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Numerical results of the study of the effect of the initial value of the fuel concentration on the parameters of the torch based on parabolized three-dimensional Navier-Stokes equations

Mirsaid M. Aripov[a], **Safar Khodjiev**[b,*]

[a] *National University of Uzbekistan*
[b] *Bukhara State University, Uzbekistan*

Abstract. This paper presents numerical results of the study of the effect of the fuel concentration in the initial mixture, the turbulence and the initial turbulence value on the parameters of the diffusion combustible mixture of propane and butane flowing from the nozzle rectangular section.

Three-dimensional systems of Navier-Stokes equations for multicomponent chemically reacting gas mixtures in physical coordinates are used to model the process under study.

To calculate the turbulent viscosity, a two-parameter model "$k - \varepsilon$" is used, with modified empirical parameters. The system of equations is solved by the finite difference method using a modification of the calculation algorithm and implemented in a SIMPLER type procedure.

It has been numerically revealed that an increase in the initial value of the concentration of a combustible mixture of propane and butane in the range of $0.085 - 0.12\ kg/kg$ does not significantly affect the maximum value of the torch temperature, but leads to an expansion of the thermal displacement zone and to a noticeable elongation and some expansion of the torch.

As a result of numerical research, it was revealed that the growth of the initial fuel concentration value and small satellites ($m_u = 0.82$) significantly affect the length and configuration of the flare, and the initial turbulence values slightly affect the maximum temperature of the flare. In a flooded flare with a dimensionless initial value of the kinetic energy of turbulence $k = 0.05$ and the fuel concentration $C = 0.12\ kg/kg$, the length compared to the concentration $C = 0.85\ kg/kg$ is 10 calibers longer (relative to the sides of the rectangular nozzle, and heating the fuel to 100 K (with initial temperature 1200 K) leads to an elongation of the torch length by 45% at the initial values fuel concentrations $C = 0.085$.

1. Introduction

Studies of turbulent jet flow and turbulent combustion of unmixed gas mixtures flowing from a rectangular nozzle are topical issues of applied mechanics, as there is increased interest in connection with the widespread use of these processes in the design of various mixing and combustion devices, ventilation pipes, as well as in solving the problem of combating environmental pollution, increasing and improving the efficiency of fuel combustion and burning others.

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* Corresponding author: Safar Khodjiev
Email addresses: mirsaidaripov@mail.ru (Mirsaid M. Aripov), safar1951@yandex.ru (Safar Khodjiev)

Despite all the practical importance of the phenomenon of turbulent combustion and its extensive applications, there is still no quantitative theory of this phenomenon, but even generally recognized fundamental concepts that could form the basis for such a theory [9, 17]

Experimental studies of turbulent jets flowing from nozzles of rectangular cross-section have been carried out by various authors [1, 2, 7, 13, 14, 16, 19], and attempts have been made to theoretically and numerically calculate the process of viscous self-mixing [8, 10, 14, 15].

Currently, mathematical modeling is being intensively developed and applied, which is sometimes the only possible method for studying gas dynamics, heat and mass transfer of jet flows of multicomponent gas mixtures.

Modeling of the aerodynamic theory of combustion is commonly called a branch of research that highlights the study of the laws of the flow of the burning stream and the corresponding processes of momentum, energy and matter transfer.

1.1. The purpose of the work

Describe a mathematical model of the combustion of a combustible gas mixture flowing from a rectangular nozzle and numerically investigate and analyze the effects of the initial concentration, temperature and velocity, as well as the kinetic energy of turbulence of a combustible jet on the processes of heat and mass transfer of three-dimensional turbulent jets during diffusion combustion, that is, on the parameters of the torch.

1.2. Problem statement

A combustible mixture consisting of propane and butane with specified initial parameters flows out of a rectangular nozzle with a finite ratio of side lengths into a flooded or entangled air oxidizer stream.

Suppose that the origin of the Cartesian coordinate system is in the center of the initial section of the jet for a nozzle with an equal aspect ratio and the axis OX is directed along the center of the jet, and the axes OY and OZ are parallel to the sides of the nozzle, respectively, the size of the sides 2a and 2b, and the jet is centrally symmetric with respect to the axis OX. Symmetry allows you to consider only one quarter of the jet when you calculating, two boundaries of the integration area are formed by planes of symmetry.

Consider the limiting case of combustion, in which the reaction rate is assumed to be infinitely high compared to the diffusion rate, the concentration of reagents in the combustion zone is zero, and the zone itself is the surface of the flame front, i.e. the so-called diffusion combustion of unmixed gases [17].

2. The solution method

The equations used to model the chemically reacting flow under consideration can be expressed in physical coordinates in the form [3, 5, 11].

The equation of continuity of the mixture

$$\frac{\partial \rho u}{\partial x} + \frac{1}{L}\frac{\partial \rho \vartheta}{\partial y} + \frac{\partial \rho \omega}{\partial z} = 0 \tag{1}$$

The equation of motion along the axis OX

$$\rho u \frac{\partial u}{\partial x} + \rho \vartheta \frac{\partial u}{L\partial y} + \rho \omega \frac{\partial u}{\partial z} = -\frac{\partial P}{\partial x} + \frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu_T \frac{\partial u}{\partial z}\right). \tag{2}$$

The equation of motion along the axis OY

$$\rho u \frac{\partial \vartheta}{\partial x} + \partial \vartheta \frac{\partial \vartheta}{L\partial y} + \rho \omega \frac{\partial \vartheta}{\partial z} = -\frac{\partial P}{L\partial y} + \frac{4}{3L^2}\frac{\partial}{\partial y}\left(\mu_T \frac{\partial \vartheta}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu_T \frac{\partial \vartheta}{\partial z}\right) - \frac{2}{3L}\frac{\partial}{\partial y}\left(\mu_T \frac{\partial \omega}{\partial z}\right) + \frac{1}{L}\frac{\partial}{\partial z}\left(\mu_T \frac{\partial \omega}{\partial y}\right), \tag{3}$$

The equation of motion along the axis OZ

$$\rho u\frac{\partial\omega}{\partial x}+\rho\vartheta\frac{\partial\omega}{L\partial y}+\ rho\omega\frac{\partial\omega}{\partial z}=-\frac{\partial P}{\partial z}+\frac{4}{3}\frac{\partial}{\partial z}\left(\mu_T\frac{\partial\omega}{\partial z}\right)+\frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T\frac{\partial\omega}{\partial y}\right)+\frac{1}{L}\frac{\partial}{\partial y}\left(\mu_T\frac{\partial\vartheta}{\partial z}\right)-\frac{\partial}{\partial z}\left(\mu_T\frac{\partial\vartheta}{\partial y}\right) \quad (4)$$

The equation of energy

$$\rho u\frac{\partial H}{\partial x}+\rho\vartheta\frac{1}{L}\frac{\partial H}{\partial y}+\rho\omega\frac{\partial H}{\partial z}=\frac{1}{L^2}\frac{1}{Pr_T}\frac{\partial}{\partial y}\left(\mu_T\frac{\partial H}{\partial y}\right)+\frac{1}{Pr_T}\frac{\partial}{\partial z}\left(\mu_T\frac{\partial H}{\partial z}\right)+Q_{\mathrm{DIS}}, \quad (5)$$

where

$$Q_{\mathrm{DIS}}=\left(1-\frac{1}{Pr_T}\right)\left\{\frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T u\frac{\partial u}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_T u\frac{\partial u}{\partial z}\right)+\frac{\partial}{\partial z}\left(\mu_T\vartheta\frac{\partial\vartheta}{\partial z}\right)+\frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T\omega\frac{\partial\omega}{\partial y}\right)\right\}+$$
$$+\left(\frac{4}{3}-\frac{1}{Pr_T}\right)\left\{\frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T\vartheta\frac{\partial\vartheta}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_T\omega\frac{\partial\omega}{\partial z}\right)\right\}-\frac{1}{L}\frac{\partial}{\partial y}\left(\frac{2}{3}\mu_T\vartheta\frac{\partial\omega}{\partial z}\right)+$$
$$+\frac{1}{L}\frac{\partial}{\partial z}\left(\mu_T v\frac{\partial\omega}{\partial y}\right)+\frac{1}{L}\frac{\partial}{\partial y}\left(\mu_T\omega\frac{\partial\vartheta}{\partial z}\right)-\frac{1}{L}\frac{\partial}{\partial z}\left(\frac{2}{3}\mu_T\omega\frac{\partial\vartheta}{\partial y}\right).$$

The equation of concentration

$$\rho u\frac{\partial\tilde{\tilde{C}}}{\partial x}+\rho\vartheta\frac{1}{L}\frac{\partial\tilde{\tilde{C}}}{\partial y}+\rho\omega\frac{\partial\tilde{\tilde{C}}}{\partial z}=\frac{1}{Sc_T}\frac{1}{L^2}\frac{\partial}{\partial y}\left(\mu_T\frac{\partial\tilde{\tilde{C}}}{\partial y}\right)+\frac{1}{Sc_T}\frac{\partial}{\partial z}\left(\mu_T\frac{\partial\tilde{\tilde{C}}}{\partial z}\right) \quad (6)$$

Equation of kinetic energy of turbulence

$$\rho u\frac{\partial k}{\partial x}+\rho\vartheta\frac{\partial k}{L\partial y}+\rho\omega\frac{\partial k}{\partial z}=\frac{1}{L^2}\frac{\partial}{\partial y}\left(\frac{\mu_T}{\Sigma_k}\frac{\partial k}{\partial y}\right)+\frac{\partial}{\partial z}\left(\frac{\mu_T}{\Sigma_k}\frac{\partial k}{\partial z}\right)+G-\rho\varepsilon. \quad (7)$$

Equation of kinetic energy dissipation of turbulence

$$\rho u\frac{\partial\varepsilon}{\partial x}+\rho v\frac{\partial\varepsilon}{L\partial y}+\rho\omega\frac{\partial\varepsilon}{\partial z}=\frac{1}{L^2}\frac{\partial}{\partial y}\left(\frac{\mu_T}{\sigma_\varepsilon}\frac{\partial k}{\partial y}\right)+\frac{\partial}{\partial z}\left(\frac{\mu_T}{\sigma_\varepsilon}\frac{\partial k}{\partial z}\right)+(C_1G-C_2\rho\varepsilon)\frac{\varepsilon}{k}, \quad (8)$$

where $G=\mu_T\left[\left(\frac{\partial u}{L\partial y}\right)^2+\left(\frac{\partial u}{\partial x}\right)^2\right]$.

Equation of state of a gas mixture

$$P=\rho T\sum_{i=1}^{N}\frac{c_i}{M_i}, \quad (9)$$

Relation of total enthalpy to temperature

$$H=C_pT+\frac{u^2+\vartheta^2+\omega^2}{2}+\sum_{i=1}^{N}C_ih_i^* \quad (10)$$

To calculate the turbulent viscosity, the expression was used

$$\mu_T=\frac{C_{\mu_T}\rho k^2}{\varepsilon} \quad (11)$$

involving additional equations (7) and (8).

The system of equations (1-11) is written in dimensionless form and taking into account the transformation $y = \overline{y}/\overline{L}$ (where $\overline{L} = a/b$) allowing to bring the inlet section of the nozzle into a square. In these equations, k is the kinetic energy of turbulence, ε is the dissipation of the kinetic energy of turbulence, and σ_k, σ_ε, C_1, C_2, C_{μ_T} empirical constants of the "$k-\varepsilon$" turbulence model $C_{\mu_T} = 0.8$, $C_1 = 1.3$, $C_2 = 1.5$, $\sigma_k = 1, \sigma_\varepsilon = 1.3$ [3]), the other designations are generally accepted.

In this paper, the diffusion combustion of a combustible mixture in a satellite (flooded) air stream with a sufficiently high reaction rate is considered. This assumption allows using the conservative Schwab–Zeldovich function [4, 6] with respect to excess concentrations $\widetilde{\widetilde{C}}$ reduce the concentration equations for a four-component mixture to one, i.e. in the form (6). Conservative variable $\widetilde{\widetilde{C}}$, it takes a value of 1 at the outlet of the rectangular nozzle (fuel), and -0 in the oxidizer air zone.

2.1. Boundary and initial conditions

A dimensionless system of differential equations (1-8) with relations (9-11) from the previously made assumptions is solved using the following dimensionless initial and boundary conditions:

I. $x = 0$:

$$\begin{aligned} &1.\ 0 \le y \le 1, 0 \le z \le 1 : u = 1, v = 0, \omega = 0, H = H_2, P = P_2, \widetilde{\widetilde{C}} = 1, k = k_2, \varepsilon = \varepsilon_2, \rho_2 = 1. \\ &2.\ 0 < y < y_{+\infty}, 1 < z < z_{+\infty} : u = u_1, \vartheta = 0, \omega = 0, H = H_1, P = P_1, k = k_1, \varepsilon = \varepsilon_1, \widetilde{\widetilde{C}} = 0, \rho = \rho_1. \end{aligned} \tag{12}$$

II. $x > 0$

$$\begin{aligned} &1.\ z = 0, 0 < y < y_{+\infty}, \frac{\partial u}{\partial z} = 0, \frac{\partial v}{\partial z} = 0, \omega = 0, \frac{\partial H}{\partial z} = 0, \frac{\partial \widetilde{\widetilde{C}}}{\partial z} = 0, \frac{\partial k}{\partial z} = 0, \frac{\partial \varepsilon}{\partial z} = 0. \\ &2.\ y = 0, 0 < z < z_{+\infty}, \frac{\partial u}{\partial y} = 0, , \vartheta = 0, \frac{\partial \omega}{\partial y} = 0, \frac{\partial H}{\partial y} = 0, \frac{\partial \widetilde{\widetilde{C}}}{\partial y} = 0, \frac{\partial k}{\partial y} = 0, \frac{\partial \varepsilon}{\partial y} = 0. \\ &3.\ z = 0, y = 0 : \frac{\partial u}{\partial y} = \frac{\partial u}{\partial z} = \frac{\partial H}{\partial y} = \frac{\partial H}{\partial z} = \vartheta = \omega = 0, \frac{\partial k}{\partial y} = \frac{\partial k}{\partial z} = \frac{\partial \varepsilon}{\partial y} = \frac{\partial \varepsilon}{\partial z} = 0. \\ &4.\ z \to Z_{+\infty}, y \to y_{+\infty} : u = u_1, \vartheta = 0, \omega = 0, H = H_1, P = P_1, \widetilde{\widetilde{C}} = 0, k = k_1, \varepsilon = \varepsilon_1, \rho = \rho_1. \end{aligned} \tag{13}$$

In the boundary conditions, the lower indices correspond to the parameters of the oxidizer jet 1, and the fuel index 2. Here k_1, k_2 and $\varepsilon_1, \varepsilon_2$ are the dimensionless initial values of the kinetic and kinetic energy dissipation of turbulence. To set the value of the distribution of turbulence characteristics on the nozzle section, different ratios are used, but these initial values should provide expressions of turbulent viscosity (11) corresponding to the actual flow pattern. The system of equations (1-11) with initial and boundary conditions (12-13) have a parabolic form and a semi-implicit method and calculation algorithm tied through pressure (SIMPLE) developed by Patankar and Spaulding [12] and their modifications are used to integrate the equations [5].

The method described [5, 12] and the solution algorithm were implemented in the form of programs in an algorithmic language for modern computing tools. With the help of this program, calculations can be carried out for both laminar and turbulent three-dimensional non-reacting and reacting jet (flooded, satellite), as well as internal flows.

It should be noted that all variants of reagents, the initial values of the physical parameters of the main and satellite jet, spatial steps, the coefficient of condensation of the calculated point along the longitudinal coordinate, the accuracy of convergence of solutions and the distribution of the boundary of the calculated area to the transverse coordinates, as well as the dimensions of the sides of the outlet section of the nozzle are included in the set of initial data, therefore, when solving a wide range of specific tasks, it is not necessary to it is required to make any changes to the text of the program and in this sense the program is universal.

In the calculations, the calculated steps of the transverse coordinates are respectively equal to the values of $\Delta z = \Delta y = 0.01$, and Δx varied from 0.01 to 0.25, and at the same time in the initial section the step did not exceed the value of 0.05.

Table 1

Parameters	1			2			3			4		
	1	2	3	1	2	3	1	2	3	1	2	3
$u_1, m/s$	0	0	0	0	0	0	5	5	5	18,3	18,3	18,3
T_2, K	1200	1200	1200	1300	1300	1300	1200	1200	1200	1200	1200	1200
$C_2, \frac{kg}{kg}$	0,085	0,1	0,12	0,085	0,1	0,12	0,085	0,1	0,12	0,085	0,1	0,12
k_2	0.05	0.05	0.05	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0.1
T_Φ, K	1740	1875	1867	1750	1800	1873	1770	1785	1830	1770	1830	1840
$L_\Phi/2b$	20.1	25	30.2	29.2	31.2	32.1	22	25.2	30.5	18.2	22.2	28.1

3. Numerical results

It is assumed that the combustible gas mixture consists of propane and butane, which flows out of a square-shaped nozzle and spreads in the entangled (flooded) space of the oxidizer. In this case, the combustible mixture and the oxidizer can be diluted with an inert gas N_2.

Numerical studies were carried out with the following initial initial data of the fuel and oxidizer [17, 18]:

I. Data of the oxidizer: $u_1 = 0(5; 10; 18,3; 30)$ m/s,$T_1 = 300(400, 500)K, (c_1)_1 = 0,232; (c_2)_1 = 0; (c_3)_1 = 0; (c_4)_1 = 0,768; k_1 = \beta_1 u_1^2; \varepsilon_1 = \gamma_1 k_1^{3/2}; P_2 = 1$ atm.

II. Fuel mixture data: $T_2 = 700(900; 1100; 1200; 1300)K; u_2 = 18,3(30, 38, 61)$ m/s; $(c_1)_2 = 0; (c_2)_2 = 0,12; (c_3)_2 = 0; (c_4)_2 = 0,88; k_2 = \beta_2 u_2^2; \varepsilon_2 = \gamma_2 k_2^{3/2}; P = 1$ atm.

Here, the lower external second indexes indicate that this value belongs to the air nozzle section -1, fuel -2. Dimensionless multipliers β_1, β_2 and γ_1, γ_2 at which the distributions of turbulence characteristics on the nozzle section are determined.

In all calculation variants, the heat of formation of the oxidizer, reaction product and inert gas is assumed to be zero $h_1^* = h_3^* = h_4^* = 0$, fuel - $h_2^* = 11490$ kkal/kg, and numbers $Pr_T = Sc_T = 0,65$.

In the numerical implementation of the system of equations at the nozzle mouth, the values of the desired parameters were set by homogeneous, stepwise and constant values.

Variants of the initial parameter values and some calculation results (length and maximum temperature of the torch) are shown in Table 1.

In all the calculated variants given in Table 1, the other parameters of the jet and the oxidizer remained unchanged, i.e. the jet velocity $u_2 = 61$ m/s, air temperature $T_1 = 300K$, concentration of oxidizer and inert gas: $(C_1)_1 = 0,232$ kg/kg, $(C_4)_1 = 0,768$ kg/kg. Some results of computational studies are presented in the form of graphs in Figures 1-8.

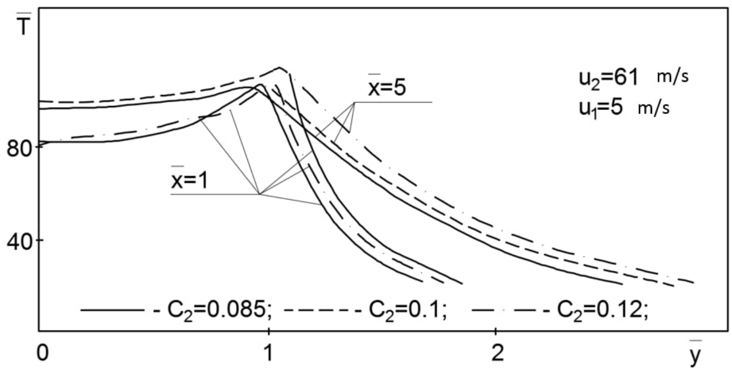

Figure 1: Transverse temperature distributions along the OY axis in different initial values of fuel concentration $u_1 = 5$ m/s.

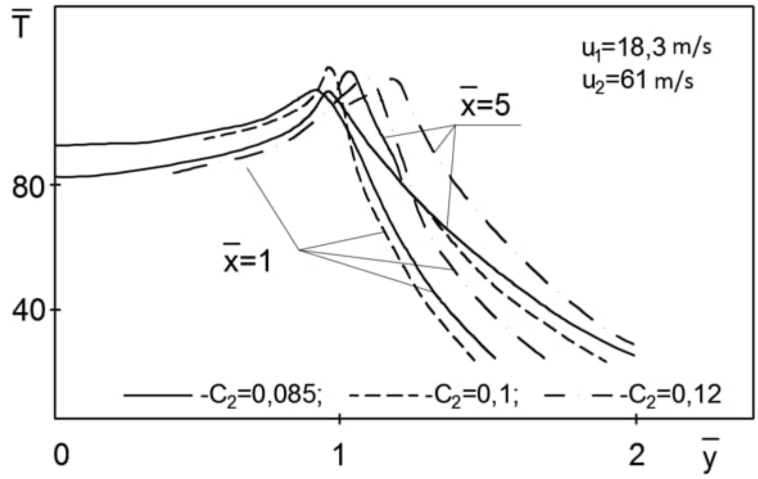

Figure 2: Transverse temperature distributions along the OY axis in different initial values of fuel concentration at u_1 = 18,3 m/s.

Fig. 1 and Fig.2 show the transverse distribution of temperature profiles depending on the initial value of the fuel concentration $((C_2)_2 = 0,085; (C_2)_2 = 0.1; (C_2)_2 = 0,12)$ and the speed of the satellite stream $(u_1 = 5\ m/s, u_1 = 18,3\ m/s)$ along the jet in sections $\bar{x} = 1$ and $\bar{x} = 5$ along the OY axis (similar flow behavior is observed along the oz axis). Analysis of these graphs shows that an increase in the initial value of the concentration of the combustible mixture does not significantly affect the maximum value of the flare temperature. Basically, the initial fuel concentration value affects the dynamic parameters of the jet. An increase in the fuel concentration in the gas jet leads to an expansion of the thermal displacement zone, i.e. the zone of intense heat release expands, and this, in turn, contributes to the expansion of the dynamic displacement zone.

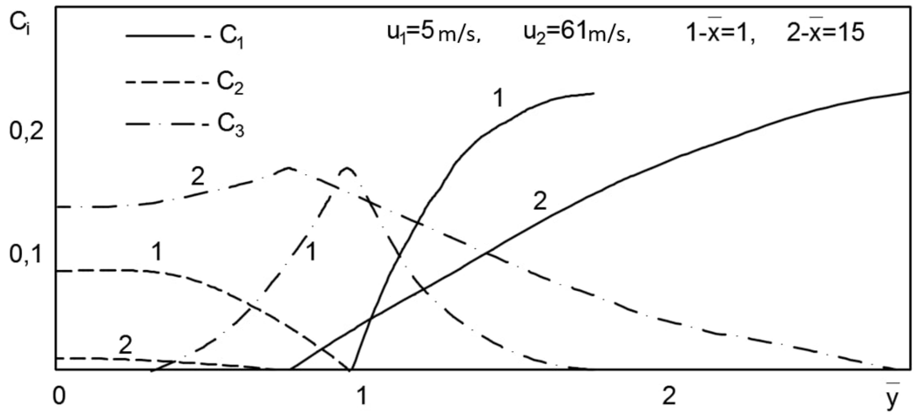

Figure 3: Transverse distributions of component concentrations along the axis OY at the initial fuel concentration value $(C_2)_2 = 0.085$

Figure 3 shows the transverse distribution of the concentration of the initial reagents and the reaction product depending on the initial value of the fuel concentration $(C_2)_2$ (C_1 - oxidizer, solid line; C_2- combustible mixture, dotted line; C_3 - reaction product, dotted line) at the rate of $u_1 = 5$ m/s along the coordinate axis OY in different sections along the jet. Judging by the graph, it can be noted that the minimum value of the concentration of fuel and oxidizer ($C_1 = 0$, $C_2 = 0$) corresponds to the maximum value of the reaction product C_3. During diffusion combustion, these values correspond to the coordinates of the flame front, and in these coordinates there is a maximum value of temperature (see Fig.1 and Fig.2), which corresponds to the physics of the phenomenon of diffusion combustion. As can be seen from the graph, at low values of fuel concentration ($(C_2)_2 = 0,085$; Fig. 3) the intensity of its loss is greater than when $(C_2)_2 = 0,12$ (the graph is similar in appearance, so it is not given), and this leads to the fastest burnout of the combustible mixture.

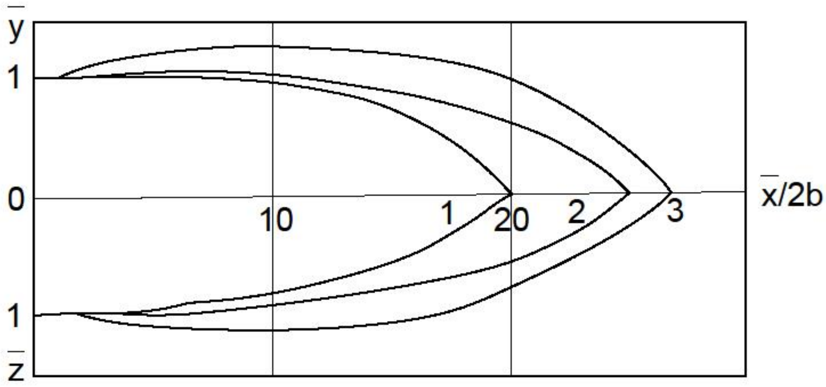

Figure 4: Configuration of the torch at the source data: $u_1 = 0$; $u_2 = 61$ m/s; $T_1 = 300$ K; $T_2 = 1200$ K; $\overline{k_2} = 0.01$; 1 -$(C_2)_2 = 0,085$; 2-$(C_2)_2 = 0.1$; 3-$(C_2)_2 = 0,12$

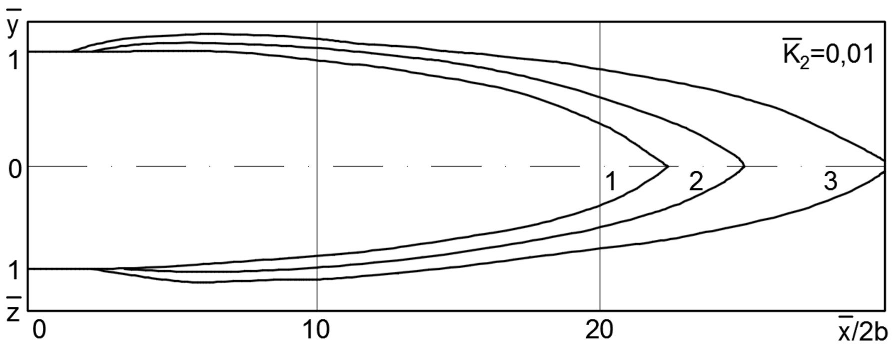

Figure 5: Configuration of the torch at the initial data: $u_1 = 5$ m/s; $u_2 = 61$ m /s; $T_1 = 300$ K; $T_2 = 1200$ K; $\overline{k_2} = 0.01$; 1-$(C_2)_2 = 0,085$; 2-$(C_2)_2 = 0.1$; 3-$(C_2)_2 = 0,12$

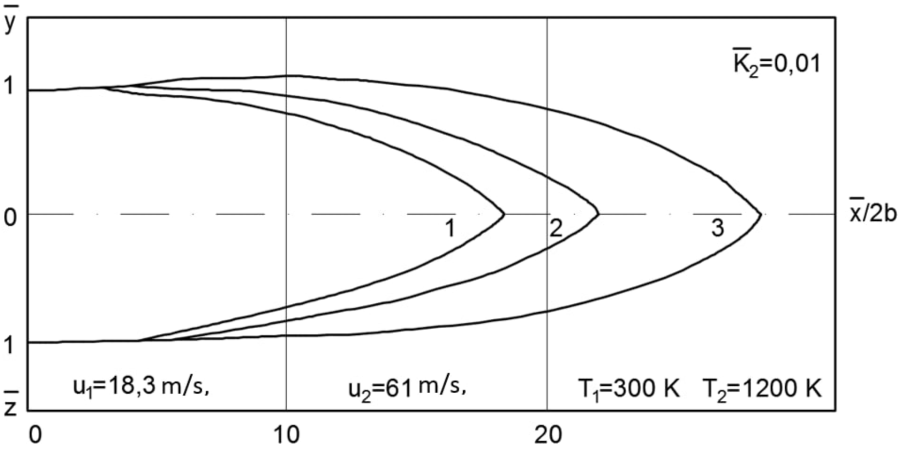

Figure 6: Configuration of the torch at the initial data: $u_1 = 18,5$ m/s; $u_2 = 61$ m/s; $T_1 = 300$ K; $T_2 = 1200$ K; $\overline{k_2} = 0.01$; 1 - $(C_2)_2 = 0,085$; 2 - $(C_2)_2 = 0.1$; 3 - $(C_2)_2 = 0,12$

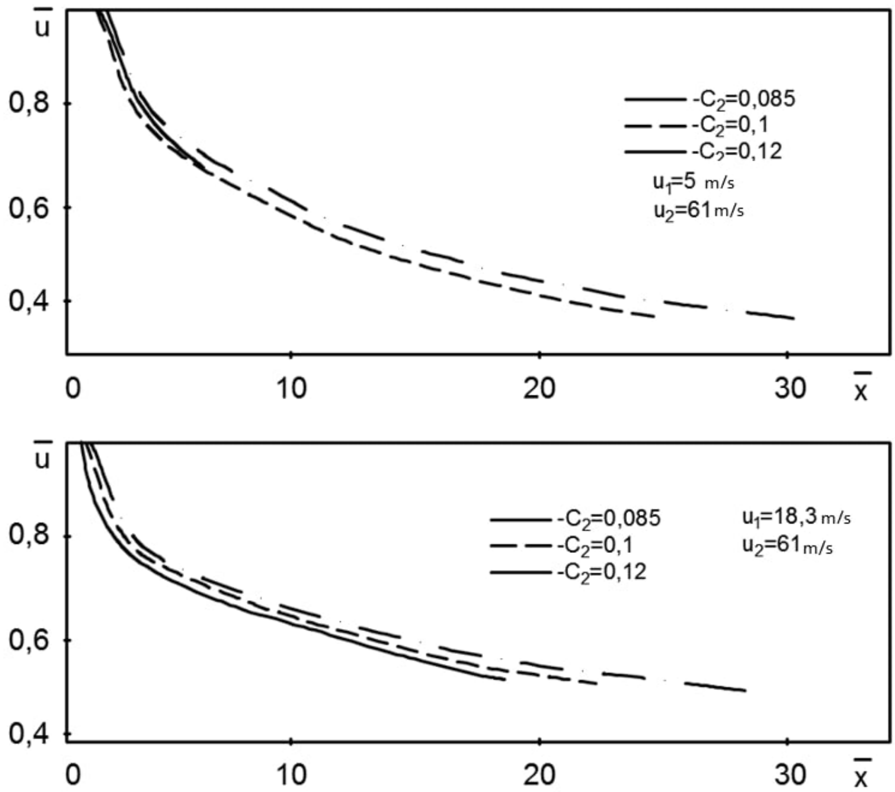

Figure 7: a), b). Effects of the initial fuel concentration value on the axial distribution of the longitudinal velocity

Figures 4-6 show the shapes of a three-dimensional diffusion torch depending on the initial value of the fuel concentration and on the velocity of the satellite flow, as well as on the initial value of the kinetic energy of turbulence. Based on these graphs and Table 1, it can be concluded that an increase in the initial value of the fuel concentration $(C_2)_2$, $0.085 \leq C_2 \leq 0.12$ in the considered variants, it leads to a noticeable elongation and some expansion of the torch.

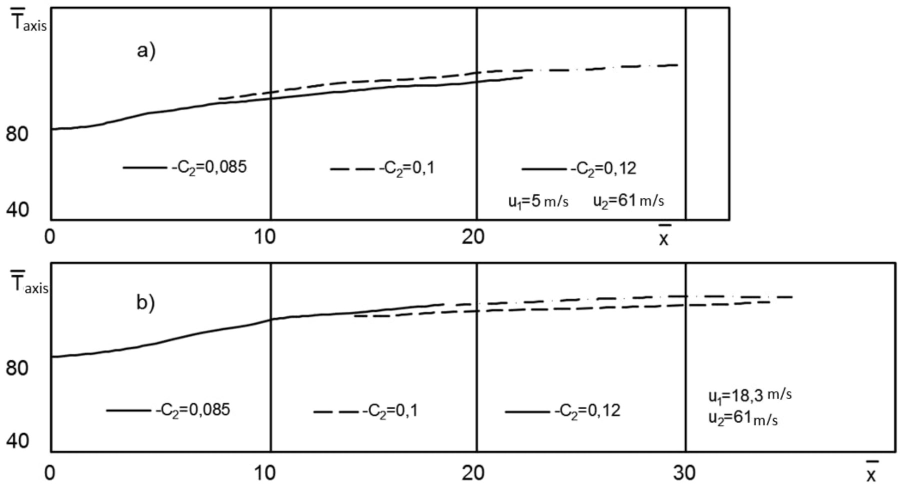

Figure 8: a), b). Profiles of axial temperature distribution

Fig. 7 (a, b) and Fig.8 (a,b) show axial changes in the longitudinal velocity and temperature depending on the initial value of the fuel concentration and on the velocity of the satellite flow. An increase in the initial value of the fuel concentration leads to an increase in the length of the torch, and this, in turn, leads to a gradual increase in the axial value of the temperature and a slow attenuation of the axial value of the longitudinal velocity.

It should be emphasized that by changing the initial value of the fuel concentration and the initial value of turbulence, it is possible to obtain, to some extent, the desired image of the torch. The results of a numerical study revealed that in a flooded flare at $k_2 = 0.05$ and $(C_2)_2 = 0.12$, its length in comparison with $(C_2)_2 = 0.085$, 10 calibers longer (relative to the sides of the rectangular nozzle).

In the experiments of [18] on the influence of the fuel concentration of a mixture of propane and butane flowing from a round nozzle with different diameters into a satellite (flooded) oxidizer stream, it was revealed that an increase in the fuel concentration in the initial mixture leads to elongation and expansion of the torch and to a slow increase in temperature on the torch axis, which is confirmed by our numerical results.

4. Conclusion

A number of numerical results of the study are presented, such as the influence of the initial concentration, temperature and velocity, as well as the kinetic energy of turbulence of a combustible jet on the processes of heat and mass transfer of three-dimensional turbulent jets during diffusion combustion of a mixture of propane and butane flowing from a rectangular nozzle with an aspect ratio (1:1).

Numerical studies have shown that with an increase in the concentration of the combustible mixture from 0.085 to 0.12 kg / kg with a flooded torch and small values of the velocity of the satellite flow of the oxidizer of the air, the length of the torch increases significantly, and the maximum temperature of the torch reaches 1875 K at the initial value of the concentration of fuel C=0.1 kg/kg.

Increases in the temperature and kinetic energy of the turbulence of the combustible jet at the nozzle section do not significantly affect the maximum temperature of the torch, and an increase in the initial value of the fuel concentration leads to a gradual increase in the axial value of the temperature and a slow attenuation of the axial value of the longitudinal velocity.

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