads to the warming up of peat, its pyrolysis, and oxidation by the air oxygen with liberation of heat, which allows the process to be self-maintained without the influence of external forces. In the process of pyrolysis and oxidation of peat, the solid material converts into a gas which is filtered to the free boundary under the action of excess pressure.

In order to model the process of combustion of peat bogs, a generalized volume-averaged model of filtration combustion is suggested [1–3], which is modified with account for the heterophase reactions of oxidation and pyrolysis of a peat bog. The model is based on the equations of continuity, momentum transfer in a gas, conservation of the mass of the gas and solid phase components, conservation of heat in the gas and solid phases, and the equation of state of an ideal gas.

Mass Conservation of the Chemical Components of a Gas and Solid Medium. The mass conservation law for gaseous and solid components of a peat deposit are represented in terms of the mass fraction \( Y \) in the following form:

\[
\frac{\partial \rho g Y_{gi}}{\partial t} + \nabla \cdot \rho g u Y_{gi} + \nabla J_{Di} = \dot{\rho}_{mgj},
\]

where \( J_{Di} = -m_g D \nabla Y_{gi} \)

\[
\frac{\partial (1-m)}{\partial t} \rho s Y_{si} = \dot{\rho}_{msi}.
\]

We sum Eq. (1) over the gas components and Eq. (2) over the components of the solid medium. By definition the mass fractions of the components of gas \( \sum_{i} Y_{gi} = 1 \) and of solid medium \( \sum_{i} Y_{si} = 1 \). The sources of chemical...
reactions are summed up and yield the total change in the mass of the gas and peat, respectively: $\dot{\rho}_{\text{mg}} = \sum_i \dot{\rho}_{\text{mg}i}$. 

$\dot{\rho}_{\text{ms}} = \sum_i \dot{\rho}_{\text{ms}i}$. As a result, we obtain the continuity equations for the gas and solid phase:

$$\frac{\partial m \rho_g}{\partial t} + \nabla \cdot (m \rho_g u) = \dot{\rho}_{\text{mg}} ,$$

$$\frac{\partial (1-m) \rho_s}{\partial t} = \dot{\rho}_{\text{ms}} .$$

Substitution of (3) into (1) and of (4) into (2) yields

$$m \rho_g \frac{\partial Y_{\text{gi}}}{\partial t} + m \rho_g u \nabla Y_{\text{gi}} + \nabla J_{\text{Di}} - \dot{\rho}_{\text{mg}} Y_{\text{g}i} = \dot{\rho}_{\text{mg}i} ,$$

$$(1-m) \rho_s \frac{\partial Y_{\text{si}}}{\partial t} = \dot{\rho}_{\text{ms}i} - Y_{\text{g}i} \dot{\rho}_{\text{mg}} .$$

Assuming that in chemical processes the density of the solid substance does not change and only its porosity varies, from Eq. (4) we obtain an equation for determining the porosity of the solid phase:

$$\rho_s \frac{\partial}{\partial t} m = - \dot{\rho}_{\text{ms}} .$$

Method of Solving the Difference Equation of Conservation of Chemical Components. On a rectangular Cartesian grid the difference scheme for Eqs. (5) and (6) has the form

$$F^k = a_{ij} Y_{ij-1}^k - b_{ij} Y_{ij}^k + c_{ij} Y_{ij+1}^k + d_{ij} Y_{i-1j}^k + e_{ij} Y_{i+1j}^k + f_{ij} (Y_{ij}^1, ..., Y_{ij}^N) = 0 .$$

In the equation for the mass fractions of solid substance (6), convective transfer and diffusion are absent; therefore the coefficients $a, c, d, e$ are equal to zero. In Eq. (8), the parameter $f_{ij}$, which describes the mass source.