The Effects of Exposure to Sea Water Steam on Thermal Conductivity of Varnished Fir Wood

***Raşit ESEN[1], Cemal ÖZCAN[1], Erkan LİKOS[1], Osman Emre ÖZKAN[2]**
[1]Karabuk University, Technical Education Faculty, Karabuk, TURKEY
[2]Kastamonu University, Faculty of Forestry, Kastamonu, TURKEY
*Corresponding Author e-mail: resen@karabuk.edu.tr

Abstract
In this study, the thermal conductivity of varnished fir wood exposed to sea water steam was investigated. For this purpose, test samples were coated by using varnishing goldspar (polyurethane varnish), original (synthetic varnish), perfection (polyurethane varnish), and schooner varnishes (synthetic varnish). After applying furnished process, samples were exposed to sea water steam during 6, 24, 60, and 96 hours. It was found that the vapour application has decreased the chemical and physical structure of test material. The thermal conductivity test was performed based on the ASTM C 1113-99 hot-wire method.
Key words: Wood, Varnish, Thermal Conductivity

Introduction

The thermal conductivity of wood is affected by a number of basic factors: density, moisture content, extractive content, grain direction, structural irregularities such as checks and knots, fiber angle, and temperature. Thermal conductivity increases as density, moisture content, temperature, or extractive content of the wood increases. Thermal conductivity is nearly the same in the radial and tangential directions with respect to the growth rings [1].

In general, the thermal conductivity of wood is low because its structure is porous. Dry wood is one of the poorest conductors of heat due in part to the low conductivity of the actual cell wall materials, and in part to the cellular nature of wood, which in its dry state contains within the cell cavities a large volume of air – one of the poorest conductors known [2].

Feist and Williams have left the wood open to external influences before its surface was varnished then exposed to external influences, trying to determine the performance of varnish layer [3].

Gratham et. al. have studies the external factors that influence the ability of varnish on the wood after using preservative varnish layer [4].

In this study, we determined the thermal conductivity coefficient that can occur in fir wood materials covered with various varnishes (e.g., original, goldspar, schoneer, and perfection) followed to the application of sea water vapor.

Material and Method

Wood species

Fir (*Abies bornmülleriana* Mattf.) was chosen randomly from timber suppliers of Ankara, Turkey. A special emphasis was put on the selection of the wood material. Accordingly, non-deficient, whole, knotless, normally grown (without zone line, reaction wood, decay, insect or fungal infection) wood materials were selected.

Varnishing Materials

Synthetic varnishes (original and schooner) and polyurethane varnishes (goldspar and perfection) were used. These varnishes are preferred by the yacht industry [5].

Determination of Density

Wood materials were kept at room temperature of 20 ± 2°C and 65 ± 3 % relative humidity until their weight became stable [6]. Air dry densities of wood materials before and after impregnating the samples were determined according to TS 2472 [7]. Afterwards, the dimensions of wood materials were measured by a compass with ±0,001 sensitivity and volumes were determined by a stereo-metric method. The air dry density (δ_{12}) was calculated using the following equation:

$$\delta_{12} = M_{12}/V_{12} \quad g/cm^3 \qquad (1)$$

where M_{12} is the perfect air dry weight (g) and V_{12} is the volume (cm^3) of the wood material.

Preparation of Experimental samples

The wood samples cut from sap wood were conditioned at 20 ± 2°C and 65± 3% relative humidity until they reached constant weight by holding them for 3 months in a climatization room. Air-dry specimens of 50 x 50 x 100 mm were cut from the drafts for varnish. The wood samples cut from sap wood were conditioned at 20 ± 2°C and 65± 3% relative humidity until they reached constant weight by holding them for two weeks under normal conditions in a climatization room. After that, finished has been applied according to principles of ASTM D-3024. The advice of the manufacturing factories involved in the finishing field has been taken into consideration (8). After varnishing, wood samples were exposed to sea water steam during 6, 24, 60, and 96 hour. All processes were carried out at 20 ± 2°C. Finished test samples were kept at 20 ± 2°C and 65 ± 3% relative humidity until they reached constant weight.

Performance of Test

A quick thermal conductivity meter based on ASTM C 1113-99 hot-wire method was used. Variac (power supply) was used to supply constant electricity to the resistance. QTM 500 device is a product of Kyoto Electronics Manufacturing, Japan. Measurement range is 0.0116–6 W/mK. Measurement precision is F5% of reading value per reference plate. Reproducibility is F3% of reading value per reference plate. Measurement temperature is -100 to 1000 °C (external bath or electric furnace for temperature other than room). Sample size required is 20 x 50 x 100 mm. Measuring time is Standard 100–120s[9, 10].

Data Analyses

By using one control, four varnishes and one control, four exposed time as parameters, a total of 500 samples (5 x 5 x 2 0) were prepared using 20 samples for each parameter. Multiple variance analyses were used to determine the differences between the thermal conductivity of the prepared samples.

Result and Discussion

The average densities are shown in Table 1. The oven dry density (0.364 g/cm^3) and air dry density (0.408 g/cm^3) was obtained in fir wood.

Table1. Average values of density (g/cm^3)

Oven dry density (g/cm^3)	Air dry density (g/cm^3)
0.364	0.408

The average solid amounts of varnish types are shown in Table 2.

The highest solid amount (52%) was obtained in original varnish. The lowest solid amount (43%) was obtained in perfection varnish.

The average values of thermal conductivity are shown in Table 3.

Table 2. Solid amounts of varnish types (%)

Katı Madde Miktarı	Polyurethane varnishes		Synthetic varnishes	
	Goldspar	Perfection	Original	Schooner
	45.5	43	52	48

The highest thermal conductivity (0.146 Kcal/mh°C) was obtained in finished schoneer varnish with 96 hours exposure time of samples. The lowest thermal conductivity (0.108 Kcal/mh°C) was obtained in unvarnished (control).

The multi variance analyses applied to the data obtained from the thermal conductivity test is shown in Table 4.

Table 3. Average values of thermal conductivity coefficients (Kcal/mh°C)

Varnish type	Exposure time (hours)	Average	Standard deviation
Original	Control	0.118	0.0042
	6	0.123	0.0056
	24	0.132	0.0101
	60	0.138	0.0048
	96	0.144	0.0064
Goldspar	Control	0.117	0.0058
	6	0.121	0.0048
	24	0.126	0.0104
	60	0.129	0.0065
	96	0.135	0.0101
Schoneer	Control	0.119	0.0023
	6	0.124	0.0067
	24	0.136	0.0085
	60	0.141	0.0042
	96	0.146	0.0065
Perfection	Control	0.116	0.0087
	6	0.122	0.0054
	24	0.129	0.0078
	60	0/132	0.0054
	96	0.135	0.0098
Control	Control	0.108	0.0110
	6	0.115	0.0054
	24	0.122	0.0042
	60	0.126	0.0054
	96	0.133	0.0045

Table 4. Multiple variance analysis for the effect of varnishes and exposed time on thermal conductivity

Source	Type II Sum of squares	df	Mean square	F	Significance
Uygulanan model	0,143(a)	24	0,007	10,323	0,000
A	4,719	1	5,428	9821,649	0,000
B	0,000	4	0,000	0,221	0,000
A*B	0,141	4	0,031	69,740	0,000

Factor A = Varnish Types (Control, Goldspar, Original, Perfection, Schooner Varnish) Factor B = Exposure time (Control, 6, 24, 60, 96 hours)

According to the variance analysis, the effects of impregnated method, the effects of varnish types, the effects of exposure time, the effects of varnish types and exposure time, were statistically significant. The Duncan test of varnish types and exposure time (Kcal/mh°C) is shown in Tables 5 and 6.

Table 5. Duncan test of thermal conductivity depending on varnish type

Factors	Mean	Homogeneity Group
Control	0.121	a
Goldspar	0.126	b
Perfection	0.127	c
Original	0.131	d
Schoneer	0.133	e

Table 6. Duncan test of thermal conductivity depending on exposure time

Factors	Mean	Homogeneity Group
Control	0.116	a
6 hours	0.121	b
24 hours	0.129	c
60 hours	0.133	d
96 hours	0.139	e

The highest thermal conductivity of 0.132 Kcal/mh°C was obtained in schoneer varnish samples. The lowest thermal conductivity of 0.121 Kcal/mh°C was obtained in unvarnished (massive) samples.

The highest thermal conductivity of 0.139 Kcal/mh°C was obtained in 96 hours samples. The lowest thermal conductivity of 0.116 Kcal/mh°C was obtained in control (massive) samples.

Conclusion

In terms of thermal conductivity of varnished wood material one may conclude that the unvarnished (control) samples had the lowest values compared to varnished wood materials. It has been observed that while schoneer varnish increases conductivity values by 9 % on average, original varnish increases by nearly 8%, perfection varnish increases by nearly 5% and goldspar varnish increases by 4% on average.

Thermal conductivity of varnished wood also depends on the duration of exposure: unexposed (control) samples had the lowest values when compared to varnished wood materials. It has been observed that while 96 hours increases conductivity values by 17% on average, 60 hours increases by nearly 13%, 24 hours varnish increases by nearly 10% and 6 hours increases by 4% on average.

Consequently, wood varnished with schoneer varnish can be used as a material in areas (construction, yacht, etc.) where thermal conductivity is required. Wood varnished with goldspar varnish can be used as a material in areas (construction, yacht, etc.) where insulation is required.

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