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THE POSSIBILITY OF POLYMERIZATION OF THE ACRYLIC PVMOF PHOTOCHEMICAL CURING UNDER THE IMPACTOF UV-RADIATION EMITTED BY SOLID-STATE SOURCES

The possibility of polymerization of acrylic VPMof photochemical curing under the impact of UV radiation emitted by solid-state sources (based on laboratory equipment) was researched; the hardness (as a characteristic of the degree of hardening) of obtained paint and varnish coatings was compared with the hardness of similar coatings, photopolymerization of which was initiated by a high-pressure mercury-quartz lamp.

Keywords: UV-curing, solid-state sources of UV-radiation, LED sources, laboratory unit, hardness of coating.

Actuality. The technologies of photochemical curingare widely used in conjunction with environmentally friendly LFM. In recent years, there has been a tendency towards the gradual replacement of traditional electrovacuum sources of UV radiation by energy-saving solid-state (LED) devices [1]. Their advantages are as follows.

- Long lifetime of LEDs (over 10,000 hours).
- Extremely low energy consumption (5-6 kW - the source of the installation radiation). Specialists from the Bürkles company calculated that the energy consumed by a typical UV-curing device decreases from 22.1 kW to 7.6 kW, which gives a save of 67%. While generating the electricity needed to power one high pressure lamp throughout the year, 25 tonnes of CO_2 are emitted into the atmosphere. In order to compensate for these emissions, about 200 trees must be planted or 10 cars be removed from the freeways annually [2].
- The radiation source enters the mode immediately after switching on and does not require time to cool between the switches. Instant on / off allows to immediately switch on / off the lamp when needed. This working cycle significantly increases the lifetime of the lamp to 6-8 years.
- Deep curingis provided even for pigmented coatings.
- LEDs are suitable for solidifying coatings on all types of wood and other heat-sensitive materials.
- LEDs show the slight decrease of radiative ability during their lifetime.
- Operation of the installation with solid-state sources does not lead to the formation of ozone.
- LED technology is more effective in converting electric energy to the energy of UV radiation, which leads to 25-30% of photopolymerization - compared to less than 10% for a mercury lamp [3].

In 2009, at the LIGNA exhibition in Hanover (Germany), the technological line of photochemical curingbased on the LED technology presented by Bürklescompany, was awarded the 1-st place in the resource efficiency segment.

This technology can be used for both organo-soluble and water-soluble UV materials in an inert environment. The market for UV light-emitting diodes is constantly changing both in the direction of increasing the specific power of radiation, and in the direction of increasing the available wavelengths [4].

One of the main factors limiting the wide usage of technologies with UV-light-emitting diodes is the lack of available VPM that photopolymerize in the range of 320-400 nm (UVA). Therefore, the search for compositions that solidify under solid-state sources and provide acceptable results regarding the physical-mechanical characteristics of the coatings is relevant.

Goal. Study of the possibility of polymerization of acrylic VPM of photochemical curingunder the impact of UV radiation emitted by solid-state sources (based on laboratory equipment); the comparison of hardness as a characteristic of the degree of hardening of the obtained coatings with the hardness of similar coatings, whose photopolymerization was carried out under a mercury-quartz high pressure lamp.

Experimental part. Materials. The experiment used acrylic varnishes for photochemical curing, water-soluble acrylic varnishes for photochemical curing and acrylic enamels for photochemical curing by Sayerlack (Sherwin-Williams Italy S.r.l.). Characteristics of paint and varnish materials are given in the table. 1.

Table 1.Technical characteristics of the acrylic VPM of photochemicalcuring, produced by the Sayerlack firm (Sherwin-Williams Italy S.r.l.)

Indicators	Composition A	Composition B	Composition C
	Acrylic lacquer UV-curing for rolling with rollers	Water soluble acrylic lacquer UV-curing for spray application	White acrylic enamel UV-curing for roller rollers
Volatile matter content,%	99±1	32 ± 2	99 ± 1
Density, kg/l	1.250 ± 0,030	1,050 ± 0,020	1.370 ± 0.030
Viscosity (DIN 4 at 20°C, seconds)	30 ± 2	90±3	38± 2
Number of layers	1-2	2 with intermediate polishing	1-2
Consumption, g/m^2	4-8	80-110	10 –15
Drying	UV-lamp of high power (360nm 80-120W/cm)	20′ - hot air for 30-35˚C High Power UV Lamps (360nm, 80-120 W/cm)	3′-4′ 'High Power UV Lamps gallium/mercury 80-120W/cm

Experiments were conducted at a temperature of 20±2°C and a relative humidity of 65±5%. Paint and varnish materials of photochemical curing were evenly applied on glass substrates of size 100x20mm using a brush. Using electronic weights (accuracy of measurement 0,001 g) the consumption for each type of LFM were observed (Table 1). The coatings were smooth and without defects on the surface.

For water evaporation, the water-soluble UV-composition was pre-stored at 60°C for 15 minutes ina thermal camera prior to polymerization under a UV-LED or high pressure mercury-quartz lamp.

The glass plates with the same VPM were dried under various UV sources (high pressure mercury lamp DRT-375 and laboratory installation with UV LED) for the time interval time necessary for obtaining technological hardness.

For the study of photopolymerization processes, traditional UV sources (high-pressure mercury-quartz lamp DRT-375) and laboratory equipment with UV-light-emitting diodes [5] were used. This installation makes it possible to make the experimental samples harden under the impact of emitted UV-light radiation of different wavelengths and power.

The main technical characteristics of the installation are given in Table. 2.

Tabl. 2. The main technical characteristics of the laboratory installation with UV-light-emitting diodes

The size of the samples under study	50x80 mm
Moving speed of the carriage (variable)	2.5 m/min - 10.0 m/min
Maximum stabilized power supply of LEDs	3A
Variable LED emitters with length radiation, nm:	365 –375 / 380 –390 / 395 –410
Power supply	220 V

Structurally, the laboratory installation of UV LED (Fig. 1) consists of three parts:

- the carriage, moving reciprocally, on which the test sample is installed;
- replaceable illuminator with UV light-emitting diode;
- the power supply unit of the UV radiator and the drive of the carriage.

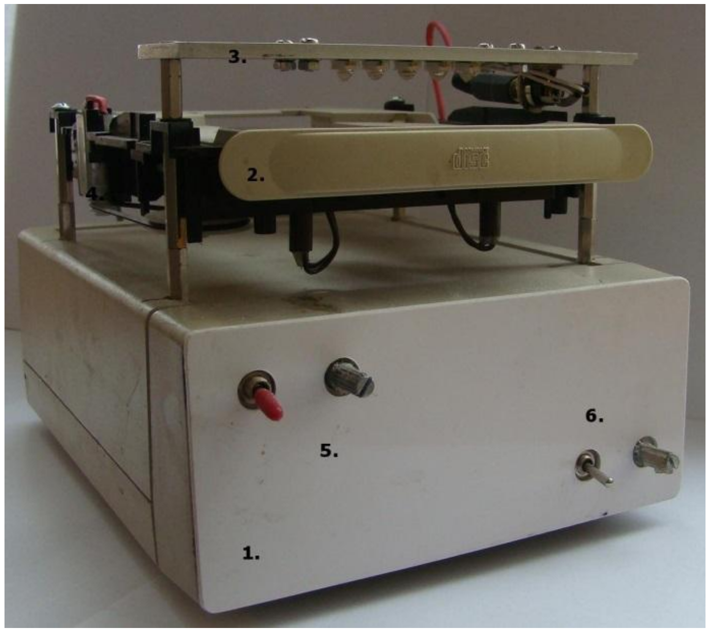

Fig. 1. General view of the laboratory installation with UV light-emitting diodes:
1 –power module; 2 – mobile carriage; 3 – UV illuminator; 4 – electric drive carriage; 5 – UV control bodies; 6 – bodies of control of the electric motor drive carriage

Fig. 2. Ruler with five LEDs:
1 – aluminium radiator plate; 2 – UV-light; 3 – power connector for the UV radiator

Mechanism of reciprocating movement of a carriage – a rail type with a drive from a reversing electric motor. LEDs are located on a massive aluminium bar, which acts as a radiator (Fig. 2). The design of the mechanical fastening of the LED strip and the presence of an electrical connector in the power supply of LEDs provide the ability to quickly replace the LED line. During the study, the radiator with LEDs EDEV-1LA1 (Edison company), whose radiation spectrum is in the range of 395-410 nm, was used.

Research methods. Before the study samples were kept at a temperature of 20±2°C and a relative humidity of 65±5% for not less than 16 hours.

The degree of hardening of the coating can be characterized by hardness, which is a function of the time spent on drying paint and varnish coating. The hardness of the coating was determined by the fading of the oscillations of the pendulum M-3 [6]. Coating was formed on a glass plate to study its hardness, since the hardness of the substrate used may affect the results. Similar coatings were polymerized both under a UV-LED and under a mercury-high pressure lamp.

Research results. The results of determining the hardness of the coatings as the degree of hardening of paint and varnish materials under the influence of UV radiation emitted by a high pressure mercury lamp and solid-state sources are given in Table 3.

Table 3.Hardness of coatings based on VPM, polymerized under high pressure mercury lamp DRT-375 and UV lamp with LEDs EDEV-1LA1

Types of paint and varnish materials of photochemical curing	Hardness of coatings, conventional units	
	photopolymerization under a UV lamp with LEDs EDEV-1LA1	photopolymerization under a high pressure lamp DRT-375
Composition A	0,39	0,54
Composition B	0,48	0,60
Composition C	0,59	The coating does not harden

Conclusions.

In the study of the possibility of polymerization of acrylic VPMof photochemical curingunder the impact of UV radiation emitted by solid-state sources (whose radiation spectrum is in the range 395-410 nm), the laboratory tests discovered the following:

1. The best hardness results can be traced to white acrylic enamel (composition C) under the LED source. Under the mercury-quartz lamp the coating was not formed. This can be explained, probably, by the low transmission of white enamel pigment in the region of maximum emission of a high pressure mercury lamp and, accordingly, by high transmittance of this pigment in the high-wavelength region of UV radiation of LEDs EDEV-1LA1 (range 395-410 nm).
2. Insufficient degree of hardening is observed in the coating with the basis of acrylic varnish (composition C) when using solid-state sources. Photopolymerization under the traditional DRT bulb was successful.
3. A coating with the basis of water-soluble acrylic varnish (composition B) reached a sufficient hardness, and, consequently, a high degree of hardening. Perhaps, this is due to the fact that coalescence occurs after the evaporation of water, resulting in less chemical bonds.

In conclusion, it is necessary to conduct a series of experiments on the study of photochemical curing of coatings based on acrylic varnish of UV-curing applied by rollers under solid-state sources. To conduct this experiment, it is necessary to choose the variable illuminators with UV light-emitting diodes (the laboratory installation is equipped with them) of another radiation length, namely 365-375 nm, 380-390 nm, or to use successive radiation by solid-state sources with the different spectrum of radiation.

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Дослідження можливості полімеризації акрилових лакофарбових матеріалів фотохімічного твердіння під дією УФ-випромінювання, емітованого твердотільними джерелами

Досліджено можливість полімеризації акрилових ЛФМ фотохімічного твердіння під дією УФ-випромінювання, емітованого твердотільними джерелами (на базі лабораторної установки); проведено порівняння твердості (як характеристики ступеня затвердіння) отриманих лакофарбових покриттів з твердістю аналогічних покриттів, фотополімеризація яких ініційована ртутно-кварцовою лампою високого тиску.

Ключові слова: УФ-твердіння, твердотільні джерела УФ-опромінення, світлодіодні джерела, лабораторна установка, твердість покриття.

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RESEARCH OF THE WOOD COMPOSITE MATERIAL DEFORMABILITY IN TERMS OF THE HEAT MASS TRANSFER

The analysis of the basic structural states in the technological process of manufacturing of wood composite materials is carried out. The parameters of temperature-humid field and kinetics of structural transformations are determinedand building a mathematical model for the determination of the stress-strain state of wood composite materials under conditions of heat mass transfer.

Keywords: fluidity, viscoplasticity, viscoelasticity, stress-strain.

Introduction. A characteristic trend in modern studies of the wood composite materials (WCM) is a shift towards process problems and formation of a new direction their basis, namely process mechanics of the wood composite materials. The central problem in this respect is to develop the phenomenological interrelated physical and mechanical WCM models, taking into account the structure formation evolution in the process. On their basis, reasonable process parameters for specific materials, basic types of structures and processes of their manufacture may be identified, recommendations may be justified, and special algorithms to control such parameters ensuring the required WCM quality may be developed.

The analysis of theoretical and experimental study findings, as well as the production experience shows that the use of traditional physical mechanics relations to determine the WCM quality indicators does not allow determining their dependence on the influence of process factors during their manufacture unequivocally. In particular,