INFLUENCE OF SPACING BETWEEN GAS JETS ON THE FLOW CHARACTERISTICS IN THE STABILIZER BURNER DEVICES

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The results of computer simulation to establish regularity of influence of the spacing between the gas jets on the flow characteristics in the stabilizer burner devices with jet fuel supply to the entraining oxidant stream are given. Particular attention is paid to the consideration of the effect of this spacing on the penetration depth of gas jets in cross-flow, the length of the zones of reverse flow beside the stabilizer, the maximum velocities in these zones and so forth.

Jet in entraining stream, micro-flame burner devices, spacing between the jets, mathematical simulation.

In the power equipment modern micro-flame burner devices with a jet supply of gas by the introduction in the entraining flow oxidant stream through the systems of holes on the side surfaces of stabilizers are widely used. This fact determines the relevance of in-depth research of transfer processes in the given burner devices. In particular, it is important to establish regularities of fuel and oxidant flow into the burners of this type.

Analysis of the references suggests that the study of the flow structure at micro-flame burning in the flame stabilizers system is given definite attention (see, for example, [1, 3-6]). However, the available research does not fully cover the range of problems relevant for the development of high-performance micro-flame burners. Thus, for example, the research on the effects of the influence of various design parameters of burners devices on the of fuel and oxidant flow pattern requires further development.

The purpose of the work. The establishment of the regularities of the influence of the relative spacing between the gas jets on the flow characteristics such as the depth *h* of penetration of jets in the oxidant crossflow, length $L_{от}$ of the area of reverse flows in the astern stabilizer area, the maximum value U_{max} of velocity in this area and so on for stabilizer burners devices.

Material and research methods. As the main research method the mathematical simulation is used. Model of the process included the Navier-Stokes equations, continuity and mass conservation of the reacting mixture components mass. The given system of equations closed using the k-ε turbulence model in the modification of the RNG. The problem was solved in a three-dimensional formulating. The implementation of the solution was carried out using the software package ANSYS. At the same time as approximate analytical dependences for finding the depth of the jets penetration were used.

Research results. In conformity with the conditions the dependence of the penetration depth *h* of gas jets in cross-flow of the oxidant from the relative spacing between the jets was obtained. Using the expression [2]

$$h = k_S \cdot d \cdot \frac{V_Г}{V_B}\sqrt{\frac{\rho_Г}{\rho_В}} \quad , \tag{1}$$

after a series of transformations the following relation was found

$$\frac{h}{H_K} = k_S \cdot \frac{4}{\pi \cdot L_0}\frac{S}{d \cdot \alpha}\sqrt{\frac{\rho_B}{\rho_Г}}\,, \tag{2}$$

where k_S - coefficient depending on the value *S/d*; $k_S = 1{,}6 + 0{,}025\left(S/d - 4\right)$, $4 \le S/d \le 16$; d - diameter of the gas supply holes; $V_B, V_Г$ - the average velocities of the incoming air and gas in the gas supply holes; $\rho_Г$, ρ_B - densities of gas and air; *S* -

the distance between the gas jets; α – coefficient of air excess; L_0 = 16,8; H_K – half the height of inter stabilizer channel.

The dependence (2) in contrast to (1) was obtained in relation to the finite size channel and not to the unrestricted flow conditions. Accordingly, it is obvious, the expression (2) can be used only when $h/H_K < 1$. As shown by mathematical modeling, a wide range of the change in the cluttering coefficient of the flow cross section of the channel k_f formula (2) gives satisfactory results when $h/H_K \leq 0,8$ ($k_f = \frac{B_{CT}}{2H_K + B_{CT}}$,where B_{CT} - the width of the stabilizer).

For fixed values of α, ρ_B and ρ_Γ the dependence (2) can be represented in the form

$$\frac{h}{H_K} = A \cdot k_S \cdot \frac{S}{d}, \quad (3)$$

where $A = \frac{4}{\pi \cdot L_0 \cdot \alpha} \sqrt{\frac{\rho_B}{\rho_\Gamma}}$.

Thus, in a given type of fuel, oxidant, and the air excess coefficient α relative penetration depth h/H_K is a function of only the spacing between the gas jets S/d. And since the change in the value $k_S = f\,(S/d)$ in the parameters under review range is relatively small, then, as can be seen from Fig. 1, the function $h/H_K = f\,(S/d)$ is very close to linear one for any fixed values of the air excess coefficient α.

The presented character of the dependence $h/H_K = f\,(S/d)$ is obviously connected the fact that with increase in S/d at a constant value of the total gas flow rate and other equal conditions, the gas flow rate per one gas feeding hole increases, and accordingly, the average gas inlet velocity V_Γ increases at well. This circumstance determines an increase in the penetration depth of the jet while increasing the relative spacing S/d.

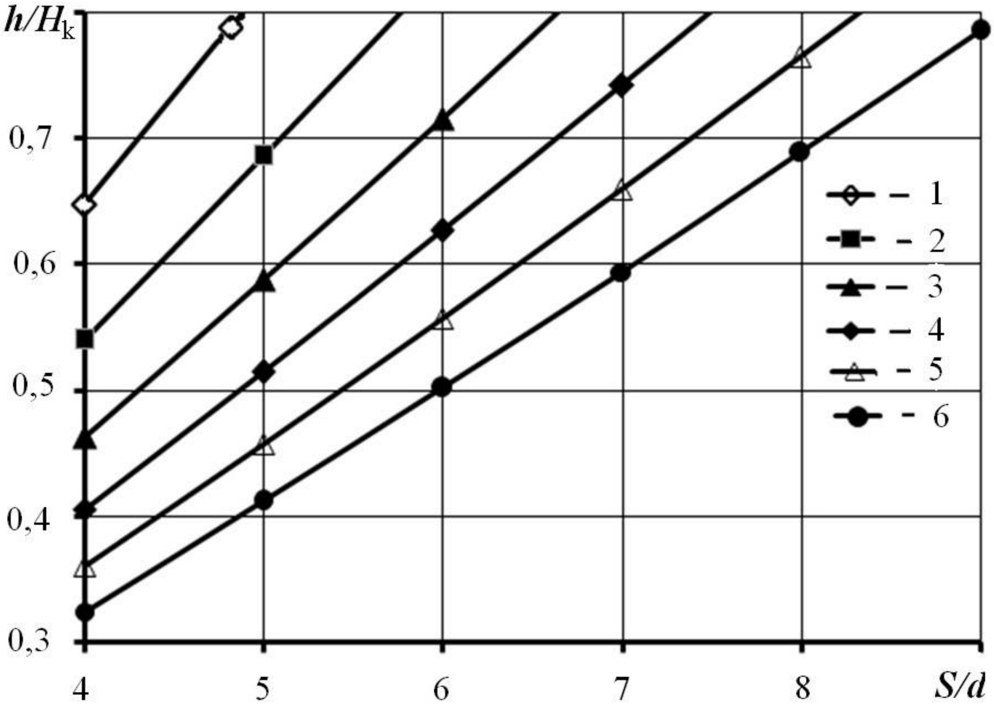

Fig. 1. The dependence of the relative penetration depth of the jets *h/H*$_K$ on the spacing between them *S/d* at different values of the air excess coefficient: 1 - *α* = 1,0; 2 - 1.2; 3 - 1.4; 4 - 1.6; 5 -1.8; 6 - 2.0.

Below in Fig. 2 and Table 1 the results of research obtained on the basis of computer simulation are presented. For determining gas velocity values $V_Г$ appearing in initial data following expression is proposed

$$V_Г = \frac{2U_{BX}^{B} \cdot B_{CT} \cdot S \cdot \rho_B}{\pi \cdot L_0 \cdot k_f \cdot d^2 \cdot \alpha \cdot \rho_Г}, \quad (4)$$

where U_{BX}^{B} – air velocity in the inlet section of the channel, in which the stabilizer grate is located.

Fig. 2 a) and b) patterns of the flow lines in the longitudinal section passing through the center of the gas feeding hole for values *S/d* = 6,4 ($V_Г$ = 74,75 m/s) and *S/d* = 3,56 ($V_Г$ = 41,54 m/s), at all other fixed parameters : *d* = 3·10^{-3} m; U_{BX}^{B} = 7,0 m/s; α = 1,35 are presented as an example. As can be seen, with increasing *S/d* deeper penetration of gas jets into the entraining air flow is observed.

a)

b)

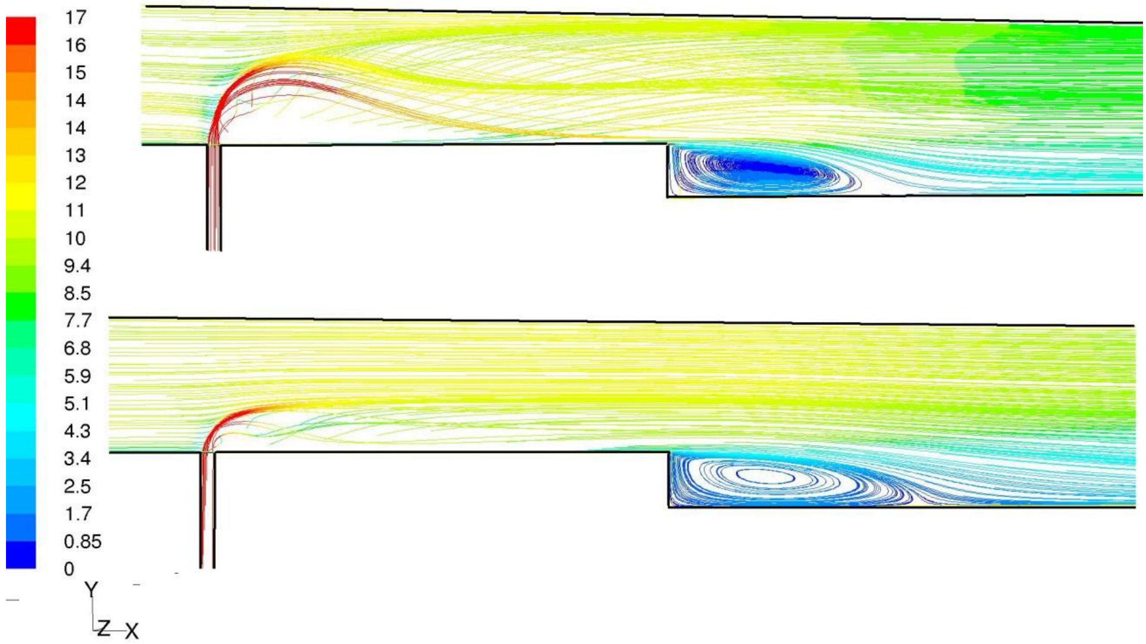

Fig. 2. The flow lines in the longitudinal section passing through the center of the gas feeding hole, for different values *S/d:* (a) – *S/d* = 6,4; (b) – *S/d* = 3,56.

The results of the computer simulation also show that the relative spacing value *S/d* significantly affects the hydrodynamic situation in the zone of reverse flows directly behind the stabilizer. The injected gas jet effect (i.e, more increasing involvement of the surrounding air into the jet) increasing with raising *S/d* causes an additional increase in the degree of vacuum in the reverse flows area of the stabilizer. Accordingly, with increasing *S/d* zones length of reverse flows are decreased, and the maximum velocities increase in them. Table. 1 shows the data of the numerical researches on value $L_{\text{от}}$ and U_{max} at different values *S/d* and different distances L_1 between blunt trailing edge of the stabilizer and the gas feeding holes.

According to the data obtained the marked effect decreasing the $L_{\text{от}}$ and increasing the velocity U_{max} with increasing the spacing *S/d* manifests itself in at least at the increase of the blockage degree k_f of the open flow cross section of the channel.

Table 1

Zones lengths of reverse flow $L_{от}$ and maximum velocities U_{max} in these areas at different values of the relative spacing between the gas jets *S/d* and the distance L_1 for k_f = 0,3.

L_1, 10^{-3}m	120		80	
S/d	6,4	3,56	6,4	3,56
$L_{от}$, 10^{-3}m	60,6	69,0	55,2	64,7
U_{max}, m/s	2,63	1,94	2,55	2,06

As seen from Table 1, when $L_1 = 80 \cdot 10^{-3}$ m and k_f = 0,3 differences in the values $L_{от}$ and U_{max} for considered values under review *S/d* are respectively 17,0 and 19,6 %.

Conclusions

For burners devices of stabilizer type with jet fuel supply to the oxidant stream identified the main regularities of the influence of the relative step *S/d* between the jets on the flow characteristics. It is shown that the penetration depth of gas jets into the flow of oxidant practically linearly depends on the value *S/d*. It was also found that the increase S/d, causing an increase of the injection action of the gas jet, reduces the extent of zones of reverse flow of area astern stabilizers and increase maximum speeds in these zones.

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