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Experimental Investigation of Surface Litter Ignition by Bark Firebrands

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Abstract. Probability and conditions for ignition of surface litter (pine needles) caused by firebrands is studied in the laboratory conditions. For modeling of firebrands, pine bark of various sizes 10x10, 15x15, 20x20, 25x25, 30x30 mm^2 and 5 mm in thickness is used. The experiment was conducted in the absence of wind and at different wind velocities: 1, 1.5, 2 and 3 m/s. To conduct investigations, an experimental setup was constructed for generation of firebrands and their impact on surface litter. The results of experiments have shown that the increase in air velocity leads to the increase in probability of surface litter ignition. Thus, wind plays a role of catalyst in the ignition process, bringing an oxidizing agent to firebrands and supporting the process of smoldering. However, if the wind velocity is insufficient for ignition, then there is only the process of smoldering. The area of "uncertainty", where there is smoldering of surface litter without transition to ignition, is found to decrease with increasing the wind velocity. Based on the received results, it can be concluded that the ignition curve of surface liter by firebrands is nonlinear and depends on the wind velocity. At the same time, there is no smoldering and ignition of surface litter for all the wind velocities and the particles with a size of 10 x 10 mm^2, regardless of their number.

INTRODUCTION

Fires in the wildland–urban interface (WUI) pose a serious threat to many countries. Devastating fires in WUI occurred in Florida (1998), in Southern California (2003 and 2007), in Greece (2007), in Victoria and Australia (2009) and recently in Khakassia, Russia (2015). Such fires can lead to billions of dollars in damage.

WUI fires spread through both vegetative and structural fuels [1]. These fires can occur in any fuel type but usually occur in natural fuels by (e.g. lighting strikes) or man-made (e.g. campfires, runaway prescribed fires, downed or arcing powerlines, arson) reasons. In fact, the WUI fire problem is a structure ignition problem and the best approach to reducing the severity of the problem is to reduce the potential for structure ignition [2].

The probability of structural ignition is dependent both on physical properties (e.g. roofing material, decks, and vents) and the fire exposure conditions (e.g. magnitude and duration of heat flux from flames and firebrands).

In the study J.D. Cohen [3] noted that one of the main factors influencing on the ignition of fuels and propagation of wildland and man-made fires was firebrands. Formation of firebrands is the process resulting in the fact that fuels such as shrubs, trees and building materials, heat and separate into smaller burning particles during fire [4, 5]. Then the particles are carried away from the fire by means of convection column [6], creating spot fires and causing ignition of buildings.

The relevance of investigations in this area can be explained by the need to better define and characterize the conditions for the impact of firebrands, formed during combustion of vegetation, on surface litter and buildings for different types of wildland fires. Over the past 40 years, investigations has been focused on understanding how far particles can fly [7-10], while quite few investigations are devoted to their generation [5, 11, 12] and ignition of fuels by firebrands [13-17].

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Thus, the probability and conditions for ignition of surface litter by firebrands is of interest to study it in the laboratory conditions.

EXPERIMENTAL PROCEDURE

Pine bark of various sizes was used as firebrands (Fig. 1). In the experiment, the particles were 10x10, 15x15, 20x20, 25x25, 30x30 mm^2 in size and 5 mm in thickness. These sizes were chosen after the analysis of collected firebrands in the field experiment [12].

FIGURE 1. Experimental samples (pine bark)

Surface litter was a layer of pine needles with a density of 105 kg/m^3, located on the site of 200x200 mm^2 and 70 mm in height. The bark particles and pine needles were previously dried in a force-draft oven (ShSP 0.5-200) at 373 K for 4 hours to obtain optimum conditions. The moisture content of particles was 2.9%; the moisture content of needles was 9.3% in the experiment. The ambient temperature was 295 K. The experiment was conducted in the absence of wind and at different wind velocities: 1, 1.5, 2 and 3 m/s. The velocity of flow was determined by an anemometer (CFM Master 8901) with a measurement error of 2%.

To conduct investigations, an experimental setup was constructed for generation of firebrands and their impact on surface litter (Fig. 2).

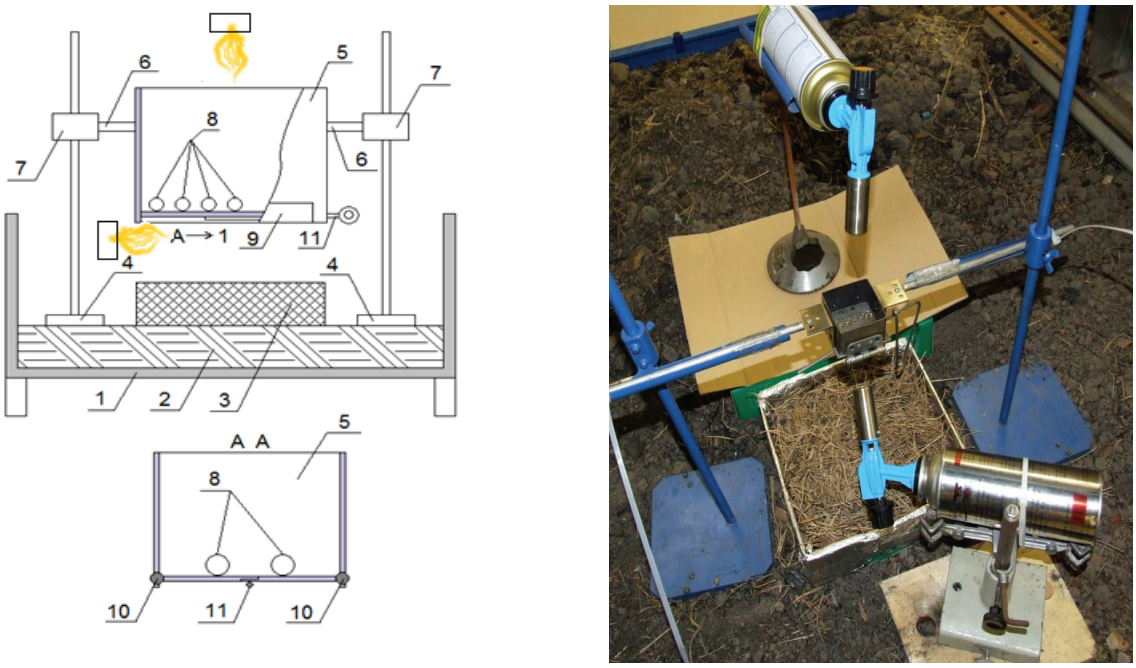

FIGURE 2. Structural scheme: 1 - pan; 2 - ground; 3 – surface litter; 4 - support; 5 - box; 6 - bracket; 7 - holder; 8 - firebrands; 9 - separated bottom; 10 - balls; 11 – stopper

The experiments were conducted as follows. Ground *2* with the forest fuel *3* on it were placed on the pan *1*. The box 5 was fixed to the supports *4,* had holes in the bottom for uniform ignition and eliminated the loss of particles during experiments. The firebrands *8* were placed in the box, where they were ignited and brought to the smoldering state by two gas burners: one was in the lower part and acted on the bottom of the box, the second one was located above the box, thereby achieving a uniform heating of the particles.

A series of experiments began with ignition of the one firebrand, then the two firebrands and up to reaching 10 of them, thus simulating the ignition of surface litter from the one particle to the "fire rain". After each falling of firebrands on surface litter and its ignition, the fuels again were placed on the site. Each experiment was repeated three times. If there was ignition at least in one of the three cases, the surface litter was considered to be ignited under the given conditions. The exposure time of flame generated by burners was determined on the basis of the particle size. For the particle size 10×10, 15×15, 20×20 mm^2 it was 12 seconds and 15 seconds for the particle size 25×25 and 30×30 mm^2 according to a series of experiments. The appearance of flame over a layer of fuels was considered to be ignition.

RESULTS

In the experiments, the dependence of surface litter ignition was obtained versus the size of firebrands and their number. Figure 3 shows the results of surface litter ignition at the wind velocities of 1, 1.5 and 2 m/s. The particles were carried away from the site of surface litter at a wind velocity of 3 m/s. The study of the particles effect at the wind velocities ≥ 3 m/s requires a change in dimensions of the site that is an extension of these investigations.

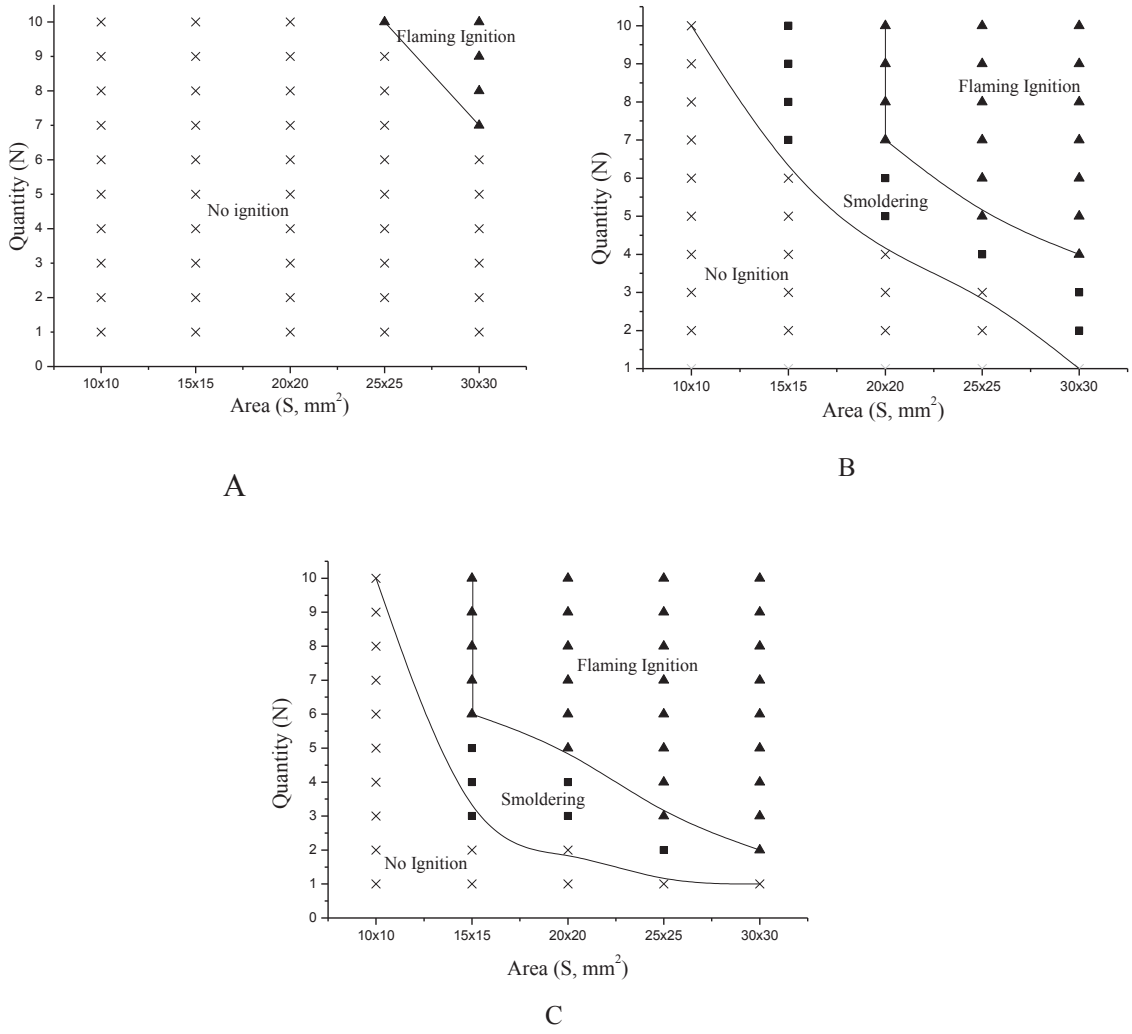

FIGURE 3. Ignition of surface litter by heated firebrands at the wind velocity:
A – 1 m/s; B – 1.5 m/s; C – 2 m/s.

The analysis of the data in Fig. 3 shows that the increase in air velocity leads to the increase in the probability of surface litter ignition. Thus, for a wind velocity of 1 m/s there is no smoldering and ignition begins for 10 particles 25 x 25 mm^2 in size (Fig. 3a). The increase in wind velocity up to 1.5 m/s (Fig. 3b) leads to the initiation of the smoldering process of surface litter without the appearance of flame. When the wind velocity increases, the area of smoldering is shifted to a smaller particle size. Thus, wind plays a role of catalyst in the ignition process, bringing an oxidizing agent to the firebrands and supporting the process of smoldering. However, if the wind velocity is insufficient for ignition, then there is only the process of smoldering (Fig. 3 a, b). At the same time, there may be a reverse effect, if the wind velocity is too high, then the particles will be blown and the process of smoldering will stop. Therefore, it is of interest to conduct the investigation of surface litter ignition by firebrands at higher wind velocities up to 5-10 m/s.

Ignition occurs at the presence of 6 particles 15 x 15 mm^2 in size, and goes down to 2 particles 30 x 30 in size at a wind velocity of 2 m/s (Fig. 3 c). Apparently, the reason is a large area of contact between the surface of particles with surface litter and the total energy released during smoldering. The results also show that the area of "uncertainty", where smoldering of surface litter occurs without transition to ignition, decreases with increasing the wind velocity.

CONCLUSION

Based on the received results, it can be concluded that the ignition curve of surface litter by firebrands is nonlinear and depends on the wind velocity. Moreover, there is no smoldering and ignition of surface litter for all the wind velocities considered for the particles with a size of 10 x 10 mm^2, regardless of their number.

ACKNOWLEDGEMENT

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