FLOW STRUCTURE IN THE MICRO-FLAME BURNERS WITH ECHELON GRATINGS FLAME STABILIZERS

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The results of studies of regularities of flow of fuel and oxidant in micro-flame burner devices with echeloned arrangement of flame stabilizers are given. The mathematical simulation data for identify of influence of the number of stabilizers on the flow pattern in the stabilizer echeloned grates are discussed.

Mathematical modeling, echeloning flame stabilizers, micro-flame burners, the flow structure of fuel and oxidant.

Combustion of the gaseous fuel in micro-flame burner devices with echeloned grates of flame stabilizers has a number of well-known advantages [2,3]. By organizing in a special way echeloned location of stabilizers is possible to form the desired temperature field in the combustion zone. Echeloning is also used as a way of eliminating the spontaneous breaking of the flow symmetry in stabilizer grates, which is typical for the conditions corresponding to a relatively high degree of blockage of the flow cross section of the channel by stabilizers.

To construct micro-flame burners with flame stabilizers echeloned grates requires knowledge of the laws of working processes proceeding in these devices. However, currently there are only a few studies focusing on specific aspects of the problem (see., for example, [1,4,5]).

The purpose of the work. Identifying the basic features of the fuel and oxidant flow structure in micro-flame burner devices with staircase echeloned grates of the flat flame stabilizers.

Materials and research methods.

The pattern of the fuel and oxidant flow in micro-flame burner device with displaced arrangement of flame stabilizers relative to each other downstream at a constant pitch $L_{см}$ (Figure 1) is considered. A mathematical model of the process under investigation can be represented in the form

$$\frac{\partial\ \rho U_j U_i}{\partial x_j} = -\frac{\partial P}{\partial x_i} + \frac{\partial\ \tau_{ij}}{\partial x_j}, \quad i,j = 1,2,3,, \tag{1}$$

$$\frac{\partial\ \rho U_j}{\partial x_j} = 0, \tag{2}$$

$$\frac{\partial\ \rho_к U_j}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\frac{\nu}{\mathrm{Sc}_к} + \frac{\nu_Т}{\mathrm{Sc}_Т}\right)\frac{\partial \rho_к}{\partial x_j}\right], \tag{3}$$

$$\kappa = 1,2,\ldots, N^*\text{-}1,$$

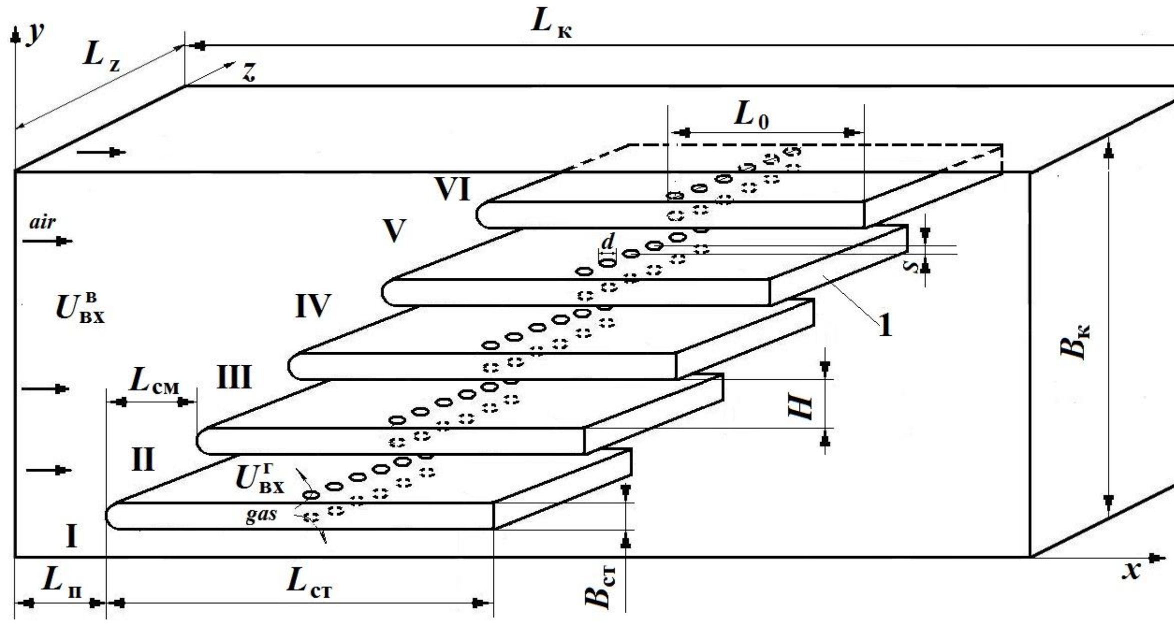

Fig. 1. To a formulation of the problem for echeloned grate of stabilizers: 1 - flame stabilizers; I, VI – near wall channels; II, III, IV, V – inter stabilizer channels.

where x_j - Cartesian coordinate, j = 1, 2, 3; U_j - the component of the velocity vector in the direction of the axis x_j; P – the static pressure; $\tau_{i,j}$ - components of the stress tensor; ρ, ν - the density and kinematic viscosity coefficient; $\nu_т$ - the turbulent kinematic viscosity coefficient; $\rho_к$ - partial mass density of the k-th component, $\rho_к = \rho \cdot W_к$; $W_к$, $Sc_к$ – the mass concentration and the Schmidt number of the k-th component, $Sc_к = \nu / D_к$, where $D_к$ - the diffusion coefficient of the k-th component; $Sc_т$ – the turbulent Schmidt number; N^* - the number of mixture components.

To close the system of equations (1) - (3) RNG k-ε turbulence model has been used. The formulated problem has been solved using the software package ANSYS.

Research results.

Typical results of the mathematical simulation are shown in Fig. 2-4 and Table. 1. The given data correspond to the following values of the input parameters: $U^{в}_{вх}$ = 6.8 m/s; $U^{г}_{вх}$= 24 m /s; $L_п$ = 0.2 m; $L_{ст}$ = 0.215 m; $L_к$ = 1.5 m; H = 0,075 m; $B_к$ = 0.225 m; $B_{ст}$= 0.03 m; $L_{см}$ = 0.06 m; L_0 = 0,02 m; d = 0,0045 m; S/d = 3,55, where S - the arrangement pitch of gas supply holes; fuel is a natural gas, the oxidant is air.

As the studies conducted has shown, in case of the echeloned arrangement of stabilizers occurs a definite redistribution of air flow rates in inter stabilizer and near wall channels of grate compared to the situation when there is no such echeloning. This fact is illustrated by the data shown in Figure 2, the corresponding to the burner device with three echeloned stabilizers of the flame. As can be seen, the values of the longitudinal velocity components in the first downstream inter stabilizer channel are significantly higher than the corresponding values for the second inter stabilizer channel (see. 5 line on the plot). The corresponding air flow rates differ by more than 10%. As for the near wall channels, there is divergence of velocity U_x in the first and in the second downstream channels is more significant, so that the air flow rates vary approximately by 17%.

Behind the stabilizer grate at some distance from it there is an flow asymmetry, reverse to that observed in the stabilizer grate proper. As an example, the relevant data are given in Fig. 3 As can be seen, the flow behind stabilizers generally deviates somewhat towards the last of them downstream. The results obtained of the computer simulation also show that further downstream behind the stabilizer grate, said flow asymmetry monotonically decreases. This is due to the effect localization of the influence of the fact of the echeloned arrangement of flame stabilizers.

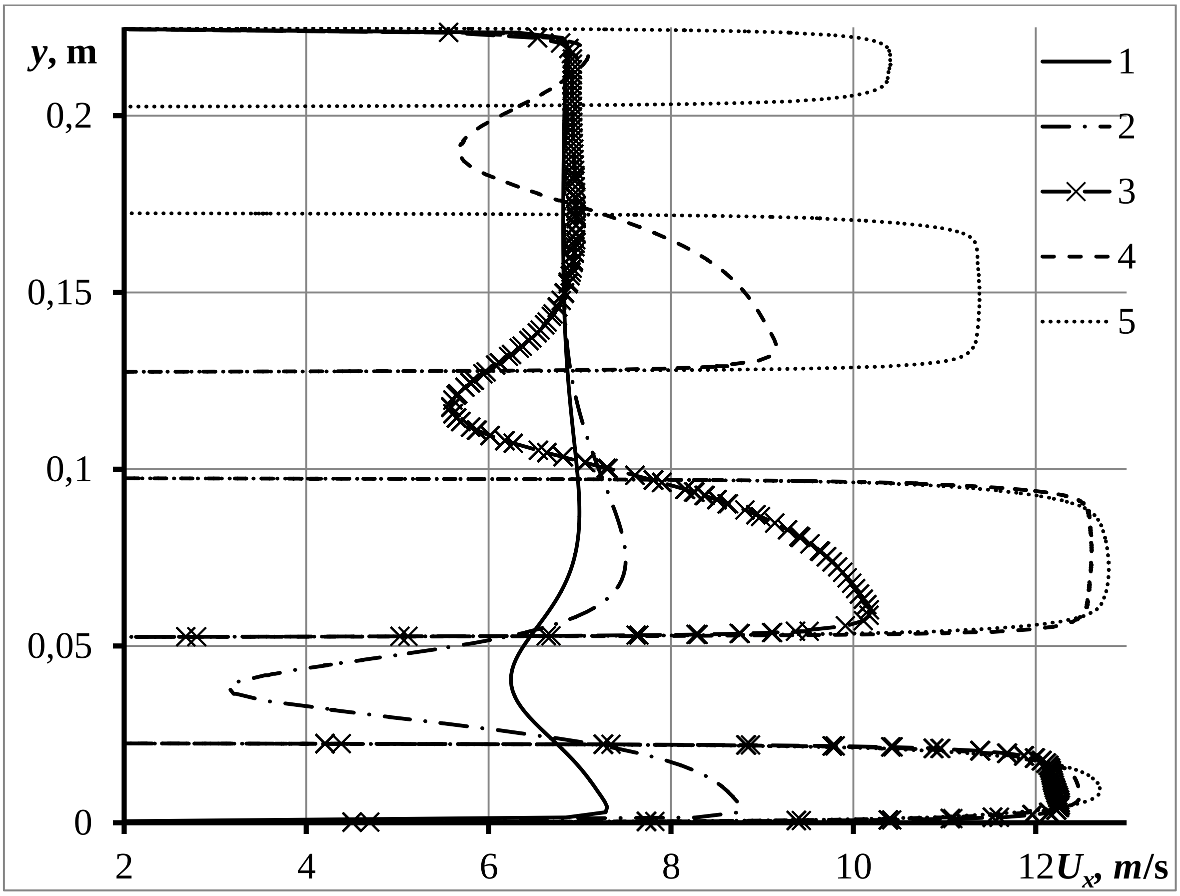

Fig. 2 Plots of the longitudinal velocity component for the grate consisting of three stabilizers away 0.03 m downstream from the frontal point of the third stabilizer (line 5), at the distance of 0.04 and 0.02 m before the first stabilizer (lines 1 and 2) and 0.03 m before the second and third stabilizer, respectively (lines 3 and 4).

In this study, research on the analysis of the influence of the number of echeloned stabilizer of the flame on the characteristics of the flow of fuel and oxidizer in the burner has been conducted. In this case the situation should be considered, when making comparisons all other characteristics of the grate remained unchanged. Under these conditions, change in the number of stabilizers corresponds to the change in the power of the burner device.

According to data obtained the most important features of the flow structure retain in the case of the different number of flame stabilizers.

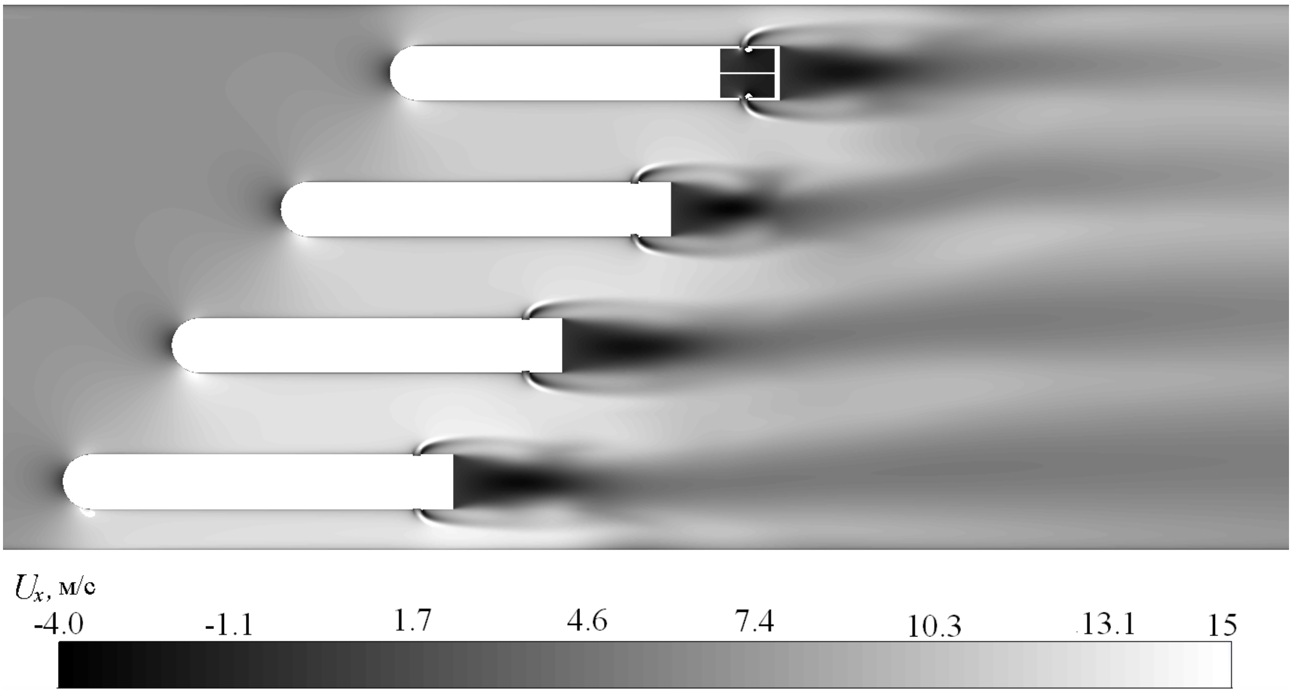

Fig.3. The field of the longitudinal component of the vector velocity in the cross section XOY, passing through the centers of gas supply holes

Below in Fig. 4 and Table. 1 as an example shows the results of the mathematical simulation for stabilizer grates consisting of 3 and 4 of the flame stabilizers are presented. As can be seen from Table 1, for compared situations of air flow rates are very close in magnitude in the near-wall channels, as well as in the first and last downstream inter stabilizer channels. The fact is also noteworthy that in case of 4 stabilizers the decrease in the flow rate in each following stabilizer channel is smaller in magnitude.

Features of flow behind said grates at some distance from them downstream illustrate the data presented in Figure 4. As can be seen, velocity plots U_x, corresponding to the two situations being analyzed greatly differ. So, if in the case of three stabilizers locations of speed minimum U_x roughly correspond to the axial sections of stabilizers, and maxima - to axial sections of inter stabilizer channels, for four stabilizers position of indicated extrema markedly shifts in the direction of the last downstream stabilizer. This fact indicates the presence of flows over the cross section of the channel in this direction. Thus at a sufficiently great distance from the stabilizer grate (see x = 0.7 m in Fig. 4) generally lower velocities are observed in the zone corresponding to the location of the first downstream stabilizer.

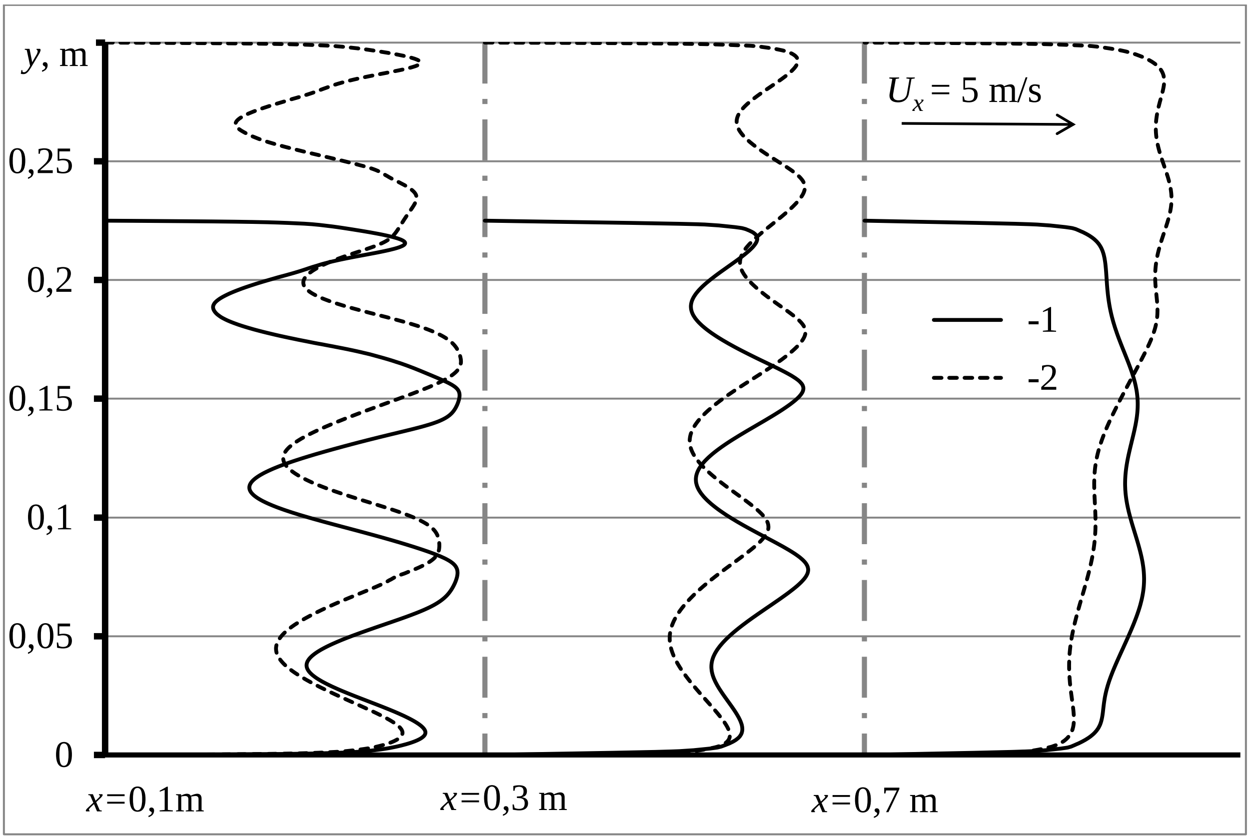

Fig. 4 Plots longitudinal component U_x of the velocity vector for grates consisting of three (lines 1) and four (lines 2) of the flame stabilizers at a fixed distance *x* behind the last of them downstream: *x* = 0.1 m; 0.3 m; 0.7 m.

It is also important to note that, according to the data obtained velocity profile leveling for three stabilizer grate occurs at a smaller distance from it than in the case of four stabilizer grate.

Conclusions.

On the basis of the research conducted it is shown that the structure of fuel and oxidizer flow in the burner devise with a echelon arrangement of flame stabilizers substantially differ from that during the installation of faces ends stabilizers in the same plane. However, the main features of the flow at the echeloned location of stabilizers consist, firstly, in a definite redistribution of airflow rates in inter stabilizer and near wall channels and, secondly, in the presence flow asymmetry, the reverse of which that takes place in the grate proper behind the stabilizers grate at some distance from it.

It has been also found that the number of flame stabilizers in echeloned grates significantly affect the characteristics of fuel and oxidizer flow in the stabilizer burner devices.

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