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Estimation of the influence of wood-fire retardants on fire behavior of some types of wood construction materials

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Abstract. In this paper the effect of fire front on the surface of wood samples (pine, aspen and larch) was considered to estimate the effect of different wood-fire retardants. Infrared thermography was used as a diagnostic method. Modern methods of IR-diagnostics and the use of thermal imagers eliminate the need for a large number of thermocouples which perturb the investigated medium during measurements. At the same time, a much better resolution in space and time can be obtained using infrared diagnostics. The surface temperature distribution was obtained for the test wood samples after exposure to a fire front that was modeled using pine needles. The ignition probability was estimated for the chosen experimental parameters for each kind of wood. In the infrared region the sample surface characteristics were recorded using a thermal imager JADE J530SB with a 2.5–2.7 micron optical filter that allowed measuring a temperature within the range of 500–850 K. In order to record a temperature within the range of 293–550 K, the recording was conducted without a filter. The fire hazard characteristics of wood after fire retardant treatment showed a significant reduction in the surface temperature and the resistance to fire for the chosen parameters of the experiment compared to the same untreated samples.

1. Introduction

The problem concerning wildland fires becomes more urgent. All countries of the world, especially Brazil, Australia, China, Greece, Portugal, the United States, and Russia are faced this problem.

Wildland fires are known to be a powerful, natural and anthropogenic factor that significantly changes the condition of forests. Tens of thousands of hectares of forests and lands burn out. Often fires occur and develop near settlements and cities. In Russia, where forests occupy a large territory, forest fires are a national problem, and damage to the real economy is estimated at tens and hundreds of millions of dollars per year.

In the literature there are a lot of experimental studies concerning the fire hazard of wood, which demonstrate the influence of various factors on the fire hazard indices (species of wood, conditions and duration of operation, humidity, fire intensity, etc.). These studies are represented by the works of [1-7]. In these works the pyrolysis and thermal oxidative degradation of wood are studied, thermal and physical characteristics are determined, and the values of carbonization rates are obtained for various temperature modes. These data can be used to evaluate the fire resistance of wooden structures, but most of the methods applied to assess the fire hazard of wood are referred to contact methods (micro thermocouple techniques, molecular-beam mass spectrometry, thermal analysis methods, etc.). Contact methods are often used for recording temperature fields, heat fluxes, carbonization rates, ignition delays, etc. to model combustion processes under laboratory conditions; however, a large

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number of thermocouples are required to record temperature fields under field and semi-field conditions, which causes difficulties for processing the results.

At present, thermal imaging equipment is not often used in the study of wildland fires, since this phenomenon depends on a large number of parameters and requires a detailed study of a radiation coefficient. It should be noted that information on the application of contactless methods in the fire tests of building fragments and structures [8], as well as the application of IR thermography in the study of urban and peat fires [9-10] is still absent in the literature. Contact methods are the traditional methods for measuring the temperature during fire-engineering tests of building structures.

In this paper, the effect of various flame retardants was evaluated to study the influence of the fire front on the surface of wood building material samples [11-12]. The IR thermography was used as a diagnostic method. At present, the IR method, along with thermal non-destructive testing methods which do not cause damage to the integrity of controlled objects and do not introduce disturbances into the process, represents high technological applied research that combines achievements in the theory of heat transfer, IR technology, and computer processing of experimental data [13].

2. Methodology of the experiment

Combustion, simulated by forest fuel (FF), consisted of pine needles (*Pinus Pinaster*) and represented a site with a width that was close to the size of the wood sample. The samples of pine, aspen and larch were used as the samples which imitated the wood used in constructions. The dimensions of the samples in the experiment were (L × W × H): 0.23 × 0.02 × 0.1 m for pine, 0.17 × 0.02 × 0.1 m for aspen, and 0.16 × 0.02 × 0.12 m for larch.

Figure 1 shows a schematic diagram of the experiment:

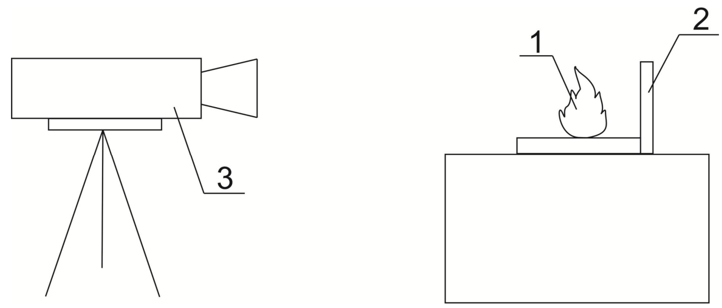


Figure 1. Experimental setup. 1 – site with FF, 2 – wood sample, 3 – thermal imager JADE J530SB.

A wood building material, in addition to the available flat pine, aspen and larch samples [14-15], was used to imitate a pine bar («Blockhouse») for evaluating the effect of the geometry of wood samples on ignition, as well as the effect of flame retardants on fire hazard characteristics. The size of the samples in the experiment was (L×W×H): 0.25×0.02×0.11 m. Figure 2 shows a photograph of the building material sample used for imitating a bar.

Figure 2. «Blockhouse» samples.

The method presented in [14-15] was used to determine the temperature fields on the surface of the studied wood samples subjected to the model forest fire by applying a non-contact method.

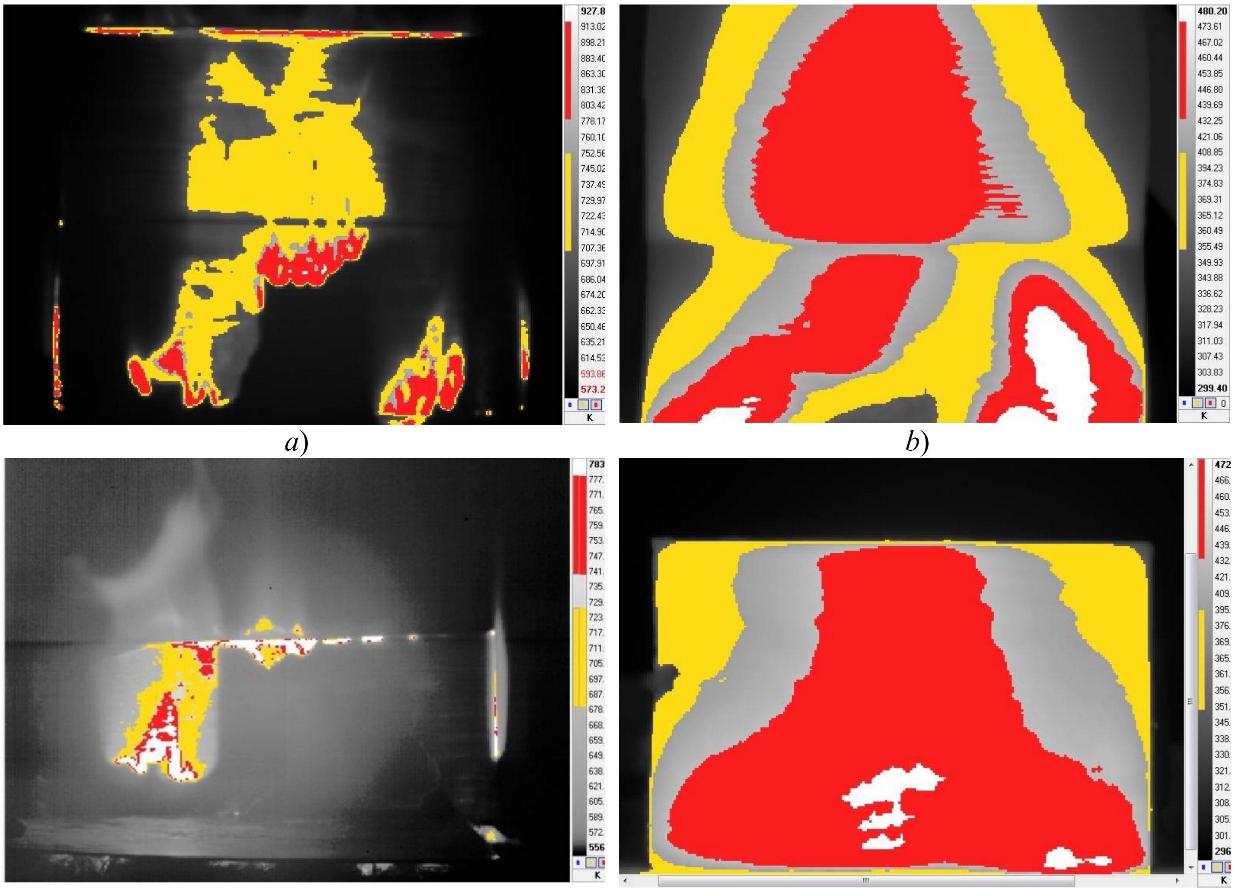
In addition, along with the «FUKAM» fire-bio retardant treatment for wood [16], the following solutions were considered: «Pirilax-Classic» fire retardant treatment with an antiseptic effect for wood [17], «SENEZH OGNEBIO PROF» fire retardant [18], as well as «MIG-09» fire-retardant composition [19].

The consumption of fire-retardant compositions, as determined by the manufacturer's technical specifications, guaranteed the II group of fire-retardant efficiency in accordance with GOST R53292 [20]. The sample surface that was subjected to the thermal action of the combustion front was uniformly coated by a flame retardant composition with a brush. The samples were kept for 24 hours and then were placed in a drying oven ShSP-0.5 - 200 at a temperature of 70°C until the moisture content was W = 2 %.

3. Results and discussion

The use of the non-contact method allowed us to obtain the distribution of the temperature fields on the surface of the sample subjected to the combustion source.

The analysis of the data obtained for untreated wood shows that the larch samples are resistant to ignition for the selected experimental parameters. The other samples (pine, aspen), irrespective of geometry, are ignited by the combustion source. Figure 3, as an example, shows the thermograms of untreated «blockhouse» sample (figure 3a) and treated one by the antiseptic for wood «Pirilax-Classic» (figure 3b); untreated aspen sample (figure 3c) and specimen treated by fire retardant «SENEZH OGNEBIO PROF» (figure 3d).



a) *b*) *c*) *d*)

Figure 3. Thermograms of sample surfaces after fire exposure.

The geometric dimensions of the most high-heat areas were measured using tools available in the Altair software. The size of the sites was determined at the time when the burning layer of forest fuels completely burned out and the flame stopped screening the area under study.

The processed thermal imaging data obtained in the experiment are listed in table 1.

Table 1. The values of the maximum temperature $T_{max\ av}$ on the surface of the wood samples, depending on the fire retardant used.

№	Wood samples	Fire-retardant compositions	$T_{max\ av}^{*}$, ^{o}C
1	Block House (pine)	«Pirilax Classsic»	278
		«SENEZH OGNEBIO PROF»	253
		«MIG-09»	266
		«FUKAM»	240
		Without treatment	664
2	Flat larch	«Pirilax Classsic»	247
		«SENEZH OGNEBIO PROF»	245
		«MIG-09»	291
		«FUKAM»	279
		Without treatment	310
3	Flat aspen	«Pirilax Classsic»	288
		«SENEZH OGNEBIO PROF»	226
		«MIG-09»	239
		«FUKAM»	290
		Without treatment	712
4	Flat pine	«Pirilax Classsic»	303
		«SENEZH OGNEBIO PROF»	236
		«MIG-09»	260
		«FUKAM»	244
		Without treatment	740

* - Averaging over three experiments.

4. Conclusions

The effect of the various fire-retardant compositions (fire-bio retardant treatment for wood «FUKAM», fire-retardant treatment with an antiseptic effect for wood «Pirilax-Classic», protective means for wood «SENEZH OGNEBIO PROF», and fire-retardant composition «MIG-09») was experimentally analyzed to study the fire-hazard characteristics for the wood samples of various geometry (flat pine, aspen and larch samples as well as wood building material for the imitation of a pine bar (Block House)). Comparative analysis shows that depending on the kind of wood the best fire-retardant characteristics are demonstrated by different compositions such as the fire-bio retardant treatment for wood «FUKAM» for the samples of block house; the fire-retardant treatment with an antiseptic effect for wood «Pirilax-Classic» for the building larch board; the protective means for wood «SENEZH OGNEBIO PROF» for the building pine and aspen board.

Using the experimental data obtained, high-heat areas were found on the surface of wooden model structures exposed to the forest ground fire. The characteristic size of found areas was: 45×60 mm for larch, 52×61 mm for aspen and 58×85 mm for pine.

For the chosen parameters of the experiment and the thermal energy released during the combustion of plant fuels in the amount of 50 g on the site (assuming 0.172–0.263 kg/m^2), the ignition of wood samples was not observed. For a sample of building pine board covered with fire-retardant "Pirilax Classsic", short ignition was observed on the surface; however when plant fuels burned out completely, combustion stopped. The experiments have shown that the carbonization depth did not exceed 1.4 mm for all the wood samples covered with flame retardant and subjected to heat released during the combustion of plant fuels with a mass of 50 g (measurements were carried out using a hand micrometer MC25 with the maximum permissible error of 0.004 mm). Thus, the above fire retardants reduce the heat load and exclude ignition.

A logical continuation of this topic is conducting analysis of fire-hazardous properties (ignition delay, carbonization rate, and probability of ignition) of a wider class of wood building materials (wooden structures, laminate weneer, plywood, chipboard, fiberboard, oriented strand board) as well as determining the dependence of fire characteristics of the construction materials under study on the application conditions, the type of fire retardant and the intensity of heat.

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