Mathematical and physical modeling of crown forest fires initiation and spread

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Forest fires are extremely complex and destructive natural phenomena which depend on availability of fuel, meteorological conditions and an initial ignition. The overall purpose of forest fires research is a better understanding of the phenomena so that firefighting techniques can be improved, controlled burnings can be undertaken with more confidence, and lives and property might be preserved. It is presented mathematical model of forest fire which is based on an analysis of known experimental data and using concept and methods from reactive media mechanics [1]. In this paper the theoretical investigation of the problems of crown forest fire initiation and spread in windy condition were carried out. It takes in to account the mutual interaction of the forest fires and atmosphere flows. It is assumed that the forest during a forest fire can be modeled as 1) a multi-phase, multistoried, spatially heterogeneous medium; 2) in the fire zone the forest is a porous-dispersed, two-temperature, single-velocity, reactive medium; 3) the forest canopy is supposed to be non - deformed medium (trunks, large branches, small twigs and needles), which affects only the magnitude of the force of resistance in the equation of conservation of momentum in the gas phase, i.e., the medium is assumed to be quasi-solid (almost non-deformable during wind gusts); 4) let there be a so-called "ventilated" forest massif, in which the volume of fractions of condensed forest fuel phases, consisting of dry organic matter, water in liquid state, solid pyrolysis products, and ash, can be neglected compared to the volume fraction of gas phase (components of air and gaseous pyrolysis products); 5) the flow has a developed turbulent nature and molecular transfer is neglected; 6) gaseous phase density doesn't depend on the pressure because of the low velocities of the flow in comparison with the velocity of the sound. The study is based on numerical solution of Reynolds equations for chemical components and equations of energy conservation for gaseous and condensed phases. The forest during a forest fire is modeled as a two-temperature multiphase non-deformable porous reactive medium. A discrete analog for the system of equations was obtained by means of the control volume method [2]. The model proposed in the article gives a detailed picture of changes in temperature fields and concentrations of components over time, and also determines the influence of various conditions on the spread of a crown forest fire with a non-uniform distribution of reserves of forest combustible materials and their moisture content. The results of calculation of the rate of crown forest fire spread obtained agree with the laws of physics and experimental data for the cases when the forest fire spread through the crowns of forest under the influence of wind. The results of calculation give an opportunity to evaluate critical condition of the crown forest fire initiation and spread, which allows applying the given model for preventing fires.

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References

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