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## INFLUENCE OF TEMPERATURE, HUMIDITY AND ULTRAVIOLET IRRADIATION ON DURABILITY AND DURABILITY OF MODIFIED WOOD

**Problem statement.** A technological mode of wood modification with the use of various substances (kerosene, paraffin, Emukril M, emulsion 252) is described. The influence of type of modifier on mechanical and hydrophysical properties of wood is discussed.
**Results and conclusions.** The effect of elevated temperature on expansion and compression of modified wood is investigated, and the values of coefficients of linear thermal expansion are determined. The analysis of the results of the influence of climatic factors (water and UV radiation, repeated freezing/thawing) on properties of modified wood is performed. The durability of modified wood is studied.

**Keywords:** modified wood, humidity, ultraviolet irradiation**,** factor of linear thermal expansion, wood durability, wood strength.

## Introduction

Wood remains one of the most demanded engineering and decoration materials despite its low water resistance and biostability. One of the methods of increase in physicomechanical properties of wood is its modification with the use of organic modifiers. Solid substance (paraffin) and organic liquid (kerosene, emulsion 252, Emukril M) are used as modifiers. Optimal modification conditions for organic liquids are determined experimentally. Duration of wood impregnation at 60 °C was 60 minutes for paraffin, 7 days for kerosene, 3 days for Emukril M at 80 °C. Unlike kerosene and Emukril M, Emulsion 252 has more viscous consistency, therefore, it did not penetrate the samples but did perform the function of surface. Samples treated by polymer solution were heat-processed at 80 $^0$C during 8 h (emulsion 252) and 10 h (Emukril M).

**1. Influence of modifier on mechanical properties of wood**

The examined modifiers effect the mechanical properties of wood (compression strength, cross-bending strength, shear strength and wood hardness). Test results obtained are shown in Table 1.

Table 1

The effect of modifiers on mechanical properties of wood

| Type of modifier | Strength, MPa | | | Modulus of elasticity under compression, MPa | |
|---|---|---|---|---|---|
| | Compression | Bending | Shear | along the fibres | across the fibres |
| Emukril M | 50.53 | 101.1 | 2.65 | 13065 | 5305 |
| Paraffin | 48.72 | 91.62 | 5.69 | 23780 | 5324 |
| Kerosene | 54.45 | 97.22 | 3.15 | - | - |
| Emulsion 252 | 26.61 | 104.8 | 2.84 | 15154 | 5491 |
| Without modifier | 57.61 | 82.97 | 4.84 | - | - |

The table shows that modification by impregnation results in increase of modulus of elasticity and wood strength under cross bending (by 12—25 %). Strength reaches the maximum values after wood modification by Emukril M.

Under compression shear strength of modified wood is lower than of natural. The one exception is paraffin. The use of paraffin results in increase of shear strength by a factor of 1.2 [1].

## 2. The influence of elevated temperature, temperature and humidity exposures and UV radiation on properties of modified wood

Wood is exposed to elevated temperatures during operation. It is attended with change in dimensions resulting in considerable thermal stresses in the material. The influence of temperature on expansion-compression of modified wood was studied in linear dilatometer [2] on heating with specified rate.

At temperature below 60 $^{o}$C samples of wood modified with polymer solutions were became longer. At temperature above 60 $^{o}$C samples became narrower because of solidification of the modifier. For wood impregnated with paraffin, relationship between elongation and temperature below 40 $^{o}$C is close to linear; at temperature above 40 °C samples did not expand.

The coefficient of linear thermal expansion (Table 2) was determined by dilatometric curves. For wood modified with paraffin the coefficient is close to the coefficient of source wood. For wood modified with polymer solutions the coefficient is reduced by the factor of 4—5, which appears to be related to the formation of rigid polymer skeleton.

Table 2

Coefficients of linear thermal expansion of wood ($\alpha \cdot 10^{-6}$ 1/°C)

| Type of modifier | | | | |
|---|---|---|---|---|
| Without modifier | Emukril M | Emulsion 252 | Kerosene | Paraffin |
| 3.96 | 0.7 | 0.55 | 1.05 | 3.34 |

In the process of operation products from modified wood are exposed to the action of UV radiation, fluctuations in temperature and humidity. The effect of radiation on cross-bending strength is shown in Fig. 1.

The figure shows that after 10 h of radiation wood modified with organic liquid loses up to 20 % of its strength, and wood impregnated with melted paraffin conserves its strength. Further radiation (up to 50—100 h) results in increase of strength of wood modified with emulsion 252 by 10—15 %, recovery of strength of wood modified with Emukril M, drop in strength of wood impregnated with kerosene by 25 %. After 100 h of radiation strength of paraffinized wood increases sharply, and for other types of modifiers it decreases by 10—20 %.

After 300 h of radiation strength was (in percent of source wood): for natural wood — 130 %, for paraffinized wood — 119 %, for wood impregnated with kerosene — 85 %, for wood impregnated with Emukril M — 83 %, for wood impregnated with Emulsion 252 — 89 % [3].

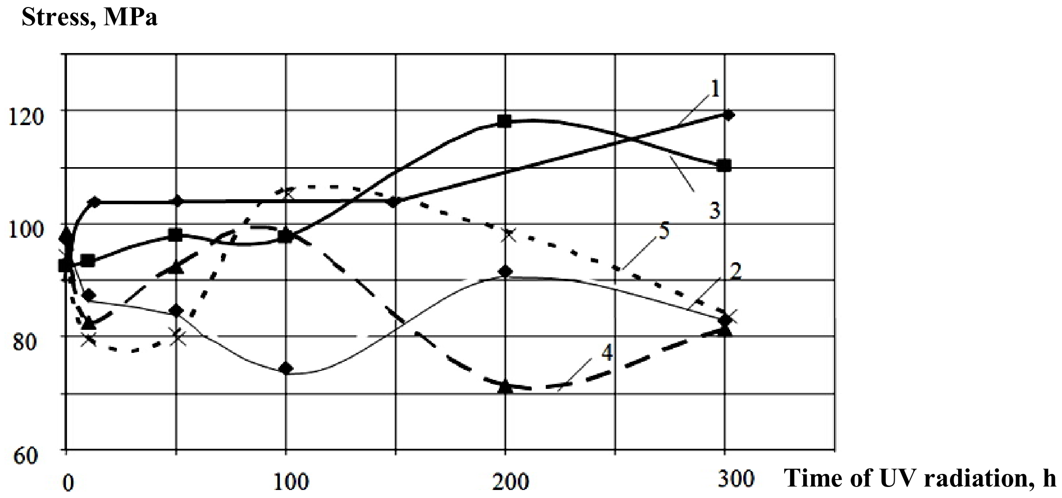


**Fig. 1.** The relationship between strength and time of UV radiation for wood (1st grade pine):
1 — source wood; 2 — wood modified with kerosene; 3 — wood modified with paraffin;
4 — wood modified with Emukril M; 5 — wood modified with emulsion 252

Water exerts the most active action on wood during operation. The process of steeping is attended with considerable increase in dimensions of wood, breaking of bonds, and decrease in strength. In this connection we studied the influence of water on the processes of swelling, water absorption and on water resistance of wood [4]. The results of tests are shown in Table 3.

Table 3

Influence of modifiers on hydrophysical properties of wood

| Period of steeping, h / Type of modifier | Water absorption *W*, % | | | Swelling *H*, % | | | Cross-bending strength, MPa | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 24 | 720 | 2 | 24 | 720 | 2 | 24 | 720 |
| Without modifier | 39.51 | 37.16 | 111.96 | 4.21 | 4.20 | 4.80 | 20.10 | 20.19 | 19.92 |
| Emukril M | 7.79 | 22.09 | 81.00 | 2.13 | 4.82 | 4.48 | 25.43 | 23.07 | 22.16 |
| Emulsion 252 | 31.43 | 40.58 | 124.14 | 4.31 | 5.78 | 5.96 | 26.03 | 22.31 | 21.90 |

End of Table 3

| Period of steeping, h / Type of modifier | Water absorption W, % | | | Swelling H, % | | | Cross-bending strength, MPa | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 24 | 720 | 2 | 24 | 720 | 2 | 24 | 720 |
| Paraffin | 8.35 | 21.26 | 61.05 | 2.80 | 4.25 | 5.18 | 19.63 | 19.16 | 17.42 |
| Kerosene | 35.71 | 44.85 | 121.96 | 3.95 | 4.80 | 3.81 | 22.18 | 22.28 | 22.02 |

The influence of repeated freezing-thawing on strength of wood was studied after modification with Emukril M. Tests were performed in the following order. Samples were steeped in water during 1 h and then they were hold at $t = -25$ °C until total frost penetration during 3 h, whereupon thawing samples were dryed at $t = +25$°C within 1 day. Sample strength was determined under cross bending after specified number of cycles. The results obtained are shown in Fig. 2.

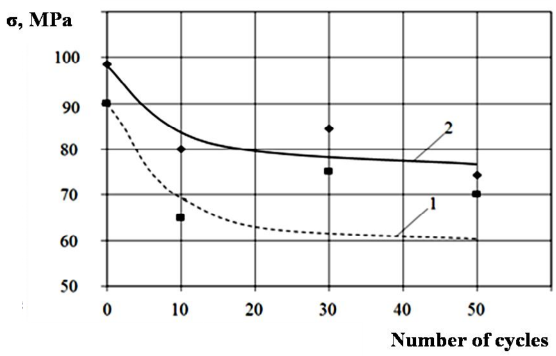


**Fig. 2**. Relationship between strength of source wood (1), strength of wood modified with Emukril M (2) and the number of freezing-thawing cycles

After 10 cycles of freezing-thawing strength of source wood decreases sharply — more than by 30 %, whereas strength of modified wood decreases only by 20 %. After that strength of the samples stabilizes, and after 50 cycles it does not change.

**3. Durability of modified wood**

To study the thermoactivation regularities of modified wood destruction, we conducted prolonged testing under cross bending at constant stresses at room temperature (18 ±2 °C). During testing we fixed time from the beginning of loading up to the sample destruction (durability $\tau$).

Experimental data obtained in coordinates of durability logarithms and stresses are shown in Fig. 3. Figure shows that relationships are linear [5] and described by equation $\tau = Ae^{-\beta\sigma}$, where $A$ and $\beta$ are physical coefficients reflecting the composition and structure of material.

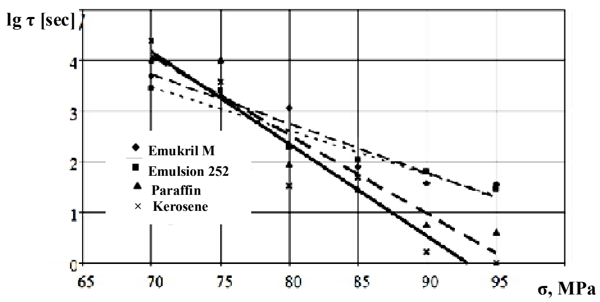


**Fig. 3.** Relationship between durability logarithm and cross-bending stress for modified wood at temperature 18 ±2 °C

Wood modified with kerosene and paraffin has the highest durability, and wood modified with emulsion 252 has the lowest durability [4].

Extrapolation of relations lg$\tau$-$\sigma$ to operation loads (stresses) makes it possible to forecast wood durability before and after modification and to take into consideration the influence of temperature, humidity and UV radiation by introducing additional adjustments calculated with respect to the change in strength value.

**Conclusions**

1. Modification by impregnation results in increase of modulus of elasticity and strength of wood under cross bending.

2. Coefficient of linear thermal expansion for modified wood is close to the coefficient for source wood. The coefficient decreases by the factor of 4—5 for wood modified with polymer solutions which is probably related to formation of rigid polymer skeleton.

UV radiation exerts considerable action on modified wood strength. Instability of strength at different time of exposure of this factor is connected with photochemical processes occurring in modifiers.

At short-time action of water (less than 2 h) water absorption and swelling of all types of modified wood are lower than of natural. At prolonged action of water, however, lower values are typical only for wood modified with paraffin and Emukril M.

Among examined modifiers, wood modified with Emukril M and emulsion 252 has the highest water resistance.

Natural and modified wood exhibit the similar behavior under repeated freezing-thawing.

3. It is found that wood modified with kerosene and paraffin has the highest durability, and wood modified with emulsion 252 has the lowest durability.

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