# Laboratory investigation of fire exposure on wood by thermal imagery and thermocouple approach

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## ABSTRACT

The impact of spot fire on wood different-shaped samples (flat and cylindered sample) is studied under laboratory conditions. Using thermal imagery and a thermocouple method, the temperature is determined on the surface of the test samples after the impact of the fire front; the possibility of wood ignition is analyzed for the chosen parameters of the experiment.

**Keywords:** combustion, wood, experiment, ignition, thermal imagery

## 1. INTRODUCTION

The problem of wildland fires is urgent because they cause substantial material losses and economic damage to the territories. Despite the improvement of methods for prediction of fire hazards, the number of fires is not reduced [1]. Wildland fires pose the major hazard to wooden structures in settlements.

The works [2-3] provide the results of modeling and studies of fires in a residential area. However in these works the authors mostly study the ignition of houses under the impact of burning particles and embers. [4] These works do not consider vulnerability of wooden buildings to a fire due to the fire front impact [5].

At present, up-to-date methods of thermal imagery are actively used for the study of combustion and wildland fires [6]. In modeling of combustion under laboratory conditions, it is sufficient to use the contact methods for the recording of temperature; however in natural conditions a large amount of thermocouples are required for the recording of temperature fields, which causes difficulties in processing the results. It should be noted that the thermal equipment is not much used in the study of wildland fires, since this phenomenon is dependent on many parameters (optical flame characteristics, spectral range) [7]. In addition, the complicated objects under study require the use of special scientific thermal imagers, which is connected with high material costs. [8] However, the use of the thermal imagery methods is of interest in view of the prospects of this method in the study of characteristics for the combustion front and detection of heat-stressed areas that are subjected to the fire front.

This paper presents the experimental results for ignition of wood different-shaped samples (flat and cylindered) during a model steppe low intensity fire using the thermocouple method and the method of thermal imagery.

## 2. METHODOLOGY OF THE EXPERIMENT

To solve this problem, it is used a test complex [9] designed to study forest, steppe and peat fires, and which is a box-polygon filled with ground and has the following dimensions: the length is 2 m, the width is 1.5 m, and the height is 0.13 m. In the infrared region the characteristics of the combustion front are recorded by a thermal imager JADE J530SB with a 320 × 240 pixels matrix and the range of temperature measurements is -15 ... + 1500 °C. These technical data allowed the flame to be recorded at 50 frames per second. To register the input data from the thermocouples, an automated data collection and recording system is used. Moisture content of the samples is controlled by the moisture analyzer AND MX-50 with an accuracy of 0.01%, the weight of the samples is controlled by the electronic scale AND HL-400 with an accuracy of 0.01 g. Thermograms are taken in the spectral range of 2.64-3.25 microns [8]. Birch is used as the samples. The samples are flat and cylindered shaped and simulate a wall of the wooden building (Fig. 1).

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Figure 1. Wood samples before the experiment.

Wood samples (birch) previously were dried in an oven at a temperature of $100^0 C$. The mass of a steppe fuel (SF) is $M_{SF} = 50\ g$, the mass of wood samples is $M_{sample} = 180\ g$, the moisture content of the samples is $W_{sample} = 4{,}3\%$, the moisture content of the steppe fuel is $W_{SF} = 4{,}5\%$, the ambient temperature is $T_0 = 20^0 C$. To register the input data from the thermocouples, it is used the automated data collection and recording system consisting of a computer, a five-channel analog-to-digital converter (ADC) with chromel-alumel thermocouples 200 microns in junction diameter. The measurement error for the thermocouples was 2.5%.

Fig. 2A shows the dimensions of the spot fire and the wood samples as well (Fig. 2B).

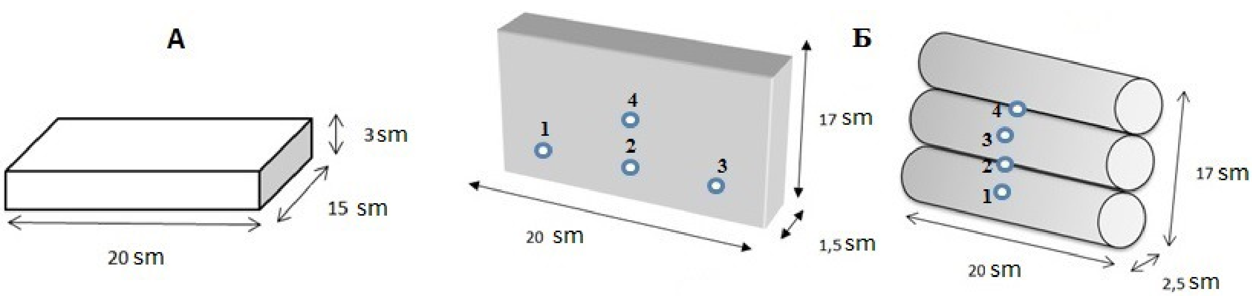


Figure 2. Dimensions of the SF block (A) and the wood samples (B); 1-4 – location of thermocouples.

Fig. 3 shows a scheme of the experiment.

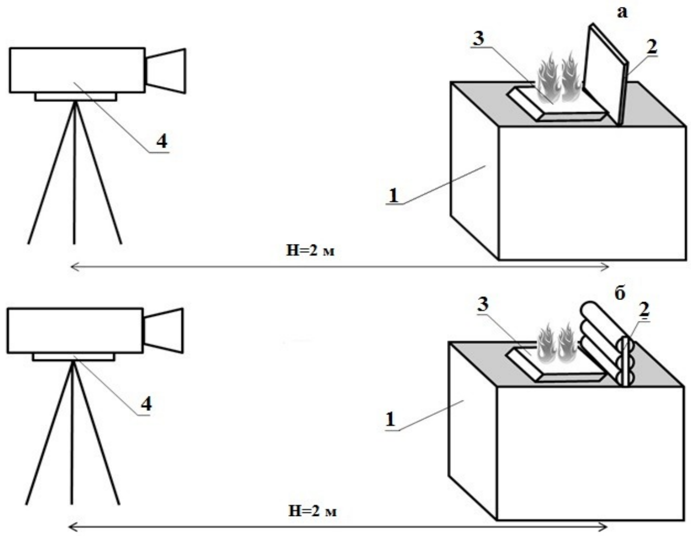


Figure 3. The scheme of the experiment: 1 – test facility; 2 – wood; 3 – steppe fuel; 4 – thermal imager Jade J530 SB.

As the spot fire it was used a model steppe low-intensity fire 3 that affects the wood sample 2. Ignition of SF was conducted using a glowing spiral. The thermal imager started recording after ignition of the SF layer and recorded not only the development of combustion, but also the surface of the wood sample when the SF layer burned and stopped screening.

## 3. THE EXPERIMENTAL RESULTS

In order to estimate the impact of the spot fire on wood samples by thermal imagery, the area 1 was selected on the surface of wood samples, using the software Altair to obtain the temperature versus time of the experiment (Fig. 4).

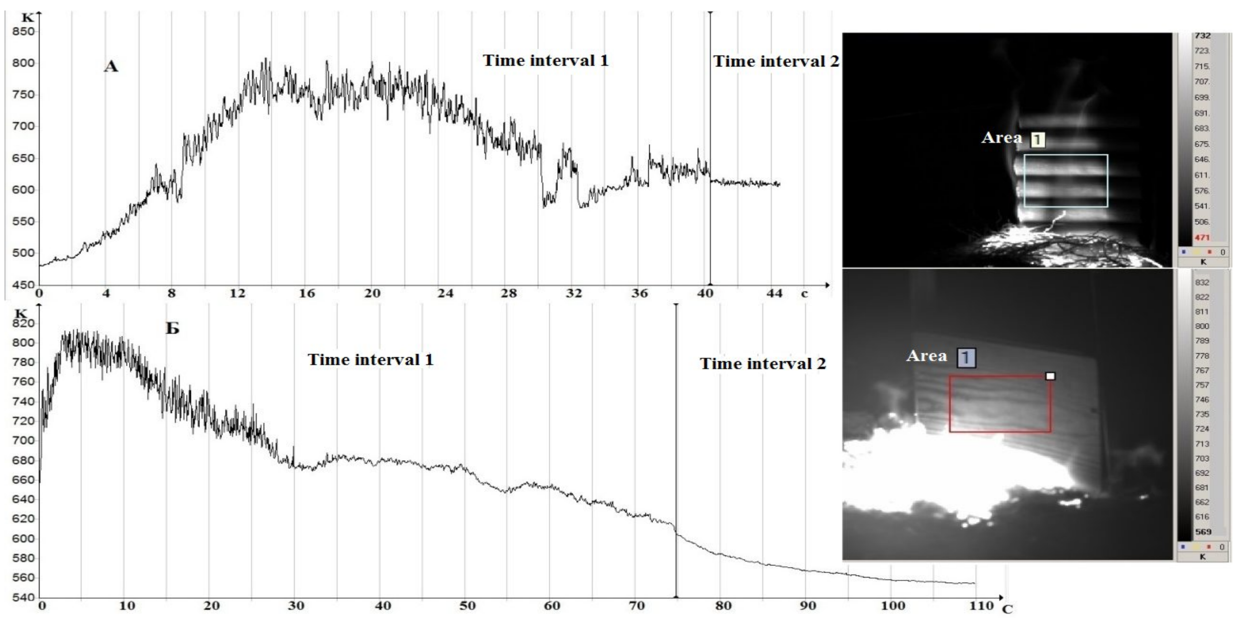


Figure 4. Typical thermogram describing the temperature versus time in a selected area 1 on the surface of the cylindered 1 (A) and flat (B) wood sample.

The plots in Figure 4 reflect the average temperature (averaging is performed automatically by the software Altair) versus time of the experiment, including combustion of the SF layer. Neglecting the time interval 1 in Fig. 4, when the SF layer burned in the flame mode, and screening the desired surface of the wood sample in the area 1, the plots of temperature changes were obtained on the surface of the sample in the area 1 after the spot fire impact (see Fig. 5).

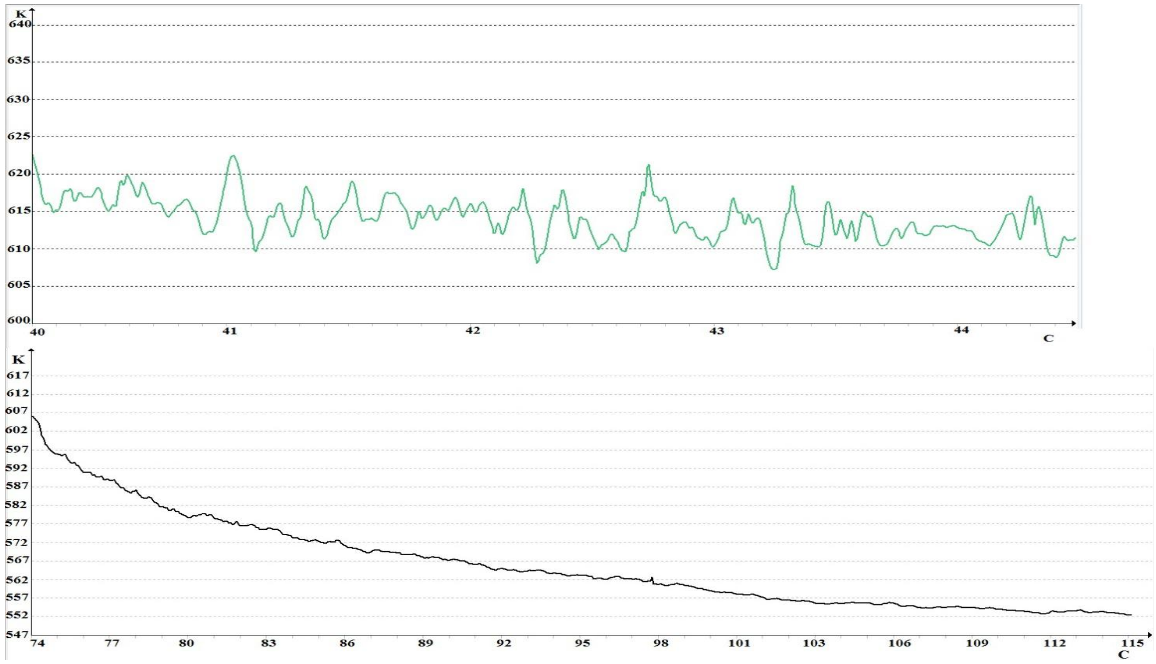


Figure 5. Average temperature versus time in the area 1 after the spot fire impact.

The experimental results were as follows: the surface temperature of the flat samples reached the temperatures of $600-610\ K$ and the surface temperature of the cylindered samples was in the range of $607 \le T_2 \le 622\ K$. Under the experimental conditions (mass of SF, moisture content of wood samples), ignition was not observed, the sample was heavily charred, the active formation of smoke was observed, but there was no combustion on the surface.

It should be noted that in this case, under same conditions and parameters of the experiment, the cylindered samples were ignited and stable combustion was observed on the surface. Thus, the probability of ignition for such samples is higher than for the flat ones, other conditions being equal.

Figure 6 shows the surface temperature of the wood sample versus time obtained using the thermocouples.

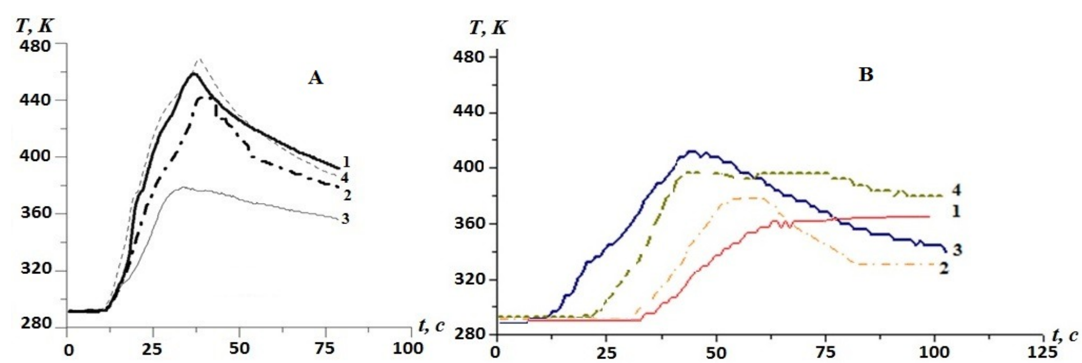


Figure 6. Temperature versus time on the surface of the wood samples (A is flat, B is cylindered).

In Figure 6A the thermocouples 1-4 start almost simultaneously registering an increase after 15 seconds from the initiation of combustion. The temperature change was first recorded by the thermocouple 4 located in the central part of the sample, which is apparently connected with the higher temperature of flame, that is consistent with the work [10]. Therefore, the total heat fluxes have different values throughout the height. The wood sample was partially charred for the selected level of the SF layer.

The thermocouple 4 recorded the highest temperature in the range of 460-470 K, and the thermocouples 1-3 located in the bottom of the wood samples recorded the highest temperature in the range of 430-450 K. The thermocouple 3, despite the fact that it was on a one level with the thermocouples 1 and 2, recorded a lower temperature, which is apparently connected with the nonuniformly laid SF layer.

The plot in Figure 6B corresponds to the experiment with cylindered samples. In this case, there is first active heating of the top convex part of the sample (the thermocouple 3 records a temperature rise up to 340 K in 20 seconds after starting the experiment), which is explained by the structure of flame during combustion of plant fuels. When the thermocouple 3 reaches the highest values, then heating is recorded by the thermocouple 4 located in conjunctions between the bars. After that, a sharp increase according to the thermocouple 2 in conjunction is recorded by the thermocouple 1. The temperature of the convex sample parts reaches 420 K and 390 K in conjunctions.

Figure 7 shows the thermogram of the spot fire impact on wood samples at the time when a large part of the fuel layer burned and flame did not screen the surface of wood samples. In this area the experimental points are located on the surface of the sample: points 1-6 are located on the edges at left, points 1-5 are located in the center of the sample at right.

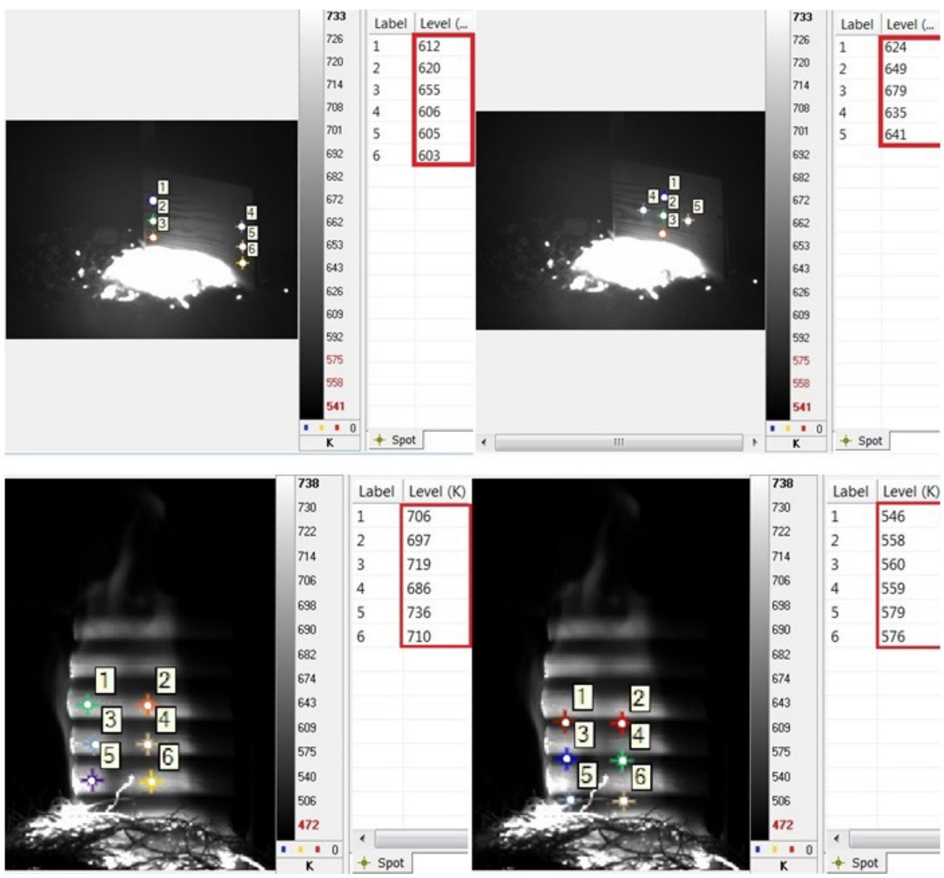


Figure 7. Thermogram of the spot fire impact on wood samples (corresponds to the time interval when the SF layer still burns, 1..6 are experimental points).

Comparison of the results received using the thermocouple method and IR diagnostics has shown that in both cases, the central part of the samples is a high-heat area on the surface of flat samples, and the convex parts and side edges are a high-heat area on the surface of cylindered samples.

## 4. CONCLUSION

Based on the foregoing information, the following conclusions can be made:

1. The different influence of the spot steppe fire on flat and cylindered birch samples was experimentally determined.

2. Using the method of thermal imagery, the maximum temperature was determined on the surface of wood different-shaped samples subjected to the spot fire in the spectral range of 2.64-3.25 microns: 600 - 610 K for flat samples, 607 - 622 K for cylindered samples.

3. Ignition of flat samples was not observed under same conditions of the experiment (mass of SF, moisture content of wood samples). The cylindered samples ignited by subsequent stable combustion.

4. The temperature versus time was obtained on the surface of wood different-shaped samples using a thermocouple method.

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