REPUBLIC OF AZERBAIJAN

on the rights of manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

RESEARCH OF THE PARAMETERS INFLUENCING THE PRINTING FORMS AND THE PRINT QUALITY IN THE OFFSET PRINTING MACHINES

Specialty: 3313.02 “Machines, equipment and processes”

Field of science: Engineering sciences

Applicant: **Elnur Maqsad oglu Huseynzade**

BAKU-2022

The work was performed at the Department of "Mechatronics and machine design" of the Azerbaijan Technical University.

Scientific supervisor: doctor of technical sciences, professor, Honored Teacher
Isa Ali oglu Khalilov

Official opponents: doctor of technical sciences, professor
Zakir Ali Agha oglu Rustamov
doctor of technical sciences, professor
Ibrahim Abulfaz oglu Habibov
candidate of technical sciences, associate professor
Huseyn Ibrahim oglu Mirzaev

Dissertation council ED 2.32 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan Technical University.

Chairman of the Dissertation council: d.t.s., prof., Honored Engineer
Vagif Zahid oglu Movlazadeh

Scientific secretary of the Dissertation council: d.t.s., prof.,
Nizami Shayi oglu Ismailov

Chairman of the scientific seminar: d.t.s., prof.,
Rasim Javad oglu Bashirov

GENERAL DESCRIPTION OF WORK

Relevance and development of the topic. At the modern stage, the increase in production and product quality are the main issues of the printing industry. The solution to these problems significantly depends on the printing and technical characteristics, technological and operating conditions of the form materials.

Despite the intensive development of printing methods, both sheet and roll offset printing today dominates the printing industry in most countries around the world. The development of offset printing, like all its technological components, is associated with scientific research on the optimization of the printing process from its inception to the present day and the assessment of the impact of optimized modes of the technological process on the quality of printing.

From the point of view of research analysis, the printing of constructive, technological, and operational parameters, taking into account the wide range of modern printing forms and printing materials, as well as moisturizing solutions and printing inks, technological capabilities of modern sheet printing machines and modern quality criteria It can be said that the use of a systematic, reliable methodology to study the impact on quality is of great interest. This methodology also allows us to study the impact of constructive, technological, and operational parameters, flat offset printing, which is an important component of the management process, on the quantitative values of materials. The lack of such information, as well as the importance of this information for the effective management of the printing process to achieve the highest quality characteristics of the printed product, determines the relevance of the dissertation.

In order to ensure the circulation resistance of print forms and improve the quality of printing in modern times, it is important to study the impact of constructive, technological, and operational parameters on these indicators, their optimization, and determination of the dependence of regularities in the process management on these parameters. One of the important issues of our time is the application of the results of complex theoretical and practical research in this area to the management of the printing process.

The dissertation theoretically studies the interaction of the blanket with the printed form, substantiates the effect of the roughness of the surface of the printed form on the deformation of the blanket, determines the relative transmission and load of the shaft in the friction print pair. Deformation of the blanket in the print contact zone was determined by the finite element method. Planning of extreme experiments was carried out, the influence of constructive, technological, and operational parameters on the contrast of the print (K), the change of the area of the raster elements (ΔS), the circulation resistance of the offset printing forms (N_o) was studied experimentally. The results of the experiments were processed and optimized to ensure the circulation resistance of print forms and the quality of optics.

Objectives and tasks of the research. The purpose of the dissertation is to ensure the circulation resistance of print forms and the stability of print quality by optimizing the constructive, technological, and operational parameters.

To achieve the set goal, the following issues are planned to be solved:

1. Development of a methodology for determining the impact of constructive, technological, and operational parameters on the circulation resistance of the form and print quality, taking into account the roughness of the surface of the printing form;

2. Development of methods for calculating the forces generated in the contact zone, taking into account the roughness of the surface of the print form;

3. Development of a method for determining the deformation of the blanket in the printing process.

4. Experimental study of the effect of constructive, technological, and operational parameters on the circulation resistance of the form and the quality of the print;

5. Development of recommendations based on theoretical and experimental research to ensure the circulation resistance of print forms and the stability of print quality in the printing process by methods of regulating the constructive, technological, and operational parameters.

6. Evaluate the effectiveness of the developed methodologies and results.

Research methods. The issues raised in the dissertation were carried out in the laboratory and in production, solved based on theoretical and experimental research. Modern equipment and devices for research, including a modern full-color offset press, CTP, densitometer, profilometer, etc. research tools were used.

The main provisions of the defense.

1. Theoretical study of the interaction of blanket with the printed form:

- The effect of the roughness of the print surface on the deformation of the blanket (soft) and dusting of the paint.

-Determination of the deformation of the blanket in the printing process by the method of finite elements.

2. Planning of extreme experiments and methods of processing of experimental results:

- Experimental study of the effect of constructive, technological, and operational parameters on the contrast of the print (K), the change in the area of the raster elements (ΔS), the circulation resistance of offset printing forms (N_o);

- Carrying out optimization in the printing process to ensure the circulation resistance of print forms and the stability of the quality of optics.

The scientific novelty of the research. The main constructive, technological, and operational parameters that affect the circulation resistance of the print and the quality of printing have been identified. Based on theoretical and experimental studies, the relationship between the circulation resistance and print quality of the printing form and the constructive parameters - decollete, print form, technological parameters - paper and operating parameters - print pressure and print speed were determined.

A methodology for researching and evaluating the impact of constructive, technological, and operational parameters on the circulation resistance of the print and the quality of printing has been developed.

Methods for calculating the forces in the contact zone, print pressure, and the size of the contact strip, taking into account the roughness of the surface of the print form, have been developed.

Taking into account the micro-engineering parameters of the surface of printed forms, the mathematical dependence of the influence of constructive, technological, and operational parameters on the circulation resistance of the printed form and the quality of the print was determined.

The theoretical and practical significance of the research.

A methodology has been developed and applied that allows increasing the circulation of print and the quality of printing. The results of research conducted based on offset printing and the identified regularities can be applied to other printing methods to improve the quality of printing and the circulation resistance of the printing form.

Improving the circulation resistance and print quality of the printed form with the proposed methods does not increase the cost, reduces idle time of machines and, as a result, increases the economic efficiency of production.

Approbation and application. The main provisions of the dissertation were presented and discussed at the following conferences, symposiums, and seminars.

1. Republican scientific-technical conference of students and young researchers on "Youth and scientific and technical progress", dedicated to the 91st anniversary of the national leader of the Azerbaijani people Heydar Aliyev, Baku, 2014;

2. International Symposium of Mechanism and Machine Science, 2017. AzCIFToMM-Azerbaijan Technical University. 11-14 September 2017, Baku, Azerbaijan;

3. Innovation in science, education, and technology. LV international correspondence scientific and practical conference (London, United Kingdom, 18-20 September 2019).

4. Innovation in Science, Education and Technology. XXI international correspondence scientific and practical conference (London, United Kingdom, April 21-22, 2021).

The main content of the work has been published in 12 authoritative journals in 12 works.

Name of the organization where the dissertation work is performed. The dissertation was completed at the Azerbaijan Technical University. The results of the dissertation work were applied in the printing process in "Chashyoglu" and "Indigo" OJSC publishing houses.

The total volume of the dissertation with a sign, indicating the volume of the structural units of the dissertation separately. The dissertation consists of an introduction, 4 chapters, general results, a list of references, and appendices.

The dissertation is presented in 270 pages in A4 format, contains 33 figures, 21 tables, 182 literature sources, and appendices.

CONTENT OF THE WORK

The introduction substantiates the relevance of the topic, defines the goals and objectives of the work. Scientific innovations, scientific and practical significance of the research have been formed. Information on the approbation and publication, structure, and scope of the work is provided.

The first chapter is devoted to the issues of the circulation resistance of offset printing forms and ensuring the quality of printing. It summarizes the features of the printing apparatus and offset printing process, wears resistance of offset printing forms, constructive-technological operational features of the printing process, circulation quality, methods and means of control over print circulation and print quality, ways to increase offset printing and print quality.

Analysis of research work on the problem has shown that improving the quality of printing and increasing the circulation of printed forms is solved in a multifaceted and different way in the printing industry.

It has been established that the methods and means of improving the quality of printing and increasing the circulation of printed forms are not universal and cannot be applied to all types and methods of printing. These methods and tools should be considered only individually and separately because the constructive and physical-mechanical properties of printing forms differ significantly for each printing method and type.

These studies have shown that the influence of constructive, technological, and operational parameters is more important than the influence of the mechanical properties of the forms and the printed material on the circulation resistance of printing forms and the quality of optics. For this reason, the use of methods to improve the quality of printing and increase the circulation of print forms by optimizing the constructive, technological, and operational parameters can be considered a rational way. Thus, the literature review showed that it is more expedient to use the optimization of constructive, technological, and operational parameters in different types and methods of printing to improve the quality of printing and increase the circulation of printed forms. It is very important to study the complex effect of these parameters on improving print quality and increasing the circulation of print forms.

All factors affecting the circulation resistance of the form are divided into 3 groups: constructive, technological, and operational.

The table shows the classification scheme of the factors determining the impact of print forms on the circulation resistance and quality of optics (Fig. 1).

Since the print pressure, which is the operating parameter, depends on the blanket and print form packages related to the constructive parameters, all their elements must be taken into account in the theoretical calculations and the printing process. However, in the summarized research, the effect of the roughness of the print surface on the circulation resistance of the forms, the quality of the optics, as well as the forces in the contact zone is almost not studied. At the same time, the effect of the roughness of the surface of the printing form on the deformation of the blanket material was not taken into account in the calculations. The process of determining the deformation in the contact zone was carried out on an imitation model.

Most of the summarized studies on the circulation resistance of print forms and the improvement of print quality show that the maximum circulation resistance of each print form in the printing process by all contact methods can be achieved under the optimal conditions of their technological processes.

Optimizing constructive, technological, and operational parameters to ensure the circulation resistance of print forms and improving the quality of printing in modern times, and determining the dependence of regularities in process management on these parameters can provide significant technical and economic benefits and is a promising direction. The application of the results of complex theoretical and practical research in this area to the management of the printing process allows to save raw materials and increase productivity in the production of printing.

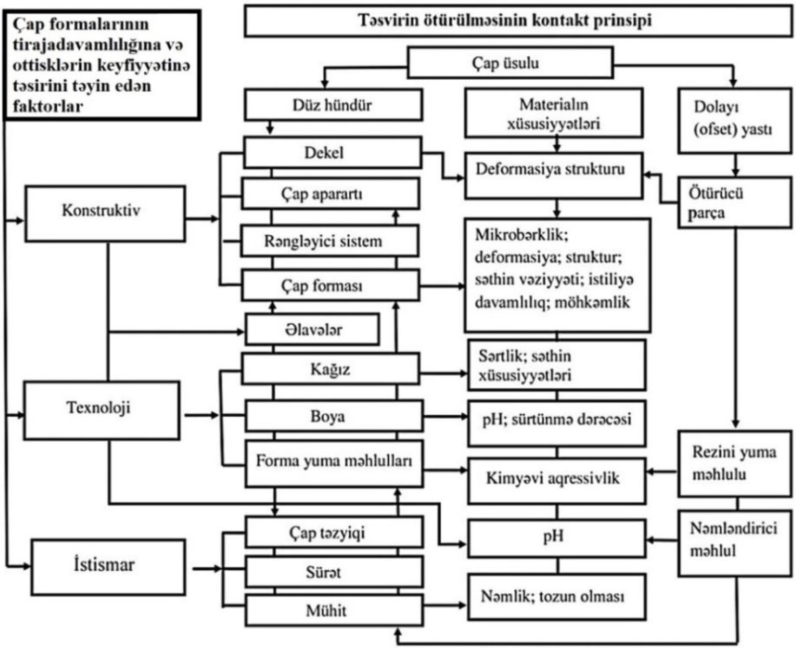

Fig. 1. Classification scheme of factors determining the impact on the circulation resistance of print forms and the quality of optics

It is known from the researched works that the effect of the roughness of the surface of the printing form on the circulation resistance of the forms, the quality of the optics, as well as the forces in the contact zone have not been widely studied. At the same time, the effect of the surface roughness of the printing form on the deformation of the blanket material is not taken into account in the calculations. The process of determining the deformation in the contact zone was carried out on an imitation model.

The second chapter is devoted to the interpretation of methods for studying the impact of constructive, technological, and operational parameters on the circulation resistance of offset printing forms and the quality of optics.

To determine the effect of constructive, technological, and operational parameters on the circulation resistance and print quality of the form, methods for calculating the forces in the contact zone and the size of the contact strip, taking into account the roughness of the print surface, developed the effect of roughness on the printing pair mechanics. The deformation of the blanket in the process was determined by the method of finite elements.

In general, the surface parts in contact come together under the influence of forces. The interaction of the printed form and the actual texture of the blanketly results in the roughness of the surface of the printed form entering the surface of the blanketly.

A discrete model of roughness was used to determine whether the roughness of the rough surface of the printed form entered the blanket. The radius of the roughness is $R = a_c^2/(2\omega R_{max})$, expressed as the sum of the same spherical segments with base a_c and height ωR_{max}. In this case, an adjusted incomplete beta function was used to describe the surface support curve.

$$\eta(c) = \frac{B_\varepsilon(p,q)}{B(p,q)} \tag{1}$$

where $B_\varepsilon(p,q)$, $B(p,q)$ is an incomplete and complete beta function, respectively;

p and q are the parameters of the beta function determined by the height parameters of the roughness;

The input value for the i roughness of the rough surface is determined by the following formula:

$$h_i = (\varepsilon - u)R_{max} \tag{2}$$

here ε is the relative approximation and i is the initial distance to the vertex of the roughness.

Several hills on the floor du:

$$dn_r = n_c \varphi_n'(u) du, \qquad n_c = \frac{A_c}{\pi a_c} \tag{3}$$

here n_c is the number of spheres; A_c is the contour area of the contact.

After taking into account the input value of the roughness of the rough surface, the relative transmission is determined as follows:

$$i_{ave} = 1 - q_o \varepsilon_o + \frac{\lambda}{R_E} + \frac{R_{max}}{R_E} (\varepsilon - u)\, \varphi_n'(u) du \tag{4}$$

When $q = 0$ - for ideal pressed decellets

$$i_{ave} = 1 + \frac{\lambda}{R_E} + \frac{R_{max}}{R_E} (\varepsilon - u)\, \varphi_n'(u) du \tag{5}$$

and when $q = 1$ - ideal for elastic blankets

$$i_{ave} = 1 - \varepsilon_o + \frac{\lambda}{R_E} + \frac{R_{max}}{R_E} (\varepsilon - u)\, \varphi_n'(u) du \tag{6}$$

As can be seen from (5) and (6), as the deformation λ or ε_o increases, the value of i_{ave} decreases for elastic blankets and increases for constraints. For both types of blanket, i_{ave} is similarly affected by the roughness of the print surface, R_{max}.

In this case, the following calculation scheme was adopted to determine the effect of the roughness of the print surface on the frictional forces (Fig. 2).

Taking into account the characteristics of the offset printing process, the total and frictional forces were determined when an elastic saturated contact is formed when the contact zones of the shape and offset cylinders interact.

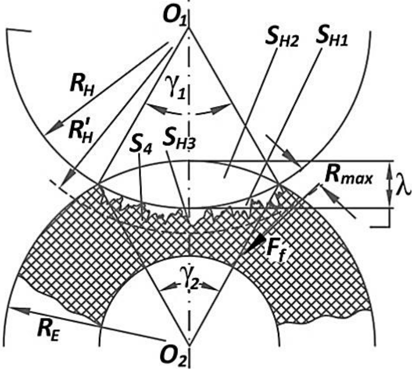

Fig. 2 Scheme for calculating the forces acting on a friction print pair, taking into account the roughness of the print surface

To determine the forces, the amount of deformed blanket material under the rough surface of the mold surface was determined. For this purpose, the following fields marked on the scheme (Fig.2) were calculated by noting:

S_{H1} is the area of the contact zone sector corresponding to the central angle γ_1, taking into account the roughness of the print surface;

The S_{H2}-print form is the area of the contact zone sector corresponding to the central angle γ_1 without taking into account the roughness of the surface;

S_{H3} is the area below the rough surface of the print form entering the sector of the contact zone corresponding to the central angle γ_1.

S_4 -print is the area of the cavity entering the sector of the free contact zone from the rough layer of the surface. This area is equal to the area of the deformed blanket layer under the rough surface of the print form in the sector of the contact zone corresponding to the central angle γ_1.

To determine the amount of deformed blanket material under the rough layer, we determine the areas marked on the scheme:

Let us determine the area of the cavity-free from the rough layer of the print surface.

$$S_4 = S_{H1} - S_{H2} - S_{H3} \quad (7)$$

Determine the amount of deformed blanket material under the rough surface of the print form surface

$$V = S_4 \cdot L \quad (8)$$

Here L is the contact length along with the origin of the cylinders in contact.
Let us write (8) as follows, taking into account certain calculations on the scheme

$$V = \frac{\pi R'_H L}{180°} \gamma_1 \left[\frac{R_{max}(2R'_H - R_{max})}{2R'_H} - R_a \right] \quad (9)$$

(9) is the total friction force, taking into account the known formulas

$$F_f = \frac{\pi \cdot L \cdot \gamma_1 \cdot n_c \cdot \omega \cdot R_{max}[R_{max}(2R'_H - R_{max}) - 2R'_H - R_a]}{2 \cdot h \cdot h_c \cdot 180°} \times$$
$$\times \left\{ \left[\tau_o + \frac{0{,}4E}{1-\mu^2} \sqrt{\frac{\varepsilon_{ave} h_{max}}{R}} \right] + \frac{0{,}125\ \alpha_{hys} \cdot b \cdot \varepsilon_{ave}^{\nu-1} \cdot E \cdot h_{max} \sqrt{\varepsilon_{ave}}}{\pi R (1-\mu)^2} \right\} \quad (10)$$

normal force

$$P = \frac{0{,}2 \cdot E \cdot \pi \cdot L \cdot \gamma_1 \cdot n_c \cdot \omega \cdot R_{max}[R_{max}(2R'_H - R_{max}) - 2R'_H - R_a]}{2 \cdot h \cdot h_c \cdot 180°(1-\mu^2)} \times$$
$$\times \sqrt{\frac{b \cdot h_{max} \cdot \varepsilon_{ave}^2}{R}} \quad (11)$$

the maximum value of the total torque applied to the shaft

$$M_E^{max} = \frac{\pi \cdot L \cdot \gamma_1 \cdot n_c \cdot \omega \cdot R_{max}[R_{max}(2R'_H - R_{max}) - 2R'_H - R_a]}{2 \cdot h \cdot h_c \cdot 180°}$$
$$\times \left\{ \left[\tau_o + \frac{0{,}4E}{1-\mu^2}\sqrt{\frac{\varepsilon_{ave} h_{max}}{R}} \right] \frac{\varepsilon_{ave}}{2} + \frac{0{,}125\ \alpha_{hys} \cdot b \cdot \varepsilon_{ave}^{\nu-1} \cdot E \cdot h_{max}\sqrt{\varepsilon_{ave}}}{\pi R(1-\mu^2)} \right\} \times$$
$$\times \{R_E - [\lambda + (\varepsilon - u)R_{max} \cdot\ \varphi'_n(u)du]\} \qquad (12)$$

we can write in the form.
The largest value of the moment M_E is M_E^{max} - under the following conditions

$Q = Q_2$, ie, Calculated when $Q_1 = 0$; $e = 1$; $e_o = m_o$
Here $e = \frac{2}{b} x_o$ and $e_o = \frac{m_o}{2}(K_m + 1)$ (13)

$K_m = \frac{M_E}{M_E^{max}}$; b - contact width $b = 2\sqrt{\frac{2R_E \cdot R_H}{R_E + R_H} \cdot \lambda}$ is also calculated based on the formula, taking into account the roughness.

The results of the research show that the roughness of the surface of the print form, as well as the inclusion of its micro-smoothness in the blanketly, leads to a decrease in the centers of the cylinders and the relative center distance, as well as the maximum torque and relative transmission.

Where E is the modulus of elasticity of the deformed material; μ - Poisson's ratio of this material; α_{hys} - coefficient of hysteresis loss of the material in the case of complex stress; h_{ave} - the average value of the inclusion of the microwave; h_{max} - maximum value of micron smoothness input; ε - average relative approximation between the surfaces of interacting solids; b and ν are the parameters of the surface support curve; A_c is the contour area of the contact; τ_o and β are frictional properties depending on the conditions of the friction pairs; R is the radius of curvature of the micron.

The results of the research show that the roughness of the print surface, as well as its micro-smoothness in the deck causes a decrease in the center of the cylinders a and the relative center distance a_o, as well as the maximum torque M_E^{max} max and an increase in the relative transmission number i.

According to the proposed methodology, the value of the relative transmission number, the total force, and the friction force were calculated taking into account the roughness of the surface of the print form. Calculations were made based on the technical parameters of the Rapida *KBA 105* printer.

According to the results of the research $e_o = f(k_m), i = f(e)$, Graphs of dependences $e_o = f(e, m)$ are constructed (Fig. 2).

1 - Graph of the dependence $i = f(e)$ taking into account the roughness of the surface of the printed form; 2 - graph of the dependence $i = f(e)$ without taking into account the roughness of the surface of the printed form; 3 - $e_o = f(K_m)$ graph of dependence f (K_m); 4 - $e_o = f(e)$ graph of dependence; 5 - graph of the dependence of $i = f(K_m)$ taking into account the roughness of the surface of the printed form and 6 - graph of the dependence of $i = f(K_m)$ without taking into account the roughness of the surface of the printed form.

According to the known methodology, the curve of the dependence $i = f(k_m)$ was constructed using the graphs of the known functions $e_o = f(k_m)$, $i = f(e)$, $e_o = f(e, m)$. Using the same graphs, we construct the dependence curve $i = f(k_m)$ at points A, B, C, D in sequence according to the scheme (Fig. 3).

$A(k_m = 1) \rightarrow B(e_o = 0{,}5) \rightarrow C(e = 0{,}75) \rightarrow D(i = 0{,}978)$.
The values of e_o, e and i are shown in parentheses for $k_m = 1$.

In the graphs of the dependences, $i = f(e)$ and $i = f(K_m)$, (initial determination of the relative transmission number taking into account the roughness) the sharp decrease of the curves is explained by the corrosion of the surface of the print form after the start of the printing machine.

Calculations according to the presented methodology are performed without taking into account the pressure in the print contact zone. This calculation method allows predicting the quality of printing optics and the circulation resistance of print forms, as well as setting up the printer correctly before the printing process. At this stage, the maximum amount of paint is predicted that will contribute to the formation of paint and varnish dust.

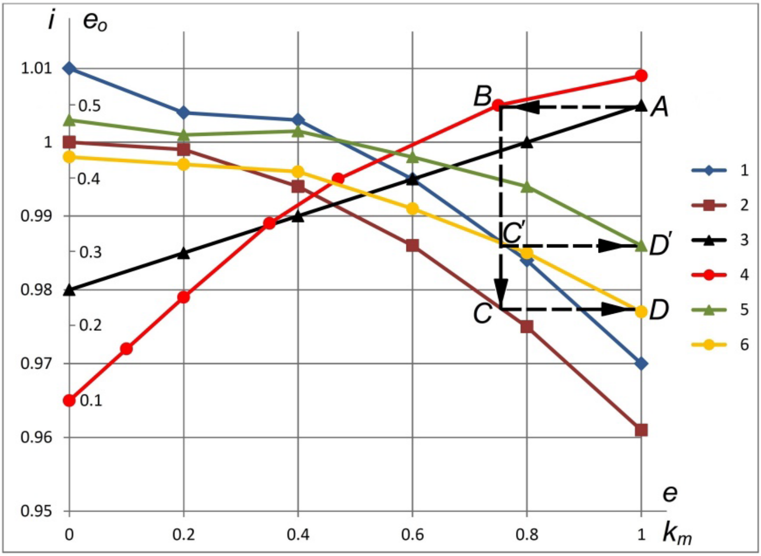

Fig. 3. Graphs of dependencies that determine the effect of the roughness of the print surface on the mechanics of the friction print pair.

To determine the optimal value of the deformation of the blanket in the printing process, the issue of elasticity in the cross-section of the contact of the printed form with the elastic blanket in the contact zone was considered under the following conditions (Fig.4):

a) The contact zone is not affected by internal and external thermal stresses and is only affected by external forces.
b) The form material is not deformed, and the blanket material is subject to the theory of elastic deformations.
c) The properties of materials do not depend on temperature.

The problem is brought to the solution of equilibrium equations. The material of the blanket is subject to Huck's law. The stress-strain state is considered in the cross-section of the blanket under the following boundary conditions.

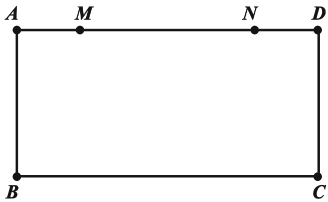

Fig. 4. Scheme for calculating the deformation in the cross-section of the blanket

$U_i(x, y) = 0$ in pieces AB, BC, CD, AM and ND
$q_i = p$ in the MN fragment
Here, $U_i(x, y)$ are displacements, P is external forces.

The problem of elasticity is solved using the principle of variation and the method of finite elements.

In the zero approaches, we will have a homogeneous elastic material. The solution of the elasticity problem is equivalent to the minimization of the functional (2) of the full potential energy of the system.

The problem of elasticity is solved using the principle of variation and the method of finite elements.

In the zero approaches, we will have a homogeneous elastic material. The solution of the elasticity problem is equivalent to the minimization of the functional (3) of the full potential energy of the system.

$$\Pi_{(\varepsilon_{ij})} = \int_v \vec{u}(\varepsilon) dv - \int_{B_q} P, U, dB - \int_v R, U, dv \qquad (14)$$

The finite element method was applied to minimize the functionality (14). It is shown by the calculation of variation that the solution of U(x, y), which satisfies the equations of the theory of elasticity, coincides with the function that minimizes the functionality (14).

The potential energy of the system is minimized because the cost of displacements is known at the boundary.

After the displacements were determined, the tensor components of deformation and stresses were calculated.

We can write the ratio of the relationship between deformation and displacement as follows:

$$\varepsilon_{xx} = \frac{\partial u}{\partial x}; \quad \varepsilon_{yy} = \frac{\partial v}{\partial y}; \quad \gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \qquad (15)$$

Here, u, v - x, y are the components of displacement according to the direction of the coordinate axes.

The values of u and v give stationary values to the function (14). u and v are defined as solutions of the system of equations (16):

$$\begin{cases} \frac{\partial \Pi}{\partial u} = 0 \\ \frac{\partial \Pi}{\partial v} = 0 \end{cases} \qquad (16)$$

The components of the element equations for the nodes are combined and linear algebraic equations of type (17) are obtained:

$$Ax = B \qquad (17)$$

To solve this system of algebraic linear equations, the iteration method was used in Gauss, Seidel, and Relaxation subtractions. As the analytical solution of these problems is quite complex, the analysis of the deformation of the blanket in the process of work with the use of computer technology was carried out in electronic form. Because the simulation applications work with the finite element method, they are depicted in the form of a mesh consisting of blanket tetrahedrons (Fig. 5).

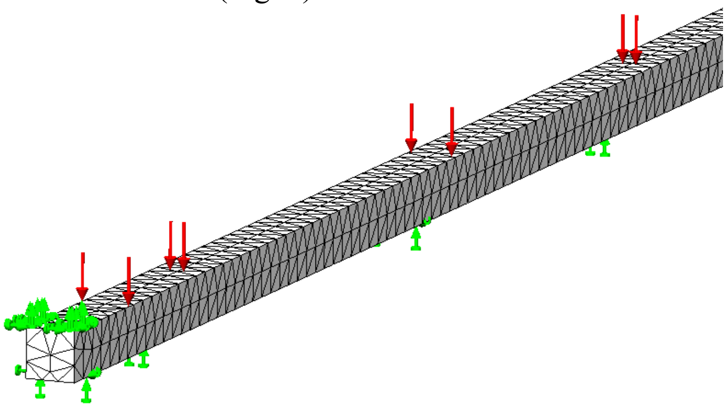

Fig. 5. Calculation scheme of deformation in the printed contact strip of the blanket by the method of finite elements in the 3D model.

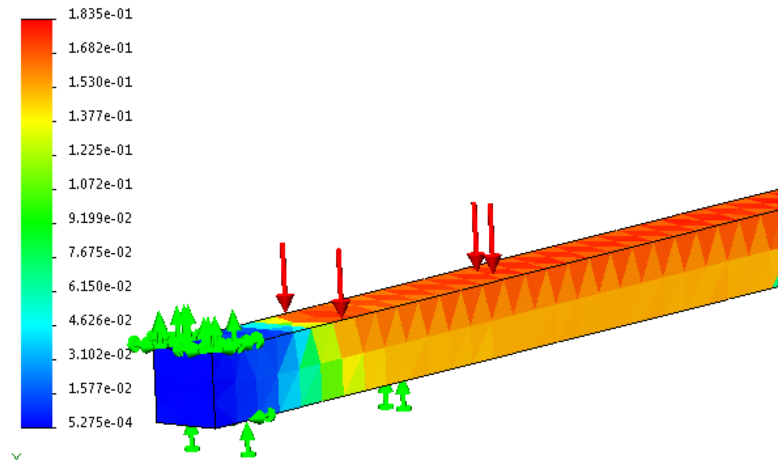

Fig. 6. Bending diagram on the printed contact strip of the decal

After entering other boundary conditions, the report was executed using the simulation application of SolidWorks. Analysis of the results shows that the relative deformation of the deck (0.98mm) was very close to the results obtained in practice. The largest deformations are evenly distributed in the contact zone along the width of the deck, starting at a distance of 10 mm from the edges (Fig. 6).

The third chapter is devoted to the experimental study of the circulation resistance of offset printing forms and the quality of optics and the discussion of the obtained results.

In order to make an objective judgment about the circulation resistance of print forms and the quality of prints, the effect of the number of prints, print contrast and area of raster elements, technological pressure, paperweight, printing speed, blanket material strength, and roughness of the print surface was studied. To study these quality criteria, 75% and 100% raster fields on printed optics were measured with a densitometer and the results obtained were compared with the optical density of the corresponding raster fields on the surface of the form.

Monometallic photopolymer LP-NV printed circuit boards were used for the experiments. The thickness of the printing plate is 0.15-0.4 mm, the resolution is 200 LPI.

A Luxel V-Vx 9600 CTP device manufactured by FUJIFILM, owned by Chashyoglu LLC, was used to transfer the rasterized information to print.

The optical density of the information on the surface of the finished printed forms was determined by the "iCPlate II" model densitometer in "Chashyoglu" LLC.

The optics from the printed forms were printed in the printing house of "Chashyoglu" LLC on the Japanese-made COMORI brand Lithron-28 model printing machine. 50x70 cm of different weights is placed on the self-loading table of the machine to make optics. format offset and chalk paper sheets are assembled. An offset drum of different hardness (rubber) was applied to the experiments. The hardness of this material varied in the range of HSA 65-70 according to the Shor A scale. Offset paper for printed optics is m_o=*60-100 q/m*^{2}, and chalk glossy paper is m_t=*90-200 q/m*^{2}, 50x70 cm. format is selected. The surface roughness of the printed form was in the range of R_{max}=0,64-2,98 mkm. Surface roughness was measured in the laboratory of AzTU with the help of profilometer-130 and profilograms were drawn (Figure 5. Sample of profilogram).

Depending on the selected blanket material and paper properties, the technological pressure varied in the range of p=0.8-2.0 MPa. Depending on the stages of the printing process, the printing speed varied in the range of V=2.5-3.5 m/s. The selected parameters are varied within the specified limits.

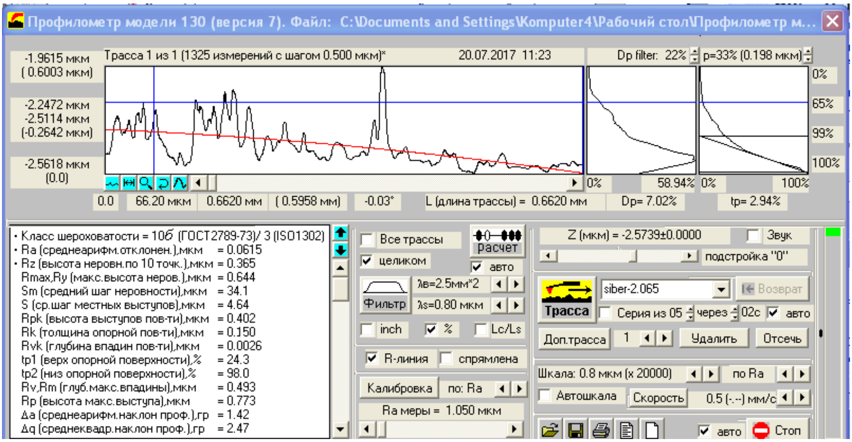

Fig. 7. Profilogram of the surface of the printed form drawn by means of profilometer mod.130

Printed optics are controlled by the operator.

The dependence of the Schirmer coefficient-K characterizing the print contrast, the change in the area of the raster elements -z ΔS and the number of optics characterizing the circulation of print forms - N_{ott} from the design, technological and operational parameters were studied experimentally:

$$\Delta S = f(v, m, P, HSA, R_{max}), K = f(v, m, P, HSA, R_{max}),$$
$$N_{ott} = f(v, m, P, HSA, R_{max}) \qquad (18)$$

The experiments were performed with an equal number of iterations according to the design matrix.

The following criteria were tested in the processing of the results of the experiment by this method:

- Hypothesis of homogeneity of test variance using the Cochrane criterion;

-Static values of regression coefficients using the student criterion;

- Hypothesis of model adequacy with the help of Fisher's criterion F.

The use of the Cochrane, Student, and Fischer criteria assumes a normal distribution of the experimental results.

The results of the experiments are shown in the black graphs in the graphs below (Figure 6-19).

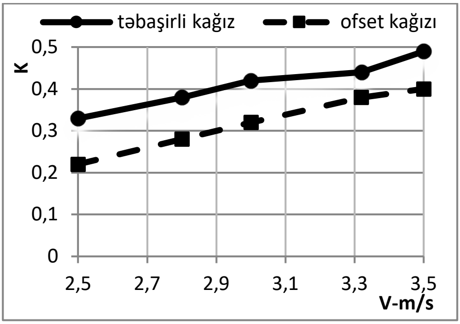

Fig. 8. Graphs of the Schirmer coefficient *k* depending on the print speed *v*.

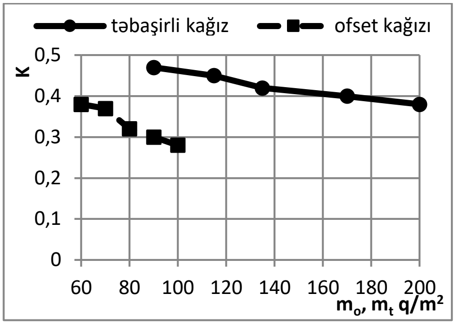

Fig. 9. Graphs m_t, m_o dependence of the Schirmer coefficient k on the weight of the paper.

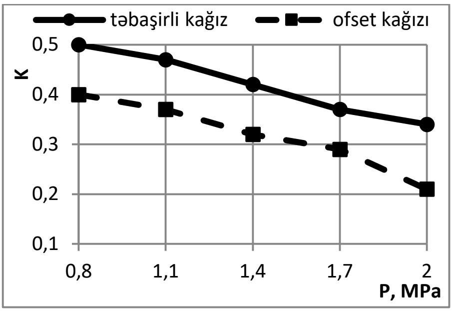

Fig. 10. Graphs of the dependence of the Schirmer coefficient k on the process pressure P.

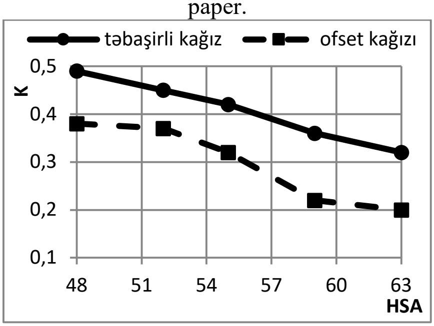

Fig. 11. Graphs of the dependence of the Schirmer coefficient k on the hardness of the flooring material HSA.

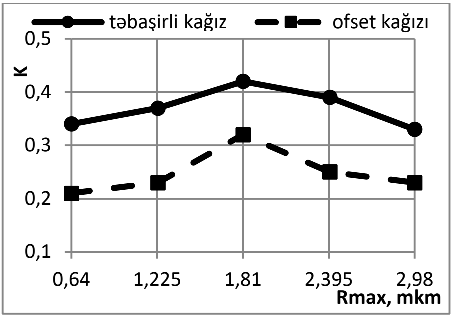

Fig.12. Dependence of the Schirmer coefficient - k on the roughness of the shaped surface - R_{max}

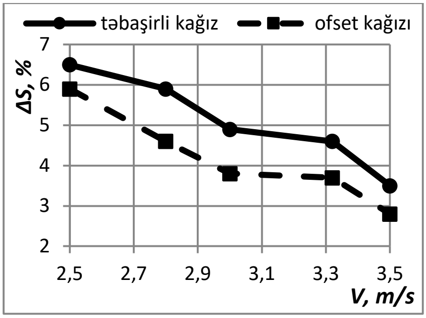

Fig. 13. Graphs of changes in the area of raster elements ΔS depending on the printing speed

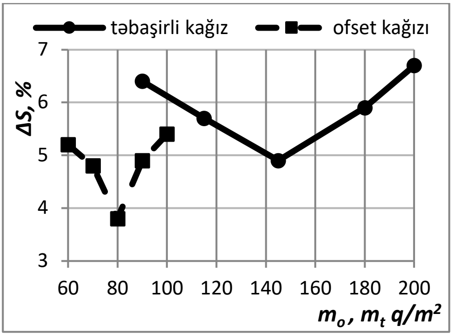

Fig. 14. Graph of changes in the area of raster elements ΔS depending on the density of the paper m_t , m_o

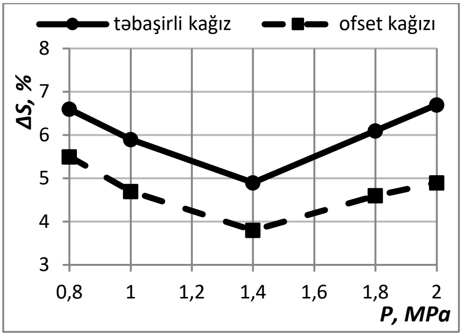

Fig. 15. The graph of the dependence of the change in the area of raster elements ΔS on the process pressure P

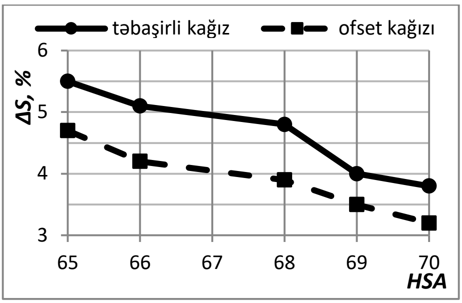

Fig. 16. Graph of the dependence of the change in the area of raster elements ΔS on the hardness of the HSA decal material

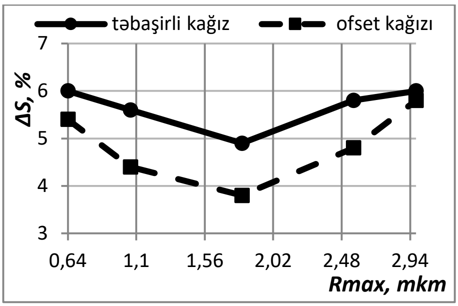

Fig. 17. R_{max} graph of changes in the area of the raster elements from the surface roughness of the form ΔS

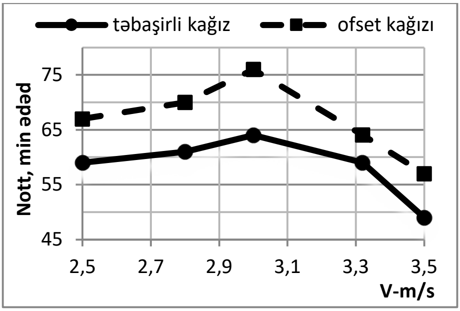

Fig. 18. The graph of the dependence of the circulation rate of the printing plate - N_{ott} on the printing speed - v

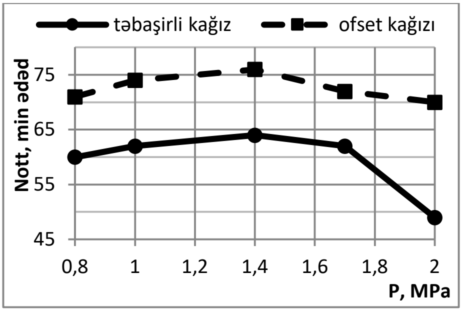

Fig. 19. The graph of the dependence of the circulation resistance - N_{ott} of the impression - process pressure - P

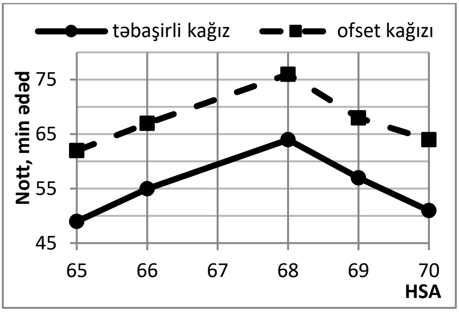

Fig. 20. Graph of the dependence of the circulation resistance N_{ott} on the hardness of the material HSA blanket

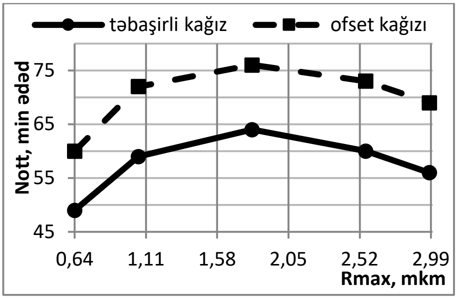

Fig. 21. The graph of the dependence - N_{ott} of the durability of the circulation on the surface roughness of the form R_{max}

The following optimal values of constructive technological and operational parameters are taken for the regulation of technological pressure when printing optics on offset paper:

- printing speed - $V = 3\ m/s$;
- weight of paper - $m_o\ = 80\ q/m^2$
- the hardness of the blanket material with a scale of salt A-$HSA67.99$
- roughness of the print surface - $R_{max} = 1{,}80\ mkm$

The optimal value of the technological pressure was adjusted within the range $p = 1{,}4\ MPa$ determined on the basis of full factor planning.

When printing optics on chalk glossy paper, the weight of the paper - $m_t = 145\ q/m^2$, the constructive technological and operational parameters were taken as if the prints were printed on offset paper.

This method, proposed for the regulation of technological pressure during the process, can ensure the circulation resistance of printing forms and the stability of high-quality optics and their uniformity.

This method does not require the printing operator to adjust the amount of ink on the basis of visual control, and the balance of the dye solution is automatically adjusted.

The fourth chapter is devoted to the discussion of the practical use of developed models and the application of research results.

Obtained in the experimental study of the effect of constructive, technological, and operational parameters on the circulation resistance of offset printing forms and print quality:

- cost of constructive, technological, and operational parameters that provide the recommended value of print contrast for optics printed on different types of paper;
- cost of constructive, technological, and operational parameters (for offset and chalk prints on glossy paper), providing allowable values of change of the area of raster elements;
- high-quality transmission of gradation at the established optimal values of constructive, technological, and operational parameters;
- 1.6-1.8 times more than the intended limits of circulation of printed forms used at the determined optimal values of constructive, technological, and operational parameters;
- Ensuring the stability of high-quality printing presses for full circulation.

In order to increase the accuracy of calculations and labor productivity, as well as to accelerate the technological readiness of production, software for calculating the optimization of parameters affecting the circulation resistance of print forms and the print quality was developed and recommended for application in production.

As a result of testing the developed software and the method of ensuring the circulation resistance of the printed form to calculate the deformation of a number of details in the contact zone, these developments were recommended for application in "Chashyoglu" and "Indigo" LLC publishing houses.

The results of research on the circulation resistance of print and print quality allow us to look for ways to expand the effective application of the new method in the future.

Analysis of technological processes and machines with a moving contact zone during the process allows us to say that the range of such technological processes and machines is wide, and it is expedient to use the method proposed in the dissertation to optimize parameters in these processes, as well as ensure high quality.

CONCLUSION

1. It is theoretically justified to influence the micro-engineering parameters of the print surface to ensure the durability of print forms and the quality of print optics.
2. The effect of micro-dynamic parameters of the surface of the print form on the deformation of the blanket and the forces generated in the zone of contact of the print is theoretically studied and a methodology for calculating these forces is developed.
3. A methodology for calculating the deformation of the blanket in the print contact zone using the finite element method has been developed.
4. To determine the quality of the optics, multifactorial planning of experiments was carried out and the gradation transmission coefficient was calculated based on the results of the experiments.
5. Based on the developed methodology, the analytical dependence of the gradation transmission coefficient on the technological and constructive parameters was determined.

6. Experimental studies have shown that the quality of optics and the durability of forms depend on the following optimal values of technological and constructive parameters: $v = 3\ m/san,\ P = 1{,}4\ MPa, m_o = 80\ q/m^2, m_t = 145\ q/m^2$, $HSA = 68\ MPa, R\_max = 1.81\ mkm$ were provided.

7. The software has been developed for multifactor planning of experiments and the determination of regression coefficients.

8. The results of the study made it possible to determine the optimal values of the technological parameters of the printing process when setting up the printing machine, as well as to ensure the quality of the optics, to minimize the dust formation of the ink, which is harmful to the health of personnel and has a negative effect on the quality of the optics [12, 13, 14, 15].

9. The developed calculation methodology can be used in other printing processes, as well as in the engineering-design practice of the given materials in the form of tables and graphs.

The main provisions of the dissertation were presented at the following scientific and technical conferences and published in scientific and technical publications:

1. Hüseynzadə E.M. Ofset maşınlarında çapın keyfiyyətinə təsir edən parametrlərin tədqiqi.//Azərbaycan xalqının ümummilli lideri Heydər Əliyevin anadan olmasının 91-ci ildönümünə həsr olunmuş "Gənclər və elmi texniki tərəqqi" mövzusunda tələbə və gənc tədqiqatçıların Respublika elmi - texniki konfransının materialları. Bakı, 2014, s.307-309.

2. Xəlilov İ.Ə., Əliyev E.A., Hüseynzadə E.M. Çap formasının səthinin kələ-kötürlüyünü kontakt zonasında sürtünmə qüvvəsinə təsiri.// AzTU elmi əsərlər, cild.1, №4. Bakı,2015. s.33-36.

3. Xəlilov İ.Ə., Əliyev E.A., Hüseynzadə E.M. Çap prosesində dekelin deformasiyasının sonlu elementlər metodu ilə təyini.// Nəzəri və tətbiqi mexanika 3-4. Bakı-2015. s.53-59.

4. Xəlilov İ.Ə., Əliyev E.A., Hüseynzadə E.M. Rotasion çap forması səthinin kələ-kötürlüyünün çap kontaktı zonasında yaranan

qüvvələrə təsiri.// Maşınşunaslıq. Beynəlxaq elmi-texniki jurnal., cild.4, №1, Bakı,2015. s.38-41.

5. Халилов И.А., Алиев Э.А., Гусейнзаде Э.М. Качество листовой офсетной печати при увелечении скорости печатания. //Актуалные вопросы современной науки. Научный журнал №1 (9) 2016. "И.Д. ПетроПресс" Санкт-Петербург. с.32-35.

6. Əliyev E.A., Xəlilov İ.Ə., Hüseynzadə E.M. Kağızın növü və çəkisinin ofset çapının kontrastına təsiri.// AzTU elmi əsərlər, cild.1, №3. Bakı,2016. s.110-113.

7. Hüseynzadə E.M. Dekelin bərkliyinin ofset çapının kontrastlılığına təsiri.// Proceedings of International Symposium of Mechanism and Machine Science, ISMMS-2017. AzCIFToMM-Azerbaijan Technical University. 11-14 september, 2017, Baku, Azerbaijan. P. 215-217.

8. Hüseynzadə E.M. Çap sürətinin çap formasının tirajadavlılığına təsiri.// AzTU Elmi əsərlər, cild.1, №3. Bakı,2019. s. 10-13.

9. Hüseynzadə E.M. Kağızın növünün və çəkisinin çap formasının tirajadavlılığına təsiri.// AzTU Elmi əsərlər, cild.1, №2. Bakı,2019. s. 248-252.

10. Халилов И.А., Алиев Э.А., Гусейнзаде Э.М. Влияние твердости материала декеля на тиражестойкость печатной формы // European Research: Innovation in science, education and texnology/collection of scientifik articles. LV international correspondence scientific and praktikal conference (London, United Kingdom, november 18-20 september, 2019). Moskow, 2019, p.16-21.

11. Khalilov I.A., Aliyev E.A., Huseynzade E.M. The effect of surface roughness of a printing plate on the mechanics of a friction printing pair // SYLWAN, Vol. 164 (7), 2020, p.13-32. (ISSN: 0039-7660)

12. Isa A. KHALILOV, Eldar A. ALIYEV, Elnur M. HUSEYNZADE. Influence of the surface roughness of the printing form to deformation of the deckle.Machine Science. An international scientific-technical journal., vol.9, №1, Bakı,2020. s.74-80.

13. Халилов И.А., Алиев Э.А., Гусейнзаде Э.М. Влияние шероховатости поверхности печатной формы на относительное передаточное число фрикционной печатной пары/ Вестник ЮУрГУ. Серия «Машиностроение». 2021. Т. 21, № 2. с. 23–32

14. Халилов, И.А., Алиев, Э.А., Гусейнзаде, Э.М. (2021). Явление пыления краски с учетом шероховатости поверхности офсетной печатной формы. Проблеми охорони праці в Україні, 37(2), 16–24.

15. Халилов И.А., Алиев Э.А., Гусейнзаде Э.М. Исследование механики фрикционной печатной пары с учетом шероховатости поверхности печатной формы/ European Research: Innovation in Science, Education and Technology / Collection of scientific articles. XXI international correspondence scientific and practical conference (London, United Kingdom, April 21-22, 2021). London. 2021, с. 6-13

Personal contribution of the applicant to published works:

Works No. [1, 7-9] were performed freely by the author.

In the works [2-6, 10-14], the author set the research issues, theoretical researches, development of results, making proposals, formation of scientific provisions. The remaining parts were performed equally by the authors.

The defense will be held on *"17" march 2022* at 11:00 at the meeting of the Dissertation council ED 2.32 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan Technical University.

Address: AZ 1073, H. Javid pr. 25, Baku city, Azerbaijan Technical University

Dissertation is accessible at the Azerbaijan Technical University Library.

Electronic versions of dissertation and its abstract are available on the official website of the Azerbaijan Technical University.

Abstract was sent to the required addresses on *"07" February 2022*.

Signed for print: 28.01.2022

Paper format: 60x84 1/16

Volume: 32403

Number of hard copies: 20