Технічні науки

UDC 536.24:533

Fialko Nataliia

Doctor of Technical Science, Professor,

Corresponding Member of the NAS of Ukraine,

Head of the Department of

Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Prokopov Viktor

Doctor of Technical Sciences, Professor, Leading Researcher of the

Department of Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Alioshko Sergiy

Candidate of Technical Sciences (PhD), Leading Researcher of the

Department of Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Sherenkovskiy Julii

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher of the

Department of Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Meranova Nataliia

Candidate of Technical Sciences (PhD),

Senior Scientific Researcher, Leading Researcher of the Department of

Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Rokytko Konstantin

Junior Research of the Department of

Thermophysics of Energy Efficient Heat Technologies

Institute of Engineering Thermophysics of

National Academy of Sciences of Ukraine

Fomin Dmytro

Student of the

National Aviation University

Loza Irina

Student of the

National Aviation University

MATHEMATICAL MODELING OF THE HEAT STATE OF THE COMBUSTION ZONE OF STABILIZER BURNER DEVICES

Summary. *The results of calculations of the temperature regimes of the combustion zone of stabilizing-type burner devices intended for use at relatively high values of the coefficient of excess air are presented. The nature of the variation along the flow of the coefficient of unevenness of the temperature distribution in the channel sections is studied. The analysis of fuel burnup characteristics in burners of this type is carried out.*

Key words: *burner devices, heat state, asymmetric fuel supply, mathematical modeling.*

A problem of increasing the efficiency of stabilizer-type burner devices requires in-depth studies of their working processes [1-10]. Studies of the heat state of the combustion zone of these devices are of particular interest. The course of such processes as the formation of toxic substances (primarily nitrogen oxides), fuel burnout, etc., which determine the energy and environmental characteristics of burner devices, largely depends on heat state.

This article is devoted to modeling the heat state of the combustion zone of stabilizer burners with asymmetric fuel supply. This modification of the burner devices is focused on the use them in conditions of relatively high values of the excess air coefficient. The features of the proposed modification are the ability to realize two-stage combustion of fuel, to regulate the shares of primary and secondary air supplied to the combustion, to choose the location of the secondary air supply and other.

The purpose of the work is to analyze the features of the heat state of the combustion zone of burner devices with asymmetric fuel supply. Certain attention is also paid to the consideration of the fuel burnout process under the studied conditions.

The module of the studied burner device, located in channel *1*, consists of two flat flame stabilizers *2* (Fig. 1). On one of the side surfaces of each stabilizer flowing around with primary air, there is a system of gas supply holes *3* through which jets of fuel gas are supplied by immersion in a carrying stream of an oxidizing agent. Secondary air enters the channel between stabilizer and is supplied to combustion downstream after flowing around the flaps *4*.

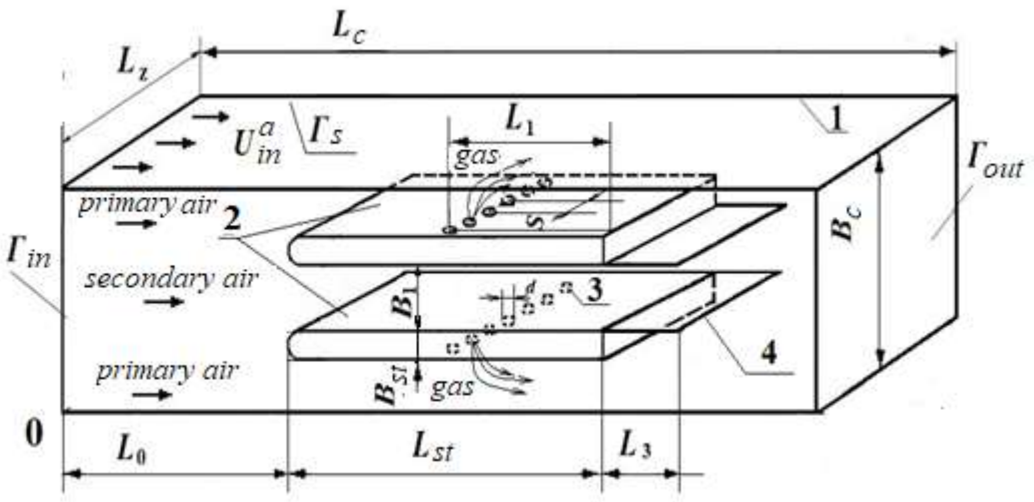

Fig. 1. Scheme microjet burner device of stabilizer type with asymmetric fuel supply: 1 - flat channel; 2 - flame stabilizer; 3 - gas supply holes; 4 - flaps.

The problem of determining the thermal state of the combustion zone was solved using the FLUENT software package. The modeling was carried out on the basis of the DES approach (Detached Eddy Simulation - modeling of isolated vortices), which is a hybrid approach with switching in different spatial zones of the RANS and LES methods (Reynolds Averaged Naiver-Stokes - a method based on Reynolds averaged stationary Navier-Stokes equations, and Large Eddy Simulation - a method for modeling large eddies).

The following calculation results correspond to such source data: B_{st} = 0.015 m; B_1 = 0.018 m; B_c = 0.075 m; L_c = 1.3 m; L_0 = 0.1 m; L_{st} = 0.2 m; L_1 = 0.02 m; L_3 = 0.09 m; d = 0.002 m; S/d = 3.5; clutter coefficient of the passage cross-section of the channel k_f = 0.4; air velocity at the channel inlet U_{in}^a= 10.0 m/s; excess air coefficient α = 3.0.

Characterizing the overall temperature regime of the combustion zone of the studied burner device, first of all, it should be noted the significant spatial unevenness of the temperature distribution in this zone. Figure 2 illustrates the temperature profiles in the cross sections of the channel for various values of the longitudinal coordinate x in the plane passing through the axis of the gas supply holes. (The value of the x coordinate is counted from the end of the flame stabilizer downstream; the *y* coordinate is counted from the plane of symmetry of the module passing through the middle of the channel between stabilizers).

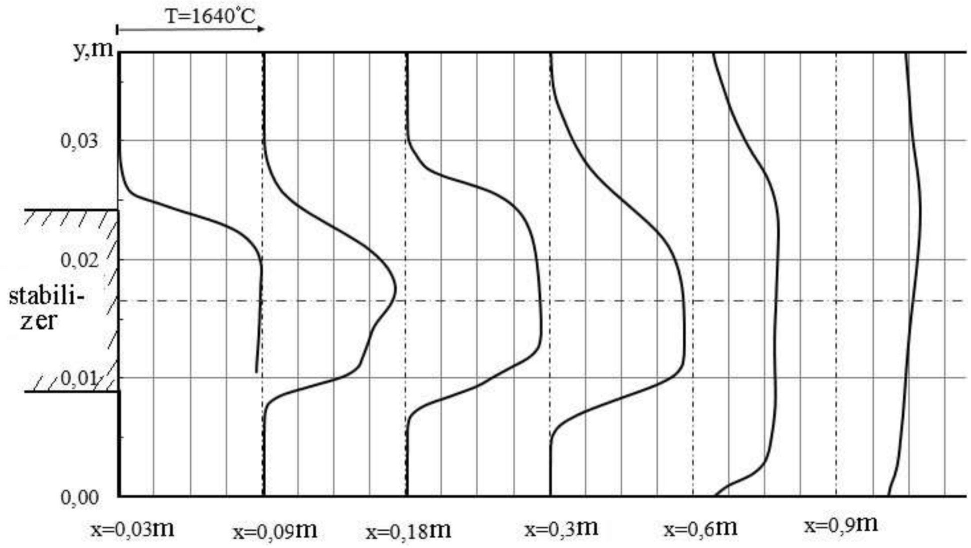

Fig. 2. The temperature distribution over the width of the channel in a longitudinal section passing through the axis of the gas supply hole, for various values of the longitudinal coordinate *x*

As can be seen from fig. 2, near the end of the flame stabilizer, at $x \leq 0.4$ m, on temperature profiles there are: the central part (the high-temperature zone corresponding to the position of the stabilizer) and two peripheral zones at whose boundaries the temperature level is close to the air temperature at the channel inlet. Downstream, the temperature in the indicated central zone gradually decreases, increasing slightly in the peripheral zones. With a further increase in the *x* coordinate ($x \geq 0.8$ m), the boundaries of these zones are blurred and the temperature profiles are becoming more and more equable.

Attention is also drawn to the fact that the temperature profiles are asymmetric with respect to the axis of symmetry of the flame stabilizer. In particular, near the flame stabilizer, at $x \leq 0.4$ m, these profiles are substantially less filled in areas corresponding to the supply of secondary air. The indicated asymmetry is obviously associated with the asymmetry of the fuel supply and the two-stage combustion process.

An integral characteristic of the non-uniformity of the temperature distribution in the channel cross sections is the coefficient of the relative non-uniformity of the temperature field γ, which is determined by the dependence $\gamma = \left(T_{max} - \overline{T}\right)/\left(\overline{T} - T_{in}\right)$, where $T_{max}, \overline{T}$ - is the maximum and mass-average temperature in a given channel cross-section x = const; T_{in} is the air temperature at the channel inlet.

According to the data obtained, in the flap location region the indicated non-uniformity of the temperature distribution decreases sharply (Fig. 3). Further, in a significant area behind the flap (0.1 m $\leq x \leq$ 0.6 m), the rate of decrease in the temperature field non-uniformity in the channel cross sections remains practically unchanged. With further distance from the end of the stabilizer, the non-uniformity is indicated asymptotically decreases.

An analysis of the distribution of the mass average temperature $\overline{T}$ over the channel length indicates that in the flap location zone ($x \leq$ 0.9 m) there is an intensive temperature increase along the flow. This is due to the fact that combustion in this zone occurs in the presence of only primary air, that is, at relatively low values of the coefficient of excess air α. A sharp decrease in the temperature growth rate along the length of the flow with the flap is associated with the intake of cold secondary air.

The data in Figure 3 illustrates the change in the fuel burnup coefficient η along the length of the channel. As can be seen, nature of the change in η correlates with the longitudinal distribution of the mass-average temperature. According to the data presented, combustion proceeds very intensively in the first stage at $x < L_3$. The burnup velocity of the fuel is significantly reduced when secondary air is supplied behind the flap. In the burnout area in the tail of the torch, the rate of burnup is further reduced.

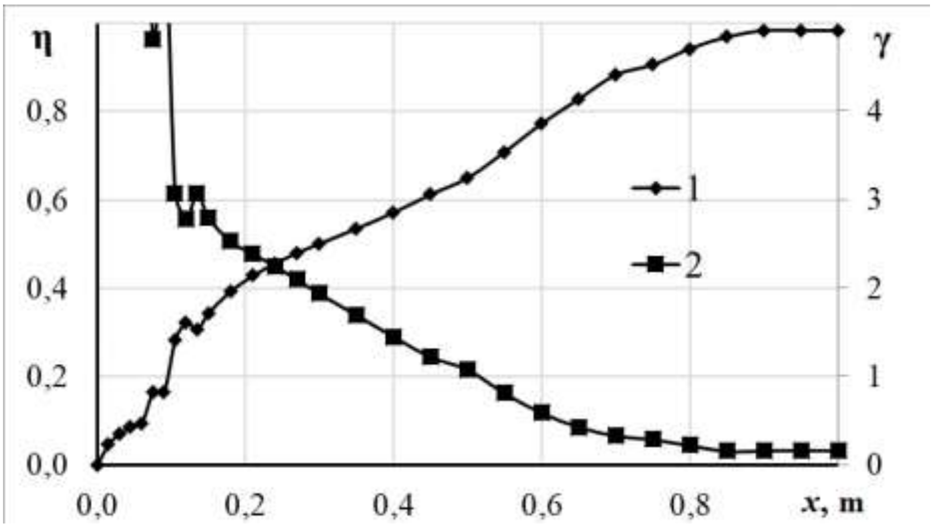

Fig. 3. Change in the coefficient of completeness of fuel burnup η (1) and the coefficient of relative non-uniformity of the temperature field (2) along the length of the channel

Thus, on the basis of computer simulation, the characteristics of the temperature conditions of the combustion zones, the processes of fuel burnout in stabilizer burners with an asymmetric supply of fuel gas were studied. It is shown that the fuel supply from only one of the side surfaces of the flame stabilizers causes a number of features of the heat state of the combustion zone, such as asymmetry of temperature profiles, more intense fuel burnup at the first stage of combustion, which corresponds to the supply of only primary air and other.

References

1. Fialko N.M., Sherenkovsky Ju.V., Mayson N.V., Meranova N.O., Butovskiy L.S., Abdulin M.Z., Polozenko N.P., Klishch A.V., Stryzheus S.N., Timoshchenko A.B. Mathematical modeling of processes of flow and mixture formation in a cylindrical stabilizer burner device. Eastern European Journal of Advanced Technologies. 2014. V.3. № 8 (69). P. 40-44. (Rus). ISSN 1729-3774. https://doi.org/10.15587/1729-4061.2014.24895.
2. Fialko, N.M., Sherenkovsky Ju.V., Prokopov V.G., Polozenko N.P., Meranova N.O., Aleshko S.A., Ivanenko G.V., Yurchuk V.L., Milko E.I., Olkhovskaya N.N. Modeling of the flow structure in the echelonized

gratings of stabilizers with a different step of their displacement. Eastern European Journal of Advanced Technology. 2015. V.2. № 8 (74). P.29-34. (Rus). ISSN 1729-3774. https://doi.org/10.15587/1729-4061.2015.39193.

3. Fialko N.M., Aleshko S.A., Rokitko K.V., Maletskaya O.E., Milko E.I., Kutnyak O.N., Olkhovskaya N.N., Regragui A., Donchak M.I., Evtushenko A.A. Regularities of mixture formation in the burners of the stabilizer type with one-sided fuel supply. Technological Systems. 2018. 3(38). PP. 37-43. (Eng). dx.doi.org/10.29019/084.3
4. Fialko, N.M., Sherenkovsky Ju.V., Mayson N.V., Meranova N.O., Butovsky L.S., Abdulin M.Z, Polozenko N.P., Klishch A.V., Stryzheus S.N., Timoshchenko A.B. Intensification of transport processes in a burner device with a cylindrical flame stabilizer. Scientific Bulletin of UNFU. 2014. 24 (5). P. 136-142. (Rus). ISBN 5-7763-2435-1.
5. Fialko N.M., Butovsky L.S., Prokopov V.G., Granovskaya E.A., Sherenkovsky Ju.V., Aleshko S.A., Kokhanenko P.S. Features of flow around flat stabilizers by a limited flow. Industrial Heat Engineering. 2010. №5. P. 28-36. (Rus). ISSN 0204-3602.
6. Fialko N.M., Prokopov V.G., Aleshko S.A., Polozenko N.P., Timoshchenko A.B., Abdulin M.Z., Maletskaya O.E., Nochovny A.V. Analysis of the influence geometric shape of the niche cavity on the aerodynamic resistance of the channel. Industrial Heat Engineering. 2012. № 1. P. 72-76. (Rus). ISSN 0204-3602.
7. Fialko N.M., Prokopov V.G., Alioshko S.A., Abdulin M.Z., Rokitko K.V., Maletska O.E., Milko E.I., Olkhovska N.N., Regragi A., Evtushenko A.A. Computer simulation of flow in microjet burner devices with asymmetric supply of fuel. Scientific Bulletin of UNFU. 2018. Vol. 28. № 8. C 117-121. (Rus). https://doi.org/10.15421/40280823
8. Fialko N.M., Prokopov V.G., Sherenkovskiy Ju.V., Alioshko S.A., Meranova N.O., Abdulin M.Z., Butovsky L.S., Mirgorodsky A.N. Computer

simulation of transfer processes in cooling systems of burner devices of stabilizer type. Industrial Heat Engineering. 2012. №1. P. 64-71. (Rus). ISSN 0204-3602.

9. Fialko N.M., Meranova N.O., Shrenkovskii Ju.V., Aleshko S.A., Rokytko K.V. Flow structure in a stabilizer burner with one-sided fuel supply. International Multidisciplinary Conference «Science and technology of the presents time: priority development directions of Ukraine and Poland». 19-20 October 2018. P. 116-120. (Eng). ISBN 978-9934-571-55-8.
10. Fialko N.M., Sherenkovskyi Ju.V., Meranova N.O., Alioshko S.A., Rokytko K.V. Peculiarities of flow and mixture formation in microjet burner devices with asymmetric fuel distribution. Industrial Heat Engineering. 2011. № 1. P.51-56. (Ukr). https:doi.org/10.31472/ttpe.1.2019.2.