Mathematical modeling of the impact of wildfires on buildings and structures

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Valeriy A. Perminov*, Vladimir M. Agranat†

* Department of Ecology and Basic Safety
Tomsk Polytechnic University(TPU)
Lenin avenue 30, 634050 Tomsk, Russia
e-mail: perminov@tpu.ru, web page: http://portal.tpu.ru/SHARED/p/PERMINOV

† Applied Computational Fluid Dynamics Analysis (ACFDA)
81 Rejane Crescent, Thornhill Ontario, L4J 5A5, Canada
Email: info@acfda.org - Web page: http://www.acfda.org/team/vagranat.shtml

ABSTRACT

The computational fluid dynamics modeling of crown forest fires actions on buildings has been carried out with a semi-empirical model to study the effects of fire intensity and wind speed on possibility of ignition of buildings. The crown forest fire is introduced as a heat and mass source defined by the empirical values of average crown fire temperature and vertical gas velocity at the top crown surface dependent on fire intensity. The hydrodynamic and thermal interactions between multiple plumes and wind flow are analyzed. The modeling approach is based on the use of standard non-stationary three dimensional conservation equations that are solved numerically under the input conditions specific for large crown forest fires [1]. The governing equations include the conservation equations for mass, momentum and energy, the turbulence model equations and the equations for radiation heat transfer. The components of gas phase transport are described by solving additional conservation equations for the mass concentrations (oxygen, gas products of pyrolysis and inert components). The standard k-ε turbulence model is applied and the atmospheric boundary layer is introduced using the logarithmic profile at the boundary of computational domain with an effective roughness height of ground surface. The buoyancy force is driven by variable gas density difference caused by a temperature difference in fire and ambient air. The variable air density is considered as a density of the whole gas mixture for the sake of simplicity. The radiation heat transfer is taken into account. The boundary-value problem is solved numerically using the method of splitting according to physical processes. In the first stage, the hydrodynamic pattern of flow and distribution of scalar functions was calculated. The system of ordinary differential equations of chemical kinetics obtained as a result of splitting was then integrated. A discrete analog was obtained by means of the control volume method using the SIMPLE like algorithm [2]. The boundary-value problem is solved numerically using control volume method and software PHOENICS [2]. The model proposed there gives a detailed picture of the change in the temperature and component concentration fields with time. It allows to investigate the dynamics of the impact of forest fires on buildings under the influence of various external conditions: a) meteorology conditions (air temperature, wind velocity etc.), b) type (various kinds of forest combustible materials) and their state(load, moisture etc.). The calculations to get the maximum distance from the fire to the building in which the last possible ignition. These results are compared with experimental data and show that this model model capacity to predict wildfires propagation.

REFERENCES

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