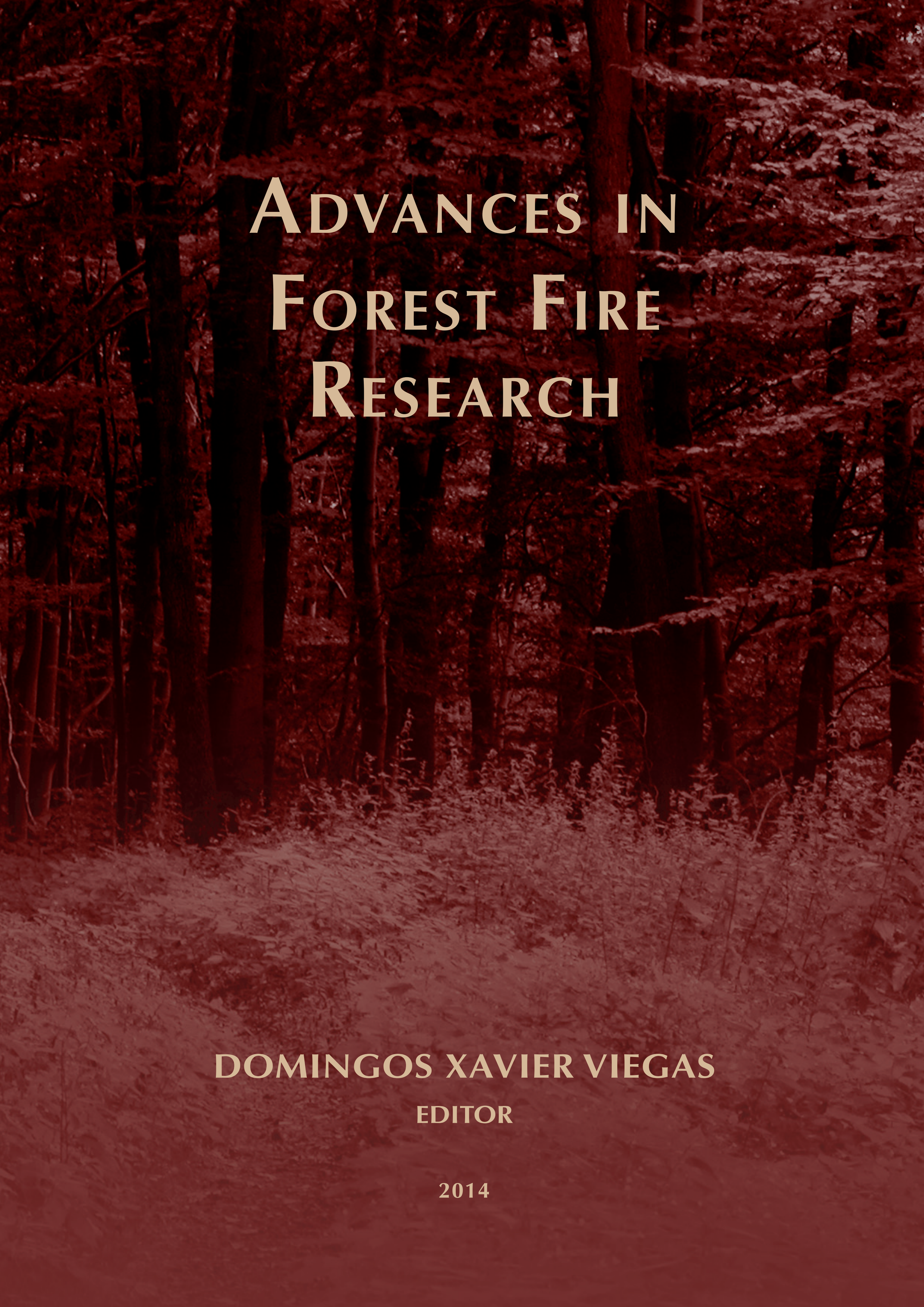

Advances in Forest Fire Research

DOMINGOS XAVIER VIEGAS

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Suppression capability of foams used fighting against forest fires with the test of weight rate remained on the crown surface R-10A Method - weight effectiveness experiment

Agoston Restas

National University of Public Service, Budapest, Hungary, Restas.Agoston@uni-nke.hu

Abstract
Introduction: The effectiveness of the foams used in fighting against forest fire depends on common effect of some coefficients. Cooling and isolation effects as main extinguishing effects as well as side extinguishing effects, like evaporation, blanket and separation effects are also included. Under the same conditions, the more extinguisher remains on the surface, the more extinguishing effect it has. Methods: A product for the test was randomly chosen out of the ones on the market. Spruce was chosen for the test due to its high flammability. The goal was to determine the amount of extinguisher at the end of the branches in the foliage. Groups of the same size were created in the selected foliage. To start with, the weight of the untreated foliage was measured, followed by the groups of foliage dipped in water and foaming agents. Results and discussion: According to the findings of research, the amount of foam remaining on the foliage is remarkably higher than that of water. Its rate is 3.36-3.76 compared to water. The research also revealed that this rate does not significantly depend on expansion rate. As a result, the fire intensity which can be extinguished by using foams expands as well.

Keywords: suppression capability, foam, weight effectiveness experiment, R-10A method

1. Introduction

The effectiveness of the foams used in fighting against forest fire depends on common effect of some coefficients. Cooling and isolation effects as main extinguishing effects as well as side extinguishing effects, like evaporation, blanket and separation effects are also included (Kuncz, 1972). The efficiency of isolation effect certainly depends on the amount of extinguishing agent measured in unit area of surface, which in the case of not horizontal surfaces is in correlation with the adhesion of the extinguisher that is the rate of remaining on the surface. Under the same conditions, the more extinguisher remains on the surface, the more extinguishing effect it has.
Since the quantity of the extinguisher has a great impact on the firefighting techniques applied as well as the effectiveness of the techniques applied (Bleszity, 1990), it is recommended to review the various factors not only because of their importance but also because of the safety of the intervention crew (Pantya, 2011). Several studies are dealing with the effectiveness of extinguishers and separate measurement methods were created (Batista, 2011; Morris, 2011). However, researches aimed at the extinguisher remaining on the foliage may be scarce, according to the author. The paper wishes to present a unique approach to this topic, comparing water and foam as extinguishers with different structures and their ability to remain on the surface. This procedure following the below assumptions got a fantasy name and was called R-10A method.

2. Methods

The method was developed in order to measure the rate of foam remained on the vegetation surface (spruce) to determine the extinguishing potential of foam blanket. This problem can have not just one aspect. In case of using very “light” foam – meaning that the expansion rate of foam is large, with other words the density is low – it will remain on the top of the crown, therefore it is unable to protect the bulk from the radiation heat or it can be blown over by the wind. In other case, when using very "heavy" foam – meaning that the expansion rate is low or the density is high – it takes the features as Newtonian fluid and will drip to ground resulting that the larger part of foam will not remain in the area of the burning cell. Both case causes useless waste. Even if the ideal expanditure rate of foam can be different depending on the situation or the type of vegetation but author's experience say it must be higher than 6 but below 13. As a series in this research author used foams expanditure rate of 6 – 9 – 12.

The other aspect is that, what is the difference between the weights of the extinguisher materials remaining on the surface (crown).

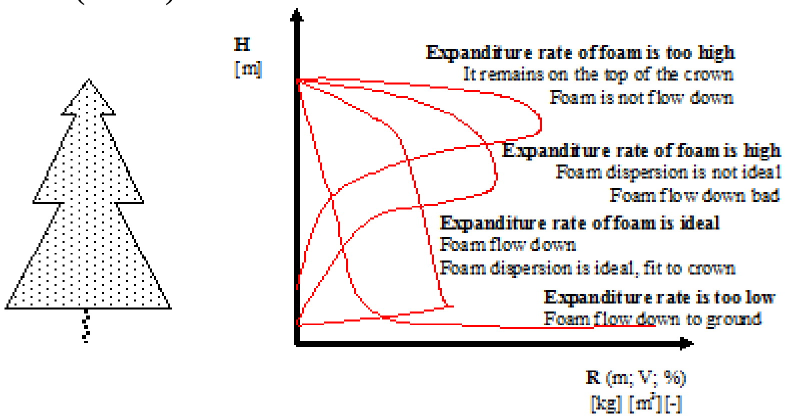

Figure 1. Structure of foam remaining on the crown depending on the rate of expanditure

2.1. Prepare the process

During the research the goal has been formulated to develop a simple, easily reproducible method used for both illustration and teaching which proves the differences in the extinguishers' adhesion and presents its consequences. The author opted for analysing the mass/volume of extinguisher left on the surface. A product was randomly chosen out of the ones on the Hungarian market. It is named Light Water, what is used in Hungary as common foam concentrate, even in case of serious forest fire, however this type of foam not typical at the international practice (or at forest fire). Using this foam is acceptable, because the aim of the test is not to determine the efficiency of the extinguisher, but to demonstrate its application.

Spruce was chosen for the test due to its high flammability. The goal was to determine the amount of extinguisher at the end of the branches in the foliage. Groups of the same size were created in the selected foliage. To start with, the weight of the untreated foliage was measured, followed by the groups of foliage dipped in water and foaming agents. In the case of the latter groups, the weight of the foliage itself was subtracted from the total weight, giving us the maximum amount of the extinguisher remaining on the foliage. During the experiment 6 – 9 – 12 expansion rated foams were applied.

Below is declared the main important things for preparing the test, and some basic process for being ready to measure the mass/volume foam left on the surface. Means required for the process:

1. Choosing samples: The highly flammable spruce was chosen as a sample. Twigs of 100-150 mm were cut down (4x10pcs= 40pcs). Thus, that part of the spruce was examined which has the greatest role both in fire spread and keeping the extinguisher.
2. Preparing the samples: the twigs are dried in sun for 4 hours in 30°C. Thus, the surface becomes totally dry similarly to the typical conditions of intense fire periods.
3. Preparing the matrix holding the samples: a matrix was created according to the set of measurements. It included the boxes (altogether 4x10 pcs) to keep water and the foams of 6 – 9 – 12 expanditure (Hk = 6 – 9 – 12).

4. Preparing the extinguishers to be examined: normal tap water and foam-forming substance was used in the experiment. The foam-forming substance was Light Water, which is generally used in Hungary.
5. The preparation of the extinguishers: Water was 20°C, normal temperature, 15 ^{0}dH (water hardness in German degrees). Preparing a foam solution in measuring bottles: the foam-forming substance is Light Water, out of which foams of different expanditure were created, using a mixture of 3%. These were in three different bottles: Hk = 6; Hk = 9; Hk = 12.

Figure 2. Preparing the spruce twigs for measurement

2.2. **Measured data of different treated samples1**

The measurements clearly show that water and foam remain on the surface of the foliage in completely different shapes (Figure 3). Water is not evenly distributed, but it sticks to the surface in drops, separately, while the foam surrounds the twig in a homogenous mass. In spite of the conspicuous difference, we do not know if the difference in structure causes any significant difference in the extinguishers' ability to remain on the surface. If so, then the extinguisher which has more quantity on surface possesses more heat capacity proportionately.

Figure 3. Different treated samples – foam and water

1 Author made this measurement in 8th May, 2013, Szendro, Hungary

The findings of the measurements carried out and the values obtained from the data can be found in Table 1.

Table 1—Measured data

R-10A	**Measured weight** (gram)			
Weight of untreated samples (n=10) (avarage:34,17)	33,48	34,26	35,33	33,60
1. Sample group				
Weight of samples treated by water (net)	50,52	-	-	-
Weight of water	17,04	-	-	-
Rate of extinguisher (water) to max. water on surface	1	-	-	-
2. Sample group				
Weight of samples treated by foam, Hk=6 (net)	-	98,33	-	-
Weight of foam, Hk=6	-	64,07	-	-
Rate of ext. (foam, Hk=6) to max. water on surface	-	3,76	-	-
3. Sample group				
Weight of samples treated by foam, Hk=9 (net)	-	-	94,84	-
Weight of foam, Hk=9	-	-	59,51	-
Rate of ext. (foam, Hk=9) to max. water on surface	-	-	3,49	-
4. Sample group				
Weight of samples treated by foam, Hk=12 (net)	-	-	-	90,81
Weight of foam, Hk=12	-	-	-	57,21
Rate of ext. (foam, Hk=12) to max. water on surface	-	-	-	3,36

2.3. **Calculations**

The following calculations were made to assess the findings. To start with, the author specified the average weight of the samples from each sample group, and then calculated the weight of the individual sample by averaging.
Secondly, by dipping the samples into water, the author specified the maximum value of water saturation. Thus the water retention capacity of the samples can be determined, by considering the differences in weight.
Thirdly, foams of different expanditure and their ability to remain on the surface were examined. The samples were dipped into foam (it results also the maximum weight on surface), weighed and then the relevant data were calculated by averaging.
The ability of the extinguisher to remain on the surface was determined by subtracting the weight of the untreated samples from the values measured. Then we get the values of the foam by comparing these data to the data of the samples treated with water. The calculations produce the following results:

1. Average weight of the individual samples of the 4 sample groups

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{n} m_{P\_Nature\_n}}{n} = \frac{33{,}48g}{10} = 3{,}348g$$

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{n} m_{P\_Nature\_n}}{n} = \frac{34{,}26g}{10} = 3{,}426g$$

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{n} m_{P\_Nature\_n}}{n} = \frac{35{,}33g}{10} = 3{,}533g$$

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{n} m_{P\_Nature\_n}}{n} = \frac{33{,}60g}{10} = 3{,}360g$$

2. Average of the average samples of the sample groups

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{4} m_{P\_Nature\_n}}{n} = \frac{3{,}348g + 3{,}426g + 3{,}533g + 3{,}360g}{4} = 3{,}417g$$

3. The average weight of the spruce sample dipped into water

$$\overline{m}_{P\_H_2O} = \frac{\sum_{i=1}^{n} m_{P\_H_2O\_n}}{n} = \frac{50{,}52g}{10} = 5{,}052g$$

4. The average weight of the spruce sample treated with foam of expanditure Hk

$$\overline{m}_{P\_Foam\_H_K=6} = \frac{\sum_{i=1}^{n} m_{P\_FoamH_K\_n}}{n} = \frac{98{,}33g}{10} = 9{,}833g$$

$$\overline{m}_{P\_Foam\_H_K=9} = \frac{\sum_{i=1}^{n} m_{P\_FoamH_K\_n}}{n} = \frac{94{,}84g}{10} = 9{,}484g$$

$$\overline{m}_{P\_Foam\_H_K=12} = \frac{\sum_{i=1}^{n} m_{P\_FoamH_K\_n}}{n} = \frac{90{,}81g}{10} = 9{,}081g$$

5. The average weight of the water on the spruce sample

$$\overline{m}_{H_2O} = \overline{m}_{P\_H_2O} - \overline{m}_{P\_Nature} = 5{,}052g - 3{,}348g = 1{,}704g$$

6. The average weight of the foam of expanditure H_K on the spruce sample

$$\overline{m}_{Foam\_H_K=6} = \overline{m}_{P\_Foam\_H_K} - \overline{m}_{P\_Nature} = 9{,}833g - 3{,}426g = 6{,}407$$

$$\overline{m}_{Foam\_H_K=9} = \overline{m}_{P\_Foam\_H_K} - \overline{m}_{P\_Nature} = 9{,}484g - 3{,}533g = 5{,}951$$

$$\overline{m}_{Foam\_H_K=12} = \overline{m}_{P\_Foam\_H_K} - \overline{m}_{P\_Nature} = 9{,}081g - 3{,}360g = 5{,}721$$

7. The rate of foam of expanditure H_K and water on the spruce samples

$$R_\gamma = \frac{\overline{m}_{Foam\_H_K=6}}{\overline{m}_{H_2O}} = \frac{6{,}407g}{1{,}704g} = 3{,}76$$

$$R_\gamma = \frac{\overline{m}_{Foam\_H_K=9}}{\overline{m}_{H_2O}} = \frac{5{,}951g}{1{,}704g} = 3{,}49$$

$$R_\gamma = \frac{\overline{m}_{Foam\_H_K=12}}{\overline{m}_{H_2O}} = \frac{5{,}721g}{1{,}704g} = 3{,}36$$

3. Results

According to the findings of research, the amount of foam remaining on the foliage is remarkably higher than that of water. Its rate is 3.36-3.76 compared to water. The research also revealed that this rate does not significantly depend on expansion rate. The surface of the foliage in a full-grown forest is able to hold 4-5 kgm^{-1} water, which is enough to control a fire of about 3400 kWm^{-1} fire intensity. We can come to the conclusion that if fire intensity is so high that the cooling capability of water is not enough to extinguish the fire, applying foam can extend the range of extinguishing possibilities to dimension where extinguishing with water is not possible for objective reasons. Its reason is that by applying foam, the mass remaining on the surface, thus the cooling capability of the extinguisher, can be tripled. As a result, the fire intensity which can be extinguished expands as well.
We have to add that in addition to the foam’s weight effectiveness increase, insulation effects can be noticed, too, resulting in additional extinguishing effects. Weight effectiveness and insulation effects do not add up but multiply, which is yet another proof of the advantages of foams.
The above results show that the factor of weight effectiveness of the foams is significant, which offers the opportunity of increasing the amount of extinguisher on one unit of surface. The unsatisfactory extinguisher effect of water can be improved and extinguisher solutions have become available which have been impossible so far.

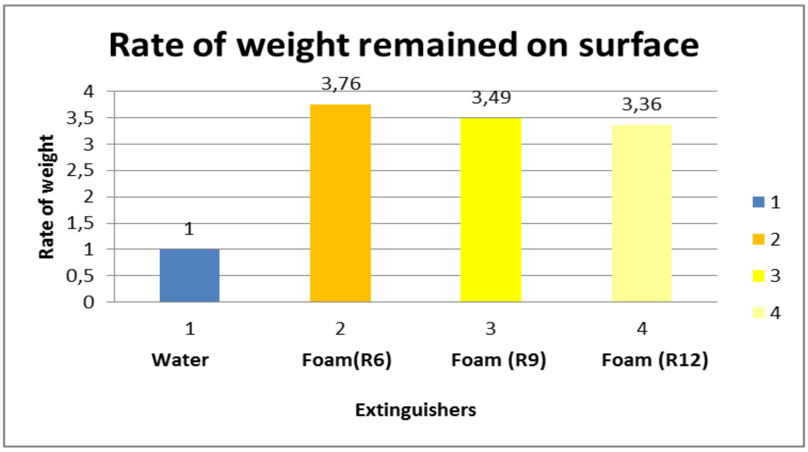

Figure 4. Rate of weight remained on surface depending on the expanditure rate of foams

4. Appendix A – Notation

1. m_{P_Nature} = the weight of the individual twig (sample), untreated;

2. $\overline{m}_{P\_Nature}$ = the average weight of the untreated samples;
3. $m_{P\_H_2O}$ = the weight of the individual samples treated with water;
4. $\overline{m}_{P\_H_2O}$ = the average weight of the samples treated with water;
5. $m_{P\_Foam\_K_k}$ = the weight of the individual samples treated with foam of H_K expanditure;
6. $\overline{m}_{P\_Foam\_K_k}$ = the average weight of the samples treated with foam of H_K expanditure;
7. $\overline{m}_{H_2O}$ = the average weight of the water remaining on the samples;
8. $\overline{m}_{Foam\_H_K}$ = the average weight of the foam of H_K expanditure remaining on the samples;
9. R_γ = the weight of the foam of H_K expanditure and water remaining on the samples;
10. $m_{\max H_2O\_m^2}$ = the weight of the water remaining on one unit of surface (constant) = 5kg;
11. $m_{\max FoamH_K\_m^2}$ = the weight of the foam of H_K expanditure remaining on one unit of surface.

5. **Appendix B – Mathematical formulas used for calculations**

1. The average weight of the untreated spruce sample

$$\overline{m}_{P\_Nature} = \frac{\sum_{i=1}^{n} m_{P\_Nature\_n}}{n}$$

2. The average weight of the spruce sample dipped into water

$$\overline{m}_{P\_H_2O} = \frac{\sum_{i=1}^{n} m_{P\_H_2O\_n}}{n}$$

3. The average weight of the spruce sample dipped into foam of H_K expanditure

$$\overline{m}_{P\_Foam\_H_K} = \frac{\sum_{i=1}^{n} m_{P\_FoamH_K\_n}}{n}$$

4. The average weight of the water remaining on the spruce sample

$$\overline{m}_{H_2O} = \overline{m}_{P\_H_2O} - \overline{m}_{P\_Nature}$$

5. The average weight of the foam of H_K expanditure remaining on the spruce sample

$$\overline{m}_{Foam\_H_K} = \overline{m}_{P\_Foam\_H_K} - \overline{m}_{P\_Nature}$$

6. The rate of the average foam of H_K expanditure and water remaining on the samples

$$R_\gamma = \frac{\overline{m}_{Foam\_H_K}}{\overline{m}_{H_2O}}$$

7. The amount of water effectively remaining on one unit of surface

$$m_{\max H_2O\_m^2} = const = 5kg$$

8. The amount of foam of H_K expanditure remaining on one unit of surface

$$m_{\max FoamH_K\_m^2} = m_{\max H_2O\_m^2} R_\gamma$$

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SWeFS: Sensor Web Fire Shield for forest fire detection and monitoring

George Bismpikis, Vassilis Papataxiarhis, Nikos Bogdos, Elias S. Manolakos and Stathes Hadjiefthymiades

Department of Informatics and Telecommunications, Pervasive Computing Research Group. National and Kapodistrian University of Athens, 15784, Greece. gbismpikis@di.uoa.gr, vpap@di.uoa.gr, bogdos@di.uoa.gr, eliasm@di.uoa.gr, shadj@di.uoa.gr

Abstract

Fires are a common, disastrous phenomenon (hazard) that constitutes a serious threat for many years. Due to their speed of propagation and intensity they often lead to property damages, personal injuries and loss of human lives. The probability of forest fire eruption in the Wildland-Urban Interface (WUI) is steadily increasing due to the climate change and human activities. WUI refers to all types of areas where forests, water bodies, and rural lands interface with homes, other buildings and infrastructures, including first and secondary home areas, industrial areas and tourist developments.

The Sensor Web Fire Shield (SWeFS) research project designs, develops and demonstrates an integrated system of sensors, networking and computing infrastructure aimed to detecting, monitoring, predicting and assisting in natural hazards such as forest fires at the WUI zones. Its goal is to deliver: (i) a methodology for developing a novel Sensor Web platform for dynamic data-driven assimilation (DDDAS) for securing the WUI zones against environmental risks, and, (ii) a prototype DDDAS system specifically optimized/tuned for addressing the serious threat of forest fires in Greece. SWeFS pushes the state-of-the-art by combining and using technologies derived from multidisciplinary research in the areas of sensor networks, distributed vision systems, remote sensing, geographical information systems (GIS), data stream fusion, space-time predictive modeling and control systems.

***Keywords**: fire detection and monitoring, active sensing, wireless sensor networks, dynamic data driven assimilation, data fusion, space-time predictive modelling, closed-loop architecture*

1. Introduction

Countries in the Mediterranean basin suffer from 50.000 fires annually with damaged land that covers 600.000 hectares. The cost of fire prevention and fire fighting in the Southern European countries scales up to 1 billion USD. The cost of the destructive fires of 2007 in Greece has been estimated to 1 billion euros. The land impacted by fires annually in the same region is equivalent to the surface of Crete or Corsica while the fires in Spain, Portugal, France, Italy and Greece have quadrupled since the 1960's. The rapid development of WUI areas is the outcome of pollution and overpopulation of city centers that grew in the '70s. Settlements were built without efficient road networks while homes and other buildings were developed in or near areas that form the flood plain of water catchments.

To minimize the aforementioned damages, early detection of environmental hazards like forest fires is critical. It is also very important to have early and accurate information about the exact origin(s) of the fire and its course as it spreads. Great technological effort has been invested on the design of systems for fire detection and monitoring. From an engineering perspective, machineries can be designed and used to help with detection or prediction of the disastrous events. One technology that enables (near) real-time detection of such events is the so-called Wireless Sensor Networks (WSNs). WSNs typically consist of a large number of small, low-cost sensor nodes distributed over a large area. The sensor nodes are integrated with sensing, processing and wireless communication capabilities. A simple WSN could be based only on a network of multi-sensor field devices that are able to detect increases in the temperature and/or decreases in the humidity percentage. However, the most promising approach for the early forest fire detection in WUI zones is the combination of various