

Effect of Fire-retardant Treatment on Flammability of Scots Pine Wood (*Pinus sylvestris L.*)

Vplyv retardačnej úpravy na horľavosť dreva Borovice lesnej (*Pinus sylvestris L.*)

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Abstract

The flammability of wood was assessed based on fire performance characteristics: the gross calorific value (GCV) and limiting oxygen index (LOI). Those parameters were also studied in the framework of this paper. The Scots pine wood test specimens with dimensions of 120 x 10 x 10 mm were used for LOI determination and specimens with dimensions of 15 x 10 x 10 mm for GCV determination. There was also studied the effect of fire-retardant treatment which was done by the foaming fire retardant based on phosphates (ammonium polyphosphate) applied as two-layer coating or as 24-hour impregnation. Higher gross calorific values were measured for specimens without any fire retardant treatment – $22\,298 \pm 131$ J/g; the coating resulted in decreased value of GCV to $22\,048 \pm 242$ J/g (by 1.12 %), and the impregnation caused decreasing in the GCV to $21\,679 \pm 104$ J/g (by 2.78 %) if compared to the non-treated specimens. However, the fire-retardant treatment was influenced more by the limiting oxygen index than by the gross calorific value.

Keywords: Scots pine, fire retardant, gross calorific value, limiting oxygen index

1 Introduction

Wood is one of the most important natural materials that is constantly used in many areas of today's modern world. Its important position is due to a number of its positive qualities. Thanks to its excellent material properties and desirable effect on the environment, wood is widely used in construction and furniture production [1]. However, its significant negative property is flammability.

A possibility how to suppress this negativum is to modify wood by fire retardant treatment. Flame retardants reduce the flammability of materials by physical or chemical ways, most

1 Úvod

Drevo je jedným z najdôležitejších prírodných materiálov, ktorý neustále nachádza uplatnenie v mnohých oblastiach aj dnešného moderného sveta. Za svoje významné postavenie vďaka celému radu pozitívnych vlastností. Vďaka svojim vynikajúcim materiálovým vlastnostiam a žiaducim účinkom na životné prostredie sa drevo vo veľkej miere uplatňuje v stavebníctve a pri výrobe nábytku [1]. K jeho výrazným negatívam však patrí horľavosť. Výrobky z dreva zvyšujú nebezpečenstvo požiaru.

often by a combination of them [2, 3]. There are three ways how to reduce wood flammability: the surface coatings, impregnation, and lamination [4].

The paper deals with the effect of fire retardant treatment on flammability of wood. The economically important pine wood (*Pinus sylvestris* L.) was chosen for the experiments. The wood density was 654 kg/m^3 (the density in absolute dry state).

The flammability of wood was assessed based on fire performance characteristics: the gross calorific value (GCV) and limiting oxygen index (LOI) according to the STN ISO 1928 [5] and STN EN ISO 4589-2 [6] standards.

2 Material and Methods

The tested wood was cut into test specimens; the specimens with dimensions of $120 \times 10 \times 10 \text{ mm}$ were used for LOI determination and specimens with dimensions of $15 \times 10 \times 10 \text{ mm}$ for GCV determination. The gross calorific value was determined by three measurements. For determination of the limiting oxygen index, at least 15 samples were required. In the LOI determination, the longitudinal section and cross section of the samples were distinguished.

Fire retardant treatment was done by the foaming fire retardant based on phosphates (ammonium polyphosphate) applied as two-layer coating or as 24-hour impregnation. Gross calorific value was determined for the specimens dried into the moisture content of 0 %, limiting oxygen index was determined at the actual moisture content of the pine specimens of 8.69 %.

Due to fire retardant treatment, the weight of the specimens increased if compared to the untreated specimens: coating – longitudinal section by 5 %, cross section by 12 %; impregnation – longitudinal section by 6 %, cross section by 21 %.

3 Results and Discussion

Gross calorific values are shown in Fig. 1. Higher values were measured for specimens without any fire retardant treatment – $22\,298 \pm 131 \text{ J/g}$; the coating resulted in decreased value of GCV to $22\,048 \pm 242 \text{ J/g}$ (by 1.12 %), and the impregnation caused decreasing in the GCV to $21\,679 \pm 104 \text{ J/g}$ (by 2.78 %) if compared to

Možnosťou ako potlačiť toto negatívum, je drevo modifikovať retardačnou úpravou. Retardéry horenia znižujú horľavosť materiálov fyzikálnou či chemickou cestou, najčastejšie ide o ich kombináciu [2, 3]. Znižovanie horľavosti dreva je možné prakticky tromi postupmi: povrchovými nátermi, impregnáciou, a laminovaním [4].

Príspevok sa zaoberá vplyvom retardačnej úpravy na horľavosť dreva našej hospodárskej významnej dreviny Borovice lesnej (*Pinus sylvestris* L.). Hustota vzoriek bola 654 kg/m^3 (hodnota hustoty stanovená v absolútne suchom stave vzoriek).

Horľavosť bola posudzovaná na základe požiarnych charakteristík spálneho tepla (GCV) a limitného kyslíkového čísla (LOI) stanovených v zmysle noriem STN ISO 1928 [5] a STN EN ISO 4589-2 [6].

2 Materiál a metódy

Vzorky dreva boli narezané na rozmery ($120 \times 10 \times 10 \text{ mm}$) pre stanovenie kyslíkového čísla a ($15 \times 10 \times 10 \text{ mm}$) pre stanovenie spálneho tepla. Spálne teplo jednotlivých typov vzoriek bolo stanovené 3 meraniami, pri kyslíkovom čísle bolo potrebných minimálne 15 vzoriek z každého typu. Pri kyslíkovom čísle sme zároveň rozlišovali pozdĺžny a priečny rez vzoriek.

Retardačná úprava bola realizovaná penotvorným retardačným prípravkom na báze fosfátov, konkrétne polyfosforečnanu amónneho, aplikovaným formou dvojvrstvového náteru a 24 hodinovej impregnácie. Spálne teplo bolo stanovené u vzoriek vysušených do 0 % vlhkosti, kyslíkové číslo bolo stanovené pri referenčnej vlhkosti vzoriek borovice 8,69 %.

Vplyvom modifikácie vzoriek retardačnou úpravou sa ich hmotnosť zvýšila oproti neupraveným vzorkám: náter - pozdĺžny rez o 5 %, priečny rez o 12 %, impregnácia - pozdĺžny rez o 6 %, priečny rez o 21 %.

3 Výsledky a diskusia

Hodnoty GCV sú znázornené na obr. 1. Vyššie hodnoty GCV boli dosiahnuté u vzoriek bez retardačnej úpravy - $22\,298 \pm 131 \text{ J/g}$, náterom sa hodnota znížila o 1,12 % na $22\,048 \pm 242 \text{ J/g}$ a impregnáciou sa hodnota znížila o 2,78 % na $21\,679 \pm 104 \text{ J/g}$ oproti pôvodnej

the non-treated specimens. The difference in the GCV between the two treatments (coating and impregnation) was 1.67 %. Alakangas [7] reports the GCV of 22 360 J/g for Scotch pine.

vzorke. Rozdiel v hodnotách GCV medzi úpravou náterom a impregnáciou predstavoval 1,67 %. Alakangas [7] uvádza hodnotu GCV pre Scotch pine 22 360 J/g.

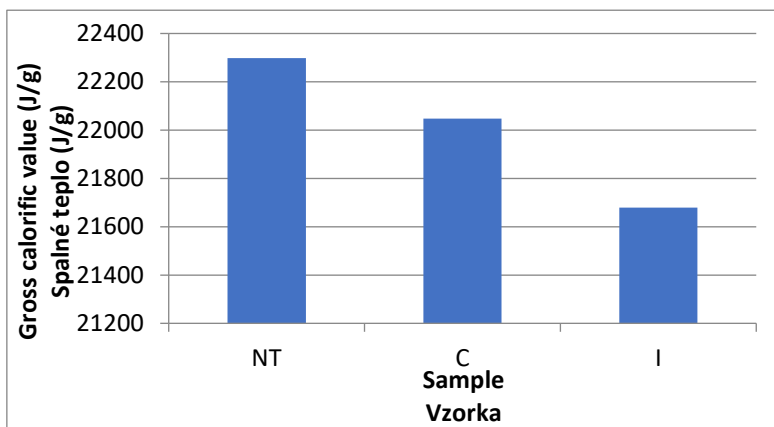


Fig 1. Gross calorific value of pine wood (NT – no treatment, C – coating, I – impregnation)

Obr. 1 Spalné teplo borovicového dreva (NT – bez úpravy, C – povrchová úprava, I – impregnácia)

The fire-retardant treatment affected not only the gross calorific values but also the resistant residue (ash). The ash values were: samples with no treatment – 0.13 %, samples with coating – 0.66 %, impregnated samples – 0.79 %.

Retardačná úprava ovplyvnila nielen hodnoty spálneho tepla, ale aj rezistentného zvyšku (popola). Popol dosiahol nasledujúce hodnoty: vzorky bez úpravy - 0,13 %, náter – 0,66 %, impregnácia – 0,79 %.

The fire-retardant treatment influenced the limiting oxygen index more than the gross calorific value. LOI values are shown in Fig 2.

Väčší vplyv mala retardačná úprava pri požiarnej charakteristike kyslíkového čísla. Hodnoty LOI sú uvedené na obr. 2.

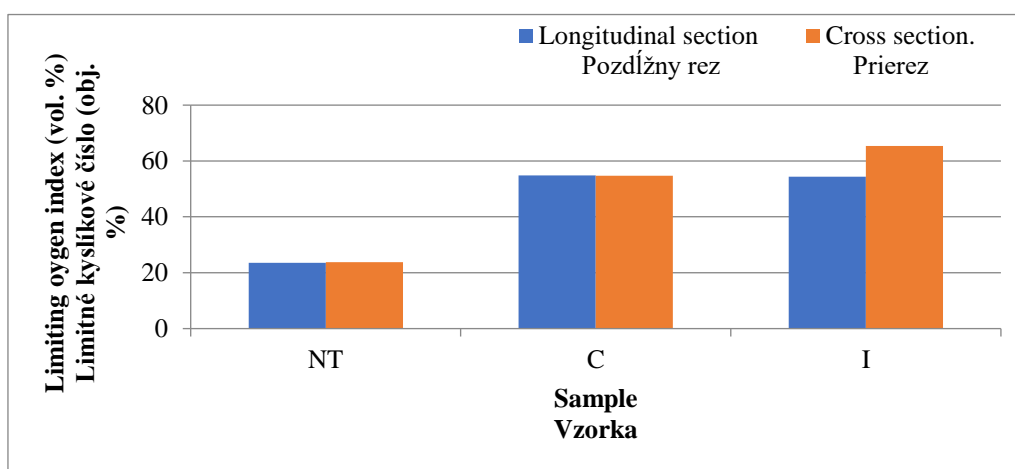


Fig 2. Limiting oxygen index of pine wood

Obr. 2 Limitné kyslíkové číslo borovicového dreva

The fire-retardant treatment caused increasing the LOI several times if compared with the untreated samples. Specimens with no treatment showed the LOI value of 23.6 ± 0.4 vol. % in the longitudinal section and 23.8 ± 0.4 vol. % in the cross section. The coating caused increasing the LOI by 132 % in both sections; the impregnation caused similar increasing the LOI in the longitudinal section. In the impregnation, the effect of the cut direction was more pronounced; in the cross section, the LOI increased by 177 %. Wang et al. [8] determined LOI for Chinese fir for 3 various fire retardants: 50.7 vol. %, 43.5 vol. %, and 55.0 vol. %.

4 Conclusions

The gross calorific value is the highest amount of heat that a material is able to deliver. In terms of fire protection and safety, respectively flammability, it is important that the gross calorific value of materials is as low as possible and the limiting oxygen index as high as possible. The higher is the LOI of a material, the less flammable material it is. The presented results show that the chosen fire-retardant treatment lowered the flammability of pine wood, if evaluated on the base of the gross calorific value and the limiting oxygen index.

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Retardačná úprava výrazne ovplyvnila výsledky hodnôt LOI, ktoré sa niekoľkonásobne zvýšili oproti vzorkám bez úpravy. Vzorky bez úpravy dosiahli hodnoty LOI v pozdĺžnom reze $23,6 \pm 0,4$ obj. % a v priečnom reze $23,8 \pm 0,4$ obj. %. Náterom sa hodnoty zvýšili o 132 % v oboch rezoch, podobne ako aj impregnáciou v pozdĺžnom reze. Vplyv rezu sa vo väčšej miere prejavil pri impregnácii. V priečnom reze sa impregnáciou zvýšila hodnota LOI až o 177 %. Wang et al. [8] stanovili u čínskej jedle pri 3 rôznych retardačných látkach hodnoty LOI 50,7 obj. %, 43,5 obj. %, 55,0 obj. %.

4 Záver

Spalné teplo predstavuje najvyššiu hodnotu tepla, ktorú je materiál schopný vydať. Z hľadiska protipožiarnej ochrany a bezpečnosti, resp. z pohľadu horľavosti je dôležité, aby hodnoty spalného tepla materiálov boli čo najnižšie a naopak hodnoty limitného kyslíkového čísla čo najvyššie. Čím má materiál vyššiu hodnotu LOI, tým je menej horľavý. Z prezentovaných výsledkov vyplýva, že retardačná úprava vybranou retardačnou látkou, mala vplyv na zníženie horľavosti dreva borovice z hľadiska hodnotenia spalného tepla a limitného kyslíkového čísla.

Pod'akovanie

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