Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 89, 2015: 89-94
(Ann. WULS - SGGW, For. and Wood Technol. 89, 2015)

Intensity of colour changes of spruce wood treated with selected coatings for windows during natural and xenotest weathering

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Abstract: In this work was searched colour stability of spruce wood (*Picea abies* Karst L.) painted with fine yellow-brown "pinia" pigmented (3 types) or transparent (4 types) coating systems recommended for wooden windows. Natural weathering was performed in accordance with the EN 927-3:2000 during 12, 24 and 36 months under a slope of 45° or 90° in smog environment of Zvolen, and accelerated weathering in Xenotest in accordance with the EN 927-6:2006 lasting from 1 to 12 weeks. Colour parameters of painted wood have been measured in the CIE-L*a*b* system using the Color Reader CR10. Finally the total colour differences ΔE were calculated. Colour stability of the pigmented coating systems was evidently better in comparison to the transparent ones. Comparing the total colour changes ΔE at the natural and accelerated weathering the following knowledge were determined: (1) by the accelerated ageing in Xenotest can be modeled the natural ageing under a slope of 90°; (2) on the other hand, higher total colour differences in exterior under a slope of 45° can be caused by a more intensive absorption of UV-light and by a more evident catching of emissions on surfaces of tested samples already in the first times of exposure.

Keywords: wooden windows, coatings, natural ageing, Xenotest, colour changes

INTRODUCTION

Wood without suitable surface modification or coating treatment is degradable by atmospheric conditions in a relatively short time (Williams et al. 2001). Coatings significantly increase the service life of wooden products in exteriors by limitation of colour changes and cracks creation. Influence of higher content of pigments in coating systems for prolongation of their durability was observed in practice and in more experiments (e.g. Grül et al. 2011, Reinprecht et al. 2013). Colour changes of wood during thermal modification (Jankowska and Kozakiewicz 2014) or weathering are usually measured in the CIE- L*a*b* colour system (CIE 1986, Evans and Chowdhury 2010, Matan and Matan 2012). They can be evaluated also visually but these results have a low uniformity with high subjectivities (Oltean et al. 2010). From instrumental more precise methods are suitable also spectrophotometric (Mamoňová and Reinprecht 2014) or other optical ones.

The aim of this experiment was to compare the total colour stability of selected coating systems used in practice for treatment of wooden windows. Exposures have been done in the natural exterior (from 12 to 36 months) and in Xenotest (from 1 to 12 weeks). This paper continues the work of Reinprecht et al. (2011) in which the same coating systems have been valued, but during shorter times, the natural exposure from 3 to 9 months and the Xenotest exposure lasting only 3 weeks.

MATERIAL AND METHODS

Norway spruce (*Picea abies* Karst L.) samples have been painted with acrylic, alkyd, polyurethane or special resin coating systems recommended for wooden windows (fine yellow-brown on pinia pigmented: P1 = ADLER, P2 = ZOWOSAN, P3 = GORI; transparent: T1 = REMMERS, T2 = SIKKENS, T3 = SIKKENS-V /Velux/, T4 = GLASURIT) – see

Table 1. Untreated – control samples were without coatings. Initial colour parameters of painted wood samples are in Table 2.
Samples 375 mm x 78 mm x 20 mm (LxRxT) have been tested in exterior conditions in accordance with EN 927-3:2000 under a slope of 45° or 90° in smog environment of Zvolen, using 4 replicates for colour measurements after 12, 24 and 36 months. This natural weathering was carried out in smog town conditions of town Zvolen, Slovakia, Central Europe – which lies in hollow with high occurrence of foggy days, smog and high temperature differences between summer (to 35 °C above zero) and winter (to -25 °C below zero).

Table 1: Types and kinds of application of tested coating systems for wooden windows

Type of coating system			**Kind of application**		
Coating system	**Paints**	**Polymer**	**Retention**	**Layers**	**Time of drying**
P1 = Adler	Primer	Alkyd-acrylic	120 ml/m^2	1	6 h
	Sealer	Acrylic-PUR	100 ml/m^2	1	3 h
	Top-layer	Acrylic-PUR	250 µm	1	12 h
P2 = Zowosan	Primer	Alkyd-acrylic	100 ml/m^2	1	4 h
	Top-layer	Acrylic-PUR	125 µm	2	6 h
P3 = Gori	Primer	Alkyd	100 ml/m^2	1	6 h
	Top-layer	Acrylic	125 µm	2	6 h
T1 = Remmers	Primer	Special resin	100 ml/m^2	1	4 h
	Top-layer	Acrylic-PUR	125 µm	2	6 h
T2 = Sikkens	Primer	Acrylic	120 ml/m^2	1	4 h
	Top-layer	Acrylic	125 µm	2	6 h
T3 = Sikkens–V	Primer	Acrylic	120 ml/m^2	1	4 h
	Top-layer	Acrylic	125 µm	2	6 h
T4 = Glassurit	Primer	Special resin	100 ml/m^2	1	6 h
	Top-layer	Acrylic	125 µm	2	6 h

Table 2: Initial colour parameters of painted and control spruce samples in CIE-Lab system

INITIAL Colour	**Adler P1**	**Zowosan P2**	**Gori P3**	**Remmers T1**	**Sikkens T2**	**Sikkens–V T3**	**Glassurit T4**	**Control**
L*	68.70	71.45	56.80	81.55	83.20	82.50	82.30	84.65
a*	11.95	17.75	17.15	1.50	3.70	4.45	3.95	0.95
b*	36.05	58.55	41.25	37.65	25.10	25.00	28.45	23.60

- L*, a*, b* before ageing are mean values from 24 measurements.
- P = pigmented on pinia; T = transparent.

Table 3 Exposure of samples in Xenotest during one week-cycle by a modified EN 927-6:2006

Accelerated weathering: 2 steps lasting 1-week (168 h)			**Functions**
1. Step		24 h	Temperature 45 ± 3 °C, Water - Spray off, UV off
2. Step	A	2.5 h	Temperature 50 ± 3 °C, Water - Spray off, UV Irradiance 0.55 W.m^{-2} at 340 nm
	B	0.5 h	Temperature 20 ± 1 °C, Water - Spray on, UV off
	A + B	3 h	
	Sub-cycle (A+B):		48 sub-cycles x 3-hours of one, (together 144 h)

- According to the EN 927-6:2006 the prescribed parameters for test chamber (2. Step / A) are as follows: UV Irradiance = 0.89 W.m^{-2} at 340 nm; Temperature = 60 ± 3 °C.

Samples 90 mm x 78 mm x 20 mm (LxRxT) have been tested by accelerated ageing in Xenotest Q-SUN Xe-1-S (Q-Lab Corporation, USA) in accordance with a modified EN 927-6:2006 during 12 weeks, measuring colours each one week (Table 3).
Colours have been valued in the CIE-L*a*b* system using Colour Reader CR-10 (Konika Minolta, Japan) by ISO 7724:1984. Total colour changes have been calculated by equation 1:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \qquad (1)$$

Then a comparison of the natural and accelerated weathering was done.

RESULTS AND DISCUSSION

Achieved results (Fig. 1 and 2) have shown a more or less good correspondence of the natural exterior and the model Xenotest weathering on the total colour changes of spruce wood treated with selected coating systems. The best colour stability, and also compatibility of different test methods have been shown for pigmented coatings P3 > P1 > P2. On the other hand, transparent coatings T1, T2, T3 and T4 guaranteed a worse colour stability of the painted spruce wood, mainly the T1. At the same time, tendencies for colour changes achieved for spruce samples painted with individual coating systems and following aged in exterior under a slope of 45° or 90°, respectively in Xenotest, have shown some lower and higher differences (Figs. 1, 2 and 3).

a) b)

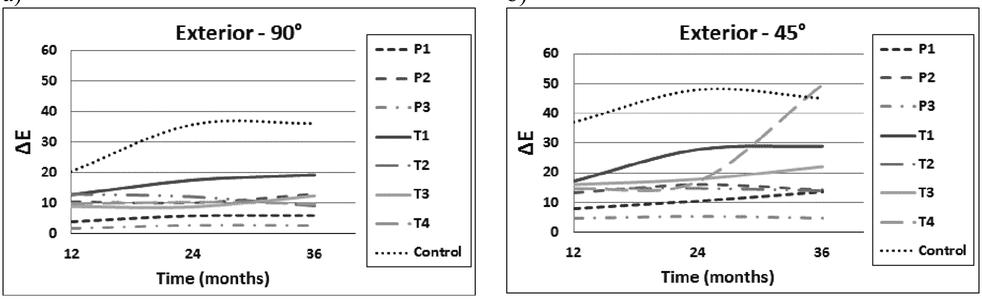

Fig. 1: The total colour change ΔE of painted and control Norway spruce samples during 3-years of exterior weathering (valued in 12th, 24th, and 36th month) under a slope of: a) 90°, b) 45°

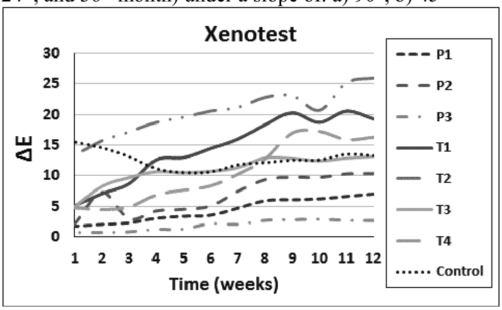

Fig. 2: The total colour change ΔE of painted and control Norway spruce samples during 12-weeks of accelerated weathering in Xenotest

Generally for natural ageing, the highest total colour changes due to more aggressive natural atmospheric conditions in the foggy town have been observed on pained spruce surfaces exposed under a slope of 45°. It can be explained by a higher absorption of UV-light and catching of more emissions – here was demonstrated more expressive combination of "sun radiance / emissions / water" – in comparison with samples exposed under a slope of 90°.

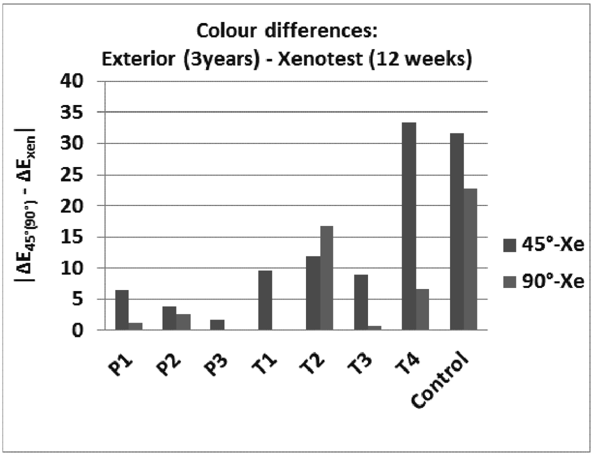

Fig. 3: Differences between the total colour changes ΔE for painted and control Norway spruce samples exposed in natural exterior conditions during 3 years and in Xenotest during 12 weeks

Results of this work well correspond with experiments of Grüll et al. (2011), Reinprecht and Pánek (2013), or other researches, who also observed positive effect of pigments for prolongation of service life of wooden window frames or other products in exteriors.
On the other hand, a suitable comparison of the natural and accelerated weathering methods for testing quality of coatings on wood is still not completely solved.

CONCLUSIONS

The pinia pigmented coating systems designed for spruce windows had a better colour stability than the transparent ones.

The total colour changes ΔE of spruce wood treated with pinia pigmented or transparent coatings were a more or less similar for both types of used weathering methods – natural in exterior and accelerated in Xenotest. However, evidently higher divergences in the colour changes occurred between the exterior exposure under a slope of 45° and the Xenotest exposure, as between the exterior exposure under a slope of 90° and the Xenotest exposure. For samples exposed under 45° it can be explained not only by a higher sorption of UV-light, but also by sorption of dark pollutants, higher differences in temperature, etc.

Acknowledgement: *The authors would like to thank the Grant Agency of the Slovak Republic (Project VEGA No. 1/0574/12) for the financial support in this work.*

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Streszczenie: *Intensywność zmian koloru drewna świerkowego wykończonego wybranymi powłokami podczas starzenia naturalnego i przyspieszonego xenotest.* Praca dotyczy stabilności koloru drewna świerkowego (Picea abies Karst L.) wykończonego żółtobrązowymi powłokami pigmentowymi (3 typy) i transparentnymi (4 typy) rekomendowanymi do okien drewnianych. Starzenie naturalne przebiegało zgodnie z normą EN 927-3:2000 przez 12, 24 I 36 miesięcy pod kątem 45° i 90° w klimacie miejskim Zvolenia, natomiast przyspieszone w Xenotest zgodnie z normą EN 927-6:2006 przez 1 do 12 tygodni. Kolory mierzono w systemie CIE-L*a*b* przy użyciu Color Reader CR10. Stabilność koloru powłok pigmentowych była ewidentnie lepsza niż transparentnych. Porównują zmiany przy naturalnym I przyspieszonym starzeniu można stwierdzić że efekt działania starzenia xenotest jest podobny do starzenia naturalnego pod kątem 90 stopni, przy 45 stopniach zmiany są większe co może być powodowane wyższą absorbcją promieniowania ultrafioletowego i osadzaniem się emisji atmosferycznych.

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