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WOOD BURNING RATE OF SELECTED GROUPS OF BROADLEAF TREES EXPOSED TO A RADIANT HEAT SOURCE

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ABSTRACT

The result of the experiment is represented by burning rate course of broadleaf wood exposed to a heat source. Broad-leaf wood is divided into three categories: hard ring-porous, hard diffuse-porous and soft diffuse-porous wood.

Key words: broad-leaf trees, relative burning rate.

INTRODUCTION

Wood has always been the material giving fire to people and man used it to his advantage. By using wood, man was able to keep the fire burning and use it when he needed to. As wood was considered a type of fuel, man´s attitude to fire was positive, however, when considering wood as a construction material, this property is regarded as rather negative. Along with the term *burning*, the term *fire* has been introduced. Burning is a phenomenon which cannot be considered identical to the term *fire.* If talking about burning and fire in general, we mean an intentional and desired process with a particular aim. Burning takes place in a given time and place using a suitable material - fuel. The energy gained is consumed. Fire represents an unwanted burning, in an unwanted space and time. All ignitable materials affected by fire become fuel for the fire (OSVALD 1997).

Wood and wood-based materials are assessed from the point of view of their reaction to fire i.e. fire proprieties or the change in properties in case of fire (thermal load). The study of this aspect of wood burning is not easy. From the chemical point of view, thermal degradation of wood is a rather complex process (BUBENÍKOVÁ *et al*. 2004, KAČÍK *et al*. 2007, DRAXLEROVÁ *et al*. 2014) influenced by a wide range of physical wood properties (OSVALD 1997, OSVALDOVÁ 2005, ZACHAR, MARKOVÁ 2009). In addition, biological character of wood (as proven in our experiment) also has an effect on the observed values. The aim of the experiment was monitoring three groups of broadleaf trees (hard ring-porous, hard diffuse-porous and soft diffuse-porous) exposed to a radiant and flame heat source of low strength, burning speed being the assessment criterion.

EXPERIMENTAL PART

Wood of the selected trees

Following types of broad-leaf wood have been used for the experiment. Trees have been divided into groups according to their anatomic characteristics.

Hard ring-porous wood

Black locust (*Robinia pseudoacacia* L.)
Sessile oak (*Quercus petraea* (MATTUSCH) LIEBL.)

Hard diffuse-porous wood

Downy birch (*Betula pubescens* Ehrh.)
Common beech (*Fagus sylvatica* L.)
Sycamore maple (*Acer pseudoplatanus* L.)

Soft diffuse-porous wood

Black alder (*Alnus glutinosa* L.)
Small-leaved lime (*Tilia cordata* Mill.)
European aspen (*Populus tremula* L.)

Test specimens for the experiment

Test specimens of 40 × 20 × 20 mm (see fig. 1) at the moisture content of 8–10 % have been prepared from wood of the above mentioned wood types. Their surface has been rubbed and the specimens have been sorted according to their density within the group (wood type). Density interval was ± 15 $kg{\cdot}m^{-3}$. 120 specimens - 15 specimens per each wood type – have been used for the experiment. These specimens met the density interval and had the smallest deviation from the average value.

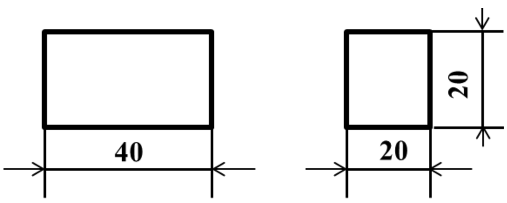

Fig. 1 Dimensions of test specimens (mm).

Thermal load

Simple device - consisting of scales, asbestos boards (to protect scales against heat radiation), stand, support frame, radiant heat source (radiator) and clamp holder for test specimens - was used for the experiment

Apparatus is composed of electronic weighing scales Sartorius Basic plus type BDBC from Sartorius AG Company, I. class of accuracy with automatic weighing instruments, measuring with an accuracy of two decimal places and the maximum weight 2100 g.

Electromagnetic radiation is common in the nature as every single body emits it. Division of energy according to its length or frequency depends on the temperature of the body. Infrared heater is used as heat radiation source. Heat transfer from the heater was carried out by diffusion of electromagnetic radiation of 0.75–12 J.m of wavelength which is, after being absorbed by a solid, transformed into heat. The heater is of a flat shape bent slightly into arch shape in the direction of the longitudinal axis of the body. Radiation was given off by the front side, back side and front edges of the heater. Dimensions and parameters of the heater are shown in tab. 1 (ZAŤKO 1996).

Test Procedure

Prior to the experiment, weight and dimensions of the test specimens were determined and density at the given moisture level was calculated. Test specimens were placed under the heater and at the same time Sarto collect program has been run. This program is set to record weight of the test specimens every 10 seconds. This means that the table contains information about the weight of the specimens in 10 second intervals. After 15 minutes, Sarto collect program stops automatically. If the test specimen burns down in less than 15 minutes, the experiment is over.

Tab. 1 Dimensions and parameters of heater.

Parameters	Dimensions
Total length	$l_ž$ = 245 mm
Working length	l_p = 200 mm
Outer width	$š_1$ = 85 mm
Inner width	$š_2$ = 64 mm
Thickness	h = 5 mm
Height	v = 30 mm
Temperature (30 mm from the heater)	$t_ž$ = 130 °C
Power input	P =750 W
Surface temperature of the heaters	t_p = 579.4 °C
Maximum wavelength	l_{max} = 3.34 mm
Surface of heater	Sc = 0.0318 m^2
Emissivity	e = 0.84
Amount of energy emitted	Qcc = 669.95 W
Intensity of emission	E_g = 2.105 W·cm^{-2}
Efficiency	h = 89.285 %

Assessment criterion - relative burning rate

Relative burning rate has been determined according to the formulas (1) and (2):

$$v_r = \left| \frac{\partial \delta_m}{\partial \tau} \right| \ (\%\cdot s^{-1}) \qquad (1)$$

or numerically

$$v_r = \frac{\left| \delta_m(\tau) - \delta_m(\tau + \Delta\tau) \right|}{\Delta\tau} \ (\%\cdot s^{-1}) \qquad (2)$$

where:

v_r – relative burning rate (%.s^{-1}),
$\delta_m(\tau)$ – relative weight loss in time (τ) (%),
$\delta_m(\tau+\Delta\tau)$ – relative weight loss in time ($\tau + \Delta\tau$) (%),
$\Delta\tau$ – time interval when weights are being subtracted (s).

RESULTS AND DISCUSSION

Fig. 2–5 show relative burning rate course of the selected wood types exposed to a radiant heat source. The curves represent average values of 15 measurements for each tree.

Fig. 2–5 show the burning rate course while exposed to a radiant heat source. As previously mentioned, laboratory equipment measured and recorded the weight loss continuously. Relative burning rate was then calculated on the basis of such measurement.

Burning rate indicates the behavior of the material in case of a fire. For this reason, the property has been chosen as the evaluation criterion.

The study of wood burning is rather complex. Wood is a heterogeneous material regarding its chemical composition as well as its properties. "Chemical studies", described in details by various authors (KAČÍKOVÁ 2007, MARTINKA, CHREBET 2014), study the influence of chemical composition of wood, hemicellulose, cellulose and lignin and their impact on thermal degradation of wood. These studies complement works dealing with the influence of physical properties of wood on the burning process (OSVALD 1997, MITTEROVÁ *et al*. 2014, MARTINKA *et al*. 2014). Two physical properties that influence the process most are moisture content and density. Therefore, a great deal of attention has been paid to the selection of the test specimens so that the two physical properties of wood do not affect the observed data and can be regarded as constant.

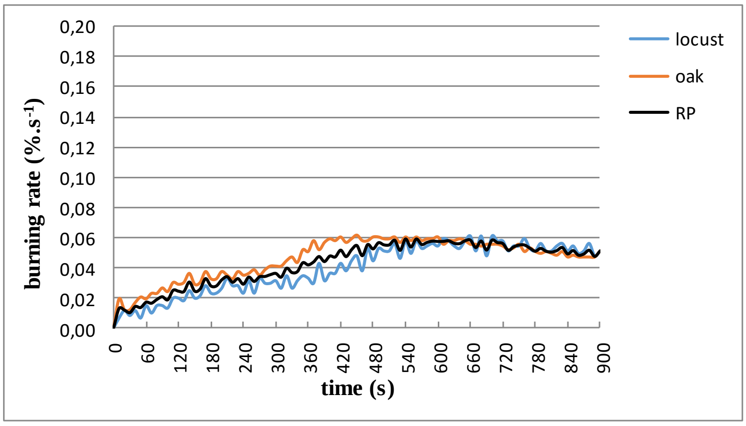

Fig. 2 Relative burning rate course for locust and oak wood exposed to a radiant heat source. Ring-porous (RP) specimens - average value for this group.

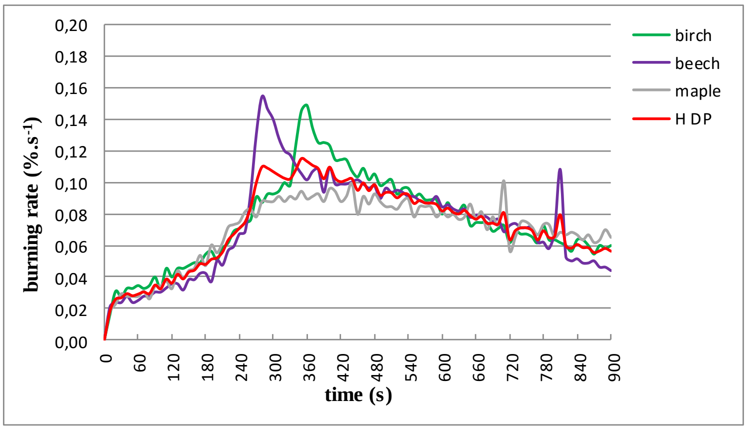

Fig. 3 Relative burning rate course for birch, beech, maple wood exposed to a radiant heat source. Hard diffuse-porous (H DP) specimens - average value for this group.

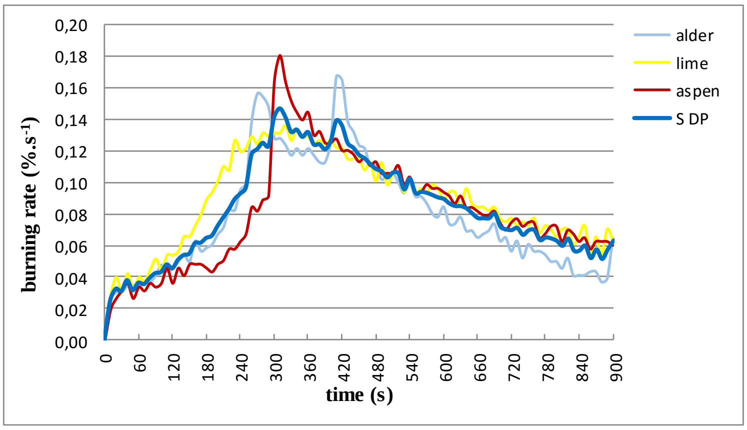

Fig. 4 Relative burning rate course for alder, lime, aspen wood exposed to a radiant heat source. Soft diffuse-porous (S DP) specimens - average value for this group.

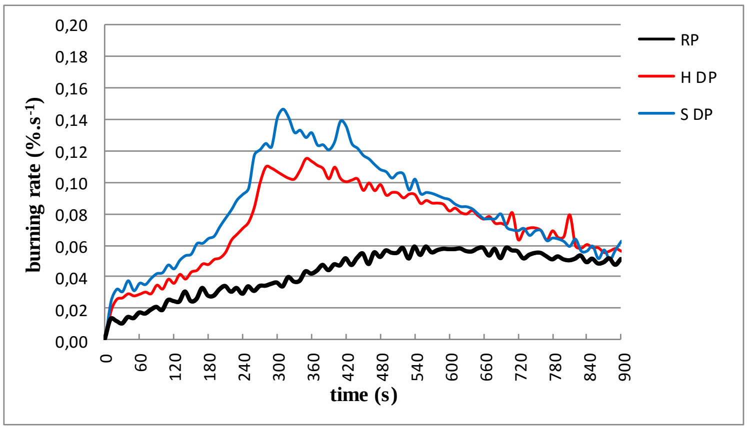

Fig. 5 Relative burning rate course for the selected groups of broadleaf wood exposed to a radiant heat source.

Further studies of wood structure (anatomy) and its influence on burning process are included in works (KAČÍK *et al*. 2001) dealing with microscopy. It is evident that conductive elements in wood structure play a role regarding its thermal degradation. Heat is transferred through these elements but the process also includes mass transfer - gas smokes from the wood structure and oxygen into the wood structure.

The aim of this paper is to find out, by means of thermal degradation, the impact of tree classification into groups of hard ring-porous, hard diffuse-porous and soft diffuse-porous trees. Fig.2 shows a group of ring-porous trees represented by locust and oak. For these types of wood (partly due to their density), the lowest values of relative burning rate have been recorded.

In case of diffuse-porous trees represented by birch, beech and maple (see fig. 3), the highest burning rate has been recorded for beech, followed by birch. Besides burning rate, time span in which the highest burning rate has been reached is considered an important indicator as well. The sooner it occurs, the worse. As for maple, relative burning rate has not been that high even though the development curve seems almost identical to the other specimens in the group.

Soft diffuse-porous trees represented by alder, lime and aspen (see fig. 4) also had relatively homogeneous burning rate course within this group. In case of alder, the highest burning rate was reached in the shortest time span. In general, the highest burning rate was however recorded for aspen. In case of lime, the highest burning rate was not recorded in a "standard way" (reaching peak values). The onset of burning had a gradual progress but it was fast from the very beginning of the experiment.

In fig. 5, average value curves for each tree category can be seen, depicting that selected groups have different burning rate course. On the basis of these findings, we recommend to pay more attention to wood structure even with the evaluation criteria classifying their thermal degradation.

CONCLUSION

Finally, we can conclude that by using a scientific approach, we have tried to complete basic information about wood degradation for different tree categories that have been exposed to thermal load - radiant heat source.

Complexity of wood as a natural heterogeneous material and its burning is caused by the fact that the material is heterogeneous both by its chemical composition and by the reactions resulting from its burning.

The results complement the information database in the given field of study. Firstly, it represents a basic research into properties of the selected trees and their reaction to fire.

The measurement was aimed at improving and upgrading information database following normative procedures which are not able to evaluate the given specifics. Therefore, the results of the experiment are considered contribution to scientific disciplines in the field of lumbering as well as in the area of fire protection.

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