Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 72, 2010: 331-335
(Ann. WULS-SGGW, For. And Wood Technol., 72, 2010)

Examination of common ash (*Fraxinus excelsior* L.) colour change after heat treatment

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Abstract: The aim of this work was to specify colour change in common ash wood (*Fraxinus excelsior* L.) after heat treatment. It was performed in steam or in the air with different durations (2, 6, 10h), in the temperature of 190°C. Darkening of ash wood increases with the treatment duration. Colour significantly depends on the treatment conditions – ash wood treated in steam is lighter in relation to samples treated in the air.

Keywords: wood colour, L*a*b* system, heat treatment, ash wood

INTRODUCTION

Market of heat treated wood intensively developes in Europe as well as in the rest of the world. New factories arise which specialize in manufacture of heat treated wood both in the raw state and in the form of finished products such as parquets, facades and plywood. Different manufacturers elaborated their own treatment processes suitable to specific wood species and final product.

Heat treatment should be performed in the oxygen-free environment what protects wood against exvessive degradation during process. Treatment environments, which are most often applied, are: steam, nitrogen, oil, exhaust gas, at the action of high temperature in the range of 160-230°C (Hill, 2006).

Natural wood durability, hardness and dimensional stability increase as the result of heat treatment of wood (Sivonen et al., 2002). Decrease of equivalent moisture level is an additional effect. Changes mentioned above are most probably caused by hemicelluloses decomposition to monosaccharides (Yildiz, 2006), partial degradation of cellulose with low polimerisation degree and the increase of crystallinity degree of cellulose with high polimerisation degree (Gawron et al., 2009; Yildiz & Gumukaya, 2007).

Apart from apllied processing parameters, one of the most important attribute of treated wood is the change of its colour. Wood darken during heat treatment process and may imitate exotic wood. Properly performed heat treatment causes the colour change in whole wood section. Darkening process can be controlled to obtain required shade, from light to very dark. This is determined by the duration and temperature of treatment process.

Despite the progress in analysis of physical and mechanical properties of wood treated by heat, there are no complex researches related to these properties. The purpose of this paper is to determine the colour changes which take place in the common ash wood (*Fraxinus excelsior* L.) after heat treatment in steam and air (to emphasise the colour change), different durations (2, 6, 10h), at the temperature of 190°C.

MATERIALS AND METHODS

The heat treatment program applied in current paper is based on the process elaborated by FINFOREST company. Treatment parameters were selected in order to make them compatible with conditions recommended and most often used in the polish marked for ash wood.

Analysed samples were gained from the coloured part of ash heartwood (*Fraxinus excelsior* L.). 224 samples (20x20x30 mm) were cut from one board. They were sorted by

density and divided into 7 groups of 32 samples. 3 groups were treated with the oxygen acces, in the temperature of 190°C, duration 2, 6 and 10 h. Following 3 groups were treated in steam in the temperature of 190°C, duration 2, 6 and 10 h.

Process started in each case from samples drying to absolute humidity 0%. Then the temperature in the treatment chamber with samples was raised to assumed value of 190°C with the heating rate of 0,4°C/min. Time of specific treatment was started one hour after riching the assumed temperature. In case of the treatment in steam, the steam was introduced to the chamber in the temperauture of 130°C. Course of treatment process is illustrated in the fig. 1.

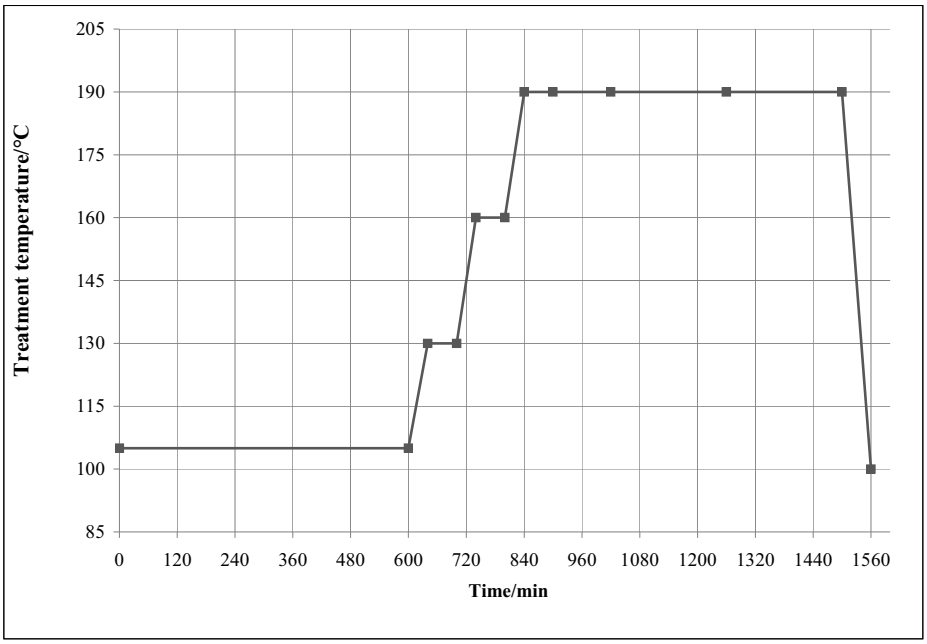

Figure 1. Course of treatment process.

Samples were cooled after heat treatment and seasoning within one month in normal atmospheric conditions, but without sunshine access. X-Rite SP-60 compact spherical spectrophotometer was applied to colour specification. Colour was described in L*a*b* system. Colour index was calculated basing on components:

- total colour difference, from the equation:

$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, where

$\Delta L^* = L^*_T - L^*_R$ - brightness difference

$\Delta a^* = a^*_T - a^*_R$ - red colour difference (a>0)

$\Delta b^* = b^*_T - b^*_R$ - yellow colour difference (b>0)

- chromaticity (colour saturation) from the equation:

$C^*_{ab} = (a^{*\,2} + b^{*\,2})^{1/2}$

• shade, from the equation:

$$H^* = arctg(b^* / a^*)$$

Mean values were calculated from obtained results (5 measurements on one sample). There have not been any standard defining the way of wood colour change analysis until now. That is why following standards were exploited: PN-ISO 7724-1:2003 Paints and laquers - Colorimetry – Part 1: Basics, PN-ISO 7724-2:2003 Paints and laquers - Colorimetry – Part 2: Colour specification, PN-ISO 7724-3:2003 Paints and laquers - Colorimetry – Part 3: Colour differences calculation.

RESULTS

Table 1 presents data obtained for individual types of wood treatment. Heat treatment causes significant colour change both in steam environment and with oxygen acces, what arises from colour coordinates analysis. Brightness value decrease with treatment time, what means wood darkening. Colour of samples treated 10 hours with oxygen acces (in the air) changed most significant (brightness mean value L*=39,13). Samples treated in the steam environment are a bit lighter (brightness mean value L*= 43,67). Also for 6 and 2 hours duration samples after treatment in the steam are lighter than ones treated in the air.

Table 1. Colour characteristics of wood untreated and treated in the air and steam environment.

Colour characteristic		Untreated wood	Wood treated with oxygen access			Wood treated in steam		
			2h	6h	10h	2h	6h	10h
Brightness (L*)	L^*_{min}	59,81	34,08	34,08	35,54	45,84	42,3	35,64
	L^*_{mean}	**71,59**	**45,00**	**40,81**	**39,13**	**51,32**	**48,9**	**43,67**
	L^*_{max}	83,57	78,16	47,58	42,92	61,48	53,65	51,12
	s*	3,36	5,41	3,12	2,08	4,02	3,27	3,68
	v**/%	4,70	12,01	7,65	5,31	7,83	6,80	8,42
Chromaticity (C*)	C^*_{min}	17,65	16,65	9,7	13,77	22,61	19,01	13,34
	C^*_{mean}	**22,36**	**22,72**	**18,27**	**16,87**	**25,62**	**22,61**	**19,63**
	C^*_{max}	27,11	27,48	75,01	20,75	28,67	25,7	24,32
	s*	1,68	2,46	3,13	1,81	1,83	1,99	2,62
	v**/%	7,52	10,82	17,12	10,73	7,13	8,79	13,33
Shade (H*)	$H^*_{min}/^o$	68,54	69,70	65,64	68,35	73,3	72,18	69,51
	$H^*_{śr}/^o$	**75,82**	**73,53**	**71,32**	**71,04**	**75,49**	**74,59**	**73,08**
	$H^*_{max}/^o$	83,19	75,83	75,01	72,77	78,16	76,38	75,92
	s*	4,06	1,30	1,71	1,00	1,24	1,06	1,30
	v**/%	5,35	1,77	2,39	1,41	1,64	1,42	1,78

*- standard deviation

** - variation coefficient

Two residual colour characteristics (chromaticity and shade) also change after heat treatment. These changes are insignificant but increasing with the treatment time. Value of shade decreased from 75,82^o to 71,04^o (in the air) and 73,08^o (in the steam). Our results show that ash colour shade is not pure yellow, but more yellow than red (angle close to 90^o indicates yellow shade, close to 0^o or 360^o – red shade).

Criterion used by International Commission of Illumination (CIE) was applied. According to this criterion, total colour difference ΔE* are classified, which are adequate to human colour perception. It is assumed that colour difference between 0 and 2 is not recognizable, from 2 to 3,5 – recognizable by inexperienced observer, values above 3,5 mean the observable significant colour deviation. All of our treated samples significantly differs from untreated ones in respect of colouring. Colour difference of wood treated with the oxygen access is slightly higher in relation to wood treated in the steam environment (fig. 2).

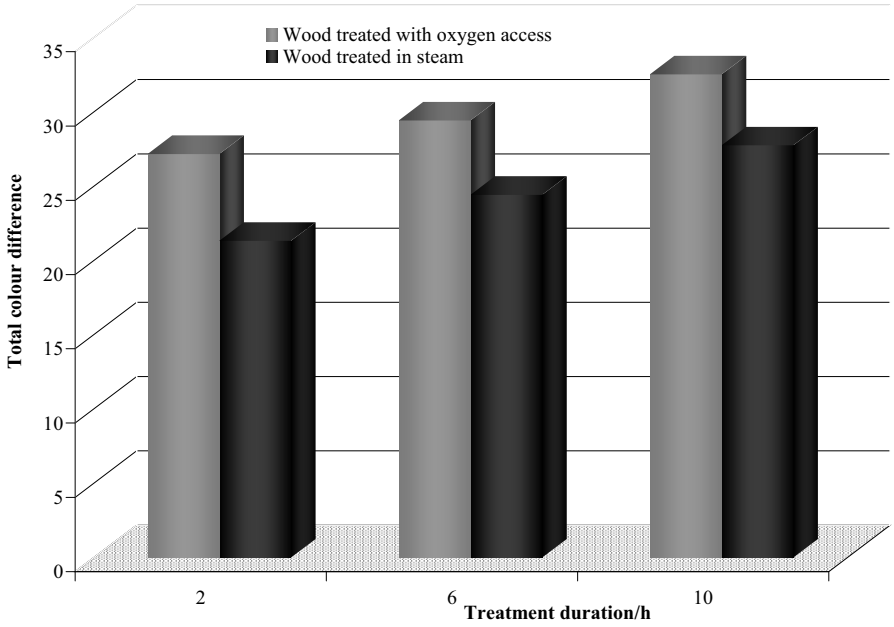

Figure 2. Total colour difference of wood treated in the air and the steam in relation to untreated samples.

CONCLUSION

Applied method of heat treatment causes colour change, apart from process parameters. Samples darkening takes place and its intensity increases with treatment time. Apart from process duration, samples treated in steam are lighter in relation to wood treated with the oxygen acces.

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9. PN-ISO 7724-3:2003 Farby i lakiery – Kolorymetria – Część 3: Obliczanie różnic barwy.

Streszczenie: *Badanie zmian barwy drewna jesionu wyniosłego (Fraxinus excelsior L.) poddanego modyfikacji termicznej.* Próbki drewna jesionu wyniosłego, pozyskanych z zabarwionej części twardzieli, poddano modyfikacji 2-, 6- i 10-godzinnej w środowisku pary wodnej i z dostępem tlenu w temperaturze 190˚C. Do pomiarów barwy wykorzystano kompaktowy spektrofotometr sferyczny SP-60, firmy X-Rite. Wykazano, że proces termicznej obróbki drewna powoduje zmianę kolorystyki tego materiału. Największym pociemnieniem barwy charakteryzuje się drewno po 10-godzinnej, następnie po 6- i 2-godzinnej modyfikacji, z tym, że drewno znajdujące się w środowisku pary wodnej przybiera nieco jaśniejszą barwę, niż drewno poddane obróbce termicznej z dostępem tlenu.

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