Effect of some oil and wax finishes on the water permeability of spruce *(Picea abies)*

Angelski, Dimitar

Department Furniture production, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria
*Corresponding author: d.angelski@ltu.bg

ABSTRACT

Conventional solvent-based finishes such as lacquer and varnishes provide a durable, high quality finish at a reasonable cost. However, they can also be significant sources of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). An alternative approach is to use finishes made from plant oils and waxes. They are easy to apply, give almost fully proved results and leave wood looking both rich and natural. Water permeability of finishes is an important factor in their wood protective function. This study evaluates the permeability of some commercial oil- and wax-based wood finish systems and ascertaines effects of coating layering on water permeability of spruce (*Picea abies*). The permeability of finishes in terms of liquid water absorption was measured acccording to standard EN 927. For this measurement, six different oil- and wax-based wood finish systems were used as protection on spruce test samples. Number of layers and finishing compositions clearly influence on the results revealed for the water permeability.

Key words: oil, spruce, water permeability, wax

1. INTRODUCTION

The fibrous nature of wood has made it one of the most appropriate and versatile raw materials for a variety of uses. However, two properties restrict its much wider use: dimensional changes when subjected to fluctuating humidity and susceptibility to biodegradation by microorganisms. The varying moisture content of wood results in dimensional and conformational instability, which can compromise the performance of other materials combined with wood, such as adhesives and surface coatings (Mantanis, G. I. *et al.*, 2000).

Finishing is one of the most utilized surfacing methods (Salca, E. A. *et al.* 2016). Oil and wax finishes offer a natural and environmentally friendly alternative to coatings and vanishing of wooden surfaces. These products are mainly based on renewable, natural vegetable oils that penetrate deeply into the wood, keeping it elastic and healthy, whilst preventing it from drying and becoming brittle. Oils and wax finishes are easy to apply with a brush or a rag, give almost foolproof results and leave wood looking both rich and natural. There are many different types of oils but some of the most popular ones are boiled linseed oil, tung oil, teak oil, mineral oil and Danish oil. The oils add a bit of protection to the wood against moisture. Linseed oil is one of the oldest penetrating finishes, but it tends to become sticky in humid weather. Danish oil offers more protection than other oils because it is a mixture of oil and varnish.

Waxes are nowadays used more and more to prolong the service life of wood. Waxes are derived from a variety of mineral, vegetable and animal sources. As a finish, waxes don't penetrate into the wood, but rather sit atop. Liquid or paste wax typically contains some solvent, and the wax "cures" as the solvent evaporates. The fact that they are soft means they offer very little protection against scratches and wear. In the past, waxes were predominately used as additives in water-repellent finishes and wood preservatives (Evans *et al.*, 2005; Zahora, 2000)

Nowadays there are several commercial treatments based on the wax alone without biocides (Berninghausen *et al.,* 2006). However, their big disadvantage is their lack of durability.

Permeability represents a material property that is of specific importance for different technical processes in the wood furniture industry (Kavalov A. *et al.* 2000). Permeability determines the flow of liquid or gaseous phases through a solid surface. Siau (1984) defines permeability as a measure of the ease with which fluids are transported through a porous solid under the influence of a pressure gradient. Although wood is a porous material (60–70 % void volume), its permeability or flow of water is extremely variable. This is due to the highly anisotropic arrangement of the component cells and to the variable condition of the microscopic channels between cells. Wood is much more permeable in the longitudinal direction than in the radial or tangential directions. Moisture uptake in wood can be explained by three different mechanisms: liquid water absorption into the wood, water vapor absorption into the wood, and water vapor desorption out of the wood (Ekstedt *et al.*, 2001). Moisture in wood can result in a wide variety of protective and decorative problems. Any failure of the protective finishes will allow water to penetrate into the wood. Once the finishing has been breached, moisture will continue to migrate into the wood which can result in decay and other failures (discoloring of the wood, twisting and cracking of the wood). The solution to all of these problems is to keep moisture from entering into the wood, to reduce the moisture content in the wood, and/or improvement of the dimensional stability of the wood.

The purpose of this study is to evaluate water permeability of some commercial oil- and wax-based wood coating (finishing) systems and ascertained effects of coating layering on water permeability of spruce (*Picea abies*). A standard test procedure, EN 927-5, has been launched for assessment of the water protection efficiency. The standard method described in EN 927-5 was developed to evaluate the water permeability of coating films, rather than the water uptake in different wood types.

2. MATERIALS, METHODS, EQUIPMENTS

For the tests, spruce (*Picea abies*) with a density of 475 kg/m^3 (at an equilibrium moisture content of 8 %) was used. The samples were prepared with the dimensions 150x70x20 mm (longitudinal, tangential, and radial directions, respectively). All faces were planed. The test samples were manufactured in accordance with the specifications in EN 927 - 5. For accurate results, specimens were selected without any defects, such as knots, cracks, resin spots, etc. The specimens were conditioned before the coating applications according to standards (20 °C ± 2 °C and 65 % ± 5 % RH.

The following ready-to-use products were used: Proterra Cerafluid GE 100 - oil-wax combination, based on non-drying vegetable oils, beeswax and carnuba wax; Proterra HardOil GE 11014 - linseed oil with lead-free additive substance; Proterra HardOil GE 11066 - a low-viscosity linseed oil; Osmo Hartwachs-Öl - based on natural vegetable oils and waxes (sunflower oil, soybean oil, carnauba wax, etc.), paraffin, siccative and water-repellent additives; Levis Hardwood Oil - based on vegetable oils; wax Liberon Black Bison - contains a blend of natural waxes (paraffin microcrystalline, carnuba wax).

The coating application was performed according to the technical data sheets supplied by the producers. After the application of the coatings, all remaining sides were sealed with two-component polyurethane (PU) system. Full description of the coating systems and the technology of the coating application is given in *Table 1*.

Table 1. Coating systems applied on spruce (Picea abies) and tested for water permeability:
I - Proterra HardOil GE 11014; II -Proterra HardOil GE 11066; III - Osmo Hartwachs-Öl;
IV - Liberon Black Bison Fine Paste; V - Levis Hardwood Oil; VI - Proterra Cerafluid GE 100.

			First coating		Second coating		Third coating	
Coating system	MWA, g/m²	Area, m²	Solid, g/m²	Liquid, g/m²	Solid, g/m²	Liquid, g/m²	Solid, g/m²	Liquid, g/m²
a. I	449.51	0.0103	32.01	46.56	-	-	-	-
b. I+I	319.61	0.0103	32.01	46.56	30.3	44.75	-	-
c. I+I+I	176.42	0.0103	32.01	46.56	30.3	44.75	30.05	43.11
d. II	724.82	0.0104	28.91	54.90	-	-	-	-
e. II+II	584.80	0.0104	28.91	54.90	24.54	44.60	-	-
f. II+II+II	578.49	0.0104	28.91	54.90	24.54	44.60	22.25	40.35
g. III	162.28	0.0101	40.59	55.18	-	-	-	-
h. III+III	33.34	0.0101	40.59	55.18	23.40	45.35	-	-
i. III+III+III	27.5	0.0101	40.59	55.18	23.40	45.35	24.98	44.84
j. IV	501.29	0.01	36.73	75.55	-	-	-	-
k. IV+IV	195.65	0.01	36.73	75.55	37.20	66.62	-	-
l. IV+IV+IV	28.75	0.01	36.73	75.55	37.20	66.62	35.12	66.67
m. II+IV	617.99	0.0102	40.28	65.18	23.7	70.55	-	-
n. II+II+IV	592.78	0.0102	40.28	65.18	23.46	45.32	23.61	70.05
o. III+IV	28.85	0.0099	32.03	46.65	24.02	71.23	-	-
p. III+III+IV	17.69	0.0099	32.03	46.65	29.98	44.32	22.98	70.05
q. V+VI	181.25	0.01	36.8	78.8	41	63.19	-	-
r. V+V+VI	27.95	0.01	36.8	78.8	35.42	69.21	40.82	63

The European standard EN 927-5 specifies a test method for assessing the liquid water permeability of coating systems for exterior wood by measuring the water absorption of coated wood panels (EN 927-5:2006). The liquid water permeability was determined as the increase in weight of the test samples after 72 hours of floating in water as specified in EN 927-5. For each set of five replicates, the arithmetic mean value of the weight increase and the standard deviation were calculated. The arithmetic mean value of the weight increase after 72 hours of floating is reported as mass of absorbed water per test face area (*MWA*).

The density was determined by measuring the dry weight after drying at 105°C. The moisture content (per cent of wood dry weight) was calculated as the difference between the weights before and after the drying process according to Standard Method EN 384 (1995).

The water absorbed by each specimen was measured as mass of absorbed water per test face area (*MWA*, g/m^2) relative to the weight of the conditioned specimen prior to the test, in accordance with EN 927-5 (1):

$$MWA_1 = (w_1 - w_0) / A \quad (1)$$

where:

MWA_1 = mass of absorbed water per area in g/m^2 at time 1
w_0 = weight in g at time 0
w_1 = weight in g at time 1
A = area of test face in m^2.

3. RESULTS AND DISCUSSION

The water absorbed by the samples for the tested homogeneous coatings systems are shown in Figure 1.

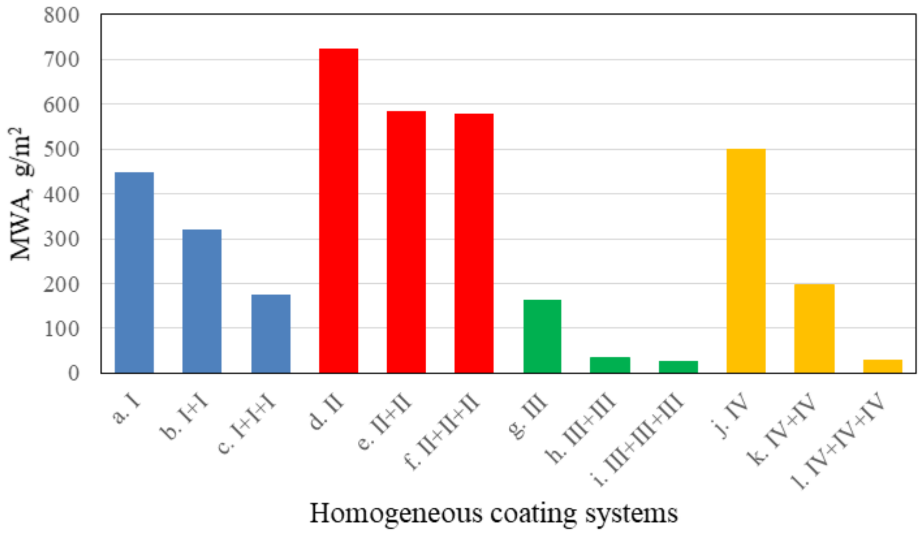

Figure 1. Mass of absorbed water per test face area (MWA) for the tested coatings systems:
I - Proterra HardOil GE 11014; II -Proterra HardOil GE 11066; III - Osmo Hartwachs-Öl; IV - Levis Hardwood Oil.

According to the European standard EN 927-2:2014, which classifies performance criteria for coating systems on exterior wood in relation to the expected dimensional changes, we have stable (maximum water absorption 175 g/m^2), semi-stable (from 175 g/m^2 to 250 g/m^2), and non-stable (over 250 g/m^2) end use categories. With single application of dominant part of the used oil- and wax-based products, the water absorption of the coatings falls into non-stable category. The best results regarding low water absorption of the coatings have been achieved with the brand Osmo Hartwachs-Öl.

For homogeneous coatings accomplished by the products Proterra HardOil GE 11014 and Levis Hardwood Oil the water absorption reduction is proportional to the number of layers applied. All coatings made with the low viscous linseed-oil based product - Proterra HardOil GE 11066 are characterized with very high water absorption.

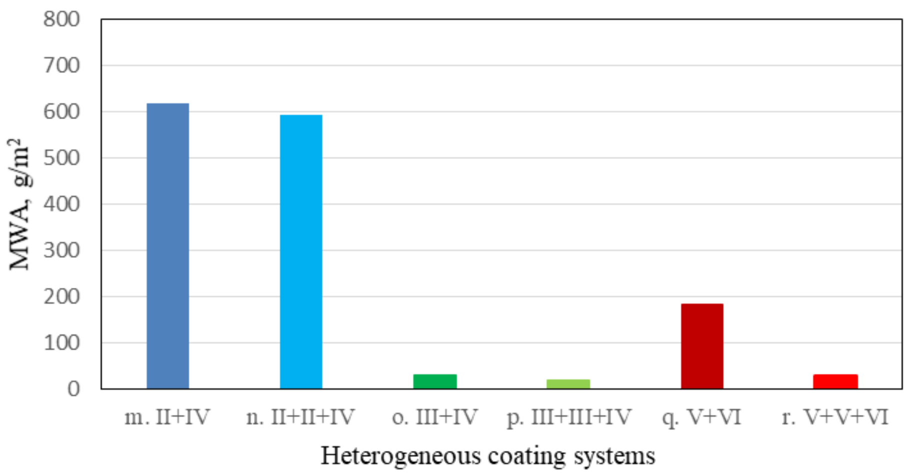

Figure 2. MWA for tested coatings systems:
II -Proterra HardOil GE 11066; III - Osmo Hartwachs-Öl; IV - Liberon Black Bison Fine Paste;
V- Levis Hardwood Oil; VI - Proterra Cerafluid GE 100.

The water absorbed by the samples for the tested heterogeneous coatings systems are shown in *Figure 2*. The combination of Proterra HardOil GE 11066 with finish coating from Liberon Black Bison Fine Paste does not result in considerable decrease of the water absorption of the so achieved heterogeneous coatings. The two-layer coatings of Osmo Hartwachs-Öl and Liberon Black Bison Fine Paste has very low water permeability. The three-layer coating *p* (2 layers - Osmo Hartwachs-Öl and finish layer - Liberon Black Bison Fine Paste) is with least value of absorbed water (mass of absorbed water per test face area) -17,69 g/m^2. The three-layer coating *r* (2 layers - Levis Hardwood Oil and 1 finish layer - Proterra Cerafluid GE 100) is again characterized with low water permeability thus classified in the stable category with respect to dimensional wood changes.

4. CONCLUSIONS

This study measures the water permeability of coating systems of six commercial oil and/or wax dispersions that resulted in wide variations of this property:

1. The water absorption is dependent on the producers of the coatings. These differences can be explained by the various content and composition of additives or by the modification of oils and waxes in tested coating systems.
2. Layering affected the permeability. By one-layer application of oil and/or wax-based products over a spruce surface, the water absorption of most of the coatings is over 250 g/m^2. This quantity of water results in dimensional changes of the wood. In this relation, in order to maintain the wood dimensions stable, it is recommended a 3-layer application of coating to be made. However, for part of the used ready products, the application of third layer leads to insignificant reduction of the water permeability of the coating.
3. The proper combination of vegetable oil and wax-based products reduces the water absorption of the coatings. The heterogeneous coatings produced with Osmo Hartwachs-Öl and Liberon Black Bison Fine Paste have very low water absorption. The same result is achieved also with the two-layer coatings (first layer - Osmo Hartwachs-Öl and finish layer Liberon Black Bison Fine Paste).

Acknowledgements: This document was supported by the grant No BG05M2OP001-2.009-0034-C01, financed by the Science and Education for Smart Growth Operational Program (2014-2020) and co-financed by the EU through the ESIF.

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