Investigation by contact and non-contact method of fire-hazardous characteristics of some building materials on the basis of wood

D P Kasymov, M V Agafontsev, V V Perminov, A Yu Chechekov

National Research Tomsk State University, 36 Lenin Ave., Tomsk 634050, Russia

E-mail: denkasymov@gmail.com

Abstract. In this paper the effect of fire front on the surface of wood samples (pine, aspen, larch, plywood and oriented strand board) was considered to estimate the effect of different wood-fire retardants. Infrared thermography was used as a diagnostic method. 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. The charring depth of the wood samples was determined depending on the type of wood, as well as on the type of the fire retardant used.

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 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.

One of the ways to reduce the flammability of artificial and natural polymer materials (including wood) is the use of flame retardants that can be introduced into polymer during the production of materials or deposited on polymer during the surface treatment of finished products.

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 [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.

In addition plywood and oriented strand board (OSB) were used as a sample of wood building materials. The dimensions of the samples in the experiment were (Length × Width × Height): 0.300 × 0.016 × 0.300 m for plywood, 0.300 × 0.018 × 0.300 m for oriented strand board. The density of materials depending on the thickness is: 570–590 kg / m^3 for OSB samples with width range 0.018–0.025 m; = 650-690 kg / m^3 for plywood samples with width range 0.015–0.016 m.
Figure 1 shows a schematic diagram of the experiment:

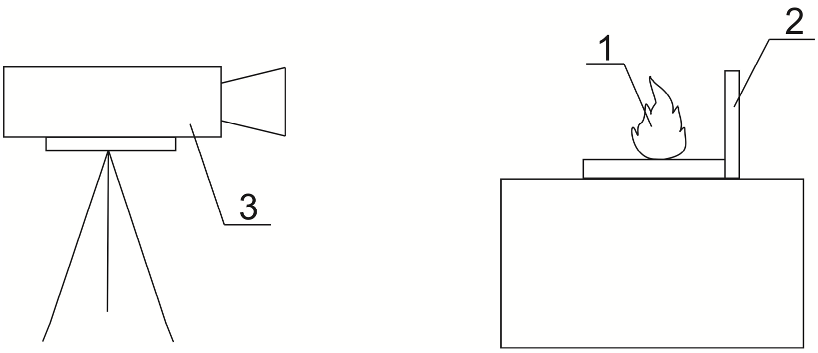

Figure 1. Experimental setup. 1 – site with FF, 2 – wood sample, 3 – thermal imager JADE J530SB.

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 samples used in experiment.

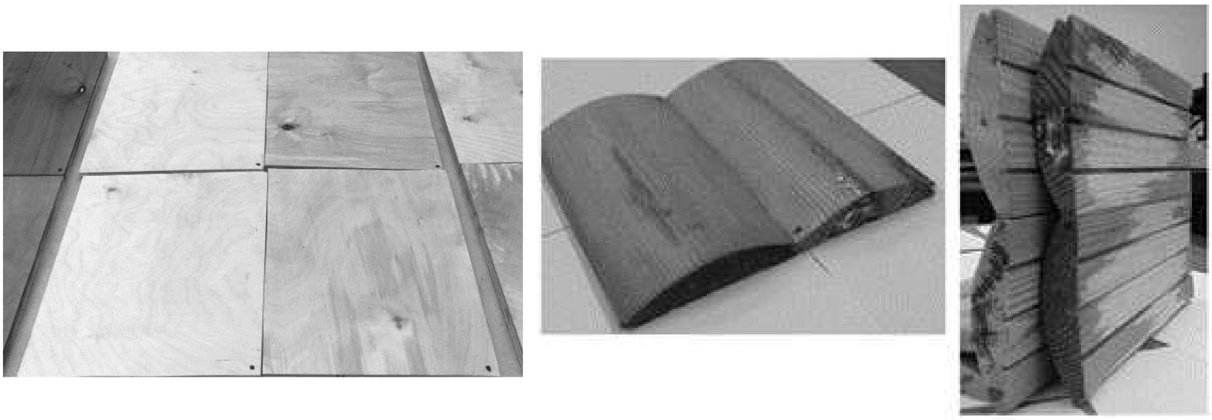

Figure 2. Wood samples.

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 IR-thermography.

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 3(a)) and treated one by the antiseptic for wood «Pirilax-Classic» (Figure 3(b)); untreated aspen sample (Figure 3(c)); specimen treated by fire retardant «SENEZH OGNEBIO PROF» (Figure 3(d)); untreated plywood (Figure 3(e)); plywood sample treated by fire retardant «SENEZH OGNEBIO PROF» (Figure 3(f)); untreated oriented strand board (Figure 3(g)); oriented strand board treated by fire retardant «SENEZH OGNEBIO PROF» (Figure 3(h)).

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.

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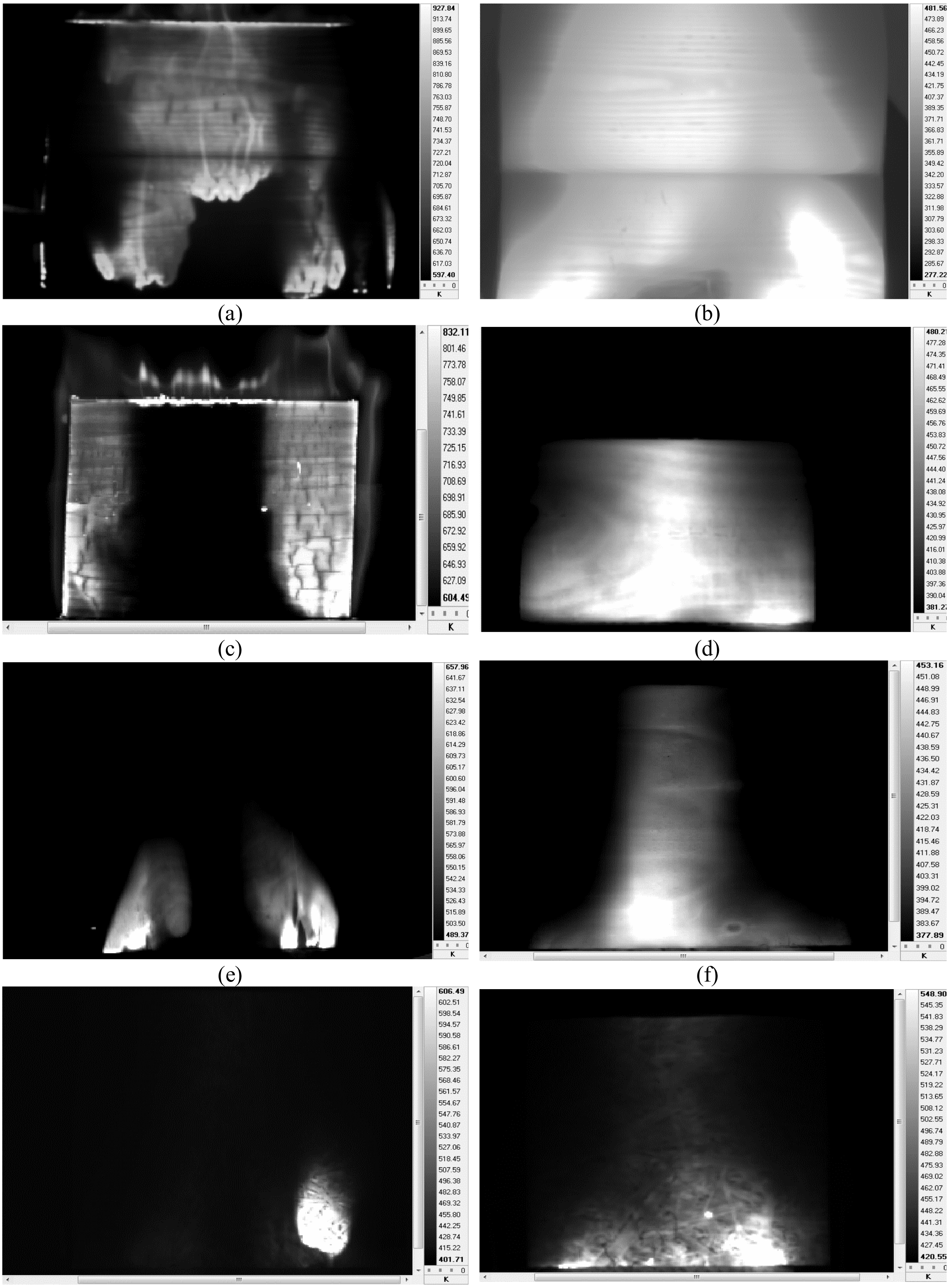

(a) (b) (c) (d) (e) (f) (g) (h)

Figure 3. Thermograms of sample surfaces after fire exposure.

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	$T_{max\ av}^{*}$, °C
Block House (pine)	«Pirilax Classsic»	278
	«SENEZH OGNEBIO PROF»	253
	«MIG-09»	266
	«FUKAM»	240
	Without treatment	664
Flat larch	«Pirilax Classsic»	247
	«SENEZH OGNEBIO PROF»	245
	«MIG-09»	291
	«FUKAM»	279
	Without treatment	310
Flat aspen	«Pirilax Classsic»	288
	«SENEZH OGNEBIO PROF»	226
	«MIG-09»	239
	«FUKAM»	290
	Without treatment	712
Flat pine	«Pirilax Classsic»	303
	«SENEZH OGNEBIO PROF»	236
	«MIG-09»	260
	«FUKAM»	244
	Without treatment	740
Plywood	«Pirilax Classsic»	247
	«SENEZH OGNEBIO PROF»	209
	«MIG-09»	218
	«FUKAM»	228
	Without treatment	663
Oriented strand board (OSB)	«Pirilax Classsic»	574
	«SENEZH OGNEBIO PROF»	468
	«MIG-09»	365
	«FUKAM»	462
	Without treatment	584

* - 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.

Acknowledgments
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