The Method of Determination of the Profile Photopolymer Printing Elements and the Optimization a Photopolymer Structure

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Keywords: Photopolymer layer, Fourier Transform, Modulation Transfer Function, Physical Model, Optical Properties, Profile, Printing Element

Abstract: The profile of the printing elements is the most important quality characteristic of the photopolymer plate. In this work the profile was determined by using the Fourier transform analysis. The photopolymer plate is considered as multi layers system. The exposing light scattering was evaluated by calculating of the transform characteristics of the system for making the printing plate. The photopolymer layer thickness and its optical properties is take into consideration. The experimental testing of the calculation method is fulfil by using the physical model of the photopolymer layers. The model photopolymer layers has the optical properties, corresponding to this in the polymer layers. The information about the light scattering along the layer thickness was registered on the sensitive film. It was found a good correlation between the different methods of determination the printing element profile. The result of this work is that it is possible to determine the profile as well as to optimize the structure of photopolymer plate according to a desire profile.

1. Statement of Task

It is known what important role play the print from the photopolymer printing plates in modern graphic arts industry. In Russia flexography printing of packing, labels from photopolymer plates now experiences

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the period of fast growth. Naturally, the interest to all aspects of technological process influencing qualitative and economic parameters is significant. By the publications in the scientific and technical literature on the graphic arts industry the interest to this problem all over the world does not weaken.

One of major factors of technological process of manufacturing of the photopolymer printing plates and subsequent printing of circulation from this printing plate is the form of a profile of a printing element. The correctly created profile of a printing element needs be increased run length of the printed plate, to reduce a dot gain, i.e. to increase qualitative and economic parameters of process (fig.1).

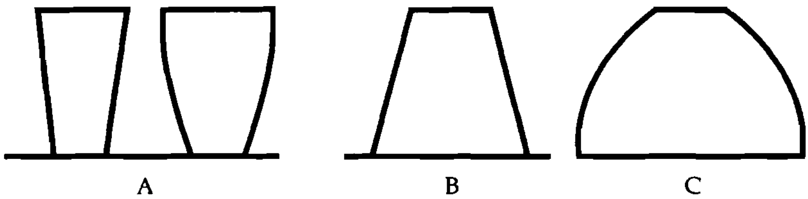

Fig1. The profiles of the printing elements.

The formation of a profile of a printing element – complex the phenomenon, which is defined by various optical parameters of process, conditions of exposure, conditions of the subsequent processing, mainly, displays of a photopolymer layer. Major in this line is the optical parameters. To them concern: the angular sizes of a source of radiation used for exposure; optical properties of elementary volume of a photopolymer layer - dispersion of light, absorption, possible distinction of these properties in volume of a layer. It is the presence inside a homogeneous layer the other layers with the different optical properties, for example. Therefore it is increased scattering or absorption; the reflection of light on the bottom border from a basis of a photopolymer layer, if it is present, or border of the unit of optical medium, the optical way of radiation in a layer, i.e. optical thickness of a photopolymer layer. All these parameters define distribution of intensity formed inside a photopolymer layer and, as a matter of this fact, are made a basis determining the creation of a profile of a printing element. The choice of an exposure and conditions of development further defines this threshold level of intensity, which will become border of a profile of a printing element.

Hence, if we want to calculate a profile of a printing element created in a photopolymer layer, it is necessary to us to calculate the diagram of distribution of intensity inside a photopolymer layer. If optical system and the optical properties of a photopolymer layer have superficial circular symmetry, the task is reduced to construction of section of distribution of intensity on border of a printing element depending on depth of an arrangement of this border from a surface of a layer.

2. The Method of Account the Intensity Distribution in Depth of Photopolymer Material.

The distribution of intensity of radiation in depth of a photopolymer material can be regarded as the diagram consisting of a set of distributions of intensity in the image of sharp edge in depth, calculated for various levels, inside a photosensitive layer of a material. It is accepted to name distribution of intensity in the image of sharp edge as edge function. A task is the development of a method of account of edge function and a method of account the dependence of edge function from depth of a level.

It is expedient to put in a basis of account of edge function a method of the spectral spatial analysis, which allows rather simply take into account the complex influence of variable optical conditions on the creation of a profile. The influence of all factors, under such spectral description of process, can be found as product the Fourier – transformations:

$$T^{i} (v) = T^{d}(v) \; (\; S^{e}(v) \; (\; T^{s}(v) \; (\; T^{m}(v) \qquad (1)$$

with,

$T^{i}(v)$: Fourier-spectrum of distribution of intensity in a photopolymer layer,

$T^{d}(v)$: the modulation transfer function (MTF) of an optical backlash between a surface of a material and a level of registration (d),

$S^{e}(v)$: Fourier-spectrum of a projection of a source of radiation on a surface of a material,

$T^{s}(v)$: MTF of a scattering layer between a surface of recording medium and a level of registration,

$T^m(\nu)$: MTF of the material which record a radiation (in this case a photopolymer layer with a thickness d),

ν: spatial frequency, mm^{-1}.

MTF of an optical backlash between a surface of a material and level of registration it is possible to calculate under the formula:

$$T^d(\nu) = \sin [\pi/2 (1-2\pi\lambda d\nu^2)] \quad (2)$$

with,

d: size of distance between a surface of a material and level of registration, i.e. depth of a layer, on which we wont to find an intensity distribution,

λ: length of a wave of radiation in a maximum actinism of system « a source of radiation – recording medium».

$S^e(\nu)$ – spatial spectrum of a projection of a luminous body of a source of radiation on a surface of printing plate. For maintenance of circular symmetry is accepted that the luminous body is circular. It is accepted also, that the luminous body has uniform on the area distribution of energy. Such assumptions rather well correspond to practical conditions of exposure. The spectrum of a projection at such assumptions pays off under the formula:

$$S^e(\nu) = 2J_1(\pi l\nu)/\pi l\nu \quad (3)$$

with,

$J_1(\pi l\nu)$: Bessel function of the first kind of the first order;

l: diameter of a projection of a luminous body of a source of radiation on a surface of a material.

Diameter of a projection of a luminous body of a source of radiation is calculated under the formula:

$$l = Ldn/D \quad (4)$$

with,

L: diameter of a luminous body of a source of radiation,
D: distance from a source of radiation before plane of registration,
n: coefficient of refraction of a layer which is taking place between a surface of a material and a plane of registration.

$T^s(n)$ – MTF of a layer of a scattering medium located between a surface of a material and a level, on which is made an estimation of intensity in a profile of distribution. It is possible to find MTF experimentally, using a model layers consisting from a real photopolymer compositions, subject to study, and a special silver halide photographic layer with known properties. The essence of a method can be understood from considered further, in section 3, method of physical modeling.
Whereas in the further experiments on physical modeling of a profile of a printing element we used of a nonscattering polymeric film, the multiplier $Ts(\nu)$ is accepted equal 1.

$T^m(\nu)$ – MTF a material of recording radiation can also be accepted for 1 owing to it by definition infinitesimal thickness. However because the settlement data further (see section 3) were compared with experimental data, received on a method of physical modeling, in which as recording medium was used a silver halide photographic material SP 385 (f. Kodak), in account was accepted MTF of this material.

The account of the Fourier spectrum of distribution of intensity of radiation in a layer was carried out for two sources of radiation – diameter D1 = 4 mm and D2 = 20 mm located on distance 800 mm from a surface of the material (max was accepted equal 0,00049 mm. The account was carried out for levels from 0,05 up to 0,95 mm. The spatial spectrums of sources of radiation, MTF of an optical backlash, MTF of a photographic film and the meanings of the generalized spectrum are shown in a fig. (2 - 7).
Further for a finding of edge function the received spectra should be counted in spatial spectra for a rectangular signal, that is carried out under the known formula of decomposition in the Fourier row for a symmetric lattice:

$$T^{\bar{}}(\nu) = 4/\pi[T^{\sim}(\nu)-1/3*T^{\sim}(3\nu)+1/5*T^{\sim}(5\nu)-1/7*T^{\sim}(7\nu)+...] \quad (5)$$

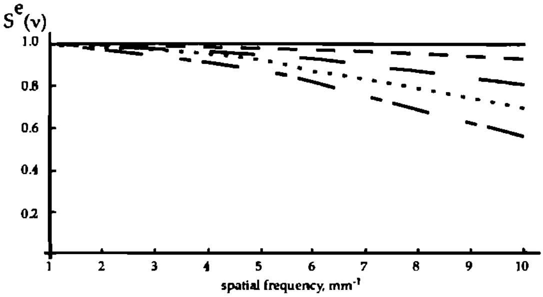

Fig.2.The spatial spectrum of the light source body 4 mm:
(——) — d = 0,1mm;
(— — —) — d = 0,3mm; (———— —) — d = 0,5mm;
(- - - - - -) — d = 0,7mm; (— — ——) — d = 0,9mm.

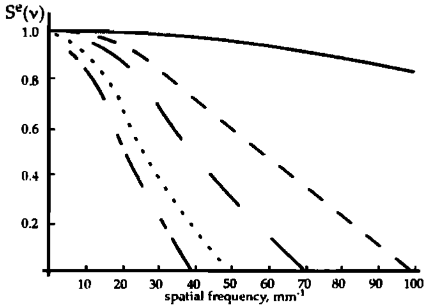

Fig.3.The spatial spectrum of the light source body 20 mm:
(——) — d = 0,1mm;
(— — —) — d = 0,3mm; (———— —) — d = 0,5mm;
(- - - - - -) — d = 0,7mm; (— — ——) — d = 0,9mm.

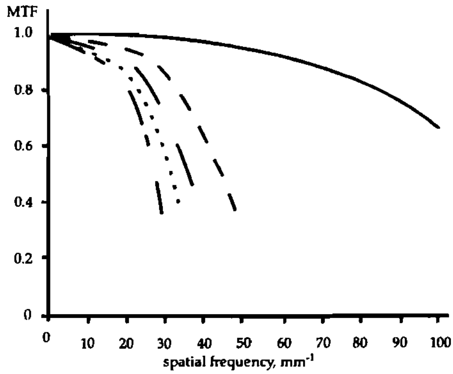

Fig.4. MTF of an optical backlash: (——) — d = 0,1mm;
(— — —) — d = 0,3mm; (———) — d = 0,5mm;
(- - - - - -) — d = 0,7mm; (—— —) — d = 0,9mm.

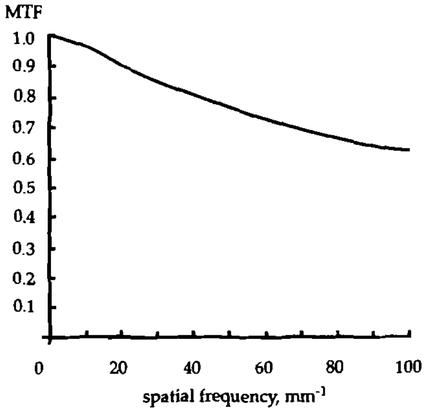

Fig.5. MTF of fotographic film: (——) — d = 0,1mm.

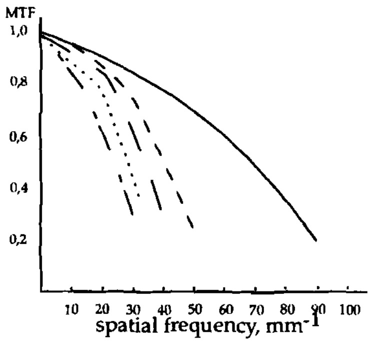

Fig.6. The generalized spectrum (source body 4 mm):
(——) — d = 0,1mm;
(— — —) — d = 0,3mm; (— — —) — d = 0,5mm;
(- - - -) — d = 0,7mm; (— - — -) — d = 0,9mm.

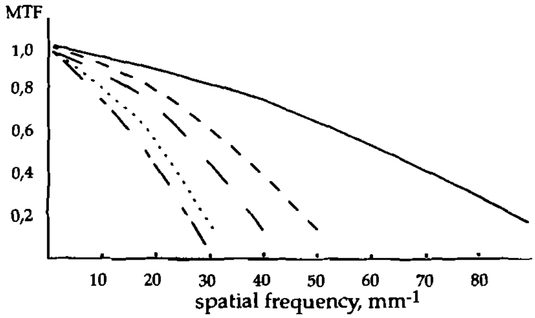

Fig.7. The generalized spectrum (light source body 20 mm):
(——) — d = 0,1mm;
(— — —) — d = 0,3mm; (— — —) — d = 0,5mm;
(- - - -) — d = 0,7mm; (— - — -) — d = 0,9mm.

Then the construction of the edge function under the formula, offered by us, is carried out:

$$E(x) = (T(\nu)+T(\nu/3)+2)/4 \qquad (6)$$

with,

$$E(-x) = 1-E(x); \; x = 1/4\nu; \; -x = -1/4\nu.$$

The families of the edge functions for various levels and for two sources of radiation are shown in a fig. (8 – 9).

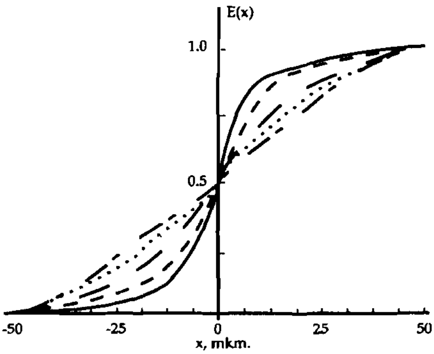

Fig.8. The family of edge function (light source body — 4mm): (——) — d = 0,1mm; (———) — d = 0,3mm; (———) — d = 0,5mm; (-·-·-·-) — d = 0,7mm; (— —) — d = 0,9mm.

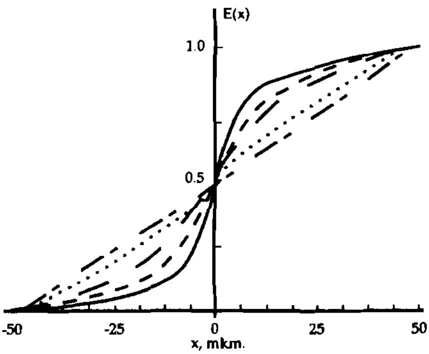

Fig.9. The family of edge function (light source body — 20mm): (——) — d = 0,1mm; (———) — d = 0,3mm; (———) — d = 0,5mm; (-·-·-·-) — d = 0,7mm; (— —) — d = 0,9mm.

It is enough to carry out an exposition straight line for construction of a profile of a printing element in absence of absorption of radiation in a layer. The straight line together with constant time of exposure determine the section of family of edge functions at any constant level of intensity, which is needed for division during a developed processing stayed and removal of photopolymer according to a threshold level of the expositions. The meanings abscissa, appropriate to crossing of an exposition straight line with the edge functions, will give sizes of distance of removal of a profile of a printing element from its geometrical border, depending on depth (fig. 10, 11).

As the exposure straight line can be in some limits chosen arbitrary, it is

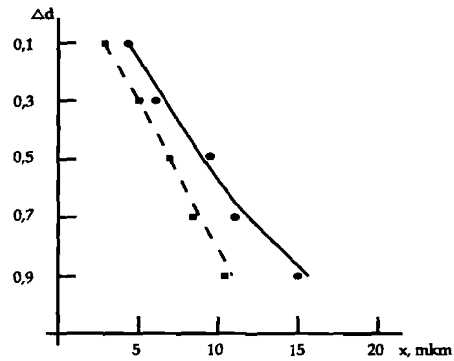

Fig.10. The profiles of the printing element (light source body - 20mm): (—) – the correct exposure; (- -) – dont correct exposure; (▪ ; •) – the experimental data.

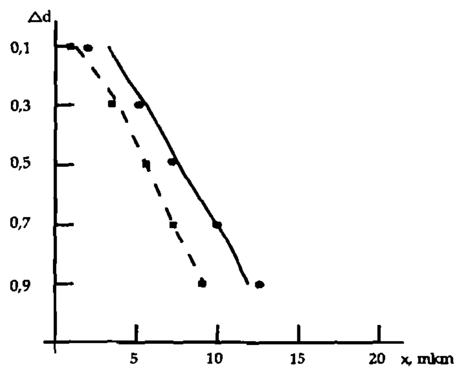

Fig.11. The profiles of the printing element (light source body - 4mm): (—) — the correct exposure; (- -) — dont correct exposure; (▪ ; •) — the experimental data.

possible to make an analysis of a influence of a choice an exposure on the quality of a formed profile of a printing element.

If in a photopolymer layer there is an appreciable absorption, the exposure straight line is replaced with a curve which is taking into account this absorption (fig.10, 11).

3. The experimental check of account. The method of physical modeling.

Represents doubtless interest to compare the received settlement results to real results of formation of a profile in a thick photopolymer layer. A profile of a printing element received at exposure of a photopolymer material is possible to estimate, for example, with the help of a method of a micro cross-cut. However method is labour, consuming and requires the special equipment. Us for an experimental estimation of a profile of distribution of intensity proposed a method of physical modeling. This method consists that the photopolymer material of any thickness is simulated by means of compound layers formed by polymeric film with a parameter of refraction, close to a coefficient of refraction of photopolymer compositions. The optical uniformity of a compound layer is provided with introduction of immersion a liquid between layers. The divergence of radiation on the chosen depth of a layer is fixed with the help of silver halide a photographic material with high resolution and with high coefficient of contrast ($\gamma = 6$). Such a photographic film serves the threshold indicator of an exposure, providing a high edge sharp, so it is suitable for measure of a border at a constant level of an exposure, and consequently, at a time constant and a constant level of intensity. Thus, if to introduce this photographic film on different depth and to set constant amount of illumination, it is possible using the object such as an edge or a lattice exposure to measure displacement of border of the image from border of object on different depth. Consequently it is possible to estimate a profile of a printing element at the chosen level of an exposure.

Besides the given method does not require a special measurement equipment, the method is good also by that allows to simulate complex optical structures of a photopolymer material. For example, the introduction inside of a photopolymer material layer a various scattering single layers with different optical properties and estimation of their influence on MTF and the profile of a printing element is possible.
The circuit of a method is shown on fig.12.

The measurements are carried out for two sources of radiation -4 and 20

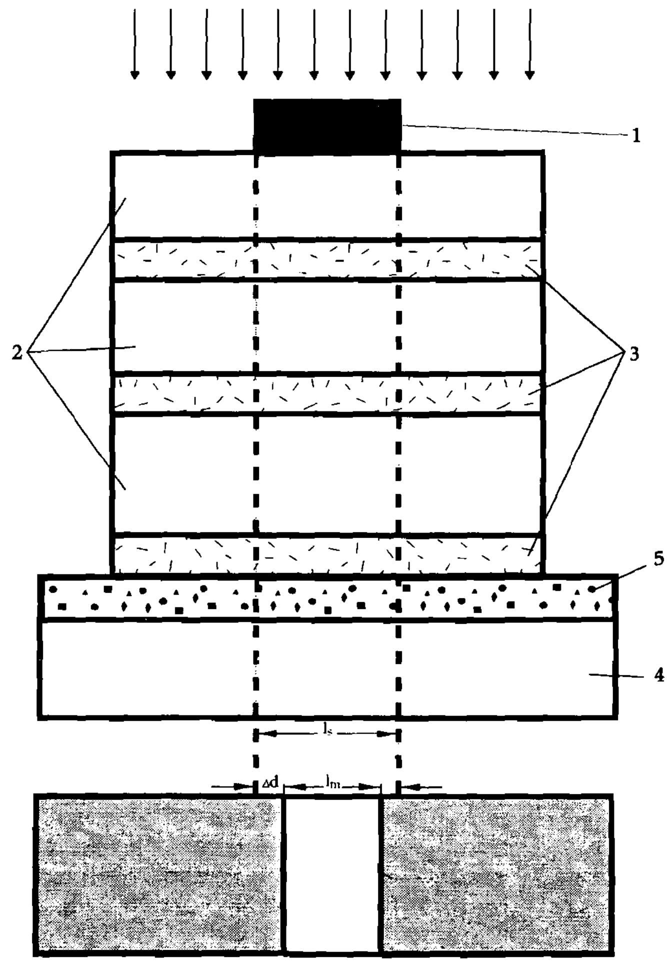

Fig.12. The circuit of the method. 1 - stroke object; 2 - a polymer film; 3 - a immersion; 4 - a photographic material; 5 - a photosensitive layer of photographic material.

mm, – and for thickness of a model layer from 0,05 up to 0,95 mm. The results of measurements are shown in a fig. 10 and 11. They show satisfactory conformity of results of account and model experiment.

4. Conclusion.

Two methods of research thick of printing plate materials are developed on the basis of compositions. The settlement method allows predict influence a profile of a printing element under the various conditions of exposure, a structure of a photopolymer material. Experimental methods created on the basis of physical modeling of layer structure of a layer, supplements a method of account, allowing it is enough simply to estimate some parameters, which are difficult determined by a settlement method of optics of a complex multilayer structure. The authors believe, that continuation of researches with model layers of real photopolymer compositions, the research of layers a more complex optical structure can give real results on the further perfection of optical properties photopolymer materials in an essential responsible for qualitative parameters of photopolymer printing plates.

Acknowledgment

The authors thank the students of the Moscow State University of Printing taken part in the experimental researches.z