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DEVELOPMENT OF EXPERIMENTAL ULTRASOUND DEVICE FOR MODIFICATION OF FLEXOGRAPHIC PHOTOPOLYMER PRINTING PLATES

S. A. Bartashevich[1], S. K. Grudo[1], S. A. Khokhriakov[2]

[1]*Belarusian State Technological University,*
13 a, Sverdlova St., Minsk, 220006, Republic Belarus

[2]*«Powder Metallurgy Institute» National Academy of Sciences of Belarus*
41 Platonov St., Minsk, 220005, Republic Belarus

This article describes an experimental ultrasound device, which is designed for a pilot study to determine the impact value of the main parameters of ultrasound irradiation on the intensity and value of secondary additional stitching of digital photopolymer flexographic printing plates, as well as to study the changes in their printing performance properties. This device has a semi-wave oscillating system based on a piezo-electric transformer, an ultrasound generator, a system of the tool working surface load control on the irradiated surface of the flexographic printing plates.

Keywords: *a photopolymer printing plate, an ultrasound modification, a semi-wave oscillating system, a piezoelectric transformer, an ultrasonic generator, contact force.*

Problem set. It is necessary to conduct additional cross-linking stitching to get the homogeneous properties of photopolymer composition of flexographic printing plates. This can be achieved by various modification ways. One of such methods for the modification of polymer materials is the ultrasonic oscillations energy impact on the irradiated material [1, p. 61–66]. To confirm the effective use of the ultrasound method of the modification of photopolymer flexographic printing plates (PPP) it is necessary to study the impact of its main technological parameters on an experimental ultrasound device that is relevant and important.

Analysis of recent research and publications. Active ultrasound influence on the substance, which leads to changes in its physic-chemical properties or changes of the physical processes occurring in it, causes the widespread use of ultrasound modification. The practical application in printing processes belongs to low-frequency ultrasound oscillations [2–3]. The mechanism of ultrasound impact, as well as the tasks solved with its help, is directly related to the treated technological zone and its properties [4]. In addition, the effectiveness of ultrasound impact depends on structural and technological solutions [5, p.46–49], implemented with the help of special ultrasound devices and defining the basic parameters such as frequency and amplitude of the ultrasound oscillations and acoustic contact between the working tool and the irradiated medium.

The aim of the article is the development and creation of an experimental ultrasound device for finishing the working surfaces of flexographic photopolymer printing plates in the zones. This device allows defining the main technological parameters for efficient energy-intensive ultrasound influence on printing and performance characteristics of printed plates.

The basic material of the study. The basis of practical application of the ultra-sound modification of PPP is the mechanism of the direct effects of ultrasound (US) oscillations on the composition of photopolymer printing plates for the purpose of breaking weak double links in it to form macro-radicals required for the restructuring process of the polymer [1]. This restructuring increases the molecular weight of the macromolecules and allows us to give a branched structure to a solid polymer material, which will increase the resistant parameters of printing plates.

The basis of the development of experimental ultrasound equipment to modify PPP is the right choice of the acoustic system and the mode of its work. [5] The effectiveness of ultrasound modification of PPP is determined by the amplitude of the oscillations, the maximum value is achieved at the stimulation of ultrasound oscillatory system at the resonant frequency [6]. The choice of the resonance frequency is made based on the physical and chemical properties of the photopolymer material, features of absorption of ultrasound energy, structural dimensions of the elements of ultrasound oscillatory system (UOS), as well as matching conditions of acoustic systems with the electrical section.

Firstly, taking into consideration the authorized limits and acceptable levels of ultrasound oscillations at service [7] for the designed device we need a desired frequency band within 22..44 kHz. At these frequencies, the oscillation amplitude can be easily implemented at 20..70 micron [8], to ensure the maximum performance of ultrasound influence on photopolymers.

Second, the effectiveness of the impact of the ultrasound oscillations on irradiated PPP depends on the acoustic contact between the device and the irradiated medium. Under the acoustic contact, we mean not only the presence of the contact itself, but also its nature, namely, the absence of an air gap between the surface of the working tool and the surface of the irradiated medium with the same even contact force, thus avoiding unproductive energy losses.

It is known that PPP has a printed raster structure differing in number of printing elements per an area unit. Therefore it is necessary to regulate the ultrasound irradiation of the printing plates not only for the specific density of the irradiation and the time of its exposure, but also for forming the force of acoustic contact between the working surface of the oscillating system and the plate surface to avoid damaging the printing raster structure. Because of this the UOS should have a high compactness and light weight.

In view of the above requirements, we have developed and produced an experimental device that performs the ultrasound finishing processing of the working surfaces of flexographic printing plates in the zones. The device structurally consists of an ultrasound generator and an acoustic system (Fig. 1), which comprises a number of parts and systems, in particular an oscillating system 1 comprising a conical concentrating pad 2 with a mounted working tool 3, a reflective cylindrical pad 4, a pair of piezoelectric transformers 5, located between the above pads and an acoustically linked special contact element.

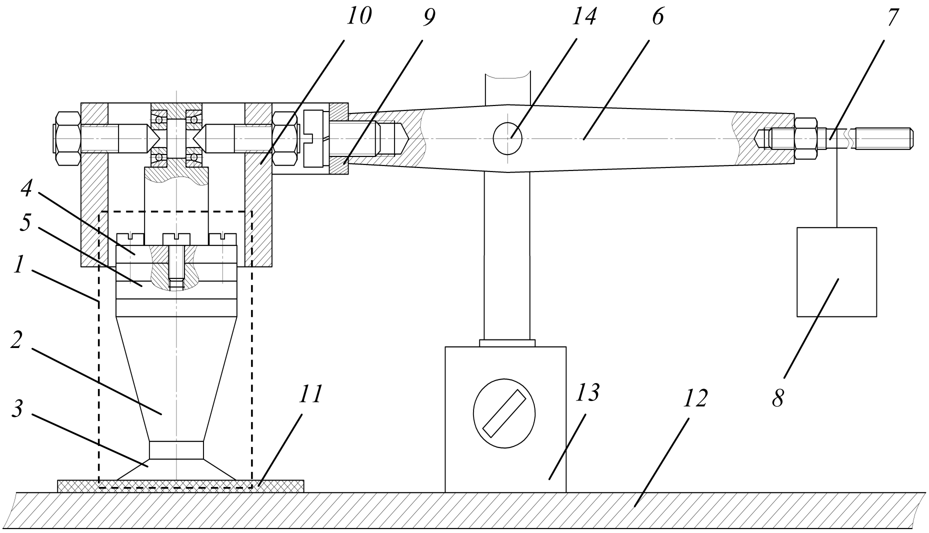

Fig. 1. General view of the ultrasound oscillating system

The oscillating system 1 is connected with the system of regulated loading of the working surface of the tool 3, consisting of the rocker arms 6, on the large arm of which via pins 7 are counterbalanced elements (loads) 8, and a lower arm via pivotally interconnected fork 9 and nozzle 10 is mounted with the possibility of pivot in two mutually perpendicular planes oscillating system 1. This connection allows the plane-parallel movement of the working surface of the tool 3 and the self-adjustment of it on the surface of the exposed printing plate 11, which in its turn will provide a complete acoustic contact of these surfaces, as well as the uniform and equal force of their pressing.

Furthermore, the ultrasound experimental device contains the mounting unit of the whole acoustic system on the working plate 12, which is designed as a magnetic rack 13 fixed to it via a pivot axis 14 of the controlled loading. Adjustable loading is set with the help of the elements 8 which allow to balance the oscillating system, as well as to set the necessary pressing force at a predetermined value. The loading value is controlled by grammometre.

The transformer of the oscillating system converts the energy of electrical oscillations into the energy of elastic oscillations of ultrasound frequency and it creates the alternating mechanical force acting on the technological medium [9]. A concentrator with the working surface creates an ultrasound field in the photopolymer composition or directly affects it. To stimulate the ultrasound oscillations in a transformer in UOS we use piezoceramic transformers of the brand TSTBS-7, which are made in the form of two identical rings with a diameter of 38 mm and a thickness of 5 mm each with a capacity of 50 watts. The piezoceramic plates with the reflective pad have a rigid connection.

To improve the efficiency of the transformer and reduce the wave resistance of the reflecting pad we use steel St 45. When constructing, the connection surface of transformers are carefully grinded in. Creating the necessary tightening effort, the durable mechanical connection is provided by the tightening bolts M10 with fine thread and soft pads. For the electrical insulation of the inner cylindrical surface of the piezoelectric elements from the metal tightening bolt we use an isolating bush. The material for the application design of the concentrator is the material D16. The calculation of the UOS is carried out basing on geometrical dimensions and physical parameters of the used piezo material and specific acoustic power [5.8]. The main parameters of ultrasound effects are shown in Table 1.

In accordance with the proposed method of modification [10] the ultrasound irradiation is carried out in the zones into which each color separation photopolymer printing plate is broken with the necessary pressing and the acoustic contact between the working surface of the ultrasound device and the surface of the printing plate. The effort of each zone acoustic contact is defined as the production of the average value of the relative area of raster dots of this zone, expressed as a percentage, to the maximum force value equal 0.6 W/cm^2.

Table 1

№	Technological Parameters	
1	Resonance frequency, kHz	44±1,65
2	Specific acoustic power, W/cm^2	1,2
3	Acoustic power, W	8,5
4	Duration of ultrasound irradiation, min	15..20
5	Effective radiating area, cm^2	7
6	Maximum value of the acoustic contact, N/mm^2	0,6
7	Force of the acoustic contact, H	0..0,2
8	Value of ultrasound energy, kJ/mol	266..348

To stimulate the ultrasound mechanical oscillations at the end of the tool UOS, we supply the required voltage of ultrasound frequency on its piezoelectric transformer via contact pads from the electronic ultrasound generator (EUG). To power UOS of the experimental ultrasound device we have designed and manufactured EUG model VNT77 [11]. It is made taking into account the specifics of exposure of PPP. EUG is designed on the scheme with separate stimulations, selfadjustable frequency and it is constructed to drive the mechanical oscillations of ultrasound frequency in piezoelectric transformers in the frequency band (35...50) kHz and the power consumption of at least 100 watts.

Besides resonant loading stimulations, the offered EUG has an opportunity at a simple revision to feed any loads (active and reactive). Moreover, the output power may be continuously adjustable separately or jointly, depending on the type of load:

– Change in the frequency of the generator by voltage of the internal source;
– Change in the frequency of the generator by voltage of the feedback;
– Change in the duration of supply voltage pulses by voltage of the internal source;
– Change in the duration of supply voltage pulses by voltage of the feedback.

EUG is made in climatic design of the category UHL of the equipment allocation 4 according to GOST 15150-69 and designed for operation at temperature (30...1)˚C, relative humidity up to 65% and atmospheric pressure from 84 kPa to 107 kPa. The degree of protection against ingress of moisture is 1R10 according to GOST 14254-80. Its power supply is done from single-phase AC voltage of 220V, 50 Hz. In addition to the power of the required loads the EUG has a possibility to connect the remote cooler 12 V and the current of not more than 0.2 A. Setting the maximum output power level is produced by the selection of coils in transformers and chokes in the matching module. Within this level the flexible adjustment of the output power is carried out in the manner described above.

The main elements of EUG are: a power supply to generate a low-voltage and high-voltage, a control unit for generating control pulses, a key output transistor amplifier (inverter), a coordination unit, monitoring and control devices. Matching of the amplifier output forming an ultrasound voltage of rectangular shape (square wave) and the given amplitude to the UOS, to piezoelements on which you want to apply a sine wave voltage and the desired amplitude adjustment is carried out using a matching block. It consists of a transformer and a choke, which together with the piezo-rings of UOS form a resonant oscillatory circuit. As a result, the surfaces of piezo-rings form a sine wave voltage, which is stimulated by piezo-rings, changing their linear dimensions. There are mechanical oscillations that are transmitted to all points of UOS and the working surface of the tool.

The EUG can function in modes «working» and «adjustment». In the mode «adjustment» we make working checks and adjust configuration of the generator at low supply voltage of the output stage. Turning into «adjustment» is done by the switch S3 “mode” (position «H»), located inside the body (Fig. 2).

Switching the generator is done by the feeding in its electronic part of the AC voltage across the electrical plug «Euro» and turn on the switch S1 «network». At the same time the output of the transformer T1 of block B2 «BP1» gets the voltage of about 14 V, which is rectified and supplied to the control unit A1 «BU1» of the generator module B1 «MG1». The control unit turns on the generator. It forms in-phase control pulses.

These pulses can be adjusted separately or together in frequency and duration by the variable resistor of the control unit «BU1» of the generator module «MG1» taken to the front panel to a screwdriver by the above methods. Moreover, when switching the EUG, the duration of these pulses after voltage on the block A1 «BU1» increases gradually over a set time.

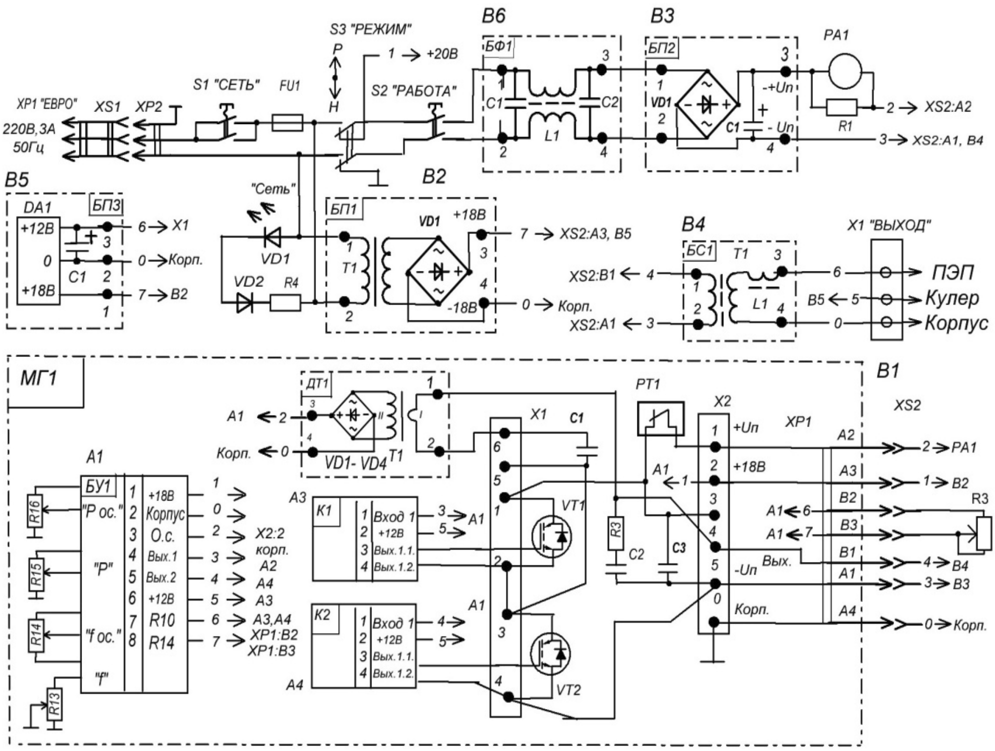

Fig. 2. Scheme of switching the ultrasound generator

As a result, the output power is increased gradually when the EUG when switching S2 «work». From the control unit the control pulses are supplied to the output keys A3 and A4 that are controlled by the output transistors VT1 and VT2. When we supply the power to the output transistors VT1 and VT2 of the generator module B1 «MG1» at its output we have rectangular pulses of ultrasound frequency, which go through the capacitor C1 and the current sensor A2 «DT1» and arrive at the matching block B4 «BS1.» In the matching block B4 these pulses are applied to the primary winding of transformer T1. Then they do from the secondary winding of the transformer via the choke coil L1, and further, via respective switching elements on the piezoelectric plates of UOS. They receive the first harmonic component in the form of sine voltage.

In the mode «work» (switch S3 «mode» is switched to the upper position «P») the low voltage is replaced by the voltage + 311 V. The output power is controlled by the indicator PA1. The power supply unit B5 «TU3» is designed to supply the remote cooler. Switching on and off of the oscillation of UOS in the working process is made by the switch S2 «work».

As we know, the maximum output power of piezoelectric transformer for the given voltage corresponds to a certain frequency. Moreover, the frequency is largely dependent on the temperature of the piezoceramic plates because when heated they shrink. Starting the work of ultrasound device (the main switch S2 of the mode «work» on EUG) the plate's temperature of UOS is growing rapidly, and the frequency varies considerably. Within 5 minutes, the heating rate and the rate of frequency change are normalized and should be ready to start the process of zone ultrasound irradiation of PPP. To stabilize the output power of the piezoelectric transformer at the desired operating temperature it is necessary to apply its inflating with the help of a remote cooler.

Conclusions. The developed and manufactured experimental ultrasound device for modification of flexographic photopolymer printing plates allows identifying the main technological parameters of effective ultrasound action to improve resistant properties of printing plates. This device can be used for different printing plates differing in hardness that extends its functionality. The process of ultrasound modification of flexographic plates implemented in the device has low energy consumption and is environmentally friendly.

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РОЗРОБКА ЕКСПЕРИМЕНТАЛЬНОЇ УЛЬТРАЗВУКОВОЇ УСТАНОВКИ ДЛЯ МОДИФІКАЦІЇ ФЛЕКСОГРАФІЧНИХ ФОТОПОЛІМЕРНИХ ДРУКАРСЬКИХ ФОРМ

С. А. Барташевич[1], С. К. Грудо[1], С. А. Хохряков[2]

[1]Білоруський державний технологічний університет
вул. Свердлова, 13 а, Мінськ, 220006, Республіка Білорусь

[2]«Інститут порошкової металургії» Національної академії наук Білорусії
вул. Платонова, 41, Мінськ, 220005, Республіка Білорусь
Bart19@belstu.by

У статті описано експериментальну ультразвукову установку, яка призначена для проведення експериментального дослідження з визначення величини впливу головних параметрів ультразвукового опромінення на інтенсивність і величину вторинного додаткового зшивання цифрових флексографічних фотополімерних друкарських форм, а також для дослідження зміни *їх друкарсько-експлуатаційних властивостей. Ця установка складається з півхвильової коливальної системи на основі п'єзоелектричного перетворювача, ультразвукового генератора, системи регулювання навантаження робочої поверхні інструменту на опромінювану поверхню флексографічних друкарських форм.*

Ключові слова: *фотополімерна друкарська форма, ультразвукова модифікація, півхвильова коливальна система, п'єзоелектричний перетворювач, ультразвуковий генератор, зусилля притиску.*

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