EXPERIMENTAL STUDY OF THE TECHNIQUE OF CREATION OF REFERENCE FIRE-FIGHTING LINES BY EXPLOSION OF SHELLS WITH A COMBUSTIBLE MIXTURE

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Abstract: About 40 thousand fires occur in Ukraine in natural ecosystems every year. Fires cause enormous damage to the environment, the population, and also the country's entire economy. Prevention and suppression of fires is one of the most relevant and most important tasks in Ukraine. To combat fires in natural ecosystems, such methods of fighting fires as the creation of reference fire-fighting lines are widely used. The results of an experiment on the creation of fire-fighting lines using an explosion of a single and double shell with a combustible mixture were carried out. To fill the shell, a stoichiometric mixture of acetylene with atmospheric pressure air was used. The shell was a plastic film 150 μm thick. During the experiment, the influence of the size (radius) of the shell and the number of lines on the width of the created reference fire-fighting lines, the distribution of the mass of vegetation along the shell with a combustible mixture before and after the explosion was studied.
The obtained results of the experiment showed that the vegetation removal degree along the charge axis to the vegetation cover after the explosion is 0.05. The dependences of the vegetation removal degree on the reduced energy per one meter of the line with a combustible mixture are obtained. It is calculated that in the experiment, the energy per linear meter of the line with the combustible mixture was 3.04 MJ/m, 6.6 MJ/m and 10.9 MJ/m for the line with a radius of 0.5 m, 0.65 m and 0.9 m, respectively.
The distribution of the vegetation removal degree was experimentally established, and based on the processing of the results obtained, dependencies were determined that made it possible to calculate the width of the reference fire-fighting line.
Keywords: reference fire-fighting line, shell with a combustible mixture, vegetation removal degree, vegetation cover.

1. Introduction

Fires in natural ecosystems have significant environmental, social and economic consequences [1, 2]. The use of methods and technical means for fighting fires, the implementation of which is carried out in a minimum time with high efficiency, is relevant [3, 4]. The authors of [5, 6] propose the use of fire reference fire-fighting lines for fighting fires in natural ecosystems by exploding hoses of the ESH-1P type. In this work, a line with a combustible mixture was used to create reference fire-fighting lines.

2. Methods

The creation of reference fire-fighting lines (hereinafter referred to as lines) using an explosion of a combustible mixture in a shell was carried out using the planning theory and previously obtained research results [7, 8]. The line width was estimated by measuring the mass of vegetation before and after the explosion. To process the results obtained during the experiment, statistical methods were used.

3. Results

In the experiment, to create the lines, a combustible mixture was used, both in a single shell and in a double one. Then, detonation of shells with a combustible mixture was initiated [9]. The analysis of changes in the vegetation cover (hereinafter referred to as the cover) after the explosion of the combustible mixture in the shell was carried out by comparing the mass of the cover per 1 m^2 before and after the explosion. After measuring the mass and calculating it according to expression (1), it was found that the vegetation removal degree is 0.05.

$$\chi = \frac{m_2}{m_1}, \tag{1}$$

where m_1 – the mass of the cover before the explosion; m_2 – the mass of the cover after the explosion.

According to the results obtained during the experiment, let's calculate the width of the vegetation removal degree from energy per linear meter of shell with a combustible mixture (**Table 1**). In addition, let's assume that if the intensity of the blast wave exceeds a certain threshold, then this means that the cover is completely cleared, which corresponds to the vegetation removal degree equal to χ=0. And if the intensity of the blast wave decreases below the threshold, then χ=1.

Therefore, let's consider the vegetation removal degree within 0÷1, that is, let's look for the dependence of the vegetation removal degree on the reduced energy per linear meter of the shell with a combustible mixture W_r at a distance r in the form:

$$\chi(W_r, r) = \Phi\left(-eW_r^{\,n} + y\cdot\ln(r)\right), \tag{2}$$

where e, y, n – the coefficients obtained from the results of the experiment; $F(z)$ – distribution function, having the form:

$$F(z) = \frac{1 + erf\left(z/\sqrt{2}\right)}{2}. \tag{3}$$

In relation to the experiment, the energy per linear meter of the shell with the combustible mixture was 3.04 MJ/m, 6.6 MJ/m and 10.9 MJ/m for the shell with a radius of 0.5 m, 0.65 m and 0.9 m, respectively. According to the data obtained during the experiment (**Table 1**), let's find that the vegetation removal degree is approximated by a dependence, the error of which is no more than 5 %.

Table 1
Dependence of the vegetation removal degree on distance

The radius of the shell with a combustible mixture	Vegetation removal degree (vegetation cover/leaves of bushes, trees) at a distance from the center of the shell at a distance, m				
	0	1	2	3	4
0.5	0.03/0.02	0.31/0.28	0.93/0.91	0.98/0.96	–
0.65	0.02/0.01	0.05/0.03	0.9/0.87	0.97/0.95	–
0.9	0.04/0.02	0.06/0.02	0.12/0.09	0.76/0.73	–
2×0.5	0.04/0.04	0.05/0.04	0.49/0.37	0.92/0.84	1/1
2×0.65	0.04/0.04	0.08/0.07	0.11/0.08	0.72/0.48	0.91/0.88

$$\chi(W_r, r) = F\left(-0,2W_r^{\,2} + 5\cdot\ln(r)\right), \quad (4)$$

where W_r – the energy per linear meter of the shell with a combustible mixture, MJ/m; r – the distance from the center of the shell, m.

Expression (4) does not take into account the transfer of the cover by the blast wave. Therefore, after the explosion of the shell with a combustible mixture, part of the vegetation settles on the cover without vegetation, and the other part on the cover with vegetation, near the shell. Let's apply the expression for accounting for the transfer of the cover by the blast wave in the form:

$$G(r) = \int_r^{r+m} k\cdot\exp\left(-j\cdot r^2\right)\cdot r^2 \mathrm{d}r, \quad (5)$$

where m, k, j – the coefficients obtained from the results of the experiment; $G(r)$ – the average mass of the dangling cover per 1 m^2.

The dependences for different shells with a combustible mixture along the radius, taking into account the results of the experiment, will be presented in the form (**Fig. 1**).

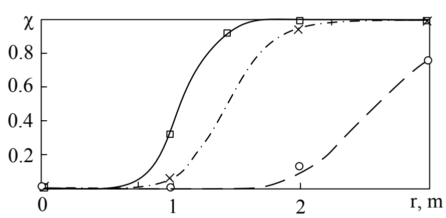

Fig. 1. Dependences of the vegetation removal degree on the distance from the center of the shell with a radius of 0.5 m (solid line), a radius of 0.65 m (dotted line), and a radius of 0.9 m (dashed line) (**Table 1**)

The experimental results will be presented in the form of dependencies:

$$\chi(W_r, r) = \frac{\exp\left[e\cdot(r-y)\right]}{1+\exp\left[e\cdot(r-y)\right]}, \quad (6)$$

where

$$e(W_r) = \frac{7}{W_r^{1,3}};$$

$$y(W_r) = 1,3 + 3(\ln W_r)^{7/5}.$$

The distribution function of the remote cover is presented in the form:

$$\frac{l\int_0^R G(r)\mathrm{d}r}{m_{rc}} = 1, \quad (7)$$

where R – the radius of expansion of the cover during the explosion of the shell; l – the width of the line from which the cover is removed, is taken equal to 1 m.

The redistribution of the remote cover after the explosion of the shell with a combustible mixture from a distance is presented (**Fig. 2**).

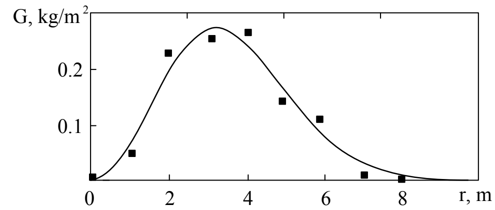

Fig. 2. Type of distribution of the removed cover after the explosion at $m_{rc=}$1 kg and a shell length of 1 m

Given the expression (4), let's represent the number of tattered cover per unit length of the shell with a combustible mixture in the form:

$$m_{rc} = G_0 l\left[R - \int_0^R \chi \mathrm{d}r\right], \quad (8)$$

where G_0 – the amount of cover before the explosion per unit area in kg/m^2.

Given the expression (8), let's write it in the form:

$$m_{rc} = G_0 l\left[R - \int_0^R \chi \mathrm{d}r\right] = l\int_0^R G(r)\mathrm{d}r\partial. \quad (9)$$

Thus, the distribution of the cover from the center of the shell with the combustible mixture, taking into account the subsidence of the tattered cover after the explosion, let's present in the form:

$$\chi(W_r, r) = F\left[-eW_r^{\,n} + y\cdot\ln(r)\right] + \int_r^{r+m} k\cdot\exp\left(-j\cdot r^2\right)\cdot r^2\mathrm{d}r, \quad (10)$$

where the coefficients take the following values: e=2; y=5; m=0,01; n=2/3; k=2; j=0,015.

The obtained results of the experiment show that when creating reference fire-fighting line with a width of 5–6 m in the vegetation cover, it is advisable to use a double shell with a combustible mixture with a radius of 0.65 m. To create a line among bushes and trees for clipping leaves, it is recommended to use a double shell with a radius of 0.5 m

4. Discussion and conclusions

It is noted in [5, 6] that an ESH-1P type explosive hose is used to create a reference fire-fighting line, while the band width is 1.4 m. Considering the size of the vegetation cover, including bushes, young trees can confidently say that the line is wide 1.4 m will not stop the fire. The standard value of the bandwidth is at least 4 m [10]. The results of the experiment show that to combat fires in natural ecosystems, it is advisable to use a double shell with a combustible mixture, instead of a single one. Also, for practical use when creating a reference fire-fighting line 7–8 m wide, it is sufficient to use a double shell with a combustible mixture with a radius of 0.65 m. To create a line up to 5 m wide, it is advisable to use shells with a radius of 0.5 m.

The implementation of the experimental results in the practical activities of the units will increase the level of response to fires in natural ecosystems by creating a reference fire-fighting zone.

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Received date 01.10.2019
Accepted date 29.10.2019
Published date 23.11.2019