Numerical Simulation of Heat and Mass Transfer under the Conditions of Phase Transitions and Chemical Reaction during Ignition of Condensed Substances by Single Hot Particles

D.O. Glushkov, P.A. Strizhak* and O.V. Vysokomornaya

* National Research Tomsk Polytechnic University
30, Lenin Avenue, 634050, Tomsk, Russia
e-mail: pavelspa@tpu.ru

ABSTRACT

Physical and mathematical models of heat and mass transfer under the conditions of phase transitions and chemical reactions were developed for the numerical analysis of condensed substances ignition by a single particle (size from 0.5 mm to 5 mm) heated up to high temperature (above 800 K). Liquid, solid and gel fuels were considered as condensed substances. Metallic and non-metallic particles were used as ignition sources. Heat and mass transfer mathematical model is presented by the system of the nonlinear non-stationary differential equations in the private derivatives corresponding to the basic provisions of the general theory of heat transfer in chemical kinetics and free convection. An algorithm for differential equations decision with the corresponding initial and boundary conditions is based on the finite-difference method. The locally one-dimensional method was used to solve difference analogous of differential equations. The one-dimensional difference equations were solved with the use of an implicit four-point difference scheme. Nonlinear equations were solved by the iteration method. Mathematical model verification and assessment of numerical research results reliability was executed by its comparison with experimental results. Also verification of energy conservation law in the solution area of ignition problem was done. Besides, testing of the applied numerical methods and the developed decision algorithm on the example of a group less complex challenges of thermal conduction and thermal convection was held. The minimum parameters of hot particles (temperature, size) and ignition delay time of condensed substances were determined for local heat sources with different shapes. Influence of thermal conduction, convection and radiative heat transfer mechanisms in the "particle – condensed substance" system was established on the characteristics of ignition process.