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Thermography of Wood-Base Panels During Fire Tests in Laboratory and Field Conditions

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Abstract. The paper represents the experimental study of combustion over the surface of a vertically-mounted oriented wood-based panels (plywood, chipboard and oriented strand board) under different environmental conditions. The IR thermography was used as a diagnostic method. An infrared camera JADE J530SB was used to obtain the sequences of thermograms characterizing the heat flow pattern on the surface of the sample during vertical combustion and determine the velocity of the combustion wave under laboratory and field conditions. In addition, during the field tests the change in the angle of the combustion front was estimated depending on time.

Keywords: Fire behavior of wood · Fire retardant · Infrared thermography · Timber · Combustion · Fire safety

1 Introduction

Wood finishing materials are becoming increasingly widespread in Russia. Thus, in rural and suburban areas with low-rise buildings, the use of wood finishing building materials reaches 80%.

On the one hand, new wood-composite materials and technologies that use structural elements and prefabricated modules in the construction industry have greatly increased the interest in wooden buildings. Ecological and economic attractiveness of these projects plays an important role in wooden house construction.

On the other hand, wooden building structures can contribute to the occurrence and spread of fire in a building or in a structure. Fires (especially in combination with forest fires) occurring in settlements with predominant wooden buildings cause great damage. In this regard, studying the fire behavior of wooden buildings and structures, as well as analyzing the regulatory requirements for the fire safety of buildings with wooden structures are urgent and important tasks. Combustible building materials like wood-base panels burn out their surfaces, release energy and thus combustible to fire propagation in case of fire.

Flammability and combustion propagation are key factors that determine the fire behavior of wood. The effect of different factors on the fire behavior of wood (species and kind of wood, conditions and duration of operation, humidity, fire intensity, etc.) was investigated in [1–8]. The data of these works can be used to conclude about the

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fire resistance of wooden structures, but most of the methods used are classified as contact methods.

At present, up-to-date methods of infrared (IR) diagnostics are actively used to study combustion process and wildland fires [9–11]. It should be noted that information on the application of contactless methods in the fire tests of building fragments and structures is still absent in the literature. In previous experiments [12] we experimentally analyzed the effect of different fire retardants on the flammability of coniferous and broadleaf wood using the methods of IR diagnostics. Development of fire resistance and fire behavior test methods using thermography based on the data obtained for wood building structures will reduce the costs of such works and simultaneously increase the efficiency of data and resolution obtained.

This paper presents the experimental study of vertical fire spread over the surface of wood-base panels under different environmental conditions. The experiments were conducted under laboratory conditions, thereby modeling the development of combustion inside a building. In addition, a series of fire tests were conducted under field conditions, modeling the development of vertical fire spread along the facade of a building.

2 Laboratory Equipment and Experimental Procedure

Experimental equipment included an infrared camera the JADE J530SB from Cedip Infrared Systems (Cedip Infrared Systems, Croissy-Beaubourg, France). The JADE J530SB infrared camera was used with a narrow-band optical filter working in the wavelength range of 2.5–2.7 microns and recording the temperature in the range of 300–1500 °C. Accuracy was ±2% of the reading temperature (with filter). Canon LEGRIA HF R88 video camera was used to estimate the propagation of the combustion front in the visible wavelength range.

Pine needles were taken as forest fuel to model the front of a ground fire. In the experiments the humidity content of needles was 6%. The mass of forest fuel (FF) remained unchanged and was equal to 150 g to model a low- intensity surface fire. This type of fire is more common, since it occurs in areas where litter is produced from fallen leaves of trees and shrubs.

Plywood, chipboard and oriented strand board (OSB) panels was chosen as a sample of building material. The main parameters of the samples are presented in Table 1.

Table 1. Parameters of the samples of building materials used in the laboratory and field experiments.

	Laboratory experiment	Field experiment
Size, m:	0.300 × 0.300	0.61 × 1.0
Thickness, m:	0.008; 0.012; 0.018	12 mm
Density, kg/m^3:	570–590 (OSB) 705–725 (Plywood) 700–720 (Chipboard)	570–590 (OSB) 705–725 (Plywood) 700–720 (Chipboard)
Humidity content, %:	4.7	10

Before the experiments, the humidity content of the samples was measured using an AND MX-50 humidity analyzer (precision of instrument is 0.01%).

Figure 1 shows a schematic diagram of the experiment and a photo of sample under the fire exposure:

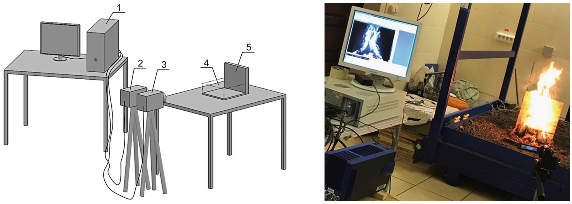

Fig. 1. Installation diagram scheme. 1 - PC, 2 - video camera Canon HF R88, 3 - JADE J530SB infrared camera, 4 - forest fuel (FF) site, 5 - wood sample.

The laboratory experiment was conducted as follows: a substrate with needles located in front of the wood building material sample mounted vertically to the substrate was ignited with a gas burner. It was resulted in the generation of the combustion front, which in turn began to affect the wood sample. The surface of the wood building material samples exposed to heat was observed using the infrared camera.

Analysis of the data obtained shows that OSB samples turned out to be susceptible to ignition with the considered experimental parameters. The thermal effect of the combustion of pine needles weighing 150 g is enough to cause a flame on the surface of the sample, followed by stable combustion. (Figure 2) presents a sequence of thermograms demonstrating the combustion over the OSB surface with a period of 120 s.

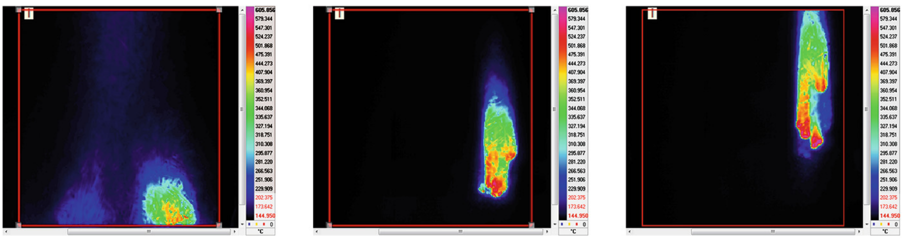

Fig. 2. Vertical propagation of the combustion front over the OSB sample. The surface of the sample in the thermogram is marked with a red rectangle.

It is note that for the selected experimental parameters, local ignition occurs in the region with the greatest amount of needles. Then the combustion wave passes vertically due to the effect of convection, and combustion on the upper part of the sample stops. For the chosen parameters of the experiment and the thermal energy released during the combustion of plant fuels in the amount of 150 g on the site (assuming 0.172–0.263 kg/m^2), the ignition of wood samples was observed for OSB and plywood panels.

Based on the obtained data and three repetitions of the experiment, the velocity of the combustion wave was 0.68 mm/s (for OSB samples) and 0.95 mm/s (for plywood) according to the data of IR diagnostics. It is of interest to conduct a similar experiment that demonstrates the development of the combustion front over the surface of a vertically-mounted sample in open space under natural weather conditions.

3 Field Tests

The experiments were conducted on the test site of V.E. Zuev Institute of Atmospheric Optics of the Siberian Branch of the Russian Academy of Science (IOA SB RAS). The air temperature and wind were measured by the weather station situated at the test site. Automated system allows one to measure a wide range of meteorological and optical atmosphere parameters as temperature (223… 323 K, ±0.2 K), relative humidity (10… 100%, ±5%), wind speed (0.5… 60 m/s, ±5%), direction (0… 360°, ±10%). Wind speed was varied over the range of 0.8–2.5 m/s, temperature was varied over the range of 301–303 K.

Figure 3 shows the sample before and during the fire test.

Fig. 3. Photographs of the wood-base panel during field fire tests.

Before the experiment, the sample fixed on wooden poles, which had previously been insulated with metal foil. The poles were driven into the soil to place the sample in the vertical position. The distance from the soil to the sample was chosen in such a way that a container with a fuel could be placed in it. After ignition of the sample and stable combustion over the surface, the propagation of the combustion wave was recorded using the infrared camera with similar settings as in laboratory experiments.

Combustion regime was observed as followed during the experiments in an open area: as a result of the thermal effect of heat flux from fuel combustion, the pyrolysis temperature was reached on the lower face of samples, then it increased with the release of combustible gases. The initiated flame increases due to the emission of combustible gases, as well as combustion area increases on the surface. Additional heat is released during further combustion reaction, the flame height stabilizes and the material is actively burned.

(Figure 4) shows the photographs demonstrating the combustion of the OSB panel as well as the thermograms obtained using the infrared camera (120 s. step).

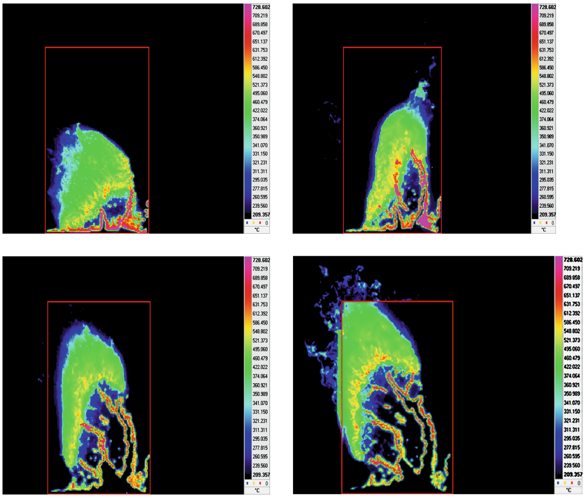

Fig. 4. Thermograms of the vertical combustion of the OSB sample.

The sequences of thermograms characterizing the heat flow pattern on the surface of the sample during vertical combustion were obtained. It is noted that the presence of changing wind in the open area leads to the fact that the combustion wave propagates nonuniformly, and the front spreads in the direction of the wind, which is shown in (Fig. 4), starting from the sixth minute. In individual cases, the speed and wind direction change drastically during the experiment. Despite the high wind with gusts of up to 15 m/s (it should be noted that such gusts were observed rarely and did not play a decisive role in the development of vertical combustion process), blowout of flame and extinguishing of the samples were not observed, the combustion process was very active. On the contrary, combustion process intensified with the presence of additional oxidants influx. The results on velocity of the combustion wave was according to the data of the infrared camera presented in Table 2. The results show good accuracy for both cases: laboratory and field conditions.

Table 2. Fire behavior parameters of the samples (* – averaging on 3 repetitions was performed).

Wood material	Vertical fire spread*, mm/s	Maximum of the surface temperature*, °C
Chipboard	0.8 ± 0.15	716 ± 25
Plywood	1.38 ± 0.33	740 ± 20
OSB	1.27 ± 0.27	765 ± 25

4 Conclusions

The vertical combustion of the sample of wood building material was experimentally studied to obtain:

1. Temperature distribution over the surface of wood-base panels;
2. The method of constructing and analyzing the temperature field on the surface of samples according to the obtained data using an infrared camera was tested;
3. The velocity of the vertical combustion front was estimated under laboratory and field conditions using infrared diagnostics. It is noted that the presence of changing wind in open areas leads to the fact that the combustion wave propagates nonuniformly, the front spreads in the direction of wind, and the front angle change is linear during the whole combustion process. Data on vertical fire spread show good accuracy for both cases: laboratory and field conditions.
4. As a result of experimental data processing, heat-stressed areas on the surface of wooden model constructions by the exposure of surface fire front were found. Available data as well as additional experiments would allow to estimate the dependence of fire hazard indexes of constructional materials of application conditions and type of fire retardant composition, geometry and design of sample, and develop laboratory method of noncontact IR diagnostics and controlling of fire hazard characteristics of constructional materials (flame front position, burnout front and flame height).

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