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MATHEMATICAL MODELING OF THE PROCESS OF FINE WATER MIST GENERATION BY SHOCK WAVES

The conducted studies made it possible to identify the features of the process of fine water mist generation from the nozzle of a fire-extinguishing system under the action of shock waves and to substantiate a mathematical model describing this process. Mathematical modeling was carried out using specialized simulation software based on the Volume of Fluid model. According to the results, the generation of fine-dispersed water at the outlet of the fire-extinguishing nozzle under the influence of shock waves occurs within 1.13–1.73 ms, followed by a transition to steady-state atomization and dispersion within 2.02–2.41 ms. At 5.11–5.24 ms, the process terminates due to the depletion of water in the nozzle. The most intense atomization was recorded at 1.73 ms, while the maximum spread of the water mist cloud occurred at 2.02 ms, defining the key stages of generation and process efficiency. The main parameters of water mist generation and delivery were determined, including the total volume, number of droplets, and density within the computational domain. The mist cloud was found to have a cylindrical shape with a water volume of 1.37 L(1.37×10^{-3} m^3), and the average water density in the air-water flow was 0.343 kg/ m^3. For water droplets of various dispersities, their main parameters were determined. Thus, for droplets with a diameter of 5 μm, the volume of a single droplet is 6.54×10^{-17} m^3, the total number of droplets is 7.2 million, and the droplet density within the fine water mist is 5.26×10^{9} drops/m^3. For droplets with a diameter of 50 μm, these parameters are 6.54×10^{-14} m^3, 7.2 thousand, and 5.26×10^{6} drops/m^3, respectively; while for droplets of 100 μm, the corresponding values are 5.24×10^{-13} m^3, 900, and 6.57×10^{5} drops/m^3. Mathematical modeling made it possible to investigate the process of fine water mist generation by the fire-extinguishing system under the influence of shock waves. The obtained parameters of fine-dispersed water determine the potential for its application in extinguishing fires of various classes, including under conditions of armed aggression.

Keywords: system, fire extinguishing, fire, fine water mist, mathematical model, simulation, generation, atomization

1. Introduction

The use of fine water-mist fire extinguishing systems during armed aggression becomes particularly important due to the increased danger to firefighting and rescue personnel, the limited water supply resulting from the destruction of water sources by enemy shelling, and the simultaneous combustion of various substances and materials with different physical and chemical properties [1]. One of the promising directions is the generation and delivery of fine water mist using gas-detonation technology [2].

The principle of gas-detonation technology lies in the atomization of a water jet by shock waves generated as a result of the detonation of a fuel-air mixture, which simultaneously leads to the generation and ejection of fine water mist through the nozzle of the fire-extinguishing system [3]. As a result, fine water mist is formed, consisting of droplets with diameters ranging from 1 to 100 μm, characterized by high dispersion and a maximum interaction surface area with the burning surface [4, 5]. This ensures rapid and effective fire suppression through intensive cooling of the flame and combustible gas medium, displacement of oxygen from the combustion zone, attenuation of radiant heat transfer by fine water droplets, and significant water savings [6].

The relevance of this research arises from the need to develop highly efficient, autonomous, mobile, and economical fire-extinguishing systems capable of operating under conditions of armed aggression, as well as in situations involving infrastructure destruction, limited water supply, and increased danger to personnel. Therefore, technologies that ensure minimal water consumption with maximum extinguishing efficiency are of particular importance. The use of gas-detonation technology for the generation of fine water mist makes it possible to significantly increase the effectiveness of firefighting by intensifying mass transfer, cooling, and inertization of the combustion environment.

Thus, the relevance of the problem lies in the necessity of scientific justification and modeling of fine water-mist generation processes under the influence of shock waves in order to improve fire-extinguishing efficiency under limited water and energy resources a factor of critical importance for ensuring the rapid operational response of fire and rescue units during armed aggression.

2. Analysis of literature data and problem statement

The use of gas-detonation technology for the generation and delivery of fine water mist is presented in works [7, 8], where experimental studies of a fire-extinguishing system generating a jet under the influence of shock waves were conducted. These studies confirmed the effectiveness of such systems for firefighting applications.

In work [9], a three-dimensional mathematical simulation of the interaction between a shock wave and a liquid droplet was performed, focusing on the initial stages of droplet deformation under shear-induced entrainment conditions. The obtained results, however, address only the early stages of droplet breakup, without investigating further fragmentation leading to fine water mist formation. This limits the understanding of the full generation and delivery process of fine water mist.

Work [10] presents the results of mathematical modeling of the quasi-stationary drag force acting on a layer of water droplets dispersed within a confined geometry to mitigate the effects of an explosive wave. However, the modeling was carried out in a one-dimensional formulation, which does not account for the three-dimensional flow structure and the non-uniform distribution of fine water mist, thus limiting the practical applicability of the research results.

In work [11], mathematical modeling of the influence of fine water mist on explosion mitigation was performed as a function of the mean droplet diameter and the volumetric fraction of droplets. It was found that reducing droplet size and increasing volumetric concentration enhance the absorption of energy and impulse, leading to a reduction in explosion intensity. Nevertheless, the study focuses solely on explosion suppression, which limits its practical relevance for fire-extinguishing applications.

In work [12], the interaction characteristics between a gaseous detonation wave and a water droplet were investigated. The effectiveness of detonation waves in fragmenting water droplets was established. However, it should be noted that these studies only considered the direct interaction of droplets with the shock wave, without analyzing the subsequent dispersion and generation of fine water mist.

Work [13] examined the prevention of hydrogen cloud explosions using micron-sized fine water mist. The results showed that the density of the mist ranged from 13.36 g/m^3 to 26.73 g/m^3. However, the use of micron-scale fine water mist was found to be ineffective for firefighting purposes.

The results of the above studies do not allow for a comprehensive assessment of the effectiveness of fine water mist generation formed from the nozzle of a fire-extinguishing system under the influence of shock waves. Therefore, conducting research on the process of fine water mist generation from the nozzle of a fire-extinguishing system using shock waves is relevant for evaluating key parameters such as the volume and number of droplets depending on their dispersity, as well as the density within the computational domain.

3. Purpose and objectives of the research

The purpose of this work is to identify the features of the process of fine water-mist generation from the nozzle of a fire-extinguishing system under the influence of shock waves.

To achieve this purpose, the following objectives were set:

– to develop a mathematical model of the process of fine water-mist generation from the nozzle of a fire-extinguishing system;

– to perform mathematical modeling of the process of fine water-mist generation from the nozzle of a fire-extinguishing system.

4. Materials and research methods

The object of the research is the process of fine water-mist generation from the nozzle of a fire-extinguishing system under the influence of shock waves. The subject of the research is the characteristics and parameters of fine water-mist generation from the nozzle of a fire-extinguishing system using shock waves, in particular the total volume, number of droplets depending on their dispersity, and their density within the computational domain.

The main hypothesis of the study is that shock waves generated from the nozzle of a fire-extinguishing system ensure the effective production of fine water mist, whose parameters including volume, droplet count as a function of dispersity, and spatial density within the computational domain determine the intensity and efficiency of the fire-extinguishing process.

As the research method, mathematical modeling was used to simulate the process of fine water-mist generation within a computational environment. Theoretical calculations were carried out to determine the total water volume, number of droplets depending on dispersity, and their density within the computational domain. The results obtained from the mathematical modeling made it possible to analyze the parameters of fine water mist during its generation from the nozzle of the fire-extinguishing system under the influence of shock waves.

5. Development of the mathematical model of the fine water-mist generation process

The process of fine water-mist generation was studied under conditions approximating the dispersion of the extinguishing agent in a fine water-mist fire-extinguishing system with jet generation by shock waves. For this purpose, a fire-extinguishing system nozzle with a diameter of 20 mm was used (Fig. 1).

Mathematical modeling of the processes of nozzle filling with water and its fragmentation in computational regions I and II was previously considered in works [14, 15]. Water was supplied through an orifice with a diameter of 2 mm for 60 ms, located 100 mm from the closed end of the nozzle and 300 mm from the open end. The nozzle outlet was positioned within computational region III (250×150×150 mm), extending 60 mm into it. The shock wave generated after the partial filling of the nozzle contributed to the ejection, dispersion, generation, and propagation of fine water mist within computational region III.

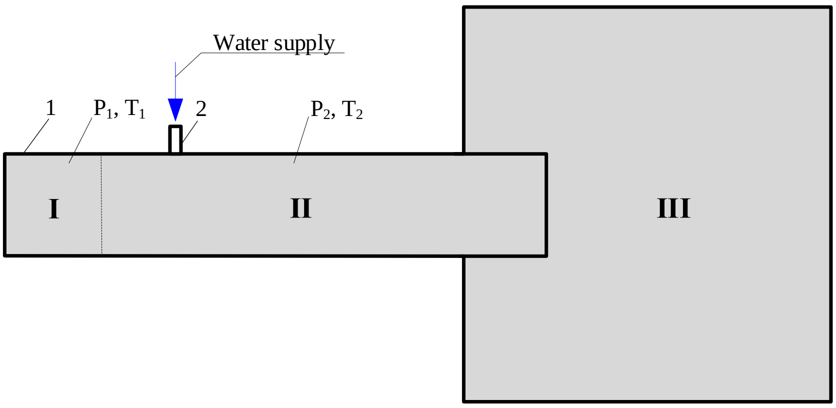

Fig. 1. Schematic representation of the problem setup: 1 – nozzle of the fire-extinguishing system, d = 20 mm; 2 – water supply orifice, d = 2 mm; I – high-pressure gas computational region; II – low-pressure gas computational region; III – fine water-mist generation computational region

Mathematical modeling of the fine water-mist generation process from the nozzle of the fire-extinguishing system was performed using a computational environment based on the VOF (Volume of Fluid) model. For the volume fraction of each phase (gas/liquid), the continuity equation takes the following form:

$$\frac{1}{\rho_q}\left[\frac{\partial}{\partial t}\left(\alpha_q\rho_q\right)+\nabla\left(\alpha_q\rho_q\vec{v}_q\right)\right]=S_{\alpha_q}+\sum_{p=1}^{n}\left(\dot{m}_{pq}-\dot{m}_{qp}\right), \tag{1}$$

where $\dot{m}_{qp}$ – mass transfer rate between phase q and phase p; $\dot{m}_{pq}$ – mass transfer rate between phase p and phase q; α_q – volume fraction of the q-th phase; ρ_q – density of the q-th phase; t – time; S_{α_q} – source of substance; $\vec{v}_q$ – velocity of the q-th phase.

The calculation of the volume fraction of each phase was carried out taking into account the specified constraint [16]:

$$\sum_{q=1}^{n}\alpha_q=1. \tag{2}$$

The determination of the volume fraction of the phase was performed using an implicit time discretization scheme according to the equation [16]:

$$\frac{\alpha_q^{n+1}\rho_q^{n+1}-\alpha_q^{n}\rho_q^{n}}{\Delta t}V+\sum_{f}\left(\rho_q^{n+1}U_f^{n+1}\alpha_{q,f}^{n+1}\right)=\left[S_{\alpha_q}+\sum_{p=1}^{n}\left(\dot{m}_{pq}-\dot{m}_{qp}\right)\right]V, \tag{3}$$

where n – index of the previous integration step; n+1 – index of the next integration step; $\alpha_{q,f}$ – surface value of the volume fraction of the q-th phase; V – volume of the computational cell; U_f – volume flux through the surface along the velocity normal.

The calculation of the averaged liquid density was performed according to the equation [16]:

$$\rho = \sum \alpha_q \rho_q \, . \qquad (4)$$

The momentum equation takes the following form [16]:

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v} \vec{v}) = -\nabla p + \nabla \cdot \left[\mu\left(\nabla \vec{v} + \nabla \vec{v}^T\right)\right] + \rho \vec{g} + \vec{F}, \qquad (5)$$

where $\vec{F}$ – momentum source; g – acceleration due to gravity; p – pressure; μ – molar mass.

The determination of energy is performed according to the equation [16]:

$$\frac{\partial}{\partial t}(\rho E) + \nabla \cdot \left(\vec{v}(\rho E + p)\right) = \nabla \cdot \left(k_{eff} \nabla T\right) + S_h, \qquad (6)$$

where E – averaged energy; T – averaged temperature; k_{eff} – effective thermal conductivity coefficient; S_h – energy source.

At the same time, the averaged energy is determined by the expression:

$$E = \frac{\sum_{q=1}^{n} \alpha_q \rho_q E_q}{\sum_{q=1}^{n} \alpha_q \rho_q}. \qquad (7)$$

The calculation of the turbulent viscosity of the liquid was performed using the Shear Stress Transport (SST) model (Menter), which takes into account the gas flow behavior behind the shock waves under the considered research conditions. The mass transfer equation (1) in this model is supplemented with terms describing the generation of kinetic energy of turbulent fluctuations and effective diffusion. In this model, the mass transfer equation has a form similar to that of the standard k–ω model:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\Gamma_k \frac{\partial k}{\partial x_j}\right] + G_k - Y_k + S_k, \qquad (8)$$

and

$$\frac{\partial}{\partial t}(\rho \omega) + \frac{\partial}{\partial x_j}(\rho \omega u_j) = \frac{\partial}{\partial x_j}\left[\Gamma_\omega \frac{\partial \omega}{\partial x_j}\right] + G_\omega - Y_\omega + D_\omega + S_\omega, \qquad (9)$$

where G_k – term of kinetic energy generation; G_ω – ω-generation term; Γ_k and Γ_ω – effective diffusion terms for k and ω; Y_k and Y_ω – turbulent dissipation terms for k and ω; D_ω – cross-diffusion coefficient; S_k and S_ω – source terms.

The effective diffusion coefficients for the SST k–ω model are described by the following equations:

$$\Gamma_k = \mu + \frac{\mu_t}{\sigma_k}, \qquad (10)$$

$$\Gamma_\omega = \mu + \frac{\mu_t}{\sigma_\omega}, \quad (11)$$

where σ_k and σ_ω – turbulent Prandtl numbers for k and ω.

The determination of turbulent viscosity μ_t is performed according to the equation:

$$\mu_t = \frac{\rho k}{\omega} \frac{1}{\max\left[\frac{1}{a^*}, \frac{SF_2}{a_1\omega}\right]}, \quad (12)$$

where S – strain rate.

$$\sigma_k = \frac{1}{F_1/\sigma_{k,1} + (1 - F_1)/\sigma_{k,2}}, \quad (13)$$

$$\sigma_\omega = \frac{1}{F_1/\sigma_{\omega,1} + (1 - F_1)/\sigma_{\omega,2}}, \quad (14)$$

$$F_1 = \tanh\left(\Phi_1^4\right), \quad (15)$$

$$\Phi_1 = \min\left[\max\left(\frac{\sqrt{k}}{0{,}09y\omega}, \frac{500\mu}{\rho y^2\omega}\right), \frac{4k\rho}{\sigma_{\omega,2} D_\omega^+ y^2}\right], \quad (16)$$

$$D_\omega^+ = \max\left[2\rho \frac{1}{\sigma_{\omega,2}} \frac{1}{\omega} \frac{\partial k}{\partial x_j} \frac{\partial \omega}{\partial x_j}, 10^{-10}\right], \quad (17)$$

$$F_2 = \tanh\left(\Phi_2^2\right), \quad (18)$$

$$\Phi_2 = \max\left[2\frac{\sqrt{k}}{0{,}09y\omega}, \frac{500\mu}{\rho y^2\omega}\right]. \quad (19)$$

The system of equations was solved using a pressure-based method in a Lagrangian coordinate system.

6. Mathematical modeling of the fine water-mist generation process

The results of the calculation of the shock-wave effects and the process of fine water-mist generation from the nozzle of the fire-extinguishing system at the simulation time are presented in Figs. 2–9. The figures show the liquid/gas phase transition surface within the field of static gas pressure, with the color scale of pressure displayed on the left.

Inside the nozzle, local zones of increased pressure are formed, influencing the distribution and velocity of the liquid flow and determining the velocity profile at the outlet (Fig. 2). At the nozzle exit, the front of the shock waves is recorded, propagating into the surrounding environment in the form of an annular region of overpressure.

At 1.13 ms, a pressure redistribution occurs within a portion of the computational domain (Fig. 3). The initial outflow of water from the nozzle of the fire-extinguishing system is observed, accompanied by the gradual generation of fine water mist and its interaction with the shock-wave front.

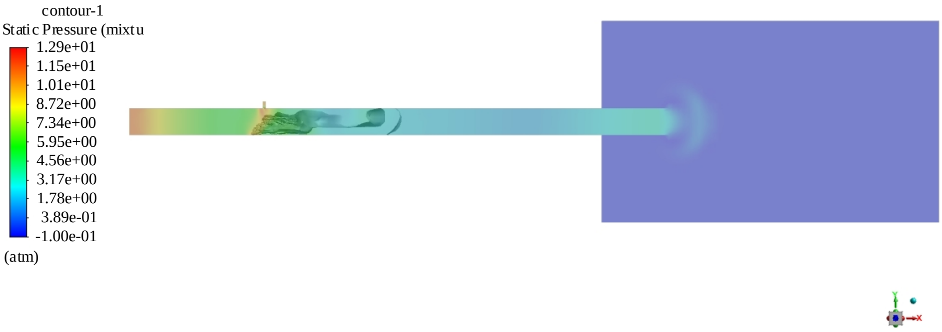

Fig. 2. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 0.9 ms

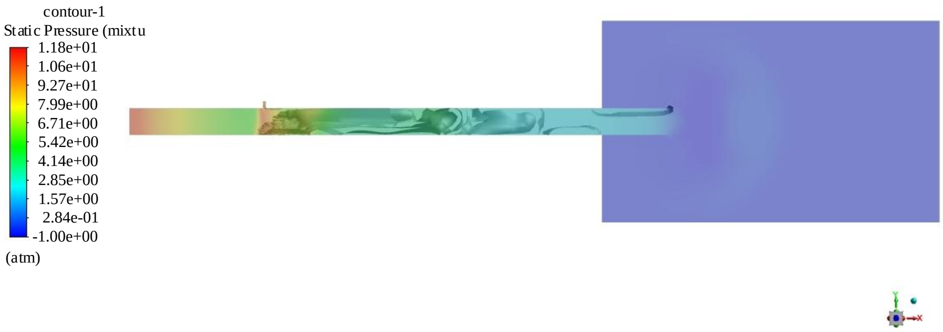

Fig. 3. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 1.13 ms

The distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system at the simulation time of 1.43 ms is shown in Fig. 4. Elevated pressure persists inside the channel, which sharply decreases at the outlet, forming a rarefaction zone ahead of the front of the fine water-mist jet generation.

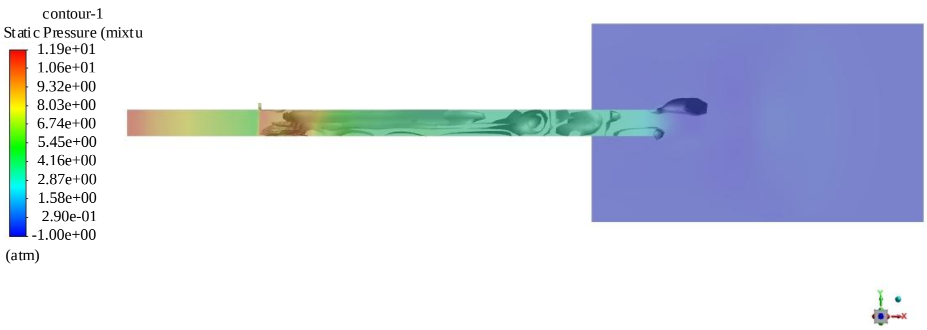

Fig. 4. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 1.43 ms

The distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system at the simulation time of 1.73 ms is shown in Fig. 5. At this stage, a cloud of fine water mist is generated near the nozzle of the fire-extinguishing system, taking on a more distinct shape. The rarefaction zone in front of the flow front expands, promoting further dispersion of the water droplets.

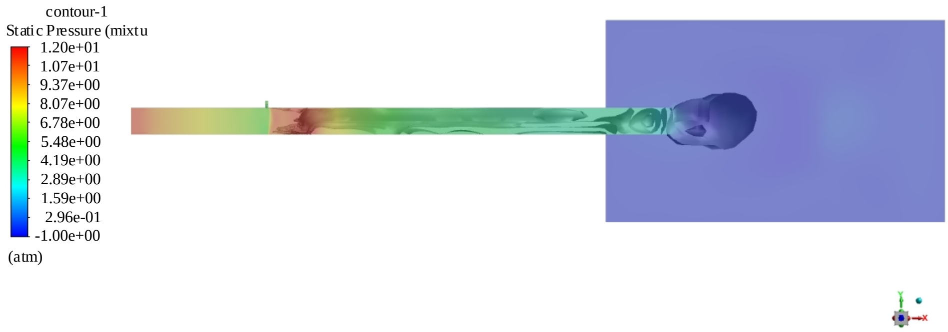

Fig. 5. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 1.73 ms

The distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system at the simulation time of 2.02 ms is shown in Fig. 6. At this stage, the front of the fine water-mist cloud divides into several zones of reduced pressure, accompanied by the formation of elongated aerosol structures in the direction of the flow.

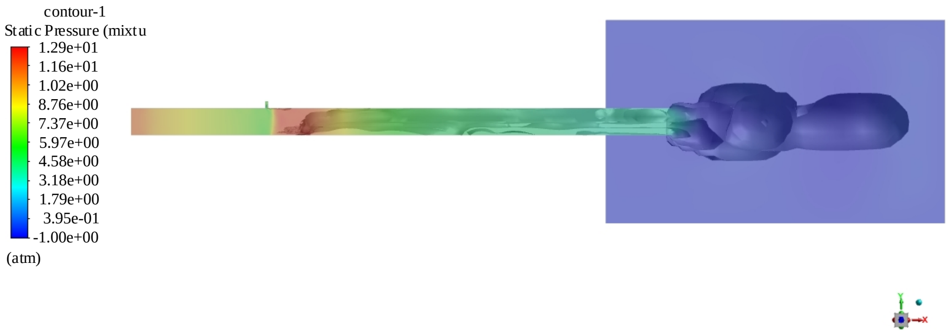

Fig. 6. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 2.02 ms

The distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system at the simulation time of 2.41 ms is shown in Fig. 7.

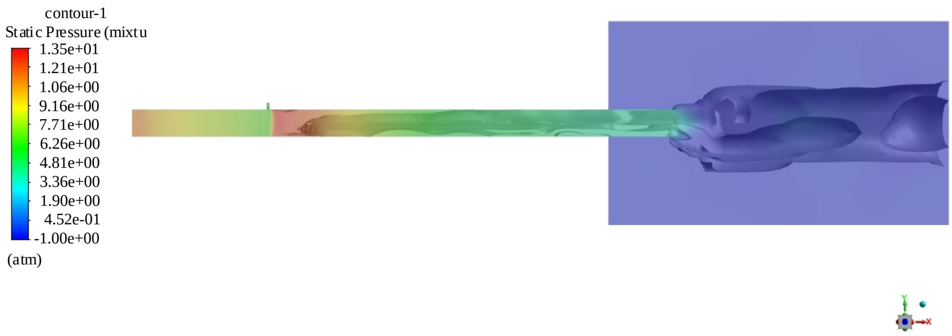

Fig. 7. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 2.41 ms

At this stage, a gradual increase in the maximum pressure up to 13.5 atm is observed. The front of the fine water-mist flow becomes elongated and fragmented, forming several low-pressure zones, which indicates further disintegration of the mist cloud and intensive droplet dispersion.

The distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system at the simulation time of 5.11 ms is shown in Fig. 8. At this stage, the structure of the fine water-mist cloud becomes significantly elongated, and the cloud itself is almost separated from the nozzle of the fire-extinguishing system. It can be observed that the mist cloud expands, forming several low-pressure zones, which indicates a reduction in flow energy and the stabilization of the atomization process.

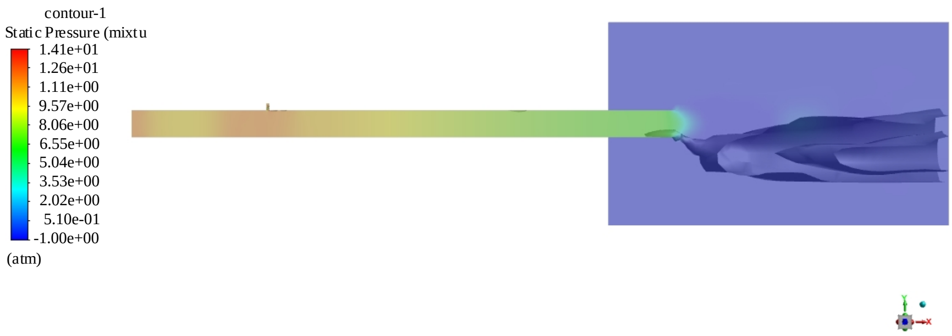

Fig. 8. Distribution of the liquid during the generation of a fine water-mist jet from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 5.11 ms

The distribution of static pressure in the region of the nozzle and the surrounding space at 5.24 ms after the initial impact of the shock waves is shown in Fig. 9. At this stage, a significant elongation of the fine water-mist cloud and its separation from the nozzle under the influence of gravity are observed, accompanied by pressure equalization within the nozzle of the system. It should be noted that no residual water remains inside the nozzle, which indicates a high quality of water atomization due to the action of the high-velocity gas flow.

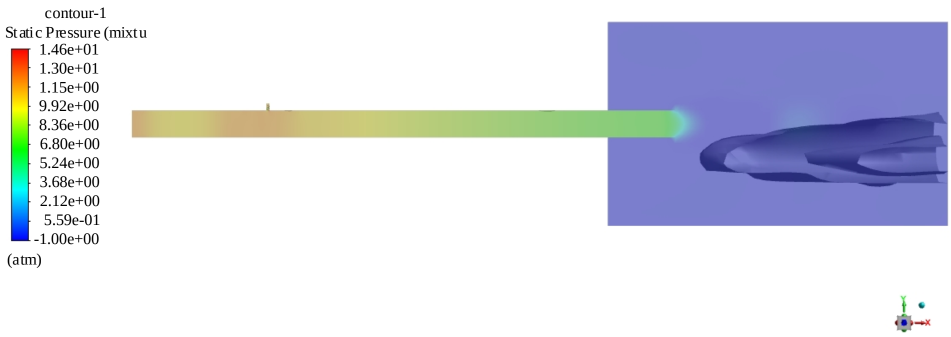

Fig. 9. Distribution of the liquid during the generation of fine water mist from the nozzle of the fire-extinguishing system under the action of shock waves at the simulation time of 5.24 ms

Thus, it has been established that the process of fine water-mist generation during its ejection from the nozzle of the fire-extinguishing system under the influence of shock waves occurs in the time interval from 1.13 to 1.73 ms, followed by a transition to steady atomization with the generation and expansion of the fine water-mist cloud within the interval from 2.02 to 2.41 ms. The process then terminates at 5.11–5.24 ms due to the absence of water remaining in the nozzle of the fire-extinguishing system.

The most intensive fragmentation of water droplets occurs at the simulation time of 1.73 ms, corresponding to the first peak in gas flow velocity, which ensures active droplet breakup. A second peak in gas flow velocity is observed at 2.02 ms, resulting in the maximum expansion of the fine water-mist cloud. These two moments represent the key stages of fine water-mist generation and determine the overall efficiency of the atomization process driven by shock waves.

7. Discussion of the results of the fine water-mist generation process

The conducted research made it possible to identify the features of the fine water-mist generation process from the nozzle of a fire-extinguishing system under the influence of shock waves and to substantiate a mathematical model describing this process. Mathematical modeling was performed in a computational environment using the VOF (Volume of Fluid) model.

To verify the obtained results, a calculation was carried out to determine the volume of water entering the nozzle of the fire-extinguishing system during one detonation cycle, followed by the formation of a fine water-mist cloud within computational region III. Considering that the diameter of the inlet orifice is 2 mm, its cross-sectional area equals 3.14×10^{-6} m^2. The duration of water supply through the orifice during one detonation cycle is 60 ms, the water density is 1000 kg/m^3, and the flow velocity of water is 2.5 m/s. Accordingly, the volume of water entering the nozzle of the fire-extinguishing system per detonation cycle, subsequently discharged and transformed into fine water mist within the computational region, amounts to 0.471 mL.

Given that the dimensions of the computational domain are 250×150×150 mm, the generated fine water-mist cloud of cylindrical shape extends beyond its boundaries, since the domain is assumed to be open under the initial conditions. Assuming the length of the fine water-mist cloud to be 400 mm and the radius approximately 33 mm, the volume of the formed cylindrical cloud is 1.37 L (1.37×10^{-3} m^3). The water density in the air-water flow was determined to be 0.343 kg/m^3.

Taking into account the obtained value of the water volume supplied to the nozzle of the fire-extinguishing system per detonation cycle, the number of droplets in the fine water-mist cloud was determined depending on their dispersity.

For water droplets with a dispersity of 5 μm (diameter 5×10^{-6} m), the volume of a single droplet is 6.54×10^{-17} m^3, resulting in a total droplet count of approximately 7.2×10^6. Thus, with a water mass of 0.471 mg delivered from the nozzle per detonation cycle and forming a fine water-mist cloud with droplets of 5 μm dispersity, about 7.2 million droplets are generated. The droplet density within the fine water-mist volume, defined as the number of droplets per unit volume, is approximately 5.26×10^9 droplets/m^3.

For water droplets with a dispersity of 50 μm (diameter 5×10^{-5} m), the volume of a single droplet is 6.54×10^{-14} m^3, resulting in a total of approximately 7.2×10^3 droplets. Thus, with a water mass of 0.471 mg delivered from the nozzle per detonation cycle and forming a fine water-mist cloud with droplets of 50 μm dispersity, about 7.2 thousand droplets are produced. The droplet density within the fine water-mist volume is approximately 5.26×10^6 droplets/m^3.

The conducted studies and the obtained results of mathematical modeling of the fine water-mist generation process by shock waves, followed by its propagation within the computational domain, represent an important stage in studying the performance parameters of the fire-extinguishing system and assessing its potential for practical application in the relevant field. The performed calculations make it possible to evaluate the quantitative parameters of fine water-mist cloud generation and to determine the influence of droplet dispersity on the structure and density of the air-water flow.

The results show that when the droplet size decreases by a factor of ten (from 50 μm to 5 μm), the number of droplets in the mist cloud increases by approximately

1000 times, which significantly increases the total surface area of water interaction with the flame and enhances the efficiency of the extinguishing process. Thus, reducing droplet dispersity promotes more intensive heat exchange, faster cooling of the combustion zone, and overall improvement in the efficiency of gas-detonation-based fire-extinguishing systems.

However, to confirm the results of the mathematical modeling, it is advisable to carry out experimental studies using a fine water-mist fire-extinguishing system with jet generation by shock waves.

8. Conclusions

The VOF (Volume of Fluid) model was substantiated and proposed for conducting mathematical modeling of the fine water-mist generation process from the nozzle of a fire-extinguishing system. This model allows for describing the interaction between water and air and for tracking the formation of the phase interface. The initial conditions for mathematical modeling of the fine water-mist generation process were defined within computational regions I, II, and III, corresponding to the main stages of water movement. Water is supplied to the nozzle through an orifice with a diameter of 2 mm for a duration of 60 ms at a velocity of 2.5 m/s.

Mathematical modeling of the fine water-mist generation process from the nozzle of the fire-extinguishing system under the action of shock waves was performed. According to the results, the generation of fine water mist at the nozzle outlet occurs within the 1.13–1.73 ms interval, transitioning to a steady atomization and expansion phase within 2.02–2.41 ms. The process terminates at 5.11–5.24 ms due to the absence of water in the nozzle. The most intense droplet fragmentation occurs at 1.73 ms (corresponding to the first peak of gas-flow velocity), while the maximum expansion of the fine water-mist cloud is observed at 2.02 ms (second velocity peak), representing the key stages of mist generation and determining the efficiency of the overall process.

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МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ПРОЦЕСУ ГЕНЕРАЦІЇ ТОНКОРОЗПИЛЕНОЇ ВОДИ УДАРНИМИ ХВИЛЯМИ

Проведені дослідження дали змогу виявити особливості процесу генерації тонкорозпиленої води зі ствола системи пожежогасіння під дією ударних хвиль та обґрунтувати математичну модель, що описує цей процес. Проведено математичне моделювання за допомогою програмного середовища з використанням моделі (volume of fluid). За результатами дослідження встановлено, що генерація тонкорозпиленої води при виході зі ствола системи пожежогасіння ударними хвилями відбувається в інтервалі 1,13–1,73 мс із подальшим переходом до постійного її розпилення та розповсюдження у межах 2,02–2,41 мс. При 5,11–5,24 мс процес припиняється через закінчення води у стволі системи пожежогасіння. Найінтенсивніше подрібнення зафіксовано на 1,73 мс, а максимальне розповсюдження хмари тонкорозпиленої води на 2,02 мс, що визначає ключові етапи її генерації та ефективність процесу. Визначено основні параметри генерації та подачі тонкорозпиленої води, зокрема об'єм, кількість крапель і густину в розрахунковій області. Встановлено, що хмара тонкорозпиленої води має циліндричну форму з об'ємом води 1,37 л ($1,37 \cdot 10^{-3}$ м^3), а середня густина води в повітряно-водяному потоці становить 0,343 кг/м^3. Для крапель води різної дисперсності визначено їхні основні параметри. Так при дисперсності 5 мкм об'єм краплі становить $6,54 \times 10^{-17}$ м³, кількість 7,2 млн, густина в об'ємі тонкорозпиленої води $5,26 \cdot 10^9$ крапель/м³. Для крапель дисперсністю 50 мкм ці показники дорівнюють $6,54 \times 10^{-14}$ м³, 7,2 тис. та $5,26 \cdot 10^6$ крапель/м³ відповідно, а для 100 мкм $5,24 \times 10^{-13}$ м³, 900 та $6,57 \cdot 10^5$ крапель/м³. Математичне моделювання дало змогу дослідити процес генерації тонкорозпиленої води системою пожежогасіння ударними хвилями. Отримані параметри тонкорозпиленої води визначають можливості її застосування під час гасіння пожеж різних класів, у тому числі під час збройної агресії.

Ключові слова: система, пожежогасіння, пожежа, тонкорозпилена вода, математична модель, моделювання, генерація, диспергування

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