Two-dimensional Mathematical Model for Forest Fire Spread

A.A. Kuleshov, **E.E. Myshetskaya***, **S.E. Yakush*****

* Keldysh Institute of Applied Mathematics of RAS, Moscow
** A. Yu. Ishlinskii Institute for Problems in Mechanics of RAS, Moscow

Forest fire is a complex phenomenon for which various mathematical modeling approaches have been developed. The considered two-dimensional mathematical model does not demand the big computer resources and can be applied for the prediction of forest fire dynamics, as an aid to expert estimations on the progress of an emergency situation, taking decisions on attacking the fire, and assessing the damage caused by the fire. The two-dimensional two-phase forest fire model discussed below is derived by averaging the original three-dimensional gas flow equations over the height of the forest fuel material layer. This model reflects the fundamental physical laws of conservation of mass, momentum and energy and takes into account all of the physical phenomena in the fire zone that are important for the fire dynamics.

The proposed two-phase model treats a forest as a single-storey two-phase medium consisting of air and gaseous products of pyrolysis and combustion (the air-gas or gas phase) and forest fuel materials and solid products of their pyrolysis and combustion (solid phase). In the developed mathematical model, the two-phase heterogeneous mixture is considered as a two-component continuum with mass, momentum and energy exchange between the phases. The gas phase is a multicomponent medium composed of combustible gases (CO, H_2, CH_4 etc.), noncombustible gases (CO_2, N_2 etc.), dispersed soot and the oxidizer (O_2). Our assumption is that the disperse soot particles move together with the gas phase and when the soot particles burn the heat exchange process is so rapid that we can consider one temperature of the gas phase. The solid phase is also a multicomponent medium composed of forest fuel materials and products of forest fuel material pyrolysis, i.e., breeze coke and ashes.

The equation set of the two-phase two-dimensional model obtained by integrating the original three-dimensional equations for heterogeneous multiphase medium over the forest fuel material layer height. To system is closed by the standard $k-\varepsilon$ turbulence model, with the gas-phase combustion rate described by the Eddy Breakup model in which the high-temperature combustion rate is governed by the turbulent mixing of components and is independent of the reaction kinetics.

Results of forest fire computations carried out on the basis of the model proposed are presented.