over into spontaneous flame propagation and quasivolume inflammation, as well as the phenomenon of delay of propagation and extinction of the flame, predicted in [5, 6], are observed. The peculiarity of these processes in a diesel is related with the effect of nonstationary heat and mass transfer between the fuel stream and the air charge on the temperature field of the reacting mixture.

LITERATURE CITED


EFFECT OF HEAT LOSSES ON THE LIMITS AND STRUCTURE OF THE DIFFUSION FLAME FORMED IN POLYMER COMBUSTION

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UDC 536.46:541.6

The problem of the limits and structure of the diffusion flame in the presence of heat losses from the heated layer of the condensed phase to a thermostated substrate is examined with reference to polymer combustion in an oxidizing atmosphere in the case of an Arrhenian dependence of the reaction rate on the temperature in the gas phase. It is shown that the diffusion combustion of polymers is characterized by two limits. The first of these is an intrinsic property of the diffusion flame and is always present, even in the absence of heat losses [1, 2]. The second limit, as in the diffusion combustion of gases [1-3], is observed only in the presence of heat losses from the combustion zone [4]. Coincidence of the two limits corresponds to total extinction.

We will consider the problem of the limits and structure of the diffusion flame formed when a polymer layer of thickness $\delta$ burns in an oxidizing atmosphere on a thermostated substrate. For diffusion burning, the system of equations determining the distribution of temperature and concentrations in the reduced film approximation has the form

$$\begin{align*}
\frac{d^2 \tau(T)}{dx^2} - \frac{u}{\alpha} \frac{d \tau(T)}{dx} &= -F, \\
\frac{d^2 (\alpha, \phi)}{dx^2} - \frac{u}{D} \frac{d (\alpha, \phi)}{dx} &= F,
\end{align*}$$

(1)

where \( a_1 \) are the mass concentrations of the reactants; \( F = z a \beta z \exp (-E/RT) \), Arrhenius heat release function; \( z \), preexponential; \( E \), effective activation energy of the combustion reaction; \( T \), temperature; \( R \), universal gas constant; \( D \), \( \chi \), diffusion coefficient and thermal diffusivity; and \( \alpha_1, \tau \), coefficients establishing the relation between the consumption of starting reactants in the reaction zone and the heat release. With the aid of the coefficients \( \alpha_1 \) it is possible to write the relation between the flow of oxidizer into the reaction zone \((\rho u)_{ox}\), the polymer burning rate \((\rho u)\), and the overall rate of consumption of reactants in the reaction zone \((\rho u)_0\)

\[
(\rho u)_0 = (1 + \psi) \rho u = \frac{1 + \psi}{\psi} (\rho u)_{ox},
\]

where \( \psi = \alpha_1 / \alpha_2 a_0^2 \); \( a_0^2 \) is the initial concentration of oxygen in the atmosphere; \( \rho \) is density. In writing system (1), we only considered the heat and mass transfer along the \( x \) axis, which is at right angles to the flame front.

The boundary conditions at the burning surface of the polymer \((x = 0)\) are:

\[
\begin{align*}
\frac{\partial \psi}{\partial x} &= LPu + \lambda \zeta, \\
\rho u &= \rho u_0 - \rho D \frac{\partial a}{\partial x}, \\
0 &= \rho u a_0 - \rho D \frac{\partial a_0}{\partial x}, \\
T &= T_o,
\end{align*}
\]

and on the outside of the reduced film \((x = 1)\):

\[
\begin{align*}
a_0 &= 0, & a_2 &= a_0^0, & T &= T_o, \tag{3}
\end{align*}
\]

where \( \varphi \) is the temperature gradient in the condensed phase at the surface of pyrolysis; \( \lambda_c, \lambda_g \), thermal conductivities of the polymer and the gas; and \( L \), latent heat of gasification of the polymer. In the limiting case of a steady-burning infinitely thick polymer layer, a natural temperature gradient \( \varphi_0 = \kappa / \rho (T_S - T_0) \) is established at the surface. In this case there are no heat losses, and the combustion temperature is equal to the adiabatic combustion temperature of a stoichiometric mixture of the polymer decomposition products and the atmospheric oxidizer \( T_{ad} \). If the thickness of the polymer layer \( \delta \) is finite, then the gradient \( \varphi \) may be greater than \( \varphi_0 \), which leads to a lowering of the combustion temperature even in the case of an infinitely fast gas-phase reaction.

The temperature of the burning surface of the polymer depends on the thermal decomposition mechanism. In our study we considered cases in which (a) the temperature of the combustion surface is constant \( T_S = \text{const} \) and in which (b) the surface temperature and the burning rate are related by the law of thermal degradation \( \rho u = k_0 \exp (-E_t / 2RT_S) \), where \( k_0 \) is the preexponential and \( E_t \) is the effective polymer degradation activation energy.

In the case \( D = \chi \), system (1) with boundary conditions (2), (3) can be reduced to the second-order equation

\[
\frac{d^2 \Theta}{d \xi^2} + \frac{p}{1 + \psi} \frac{d \Theta}{d \xi} = Da \left[ \Theta_0 - \Theta - \frac{(1 + \psi) (\Theta_M - \Theta_0)}{(e^1 + \psi - 1)} \Theta_0 \right] + \left( \Theta_0 + \Theta_0' - \Theta - \frac{(1 + \psi) (\Theta_M - \Theta_0 - \Theta_0')}{(e^1 + \psi - 1)} \Theta_0 \right) \frac{e^1 + \psi - 1}{e^1 + \psi - 1} \Theta_0
\]

with boundary conditions

\[
\begin{align*}
\xi = 0: & \quad \Theta = \Theta_0, & \frac{d \Theta}{d \xi} = \frac{p}{1 + \psi} \left( \Theta_0 + \psi (\Theta_0 + \Theta_0') - (1 + \psi) \Theta_M \right), \\
\xi = 1: & \quad \Theta = \Theta_0,
\end{align*}
\]

where \( \Theta_0 = \text{const} \) in case (a) or \( \Theta_0 \) is related to \((\rho u)_0\) by the thermal degradation law

\[
\frac{(\rho u)_0}{M} = A \exp \left( \frac{E_1}{2E_1} \right) \frac{\Theta_0}{1 + \gamma \Theta_0}
\]

in case (b).

In Eq. (4) and boundary conditions (5) we have used the following notation: \( \Theta = E (T - T_{ad}) / RT_{ad}^2 \) is the dimensionless temperature; \( \xi = x/l \) is the dimensionless coordinate; \( Da = (M \alpha \beta / \rho \alpha \beta \alpha_0^2) \sqrt{1 / 21} \) is the Damköhler number; \( M \), mass burning rate of the equivalent gas mixture; \( M^2 = \frac{2 \beta}{\alpha \beta^2} \rho \alpha \beta \left( \frac{\sqrt{2 \beta^2}}{E} \right) \exp (-E / RT_{ad}^2) \);