Stability of Thermal Front with Heat Conductivity Dependent on Temperature

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ABSTRACT

The structure of combustion wave and nonstationary wave propagation with a nonlinear heat transfer $\lambda(T) = \lambda_c(T/T_c)^n$ was studied using a one-dimensional numerical model. At the assumption on strong activation of the chemical reaction and high-energy exothermic conversion, approximate analytical solutions that characterize the flame front structure were obtained. Despite the nonlinearity of the $\lambda(T)$ dependence, a classical expression retaining the exponential character of the temperature dependence was derived for the front propagation velocity $u$. In the first approximation, it was found that the area of reaction zone of an efficient chemical interaction was weakly dependent on $n$, and it corresponded to the commonly used term in the expression of combustion theory. A significant decrease in the heating zone width led to a reduction in enthalpy excess $\Delta H$ in the combustion front. The enthalpy excess $\Delta H(n)$ was examined to evaluate the stability of the wave structure. At $n$ the enthalpy excess in the heating zone was $\Delta H(n) = \Delta H(0)/(n+1)$.

To investigate the stability of the solutions, the procedure of the small-perturbation method was used. The frequency of oscillation at the boundary of oscillation stability and the critical value of Zeldovich number $Ze$ characterizing the boundary of the combustion front stability was determined.

The nonstationary problem of the flame front propagation was numerically analyzed for various values of parameter $n$. The width of the reaction zone was weakly affected by variations of $n$. The heating zone width was reduced with the increase in the $n$ value. The dynamics of transition from the bi-frequency periodic oscillatory regime at $n=0$ to a uni-frequency oscillatory regime at $n=1$ and a stable stationary one at $n=3$ was studied.