UDC 614.84

D.I. Saveliev, Postgraduate student, NUCPU

INFLUENCE OF CONSUMPTION RATE AND DRYING TIME OF GEL- FORMING SYSTEMS ON THIER FIRE RETARDANT PROPERTIES WHEN APPLIED TO CONIFEROUS FOREST LITTER

(presented by DSc Kireiev A.)

The article discusses the results of experiments on the fire retardant properties of the gel-forming system (35% $CaCl_2$ + 5% Na 2 O·2,7SiO_2) applied to coniferous forest litter. On the basis of the regressive equation the influence of the concentration of system components, mass of the coating and drying time of the forest litter covered with the composition under analysis on its fire retardant properties were studied. The relationship between the fire retardant action, gel-forming system consumption rate and drying time of the forest litter covered was considered.

Keywords: forest fires suppression, surface forest fires, coniferous forest litter, gel-forming systems, separate-successive application, chemical firebreaks.

Problem formulation. The problem of enhancing the efficiency of forest fires suppression is topical for many countries. This may be explained by a range of reasons including high costs required for their elimination and compensation of material damage caused, as well as possible casualties. Surface forest fires constitute the majority of forest fires, sufficiently exceeding both crown fires and ground fires. Surface fires which heat the crowns of the trees, often lead to crown fires, therefore, being an early stage in their development [1].

High intensity forest fires are often fought by establishing fire retardant barriers. The latter can be made by means of backfiring which is a creation of a low-intensity fire usually set up at the edge of a firebreak and directed towards the fire front. Firebreaks can be created by digging and shoveling ground or covering areas of ground with chemical solutions. Firebreaks are usually set up at least at 80-metre distance from the fire front. At the back of a blaze, as well as at its flanks, as a rule, the stage of backfiring is omitted [2].

The methods of creating fire retardant barriers currently used have a number of disadvantages. Thus, heavy equipment is often required and it might take much time to be transported to isolated areas, while the use of manual labour is in most cases associated with too many people involved in the process. Forest fire suppression can be difficult if the forest on fire has no proper water resources available. The use of various chemical substances for extinguishing forest fires is not usually environmentally friendly. Moreover, most chemical substances have a short-term effect. Taking the above-mentioned into consideration, it should be concluded that the lack of the efficient methods of forest fire suppression, as well as effective means of creating firebreaks, determine the importance of conducting a more detailed analysis of this issue.

Analysis of recent researches and publications. The analysis of the studies into the problem of composing more effective fire extinguishing and fire retardant substances for forest fire suppression reveals constant interest of Ukrainian and foreign scholars in this issue. Thus, in the recent publications the use of magnesium chloride (bischofite) as a chemical fire retardant and involving aviation have been suggested. The enhancement of forest fire suppression efficiency has also been discussed in the context of water and foam compositions, gel-forming and foam-forming compositions [1; 3] and the application of compression and hardening foams [4].

In the course of an experimental study into the peculiarities of using gel-forming systems for surface forest fires suppression it was demonstrated that flame can penetrate into the layers of forest litter under the layer of the gel if the components of the gel-forming system (GFS) are applied to the surface in a separate-simultaneous manner [5]. To deal with this drawback foam-forming systems (FFS) with external foam formation were used [1]. In comparison with GFSs, FFSs proved to have higher penetrating qualities in case they were applied in a separate-successive manner. On the other hand, the foam which appeared as a result was destroyed quickly and, consequently, lost its fire retardant properties with time. The afore-mentioned considerations encouraged us to look into the possibility of using GFSs for forest fire suppression on condition the problem of flame penetration into forest litter layers is successfully dealt with.

Consequently, it was established that the concentration of the components of the GFS had an impact on its fire retardant properties. The experiments allowed us to draw the conclusion that the application of Na2O·2,7SiO2+CaCl2 gel-forming system might be quite an effective medium in fighting forest fires if its components are applied separately and successively [3].

Statement of the problem and its solution. The aim of this article lies in revealing the influence of the consumption rate of the gel-forming system and the time needed for the forest litter surface covered with the components of the system to dry out on the time of the fire retardant action of the gel-forming system used.

Previously, in a series of experiments the influence of the concentration of the GFS components, its mass and time needed for the forest litter treated with the gel to dry out on the time of ignition of the forest litter was demonstrated [6]. The corresponding regressive equation (1) was received and was written down with the help of the encoded coordinates where x1 corresponds to the concentration value of Na2O·2,7SiO2; x2 corresponds to the concentration value of CaCl2; x3 corresponds to the consumption rate value; and x4 corresponds to the drying time.

$$\begin{aligned} T_в = 3{,}922 - 1{,}729x_1 + 0{,}762x_2 + 1{,}38x_3 - 0{,}48x_4 - 0{,}79x_1 \cdot x_2 - \\ - 0{,}603x_1 \cdot x_3 + 0{,}769x_1 \cdot x_4 - 0{,}396x_2 \cdot x_4 + 0{,}36x_1^2 + 0{,}966x_3^2 + 0{,}46x_4^2 . \end{aligned} \quad (1)$$

The analysis of the equation revealed that the maximum time of the fire retardant action was achieved when the concentrations of C (Na2O·2,7SiO2) and C (CaCl2) equaled 5% and 35% respectively, the consumption rate equaled 1 gr/cm2, and the drying out time of the forest litter equaled 0 min. At such values the time of forest litter ignition was 30 minutes. It was also concluded that the maximum fire retardant action of the GFS was reached at the minimum value of 5% for C(Na2O·2,7SiO2) and the maximum value of 35% for C(CaCl2) = 35%.

It should be emphasized that the use of sodium chloride as a component of the GFS is economically justifiable as polysilicate which can also be part of the gel-forming composition is significantly more expensive. Moreover, sodium chloride solutions are released in large quantities as industrial waste in soda production [7; 8]. Having to pay for its utilization, soda production plants tend to accumulate sodium chloride polluting the environment, and might sell it at a very low price. With regard to the fire retardant and economic characteristics of (CaCl2(35%) + Na2O·2,7SiO2(5%)) gel-forming system, the composition suggested may be considered optimal and used for further experiments.

The fire retardant properties of the GFS are also affected by the consumption rate and drying time of the forest litter to which it is applied (τ). The consumption rate of the GFS is calculated in accord with the following relation:

$$\Phi = \frac{m}{S}, \tag{3}$$

where m corresponds to the total mass of the GFS, while S corresponds to the area of the surface which the GFS is applied to.

In order to determine the parameters of the GFS which will provide for the fire retardant action time required, it is necessary to analyse the influence of two factors on its fire retardant properties, namely the consumption rate of the GFS and the drying time needed for the forest litter to dry out after its application. The corresponding correlation between the fire retardant action time and the two factors mentioned is demonstrated on a graph below.

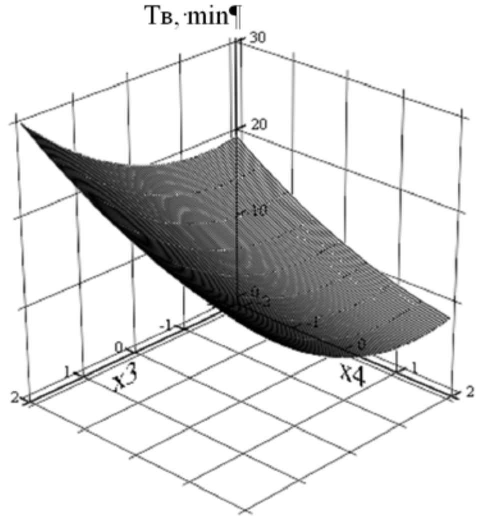

Fig. 1. Dependence of the fire retardant action time on the consumption rate of the fire retardant composition (x_3) and drying time of the fire retardant layer (x_4)

The analysis of this graphical dependence demonstrates that the increase of the consumption rate of the GFS leads to the enhancement of its fire retardant properties, while the growth of the drying time has an opposite effect and results in their deterioration. It is also worth mentioning that the deterioration of the fire retardant properties of the GFS tends to slow down with the increase of the drying time. This can be explained by the hygroscopic properties of one of the components of the GFS – calcium chloride whose concentration in the composition under study is quite high. The stoichiometric calculations show that after the reaction the gel will include 16,3% of $CaCl_2$

$$Na2O \cdot 2,7SiO2 + CaCl2 = CaO \cdot 2,7SiO2\downarrow + 2NaCl. \quad (4)$$

Calcium chloride solutions with such concentration liberate water very slowly. On the basis of the analysis presented in [9] it may be concluded that the process of water evaporation from the gel of such composition continues for approximately 25 hours and ceases when the concentration of $CaCl_2$ in it reaches 26 %.

Therefore, a thirty-minute span of fire retardant time which the GFS of the optimal composition at the consumption rate of 1 g/cm^2 ensures is more than enough for extinguishing surface forest fires as firebreaks are usually exposed to fire from tens of seconds to two minutes [10-12]. Consequently, it is necessary to ensure that the fire retardant time of the gel used to create a firebreak covers this time span. It should also be pointed out that it is important to determine the corresponding drying time which will guarantee a proper level of fire retardancy since firebreaks are constructed in advance before a fire front reaches them.

To choose the required consumption rate of the GFS and the drying time a graph demonstrating the dependence of the time of fire retardant action and the drying time for different consumption rates of the GFS system can be considered (fig. 2).

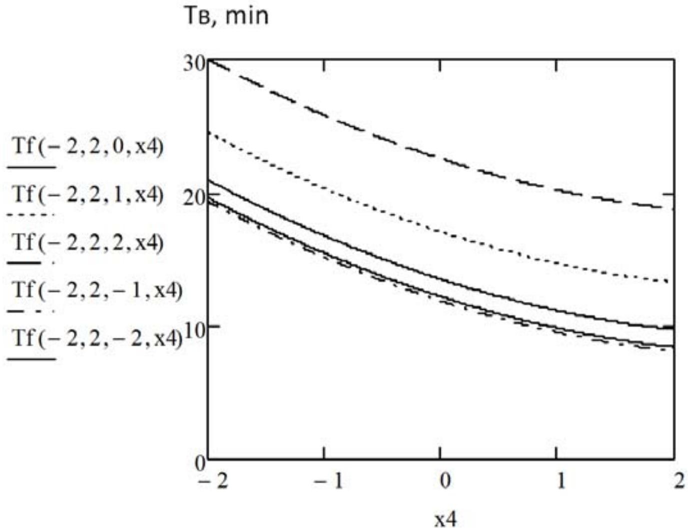

Fig. 2. Dependence of the Time of Fire Retardant Action on the Drying Time for Different Consumptions Rates of the GFS

The analysis of the graph shows that if the drying time equals 60 minutes, the necessary two-minute time span of the fire retardant action is ensured by the GFS with any consumption rate considered. In case there are large branches on the forest litter, the burning time rises to 10-20 minutes. Therefore, the time of fire retardant action of the composition used should be from 10 to 20 minutes as well. If the burning time is from 10 to 20 minutes, the GFS with any consumption rate considered can also be applied, but the drying time should be no longer than 45 minutes. For the burning time of more than 20 minutes, the GFS with only two consumption rates (namely, 0,85 g/cm^2 an 1 g/cm^2) can be used effectively. As for the drying time in this case, it must not exceed 15 and 25 minutes respectively.

Conclusions. $CaCl_2$+Na_2O·2,7SiO_2 gel-forming system may be used as an effective fire retardant means for constructing firebreaks in the process of suppressing surface forest fires. The best fire retardant properties are demonstrated by the composition with 5% of sodium polysilicate which acts as a gel-forming component and 35% of calcium chloride. The qualitative relationship between the fire retardant action and the consumption rate and drying time is revealed. The composition of 35%$CaCl_2$ + 5%Na_2O·2,7SiO_2 gel-forming system ensures the fire retardant action which lasts for more than 20 minutes if the consumption rate equals 1 g/cm^2 and the drying time is less than 45 minutes.

REFERENCES

1. Saveliev D.I. Eksperimentalnoie issledovaniie ognepregrazhdaiushchikh svoistv lesnoi podstilki, obrabotannoi penoobrazuiushchimi sistemami / D.I. Saveliev, A.A. Kireiev, K.V. Zhernokliev // Problemy Pozharnoi Bezopasnosti. – 2016. – V. 40. – P. 169-173. – Available at: http://nuczu.edu.ua/sciencearchive/ProblemsOfFireSafety/vol40/saveliev.pdf.

2. Kimstach I.F. Pozharnaia taktika: ucheb. posobiie dlia pozharno-tekhn. uchilishch i nachsostava pozharnoi okhrany / I.F. Kistach, P.P. Devlishev, N.M. Yevtiushkin. – M.: Stroiizdat, 1984. – 590 p.

3. Saveliev D.I. Povysheniie effektivnosti geleobrazuiushchikh sostavov pri borbe s nizovymi lesnymi pozharami / D.I. Saveliev, A.A. Kireiev, K.V. Zhernokliov // Problemy Pozharnoi Bezopasnosti. – 2016. – V. 39. – P. 237-242. – Available at: http://nuczu.edu.ua/sciencearchive/ ProblemsOfFireSafety/vol39/Saveliev.pdf.

4. Krektunov A.A. Ispolzovaniie kompressionnoi peny pri tushenii lesnykh pozharov / A.A. Krektunov, Ye.Yu. Platonov, S.V. Toropov, A.F. Khabibulin // Agrarnoie obrazovaniie i nauka. – 2015. – №1(12). – P. 154.

5. Sumtsov Yu.A. Vybor geleobrazuiushchikh sostavov dlia borby s lesnymi pozhrami / Yu.A. Sumtsov, A.A. Kireiev, G.V. Tarasova // Problemy Pozharnoi Bezopasnosti. – 2006. – V. 19. – P. 143-148.

6. Saveliev D.I. Issledovaniie ognezashchitnogo desistviia geleobrazuiushchikh sostavov po otnosheniiu k khvoinoi lesnoi podstilke / D.I. Saveliev,

S.N. Bondarenko, A.A. Kireiev, K.V. Zhernokliov // Problemy Pozharnoi Bezopasnosti. – 2016. – V. 41. – P. 169-173. – Available at: http://nuczu.edu.ua/sciencearchive/ProblemsOfFireSafety/vol41/savelev.pdf.

7. Shaporiev V.P. Suchasni napriamy pidvyshchennia ekolohichnoiie bezpeky vyrobnytstva sody : monohrafiia / V.P. Shaporiev, M.A. Tseitlin, V.A. Raiko. – Sumy : Sumskii derzhavnyi universytet, 2014. – 246 p.

8. Tkach G.A. Proizvodstvo sody po malootkhodnoi tekhnologii / G.A. Tkach, V.P. Shaporiev, V.M. Titov. – Kharkiv : KHGPU, 1998. – 429 p.

9. Sumtsov Yu.A. Issledovaniie vremeni rabotosposobnosti geleobrazuiushchikh sostavov pri borbe s lesnymi pozharami / Yu.A. Sumtsov, A.A. Kireiev, G.V. Tarasova // Problemy Pozharnoi Bezopasnosti. – 2006. – V. 20. – |P. 197-202.

10. Valendik E.N. Borba s krupnymi lesnymi pozharami / E.N. Valendik. – Novosibirsk: Nauka, 1990. – 193 p.

11. Artsybashev Ye.S. Lesnyie pozhary i borba s nimi / Ye.S. Artsybashev. – M.: Lesnaia promyshlennost, 1974. – 280 p.

12. Vorobiov Yu.L. Lesnyie pozhary na territotii Rosii: sostoianie i problem / Yu.S. Vorobiov, V.A. Akimov, Yu.I. Sokolov. – M.: DEKS-PREESS, 2004. – 312 p.

Received by editorial Board 10.10.2017

Д.І. Савельєв

Вплив питомої витрати і часу сушіння гелеутворюючого складу на її вогнезахисні властивості стосовно хвойних лісовій підстилки

Проаналізовано результати експериментальних досліджень вогнезахисного дії гелеутворюючої системи (35% CaCl2 + 5% Na2O · 2,7SiO2) по відношенню до хвойної лісовії підстилці. На основі отриманого регресійного рівняння вивчено вплив концентрації компонентів системи, маси нанесеного покриття і часу сушки обробленого лісового горючого матеріалу на час її вогнезахисного дії. Розглянуто залежність часу вогнезахисного дії від питомої витрати ДОС і часу сушки обробленого ділянки лісової підстилки.

Ключові слова: гасіння лісових пожеж, низові лісові пожежі, хвойна лісова підстилка, гелеобразующіе системи, роздільно-послідовна подача, вогнезахист, хімічні опорні смуги.

Д.И. Савельев

Влияние удельного расхода и времени сушки гелеобразующего состава на её огнезащитные свойства по отношению к хвойной лесной подстилке

Проанализированы результаты экспериментальных исследований огнезащитного действия гелеобразующей системы (35% $CaCl_2$ + 5% $Na_2O{\cdot}2,7SiO_2$) по отношению к хвойной лесной подстилке. На основе полученного регрессионного уравнения изучено влияние концентрации компонентов системы, массы нанесенного покрытия и времени сушки обработанного лесного горючего материала на время её огнезащитного действия. Рассмотрена зависимость времени огнезащитного действия от удельного расхода ГОС и времени сушки обработанного участка лесной подстилки.

Ключевые слова: тушение лесных пожаров, низовые лесные пожары, хвойная лесная подстилка, гелеобразующие системы, раздельно-последовательная подача, огнезащита, химические опорные полосы.