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Wear resistance of photopolymer material for screen printing plate manufacturing

Keywords: *photopolymer, printing plate, resistance*

The important performance characteristic of photopolymer materials for screen printing plate manufacturing is wear resistance in the printing process [1, 2–5].

The aim of the research is to study the wear resistance parameters of photopolymer material for screen printing plate manufacturing and to perform a theoretical description of the dependencies of photopolymer material parameters on the number of wear cycles.

For the purpose of this research, a liquid photo cured composition used for screen printing plate manufacturing by laser engraving has been used. The composition of the test material is shown in Table 1.

Table 1. Composition of the photocururable material for screen printing plate manufacturing by laser engraving

Oligouretanacrylate based on aliphatic diisocyanate	50%
TGM-3	26%
Photopolymerization accelerator	18%
Photoinitiator	3%
Photosensitizer	3%

The wear resistance of the photopolymer material was determined by the abrasion method on IMR device. The abrasion of the samples was performed with the P320 sandpaper. The paper was changed every 500 cycles to prevent clogging. The load on the device rod was 0.5 kg.

Figures 1–3 show the results of the experimental studies – the dependencies of the specific wear by mass and volume and the gradient of the wear rate of the studied photopolymer material on the number of friction cycles.

As it can be seen from Figures 1 and 2, there are two wear phases of the photopolymer material: the initial wear observed during working out the friction surfaces, which is accompanied by a change in the geometry of the friction surface, the structure of the surface layers of the material (the formation of secondary structures) and the smooth transition to stabilized (standard) wear, which is characterized by a small and constant wear rate.

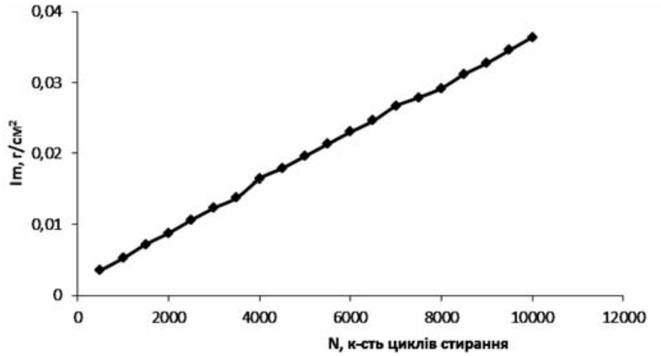

Fig. 1.
The dependency of the specific wear of the photopolymer material (loss of mass) on the number of friction cycles

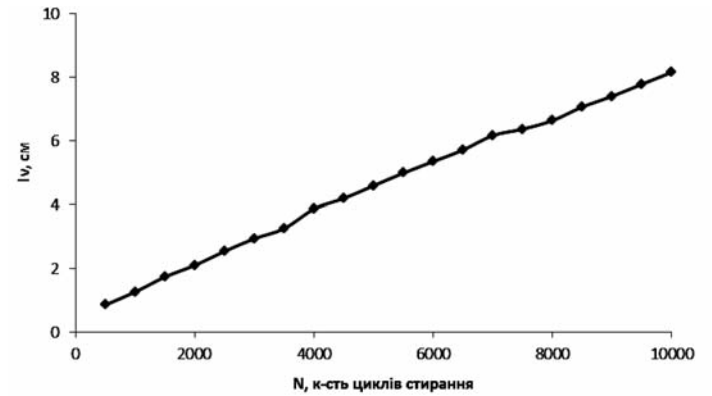

Fig. 2.
The dependency of the volume wear of the photopolymer material on the number of friction cycles

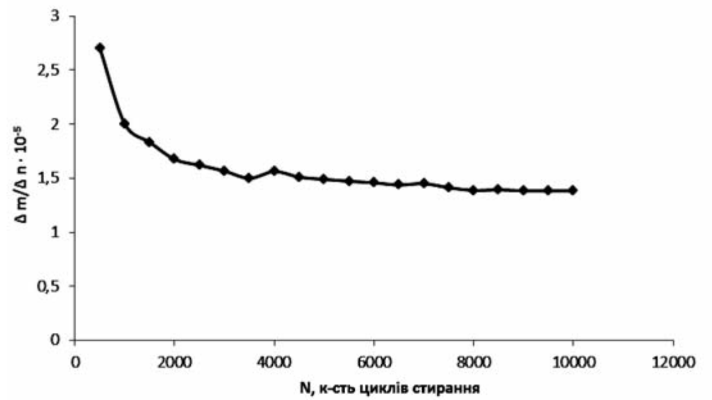

Fig. 3.
The dependency of the gradient of the mass wear rate of the photopolymer material on the number of friction cycles

The gradient of the wear rate (Fig. 3) is high in the initial stages of abrasion, and then stabilizes and decreases. This indicates that there are several wear periods related to the structure of the photopolymer material. The mechanism of the material wear is quite complex and is related both to the specifics of the surface layers and to processes occurring at the friction areas with the counter body.

The gradient of the wear rate $\Delta m/\Delta n$ of the photopolymer material changes in the range from $2{,}7 \cdot 10^{-5}$ (500 cycles) to $1{,}385 \cdot 10^{-5}$ (10000 cycles).

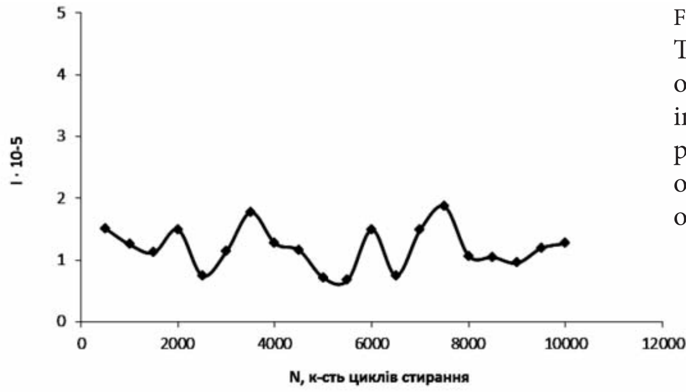

Fig. 4.
The dependency of the mass abrasion intensity of the photopolymer material on the number of friction cycles

The wear resistance of the polymeric material was evaluated by such parameters as the specific mass wear W_m, the specific volume wear W_v, the wear rate of the material υ_w, and the abrasion intensity I_w (Fig. 4) [3, 4]. The results of measurements and theoretical calculations of these parameters are shown in Fig. 5 and 6. The specific volume wear W_v is more informative in terms of assessing the stability of the polymer material. The specific mass wear W_m is required as a primary measured characteristic.

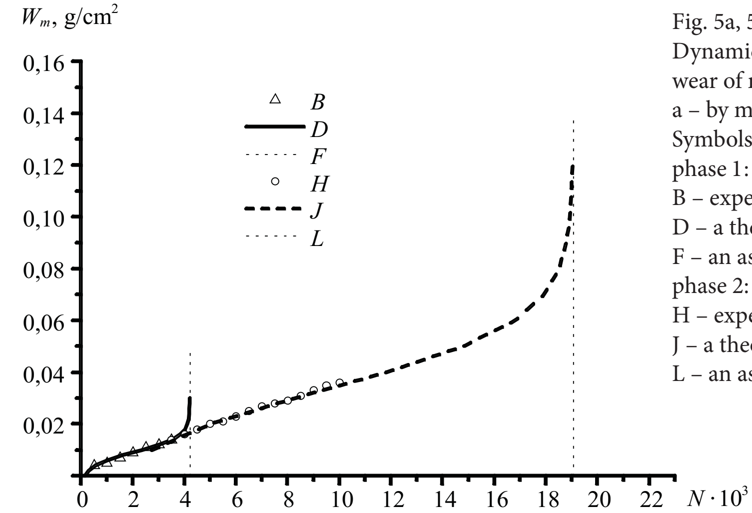

Fig. 5a, 5b *on the next page*
Dynamics of the specific wear of material samples:
a – by mass, b – by volume.
Symbols
phase 1:
B – experimental data,
D – a theoretical function,
F – an asymptote,
phase 2:
H – experimental data,
J – a theoretical function,
L – an asymptote

The analysis of the experimental data using the kinetic function suggested in [8] has shown that the wear process of the studied polymer material includes 2 phases. The transition to the second phase indicates a certain change in the wear material. Since the first phase corresponds to the wear depth of 0.08 mm, this is a surface film. The second phase is associated with the wear of the material volume.

When converting the mass wear rate to the volume wear rate, parameters that are used do not depend on the number of friction cycles. Therefore, the de-

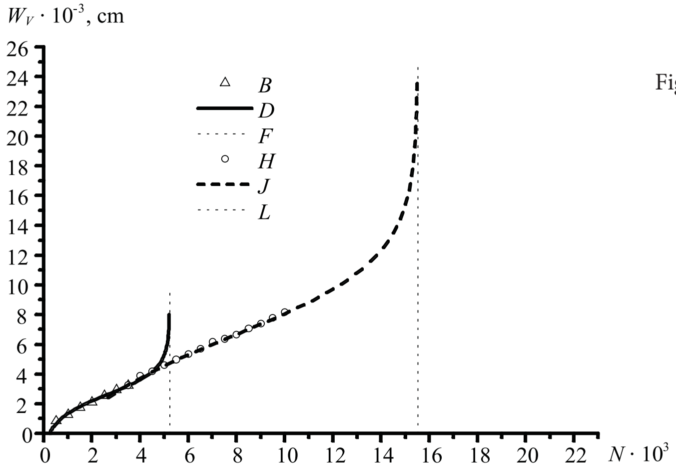

Fig. 5b

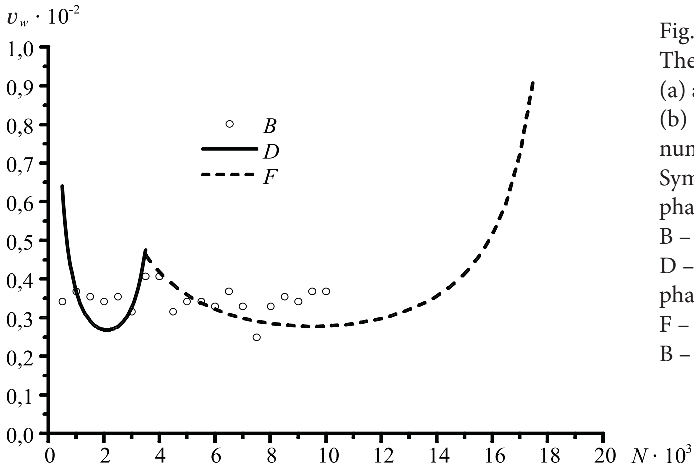

Fig. 6a, 6b
The dependency of the wear rate (a) and the intensity (b) of material samples on the number of abrasion cycles.
Symbols
phase 1:
B – experimental data,
D – a theoretical function,
phase 2:
F – a theoretical function,
B – experiment data

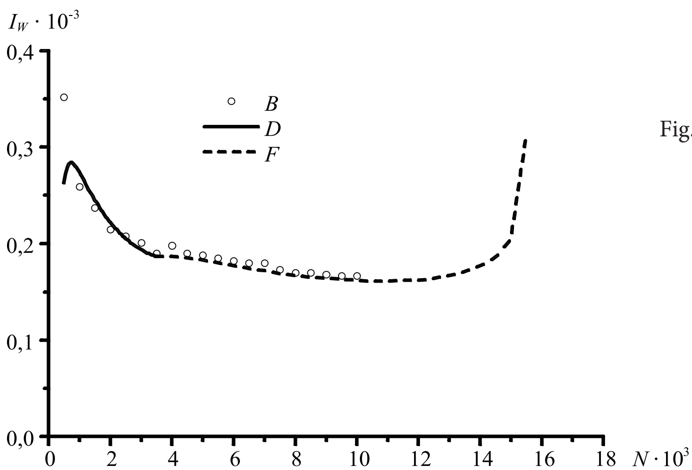

Fig. 6b

pendencies are scaled, but their nature does not change. This can be seen in the table with the values of parameter A. This is also proved in Fig. 5.

Modelling the polymer material wear. Based on the analysis of the physical processes of wear resistance of the plates and the formation of their print run resistance, a kinetic function was constructed in [8] that describes the dynamics of printing plates wear over the entire period of their performance. This paper suggests carrying out a theoretical study of the wear of the analysed polymer material using this function.

The dependency of wear W on the number of abrasion cycles N is described by the following function:

$$W(N) = \frac{1}{Ab_0} \ln\left[\frac{(A - N_0)N}{N_0(A - N)}\right]. \tag{1}$$

When processing the experimental data, the parameters of the function (1) – A, b_0, N_0 were determined using the least squares method. The calculation results are shown in the table.

Table 2. Values of the wear function parameters for polymer material samples

Wear type	Wear phase	Values of parameters			Fisher test values	
		A, cycles	b_0	N_0	calcu-lated, F_p	table, F_T
By mass, specific, g/cm^2	first	$4{,}217 \times 10^3$	84,034	150	1,162	4,280
	second	$19{,}058 \times 10^3$	3,972	1400	1,151	2,600
By volume, specific, cm	first	$5{,}226 \times 10^3$	0,221	250	1,063	4,280
	second	$15{,}518 \times 10^3$	0,025	1200	1,016	2,600

The wear rate υ_w is a derivative of the function (1). The final expression for it has the following form after simplification:

$$\upsilon_w(N) = \frac{1}{b_0 N(A - N)}. \tag{2}$$

During the experiment, the measurement of the sample mass is performed periodically after a certain number of friction cycles. Therefore, when determining the rate from the experimental data, after the i-th measurement, the difference formula was used for the first derivative of the second order of accuracy in steps:

$$\upsilon_w(N_i) = \frac{W_{m_{i+1}} - W_{m_{i-1}}}{N_{i+1} - N_{i-1}}. \tag{3}$$

The wear rate, as a derivative of (1), significantly depends on the wear stage [8]. In the first stage (initial wear), the rate is big. As one moves to the second stage (stabilized wear), the rate drops, in some cases sharply. At the beginning of the third stage (increased wear), the rate increases again.

As it can be seen in Fig. 6a, this pattern is preserved at each phase of wear. As a result, there is a "surge" in the rate during the transition from one phase to another.

In accordance with the definition [7], the wear intensity I_W is defined as the ratio of the wear to the total length of the friction way L. If the wear rate is a local characteristic, then the intensity characterizes the integral wear after passing a certain friction way.

In this paper, when processing experimental data, one has used the specific volume wear W_V [6], that is proportional to actual decrease of plate material height Δh:

$$W_V = \Delta mk / \rho S = k\Delta h \quad (4)$$

where k is a correction coefficient, taking into account the wear of the rod of the measurement device IMR-1, k = 0.98; ρ is the material density.

The friction way in this case was determined through the number of friction cycles:

$$L = kl_pN \quad (5)$$

where l_p is a friction way within one cycle and equals 5 cm.

Thus, the wear rate is finally determined by the following formula:

$$I_W = W_V / kl_pN. \quad (6)$$

As it can be seen in Fig. 6b, at the first stage, the wear intensity increases, but as the wear slows down, the intensity begins to decrease, since the wear way increases faster. In the third stage, the wear intensity increases slightly. Fig. 6b also indicates that the intensity value depends on the wear phase.

Asymptote A is a characteristic of the final value of the material wear resistance. The value of the asymptote depends on the structure and quality of the materials used. By setting the value of the maximum allowable wear, according to the formula (1), one can determine the number of friction cycles that will characterize the material wear resistance.

The allowable wear can also be determined by setting the maximum number of friction cycles in the form of a fraction of the asymptote k_c. For example, if one considers the specific volume wear and assuming k_c = 0.97, then one obtains the value of the maximum number of friction cycles equal to $N_c = k_cA$ = 0,95 × 15 518 = 14 742. In this case, the allowable specific wear of the material by volume in accordance with (1) will be $W_V(N_c)$ = 13,980 × 10^{-3} cm.

Conclusions. As a result of the study of the wear of the polymer material, it has been found out that it has the properties required for its purpose and can be used to manufacture screen printing plates. A statistical model of the material wear has been constructed. The adequacy of the model has been confirmed by comparing the results of calculations with experimental data.

The suggested model allows predicting the wear resistance of the polymer material. The simulation results can be used in studies of other plate materials.

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Abstract

Wear resistance of photopolymer material for screen printing plate manufacturing

The study of the wear resistance of photopolymer material for screen printing plates manufacturing by laser engraving has been done to obtain the main results to determine its performance in this work.

As a result of the research of the wear of the developed photopolymer material, it has been established that it has the necessary properties and can be used as a basis for the printing plate manufacturing for screen printing method. A statistical model of the material wear has been constructed. The adequacy of the model has been confirmed by comparing the results of the calculations with the experimental data.

The suggested model allows predicting the wear resistance of the polymer material. The simulation results can be used later in the study of other plate materials.

Streszczenie

Odporność na zużycie materiału fotopolimerowego do produkcji płyt sitodrukowych

Przeprowadzone zostało badanie odporności na zużycie płyt sitodrukowych wykonanych z materiału fotopolimerowego, sporządzonych metodą grawerowania laserowego. Celem badania było określenie charakterystyk wydajności płyt.

W badaniach zużycia materiału fotopolimerowego ustalono, że ma on niezbędne właściwości i może być wykorzystywany jako podstawa do produkcji płyt do sitodruku. Skonstruowano model statystyczny zużycia materiału. Adekwatność modelu potwierdza się w porównaniu z wynikami obliczeń przeprowadzonych na danych eksperymentalnych.

Proponowany model pozwala przewidzieć odporność na zużycie materiału polimerowego i można go wykorzystać w badaniach również innych materiałów do produkcji form.