

*D. Dubinin, PhD, Assoc. Prof. of Department, NUCPU,
A. Lisnyak, PhD, Assoc. Prof., head of Department, NUCPU*

THE DOUBLE CHARGE EXPLOSION MODELS OF EXPLOSIVE GASES MIXTURE TO CREATE A FIRE BARRIER

(presented by DSc Klyuchka Y.)

In the work we analyzed the risk of wildfires and proved the efficient use of the explosive method to combat wildfires. A mathematical model of the double charge explosion from explosive gases mixture is presented, as well as the resulting initial and boundary conditions required for the numerical calculation of the double charge explosion from explosive gases mixture to create a fire barrier.

Keywords: fire barrier, ground fuels, natural fire, double charge, simulation of the explosion of the charge.

Problem formulation. Every year there are about 400 thousand wildfires on the land surface, which destroy about 1% of the total area of the vegetation of the globe and emit millions tons of combustion products. The problems associated with wildfires are relevant to many countries in the world. Wildfires cause enormous damage to the environment, life quality, efficiency and overall economy of the country. One of the ways to increase the level of population protection from natural fires, is to create firebreaks. For this the operative-rescue services require very high costs. Implementation of mathematical modeling solves the problem by reducing the number of human resources, material costs and provides effective tool to assess the proposed method to combat wildfires.

Analysis of recent researches and publications. To improve the performance of creating a fire barrier and laying it through in areas which are hard to reach by heavy trucks the work [1] proposes the creation of barriers by explosion of constricted discharge type EIII-1П. In particular, the constricted discharge provides creating a fire barrier with a width of 1.4 m, while to confine a wildfire it is necessary, as a rule, a fire barrier with a minimum width of 2.8 m [2, 3]. In [4, 5] as an alternative for the constricted discharge it is proposed to use a single charge of explosive gases mixture that have a number of advantages, namely a high level of security when working with charges, increased pulse pressure and higher specific fuel combustion heat. To confine a wildfire it is offered to use double charges with explosive gases mixture that will increase the fire barrier width. It is assumed that when exploding the double charge, the width of the fire barrier may make about 7-8 m, which greatly exceeds the standard [2, 3].

Statement of the problem and its solution. The aim of this work is to define and describe the conditions for carrying out a mathematical model of the double charge explosion of explosive gases mixture to create a fire barrier.

The mathematical model of the explosion of a double charge double charge explosion of explosive gases mixture is represented as a system of eq-

equations describing the unsteady three-dimensional flow of two-component mixture of gases in a Cartesian coordinate system

$$\frac{\partial \bar{a}}{\partial t} + \frac{\partial \bar{b}}{\partial x} + \frac{\partial \bar{c}}{\partial y} + \frac{\partial \bar{d}}{\partial z} = \rho \bar{n}, \quad (1)$$

where $\bar{a}, \bar{b}, \bar{c}, \bar{d}, \bar{n}$ – the vector-columns are in the form:

$$\begin{aligned} \bar{a} &= [\rho, \rho u, \rho v, \rho w, E]^T, \\ \bar{b} &= [\rho u, P + \rho u^2, \rho uv, \rho uw, (E + P) u]^T, \\ \bar{c} &= [\rho v, \rho uv, P + \rho v^2, \rho vw, (E + P) v]^T, \\ \bar{d} &= [\rho w, \rho uw, \rho vw, P + \rho w^2, (E + P) w]^T, \\ \bar{n} &= [0, f_x, f_y, f_z]^T, \end{aligned}$$

where $f_x = -sc_d \cdot \rho u \sqrt{u^2 + w^2}$; $f_z = -sc_d \cdot \rho w \sqrt{u^2 + w^2}$ – projection of the resistance force on the axis of coordinates (sc_d – a parameter that characterizes the resistance force per unit volume of the phytocenosis); ρ, T, P – the density, temperature and pressure of the gas phase, respectively; e – is the internal energy per unit mass of the gas phase; t – is time; u, w – components of the velocity vector of the gas flow; x, z – are the coordinates in a Cartesian coordinate system along the earth's surface; s – specific surface phytomass of forest canopy; c_d – is an empirical coefficient of the forest canopy resistance; v – component of the velocity vector of the gas flow \vec{q} on the X-axis; y – Cartesian coordinate along the axis perpendicular to the earth's surface; E – the total energy per unit volume of the gasmixture: $E = \rho \left(e + \frac{1}{2} (u^2 + v^2 + w^2) \right)$.

A law of transferring the components of the mixture given the speed of diffusion has the form [4]

$$\frac{\partial(\rho Q)}{\partial t} + \frac{\partial(\rho u Q)}{\partial x} + \frac{\partial(\rho v Q)}{\partial y} + \frac{\partial(\rho w Q)}{\partial z} = \rho_{Q_t}, \quad (2)$$

where Q – is the relative mass density of the admixture (the ratio of a gaseous substance impurities density to the mixture density), ρ_{Q_t} – the intensity change of the impurity density due to diffusion (according to Fick's law – $\rho_{Q_t} = \text{div}(\rho \vartheta_D \text{grad} Q)$; ϑ_D – is the diffusion coefficient, which was determined by the method of N. E. Berland [6].

It is based on the assumption that when using double charges of explosive gasmixture due to their simultaneous explosion in the field where shock waves interact there is a rapid increase in pressure, which will increase the width of the fire barrier at the expense of emission of vegetative combustible material at a

considerable distance from the center of the explosion. Therefore, the location of double charges in the field of simulation was set according to the scheme (fig. 1).

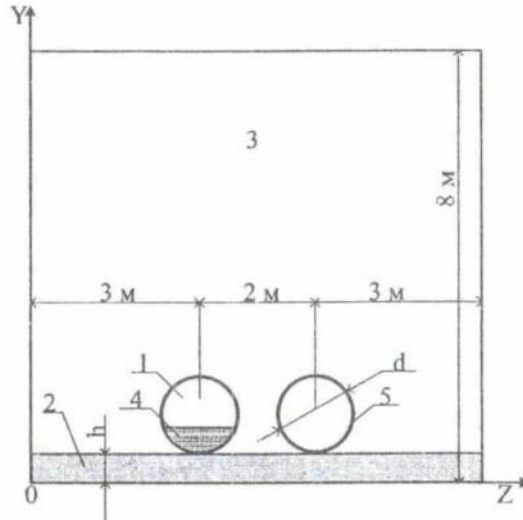


Fig. 1. The placement of double charges of explosive gasmixture in the computational domain: 1 – detonation products, 2 – the layer of vegetation, 3 – air, 4 – the calculated area, 5 – the initial border to locate the detonation products, h – the thickness of the coating layer, d – is the initial diameter of the charge

For this, the double charge of explosive gasmixture must be placed directly on top of the ground of combustible material at the distance of 2 m between the axis of the charges, which corresponds to the average distance between the ruts of a fire truck. Laying down the double charges can be carried out in an automated manner by firefighting and rescue heavy trucks. If ground combustible material is high, charges are laid along the way of vehicles that will bring them to the ground and thereby increase the energy efficiency of explosion.

To determine the initial conditions for the explosion processes of a double charge of explosive gasmixture we take the diameter of the shell charge $d = \{0,95; 1,3\}$, and the thickness of the ground layer of combustible material is equal to $h = 0,1$ m. Velocity of the wind is equal to $q_z = 3$ m/s as the average wind speed for Kharkiv city and Kharkiv region [4].

Thus, the initial conditions for the double charges of explosive gasmixture are the following.

In the area of detonation of a charge:

$$\left(y - h - \frac{d}{2}\right)^2 + \left(z - \frac{H_z}{2} + 1\right)^2 < \frac{d^2}{4}, \quad \left(y - h - \frac{d}{2}\right)^2 + \left(z - \frac{H_z}{2} - 1\right)^2 < \frac{d^2}{4},$$

$$0 < x < H_x, \tag{3}$$

we accepted: $P|_{t=0} = 1,4$ МПа; $T|_{t=0} = 3480$ K; $\gamma|_{t=0} = 1,267$, $u|_{t=0} = 0$; $v|_{t=0} = 0$; $w|_{t=0} = 0$; $N|_{t=0} = 1$.

In the area of airspace:

$$\begin{aligned} h < y < H_y, \quad 0 < x < H_x, \quad 0 < z < H_z, \quad \left(y - h - \frac{d}{2}\right)^2 + \left(z - \frac{H_z}{2} + 1\right)^2 \geq \frac{d^2}{4}, \\ \left(y - h - \frac{d}{2}\right)^2 + \left(z - \frac{H_z}{2} - 1\right)^2 \geq \frac{d^2}{4}, \end{aligned} \quad (4)$$

accepted: $P|_{t=0} = 0,1$ МПа; $T|_{t=0} = 293$ К; $\gamma|_{t=0} = 1,4$; $u|_{t=0} = 0$; $v|_{t=0} = 0$; $w|_{t=0} = 3$ м/с; $N|_{t=0} = 0$.

In the area of phytocenosis:

$$0 < y < h, \quad 0 < x < H_x, \quad 0 < z < H_z, \quad (5)$$

accepted: $P|_{t=0} = 0,1$ МПа; $T|_{t=0} = 293$ К; $\gamma|_{t=0} = 1,4$; $u|_{t=0} = 0$; $v|_{t=0} = 0$; $w|_{t=0} = 0$ м/с; $N|_{t=0} = 0$.

Thus, the boundary conditions take the following form. The earth's surface in the calculations is presented in the form of a set of isolated sites, which together model the estimated area of the surfaces [4]. On these surfaces the condition of the non-flow was performed: $q\vec{n} = 0$, where \vec{n} – the vector normal to the surface.

When setting boundary conditions it is considered that the expenditure component of the wind speed does not exceed the speed of sound. The incoming flow of a gaseous substance at the entrance of a certain area is determined by the quantities [4]:

$$\text{– full enthalpy } I_{00} = \frac{\gamma}{\gamma - 1} \frac{P}{\rho} + \frac{1}{2} (u^2 + v^2 + w^2), \quad (6)$$

$$\text{– of the entropy function } S_0 = \frac{P}{\rho^\gamma}, \quad (7)$$

– relative mass density of impurity Q ($Q \leq 1$, for admission of the gaseous impurity substances).

The impact of the explosion products expanding is described by a system of nonstationary equations of gas dynamics taking into account the resistance of the medium, supplemented with the equation of state of an ideal gas in a three-dimensional Cartesian coordinate system.

The developed mathematical model allows to investigate how the explosion energy from a charge of explosive gas mixture impacts on the width of the fire barrier depending on the diameter of charges and their spatial location. Model of open ground combustible material in the double charges explosion made in the statement of the problem the instant of the explosion.

Conclusions. The paper presents the mathematical model, initial and boundary conditions, which allow to carry out numerical calculations and to investigate the process of the explosion of a double charge for explosive gas mixture when creating a fire protection barrier with the help of mathematical modeling. This will allow using proven programs with the use of mathematical models and initial conditions to determine the dependence of the width of the fire barrier from the charge diameter and type of vegetation. Obtaining and

justification of the magnitude of the fire barrier as a result of the mathematical modeling will allow to carry out experimental research in real conditions to evaluate the effectiveness of this method to confine wildfires.

REFERENCES

1. Grishin A.M. Matematicheskoe modelirovanie lesnyh pozharov i novye sposoby bor'by s nimi. – M.: Nauka, 1992. – 408 s.
2. Pravyla pozhezhnoi' bezpeky v lisah Ukrainy: NAPB A.01.002-2004. – K.: Derzhkomlissgosp Ukrainy, 2004.
3. Metodychni rekomendacii' shhodo znyzhennja nebezpeky plyvu lisovyh pozhezh na arsenaly, bazy i sklady bojeprypasiv, shho roztashovani v lisovyh masyvah. Nakaz MNS Ukrainy vid 25 serpnja 2011 r. № 890. – Rezhym dostupu: <http://www.dsns.gov.ua/files/2011/8/26/890.pdf>.
4. Dubinin D.P. Matematychno modeljuvannja vybuhu zarjadu z sumishi vybuhonebezpechnyh gaziv dlja stvorennja protypozhezhnogo bar'jeru / D.P. Dubinin, A.A. Lisnjak // Problemy pozharnoj bezopasnosti. – 2016. – Vyp. 40. – С. 84-89. – Rezhym dostupu: <http://nuczu.edu.ua/sciencearchive/ProblemsOfFireSafety/vol40/dubinin.pdf>.
5. Govalenkov S.V. Matematicheskoe modelirovanie parametrov vzryva ob#emno-shlangovogo zarjadu v pologe lesa / S.V. Govalenkov, D.P. Dubinin // Sistemi obrobki informacii: – H., 2011. – № 2 (92). – S. 282-285.
6. Fizyka / I.Je. Lopatyns'kyj, I.R. Zachek, G.A. Il'chuk, B.M. Romanyshyn. – L.: Afisha, 2005. – 385 с.

Received by editorial Board 15.03.2017

Д.П. Дубинин, А.А. Лисняк

Модели взрыва двойного заряда с смеси взрывоопасных газов для создания противопожарного барьера

В работе проведен анализ опасности возникновения природных пожаров. Обоснована эффективность применения взрывного способа для борьбы с природными пожарами. Предложенная математическая модель взрыва двойных зарядов из смеси взрывоопасных газов. Полученные начальные и граничные условия необходимые для проведения численного расчета взрыва двойных зарядов из смеси взрывоопасных газов для создания противопожарного барьера.

Ключевые слова: противопожарный барьер, наземные горючие материалы, природный пожар, двойной заряд, моделирование взрыва заряда.

Д.П. Дубінін, А.А. Лісняк

Моделі вибуху подвійного заряду з суміші вибухонебезпечних газів для створення протипожежного бар'єру

У роботі проведено аналіз небезпеки виникнення природних пожеж. Обґрунтована ефективність застосування вибухового способу для боротьби з природними пожежами. Запропонована математична модель вибуху подвійних зарядів з суміші вибухонебезпечних газів. Отримані початкові та граничні умови необхідні для проведення чисельного розрахунку вибуху подвійних зарядів з суміші вибухонебезпечних газів для створення протипожежного бар'єру.

Ключові слова: протипожежний бар'єр, наземні горючі матеріали, природна пожежа, подвійний заряд, моделювання вибуху заряду.