

An experimentally determined list of the required and sufficient technological operations to produce semi-hard book covers has been proposed, with the calculated contour and structural design, which implies strict tolerances in the deviations from a rectangular planar geometry.

It has been proven that the main features in the modeling and manufacturing of covers affect the conditions for ensuring tolerances, as well as stable circulation quantity. They imply that the edges and flaps as the additional structural elements of the covers form, after folding and gluing to the main part, a double composite structure.

Due to this, there are no laps in the joints of edges and flaps, so the plane of the inner part of the covers acquires a flat shape, without defective contours. Therefore, one can argue that the parallel deviation of the outer contours of semi-hard covers from a rectangular design will not exceed the ranges for bookbinding divided into groups based on quality indicators.

It should be particularly noted that the conditions for providing tolerances, circularity stability, as well as the composite structure of semi-hard covers, are influenced by the roller-roll mechanisms, which perform their rotary pressing and high-speed coordinated transportation during manufacturing.

The current study into the effect exerted by the plastic deformation has established the mechanisms of the process of improving a cylindrical surface of the rotary-pressing rollers. It has been proven that they imply the formation of a completely regular microrelief of the hexagonal type with a concave shape and a partly regular micro-relief, in the form of the flat-parallel slotted recesses arranged at an angle to the central axis of the rollers. As well as the application of technology of the ionic nitriding of the obtained microrelief in the plasma of the helicon discharge.

The final stage of strengthening a near-surface layer of the rollers with ionic nitriding in the plasma of the helicon discharge captures the maximum level of the increased durability of the near-surface layer. It fluctuates in the range of the ratio of the plane onto which a regular microrelief is partially applied to the general plane of the roller's surface

Keywords: composite structure, strengthening treatment, cylindrical surfaces, slotted recesses, microrelief

UDC 686.1.027

DOI: 10.15587/1729-4061.2020.208798

DEFINING TECHNOLOGICAL FEATURES IN THE MANUFACTURE OF SEMI-HARD BOOK COVERS

O. Paliukh

PhD, Associate Professor*
E-mail: alekspalyuh@gmail.com

P. Kyrychok

Doctor of Technical Sciences,
Professor, Director**
E-mail: petro.kyrychok.kpi@gmail.com

R. Trishchuk

Assistant*
E-mail: 3182233@ukr.net

M. Korobka

Postgraduate Student*
E-mail: kiparisplus@ukr.net

E. Dziadyk

Postgraduate Student*
E-mail: jdcrow499@gmail.com

* Department of Printing Technology**

**Institute of Publishing and Printing
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute»
Peremohy ave., 37, Kyiv, Ukraine, 03056

Received date 08.05.2020

Accepted date 14.07.2020

Published date 17.08.2020

Copyright © 2020, O. Paliukh, P. Kyrychok, R. Trishchuk, M. Korobka, E. Dziadyk

This is an open access article under the CC BY license

(<http://creativecommons.org/licenses/by/4.0>)

1. Introduction

Modern means of information reproduction by electronic media, despite the increased attention to them, especially from the younger audiences, are developing together with the paper information media, first of all, in the form of book products. Minor annual fluctuations in the preferences to one or another category of information media do not affect the sustainable promising development of each of them.

The highly technological competitive environment of information resources reproduction promotes innovative development, the pace of which increases annually; not only electronic means against paper-based, or vice versa, but stimulates the intra-structural development of each direction.

The global publishing industry is characterized by a distinctive active innovative search for the areas of development, which is manifested by the assortment features of

book products in terms of the structural, energy-saving, and ergonomic components of their production [1].

Accordingly, the latest strategic approaches in the planning of printing technologies are aimed at the effective utilization of material resources and the maximal possible reduction of their use [2].

Thus, it is a relevant task to identify special features in the production of ergonomic and resource-saving semi-hard covers for book blocks, which traditionally use frames in the form of bindings. Planning experimental studies that would contribute to creating the possibility of targeted control over the processes of semi-hard covers production implies the identification of features in the gluing of structural parts of book openings.

The designs of individual types of semi-hard covers [3] that have prospects of widespread use in the manufacture of book products, as well as devices of variable geometry for the

cutting of blanks for semi-hard covers, were developed and reported by the authors of [4].

Separately investigated and determined is the mutually associated influence exerted by the design, contact surfaces, and the operating conditions of roller-roll mechanisms that ensure regulated uniformity and geometric accuracy of covers glued together.

Revealing the peculiarities of production of semi-hard covers, in the process of screw folding, bonding of structural parts, as well as rotary pressing, with a simultaneous coordinate displacement, is the relevant area of research into the factors, which lead to defects during production, as well as their elimination.

2. Literature review and problem statement

Semi-hard book covers, in terms of their structural features, belong to bookbinding whose manufacture uses one sheet of a binding material. A continuous sheet is used to cut out the workpiece of a would-be cover; the edges and flaps, depending on the design of additional parts, are given an adhesive polymeric composition.

By using a screw folding, additional parts are folded into the middle plane of the covers and pressed by pressing rollers at a folding-gluing line.

A study whose results are reported in [5] established three main steps to form the glued (adhesive) connections: the application of an adhesive on the surfaces to be glued, the assembly of the product's components, the polymerization of the adhesive until the product is firmly glued. The main attention in the cited study is given to a detailed and modern analysis of surface treatment methods, prior to gluing, as well as the factors influencing the gluing process, at the stage of surface preparation. This means that the list of the examined technological processes lacks the gluing of the products' components, at which the gluing of additional parts is gradual, over individual consecutive plots, in the process of technological zonal clamping.

Taking into consideration the absence of information and a procedure related to determining the optimal parameters and technological regimes for different starting layers of the materials glued together, and different types of adhesives, the purpose of work [6] was to study the impact of the heterogeneity of the structure of paper and cardboard surface. The stages of the reported research account for applying the glued materials gradually, with a blanking plane of the wet adhesive contact, but do not take into consideration their relative positions and the preservation of the defined positioning during the clamping period over the hardening of the adhesive.

According to the authors of [7], the use of adhesive polymeric compositions to glue different materials with homogeneous and distinctive structures improves the strength of the structural connection of parts made from these materials, their operational stability, and the duration of use. Still to be investigated is the direction that determines the peculiarities of bonding parts that are components of a single initial workpiece of a would-be product. For example, such as unfolding the workpiece of a semi-hard cover with edges and flaps.

However, work [8] noted that when gluing identical flat parts made of paper or cardboard, such as components of semi-hard covers, there are no open surfaces for evaporation. Therefore, the process of natural glue polymerization is prolonged in time. Given the practical significance of the re-

ported research [8], it should be noted that the work did not consider the conditions for ensuring a stable contour geometry of the products glued together during the transportation and gradual solidification of the adhesive.

Proceeding from the basic provisions of the theory of heat and mass transfer, paper [9] investigated the dynamics of the natural and microwave drying of adhesive compositions used for the manufacture of book product components. The authors established the influence of the processes that accelerate the polymerization of adhesive composition; however, additional research is needed to define the bonding conditions, at clamping.

The production of high-quality semi-hard covers with a constant contour geometry, dense composite structure, and stable circulation quantity implies not only proper gluing conditions but the high surface strength of roller-roll mechanisms of rotary pressing.

To expand the areas of studying the effective methods of the strengthening treatment of rollers and shafts, the authors of [10] devised a technological process of their hardening by oscillating smoothing. This ensures the increased stress intensity at the site of elastic-plastic deformation. However, there are no variants for creating a profile reinforced surface of the rollers whose rotating movement would contribute to the coordinated movement of blanks in the predefined direction.

Identical experimental investigations [11] established the nature of the effect exerted by the basic parameters of oscillating smoothing on the roughness of cylindrical parts, which decreases after smoothing with a slower feed of the tool. However, there is a reason to believe that the formation of a micro-relief by oscillating smoothing does not fully promote the formation of the profile surface of the rollers operating in a pair, which execute the coordinate movement of products. Therefore, the reported operational parameters predetermine additional research into the profile plastic deformation of a rollers' surface layer.

As shown by [12], the difference in the efforts that deform the surface layer of round parts becomes significant at the diameters of a circular contact exceeding two millimeters. Given this, it was investigated that a significant impact on the stressed state in the body of a part, at the same contact area, contributes to that the maximum stress would occur in the center of the contact.

In this regard, it is a relevant task to determine graphic dependences of the height of the micro-relief's laps on the surface of the cylindrical parts on the efforts of pushing the indenters' matrices with the fixed dimensions of their radii.

The mechanism of the effect exerted by the surface-plastic treatment of discrete, sequentially-singled plots, comparable, by their size, to the working surface of indenters' matrices, has several varieties [13]. In one case, given the redistribution of the material structure of the surface layer, there is a change in the geometry of the surface of the cylindrical parts. In another case, the residual stresses can change the rigidity of a part, without altering its external geometry. At the same time, the factors of the controlled surface plastic deformation, described in the cited paper, are insufficient to devise a methodology for the formation of a surface layer, with the regulated properties of strength, high bearing capacity, and the distribution of the predefined residual stresses of compression.

Identifying the properties of one of the types of decorative-strengthening processing, the smoothing of cylindrical surfaces, which are enshrined in a diamond crystal, was the subject of an experimental study reported in work [14]. It is

noted that the wear resistance of the smoothed surfaces increased by 2–3 times, compared with the grounded ones, by 20–40 %, compared to the polished ones. The contact endurance of the smoothed surfaces proved to be 35–50 % higher than that of the polished ones. However, there is reason to believe that the surfaces of the same roughness, obtained by various methods of processing, are different in performance properties. Therefore, it is necessary to carry out an additional study, not only of the height of the obtained roughness but also the height of the supporting surface area, which, usually, is only a small part of the contour area.

The above studies and the findings from them relate to the manufacture of semi-hard book covers, which is performed via a continuous speed flow of straight-line displacement of blanks between the sections of a folding-gluing line. Given that semi-hard covers, as the book frames, are the finished products, which are consequently connected to a book block, technological norms imply strict tolerances in their deviation from a contour rectangular geometry.

This allows us to argue that the problems that arise in the manufacture of semi-hard book covers can be solved by identifying and investigating their technological features. As well as the operating conditions of the roller-roll mechanisms that directly affect the quality of cover production, in order to devise and implement a procedure for strengthening their cylindrical surfaces, which would increase the operational duration of the mechanisms.

It should be noted that the lack of convincing statistical results and the tangent certainty of the examined studies stipulate the expediency and benefits of research in the area of resolving the above scientific issues.

3. The aim and objectives of the study

The aim of this study is to determine features in the production of semi-hard covers in the process of technological operations, complying with which would facilitate the manufacturing of covers with the calculated contour and structural design. That could make it possible to implement a procedure to strengthen the cylindrical surfaces of the pressing roller-roll group at the production line of semi-hard covers, which would provide for the stable conditions to execute technological processes.

To accomplish the aim, the following tasks have been set:

- to identify the influence of the processes of screw folding of edges and flaps and their speed gluing on the conditions of technological compliance with the rectangular geometry of semi-hard covers, during their manufacture;
- to propose a procedure for strengthening the cylindrical surfaces of a roller-roll group at the production line of semi-hard covers by means of plastic deformation and formation of a regular micro-relief with its subsequent ionic nitriding in the plasma of the helicon discharge.

4. Materials and methods to study the processes of making semi-hard book covers

4.1. Materials and equipment for making semi-hard covers with a rectangular contour geometry

The procedure for investigating the processes of making semi-hard covers implies the use of the mechanisms to apply an adhesive onto the structural components of covers, their

screw folding, and rotating pressing. For the manufacture of covers, we selected thin cardboard chrome-ersatz, a thickness of 0.6 mm (Ukraine), and the poly-vinyl-acetate dispersion PVAD DF 51/15B (Ukraine), which are widely used in the bookbinding processes.

The roller-roll mechanisms used for experiments are the integral structural components in the scheme of a folding-gluing line that we designed to produce semi-hard covers. Unlike the equipment for the manufacture of book frames, which performs limited-speed technological processes, the line ensures the high-speed continuous technology for running the experiments.

It was taken into consideration that, after the application of an adhesive, in the process of screw folding, the edges and flaps are attached to the main plane of the cover, not at the same time but gradually, as they are folded in the folding device. Therefore, research depends on the preliminary settings and the stable operation of the roller-roll mechanism of rotating pressing, which should ensure the alignment of covers and prevent the displacement of edges and flaps.

A roller-roll section with an adjustable head of rotating pressing is shown in Fig. 4; it consists of the clamping rollers mounted on the drive shaft, having the option of moving along the shaft. As well as the supporting force shaft, rotating by the autonomous drive; it enables speed control during experiments.

4.2. Materials and equipment for conducting experiments to strengthen the parts of the mechanism for the rotating pressing of covers

We have applied a procedure from [15] of the technological process to form a regular microrelief, which changes the structure of the surface zone of the metal of rollers in contrast to the core and which is carried out in several stages of the physical and mechanical treatment.

Initially, a constant regular microrelief is formed on the surface of rollers, with parametric indicators given in Table 2. The next stage of strengthening the near-surface layer of the rollers is a partially regular microrelief, whose technological difference is in the formation of slotted flat-parallel recesses, geometrically coordinated at an angle to the axis of rollers.

To perform experiments to strengthen the near-surface layer of the low-carbon steel rollers, we used the screw-cutting lathe 16K20. The clamping unit of the lathe spindle hosted the parts for further processing. In addition, the lathe support hosts the mounted machine [15], with clamps, which hold replaceable deforming matrices with the defined radii of the working areas. The matrices perform the surface plastic deformation with a constant radial effort when executing the feed motion along the axis of the matrix's displacements.

We modified the surfaces of the pressing rollers, after the formation of a partially-regular micro-relief, by applying the procedure of ion-plasma nitriding in the helicon discharge, without altering the microgeometry of the surface. The study involved the samples made from structural steel 20x, which were not exposed to preliminary heat treatment.

Diffusion layers were formed, using the ion-plasma nitriding, in a specialized technological installation [16]. The installation hosts a helicon plasma source with a working frequency of 13.56 MHz, as well as the plasma-arc boosters combined in a single vacuum chamber. The technological process of ionic nitriding in a discharge plasma chamber was carried out in two stages: preliminary cleaning of the sample (by plasma in the environment of argon) with the

subsequent process of nitriding. Preliminary cleaning of each sample was carried out in the following sequence.

We pumped out air from the chamber used for the experiments by the jointly applied diffusion and forevacuum pumps to the value of pressure in the working chamber of a hybrid helicon-arc reactor of the order of 10^{-4} mm Hg. Art. The value of the generator power, which implemented a helicon discharge, is $P=600$ W. The pressure of the working gas (argon) at the time of purifying the substrate was $7 \cdot 10^{-3}$ mm Hg. The duration of the purification process is 5 minutes. After cleaning, the working gas argon was pumped out of the chamber; instead, nitrogen (or a mixture) was pumped in, in the atmosphere of which the mode of the helicon discharge was implemented. The duration of the nitriding process is 30 minutes.

5. Studying the factors that influence maintaining the contour geometry of semi-hard covers

In their design, modern book frames are divided into covers and bindings, with the number of variants exceeding 200 items [17]. In its turn, the covers, as a significant part of this list, include a series of different structures. A distinctive feature of such structures is the manufacture of covers from a single part – a plane sweep cut out from the binding material before attaching to the book block, or trimmed together with a book block, after gluing to it.

The integral covers, as an improved version of the cut binding, have, on the upper, lower, and front fields, narrow edges, the width of 7–12 mm, bent and glued to the main plane of the cover. The glued edges help strengthen the contour part of the integrated cover.

To achieve additional indicators of operational strength, the folded and supplemented covers, as the next structural series, form a double spatial structure from the tape of a binding material whose width the height of the cover [3]. Or, form a double spatial structure due to the edges and flaps of different planar geometry of the folded and non-glued to the middle of the cover. The double spatial structure of such covers enhances their overall strength and duration of operational use.

The most tangible in terms of performance properties for bindings are the semi-hard covers, in which the edges and flaps create, together with the main part of the covers, a continuous double glued structure [18]. Therefore, in terms of strength and durability, the semi-hard covers are an intermediate option between the soft and hard book frames, such as covers and bindings.

The specified structural features of the covers as book frames correspond to the State standard of Ukraine «Covers and bindings». The designs of semi-hard covers and technological processes of their manufacture, considered in the current paper, are innovative, confirmed by our intellectual property patents.

According to preliminary estimates, the cost of semi-hard covers, with a double-glued composite structure, is correlated with the cut covers of the single thickness, and in terms of the practicality of use – with bindings. The mass of books in semi-hard covers decreases, compared to the books in bindings, by about 12–15 % [18].

Fig. 1 shows some of the designs of semi-hard covers [18], which were practically implemented in the technological processes of book production. The edges and flaps in Fig. 1, *a*, after folding and gluing to the main rectangular part of the cover, form a double continuous structure, in the places

denoted by their geometric dimensions. The part of the spine zone, of width t_1 , retains the initial single thickness of a binding material.

In Fig. 1, *b* the triangular flaps form a double-glued thickness across the entire rectangular area of the cover, as well as in the spine part, of width t_2 . In Fig. 1, *c*, the flaps of a geometrically complex configuration form a double glued configuration only in the zones of their gluing. The spine part, of width t_3 , remains along the entire length with initial single material thickness.

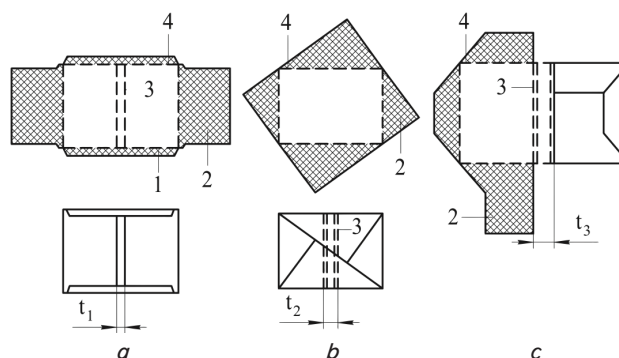


Fig. 1. Structural differences of semi-hard covers: *a* – rectangular flaps; *b* – triangular flaps; *c* – flaps of complex configuration; 1, 2 – edges and flaps with an applied binding glue; 3 – radial blanking lines; 4 – blanking contour lines

In places of joints between the edges and flaps, or only flaps, no laps of one part of their structural elements on the other are observed. Therefore, the formed adhesion plane acquires a flat shape, convenient for gluing flyleaves, without the manifestation of defective contours in the joints. At the same time, due to folding, in places of blanking and double gluing, the strengthening of the contour part of the covers occurs; for cases shown in Fig. 1, *a*, *b*, along a continuous perimeter; for the case shown in Fig. 1, *c*, with discrete breaks in the spine zone.

For experimental studies and the possible industrial application, we have designed and fabricated a modular-sectional line to manufacture resource-saving semi-hard covers. Determining mechanisms in the line, in terms of ensuring high-quality production of semi-hard covers, are the mechanisms of a roller-roll assembly that perform the rotating pressing of the glued parts of covers, with their simultaneous coordinated transportation.

Technological norms for the production of high-quality competitive book products imply strict tolerances for a deviation from the rectangular geometry of book frames since the frames are the finished intermediate products with their subsequent attachment to book blocks. There are also tolerance margins when assembling a book, for the parallelism and the calibrated dimensions of the edging formed after the blocks are attached to the book frames (Table 1).

The qualitative indicators of dimensional deviations, specified in Table 1, when making the book frames and attaching them to the book blocks, are conditionally divided into three groups. These include: 1 – textbooks and reference books, 2 – fiction, 3 – books on fine arts.

Fig. 2, *a* shows the layout of a book in the frame with the following designations: 1 – book frame, 2 – book block, 3 – edging from the inner side of the frame, 4 – contour lines of the edging from the outer side of the frame.

Table 1
Dimensional tolerances for deviation of the geometry of book frames and the parallelism of edging

| No. | List of attributes of dimensional deviations | Dimensional tolerances | | |
|-----|---|-----------------------------------|-----------------------------------|-----------------------------------|
| | | Quality indicator of group 1 (mm) | Quality indicator of group 2 (mm) | Quality indicator of group 3 (mm) |
| 1 | Parallel deviation of the outer contours of a book frame (per 100 mm length) | 0.4–0.5 | 0.3–0.4 | 0.2–0.3 |
| 2 | The skew of the deviation of the book block attached to the frame (per 100 mm length) | 0.8–1.0 | 0.6–0.8 | 0.4–0.5 |

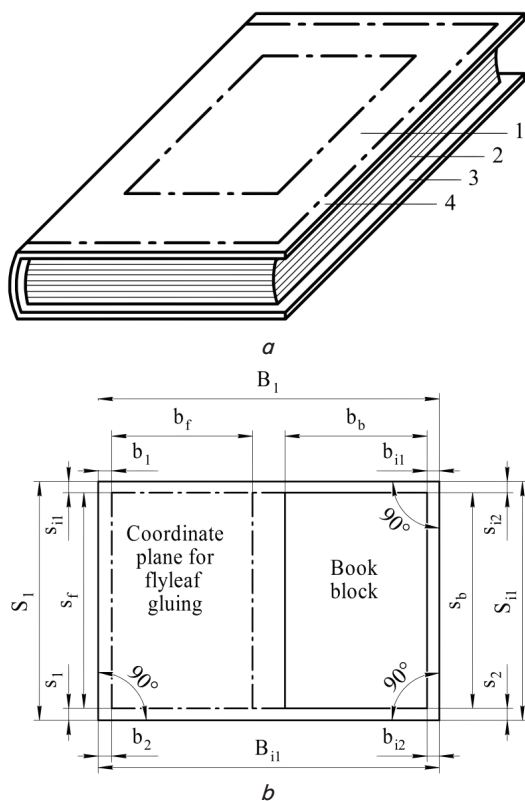


Fig. 2. Dimensional indicators of the contour part of a book frame and the coordinates of the block connected to the frame: *a* – assembled book block; *b* – the geometry of a book frame and the attached block

Given the minimum deviations, specified in Table 1, for the contour sizes of book frames, we shall consider the required conditions for the geometry of semi-hard covers, shown in Fig. 2, *b*. As well as the necessary conditions for attaching a book block to the cover, assuming as the technological basis that the outer part of the block is rectangular.

After folding and gluing the edges and flaps, the completed semi-hard cover should meet the following conditions. The cover width at the top and bottom parts must be the same, $B_1=B_{ii}$, the cover length in the left and right side should also be the same, $S_1=S_{ii}$, and all the angular sizes of the cover must be equal to 90° .

Failure to comply with the listed conditions of the dimensional deviations, specified in Table 1, would lead, after

attaching the book block to the cover, to the formation of edging, with deviations. The deviations would turn the assembled book into a product with technological defects, which should be sorted out and removed from the circulation.

Rectangular contours of the book block, at plane $s_b=b_b \times s_b$, attached to a semi-hard cover, as well as the coordination plane of flyleaf gluing $s_f=b_f \times s_f$, would ensure the formation of the technologically defined edging $b_1=b_2=b_{i1}=b_{i2}$ and $s_1=s_2=s_{i1}=s_{i2}$, which, to a necessary degree, would promote quality production of books.

6. Implementation of methods for strengthening the cylindrical surfaces of a roller-roll assembly at the line of semi-hard cover production

Fig. 3 shows the roller-roll coordinate-transporting section of the line to produce semi-hard covers with the adjustable head of rotating pressing. The drive shaft (1), of diameter D_1 , hosts the fixed clamping rollers (2, 3), of diameter D_2 . The rollers are of the same thickness ($L_1=L_2$) and can be moved along the driveshaft and are fixed to the dimensions predefined by the cover formats.

The supporting power shaft (4), of diameter D_3 , is driven into rotation by an autonomous drive of the coordinate-transporting section and ensures the regulation of the speed of the section in a wide range. The mechanisms for adjustment of clearances T_1 (5, 6) of the circular pressing by the clamping rollers are not only adjusted to dimensional indicators but also ensure their stable maintenance over the circulating cycle of cover making.

The main functional component of the coordinate-transporting section should be high accuracy when working with bookbinding materials of natural and artificial origin, of different thickness. As a rule, the blanks of covers, following the application of an adhesive and the screw folding of edges or flaps, are moved to a calendaring zone by the belt pair-contact transporters at high speed.

Under such conditions, when the clamping rollers touch the front of the cover, its partial jam could occur, or a loss of the rectangular geometry of the outer contour. Therefore, the diameters of the roller group D_2 and D_3 (Fig. 3) must correspond to the conditions for a defect-free speed contact with the cover, at the time it enters the rotational pressing zone.

After applying the adhesive, in the process of screw folding, the edges and flaps are attached to the main plane of the cover not at the same time, as it happens in the machines for making bindings, but gradually, as they are folded in the folding device (Fig. 4).

Therefore, the composite structure of the cover, with the attached, by the adhesive layer, edges and flaps, is, before entering the coordinate-transporting section, for further compaction, in a shaky spatial state, prone to a slight loss of the rectangular geometry of the outer contour.

It should be taken into account that the rigidity of the cover, at the beginning of entering the pressing zone, is minimal, and then grows rapidly, as the composite structure is compacted in a roller-roll mechanism, $T > T_1$ and $t_{gi} > t_{1-gi}$ (Fig. 5). The clamping effort is adjusted by the clearances T_1 (Fig. 3, 5), which are set between a pair of clamping rollers and the drive supporting shaft. At the input to the section, one must take into consideration the double thickness of the binding material and the thickness of the adhesive layer $T = 2 \times t_m + t_{gi}$, as well as the thickness of the cover T_1 , which should be obtained after exiting the section (Fig. 5).

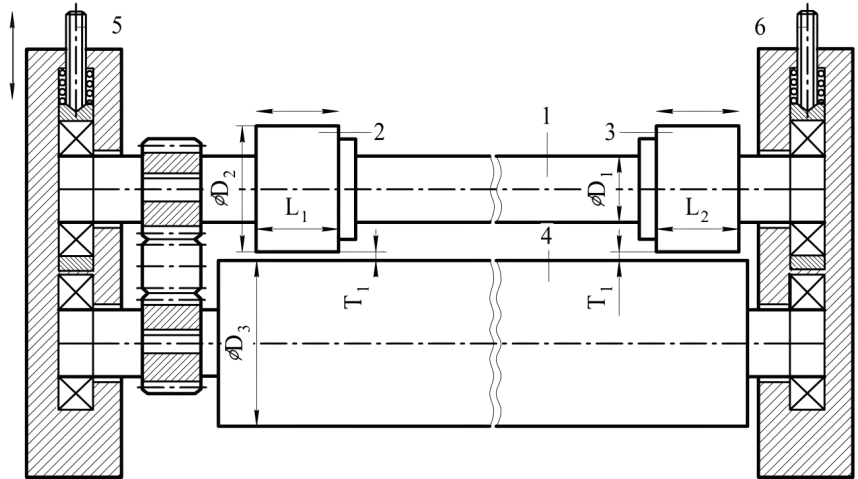


Fig. 3. A coordinate-transporting section with the adjustable head of semi-hard cover pressing:
 1 – the drive shaft of clamping rollers; 2, 3 – the clamping rollers with fixed linear movements; 4 – drive supporting shaft;
 5, 6 – the mechanisms of gaps adjustment for the rotating pressing of covers; T_1 – adjustable gaps

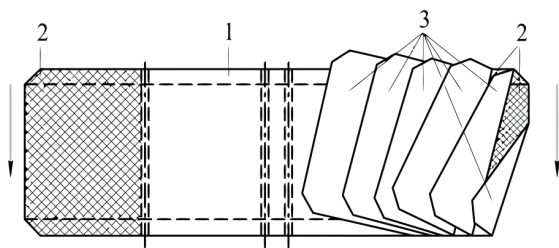


Fig. 4. Screw folding of semi-hard covers:
 1 – cover; 2 – the layer of an adhesive on flaps; 3 – stages of gradual screw folding of the flap of a cover

A roller-roll assembly of the calendering mechanism ensures stable conditions for the execution of technological processes due to the stiffness of the clamping rollers and by maintaining constant pressure between them and the supporting shaft. Rollers are usually made of different types of low-carbon steels employing the technology to improve surfaces to the indicators of high strength and durability.

In turn, the semi-hard covers are formed by using binding adhesives that contain the potent components to ensure the gluing strength. Such as solvents, plasticizers, protective colloids, in the form of polyvinyl alcohol, as well as components that increase the stickiness to improve adhesion. A separate group, which is conditionally termed the «cold» adhesives, includes those glues that contain a significant amount of moisture.

The cover pressing process implies compacting their structure, in the middle of which, between the outer layers of a binding material, there is one of the types of the specified adhesives, so it is possible to partially extrude the adhesive outward. The extruded adhesive comes into contact with the outer surface of the clamping rollers and, given its chemical aggressiveness, affects the gradual destruction of the surface of the rollers. By forming small sinks that lead to a decrease in the contact area of the rollers with a cover, at the time of its rotating pressing.

It should be taken into account that the contact of rollers with the plane of the cover generates the touch zone almost in a straight line.

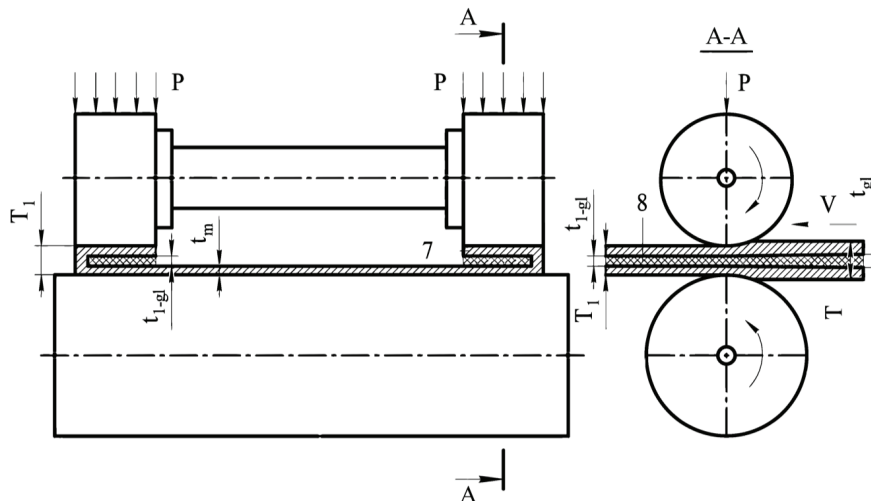


Fig. 5. The kinetic diagram of the rotating pressing of a semi-hard cover:
 1 – a binding cover material; 2 – adhesive; T – cover thickness prior to pressing; T_1 – a gap between the rollers and supporting shaft, the thickness of the cover after pressing; t_{gl} – the adhesive thickness prior to pressing; t_{1-gl} – the adhesive thickness after pressing; P – the distributed efforts at the moment of pressing; V – speed and direction of cover movement

Therefore, reducing the size of the pressing touch line, through the gradual destruction of the surface of the clamping rollers, leads to the slipping or distortions of covers and the loss of their qualitative characteristics. In addition, in the process of pressing and transporting along the line, at high speed, the outer working surface of the roller-roll assembly withstands significant dynamic loads. The surface becomes prone to polishing and to reducing the diameter of the rollers from the original sizes.

It should be noted that the operational polishing of the rollers forms an uneven wavy surface, with a slight amplitude of dimensional deviations, although sufficient for the partial loss of the contact with the surface of the covers during transportation. Therefore, it is a relevant task to implement a procedure to strengthen the cylindrical surfaces of the pressing roller-roll assembly in the coordinate-transporting section of the production line for semi-hard covers.

There are known technologies for improving the surface layer of steel parts of printing machines by the method of plastic deformation [10], which make it possible to obtain the compacted surface of parts in the form of a regular microrelief. The plastic deformation is carried out in a cold state by a special tool, the indenter, at a screw-cutting metal-cutting lathe by the method of vibration run-in [12].

Vibration run-in is based on the complex relative displacement of the tool's deforming matrix with respect to the machined surface, on which a completely new microrelief is formed. In the process of plastic deformation, a small part of the metal is displaced upwards while the main volume of the metal is compacted into the part's thickness.

A procedure was devised in [19] to apply the technological process of forming a regular micro-relief, which changes the structure of the surface zone of the rollers' metal, in contrast to the core, and which implies several stages of physical and mechanical treatment. During the implementation of these stages, at the expense of the contact force interaction between the deformed tool and the steel rollers' surface, the surface enters the stressed-strained state of compaction.

After forming a completely regular microrelief at the first stage of strengthening the near-surface layer of rollers, the second stage of the complex treatment forms a partly regular microrelief. The technological execution of such a microrelief implies the application of flat-parallel recesses, in the form of slots, geometrically coordinated at an angle α to the axis of the rollers (Fig. 6). This, in turn, contributes to the change in the magnitude of the residual compression stresses, depending on the structure of the formed partially regular microrelief.

When applying a partially regular micro-relief, there occurs the complete smoothing and formation of a new micro-relief, at the place of that formed previously. The height, shape, and location of such a microrelief are determined not only by the amount of the compression effort but also by the radius of the deforming matrix, the amplitude of its oscillation, the velocity, feed, and the number of oscillations.

To improve the physical and mechanical characteristics of the near-surface layer, the final stage of modifying the surface strength of the rollers employs the technology of ionic nitriding in the hydrogen-free environment, in the plasma of the helicon discharge [20]. The result of such a treatment is the changed composition of the near-surface zone of the rollers' metal, due to the diffusion processes that cause the formation of a new structural and phase state, different from that of the core.

Fig. 6 shows two clamping rollers, separated from a drawing in Fig. 3, of diameter D and width L each, in the mechanism of coordinate transportation of semi-hard covers mounted on a drive shaft.

The surface of the first roller shows the (enlarged) permanent regular micro-relief (1) of hexagonal type (according to the profile of a pressing matrix). The surface of the second roller demonstrates a partially regular micro-relief (2) whose flat-parallel slotted recesses, of width b mm, are applied at a step of $2b$ mm, at an angle α to the axial line of the rollers.

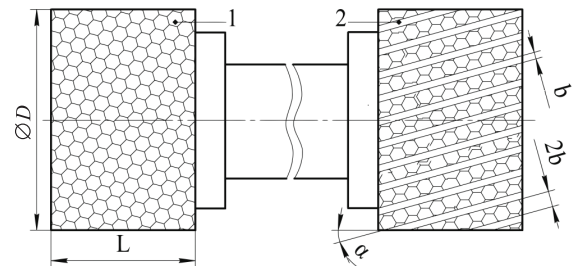


Fig. 6. Strengthening treatment of the cylindrical surface of the rollers of the mechanism of coordinate transportation of semi-hard covers: 1 – permanent regular microrelief; 2 – partially regular micro-relief; b – the width of flat-parallel recesses; $2b$ – the distance between recesses; α – recess inclination angle; $\varnothing D$ – the diameter of the rollers; L – the width of the rollers

A parametric system was built to link the characteristics of the steel rollers in a folding-gluing line to the indicators of a stable rectangular geometry of the fabricated covers. It considers the modes and technological features of the processes of surface reinforcement of parts of the roller-roll mechanism.

The parametric system, given in Table 2, arranges the investigated sample range and the conditions for using the required technological indicators. At the final stage of the technological improvement of the surface layer, we derived indicators of the partially regular microrelief, given in Table 3, which take into consideration the type and shape of microrelief, as well as the distribution of microhardness obtained after the ionic nitriding in the plasma of the helicon discharge.

In Tables 2, 3, the following designations are used: b – the width of flat-parallel slotted recesses, α – the inclination angle of slotted recesses, D – the diameter of a rotating-pressing roller, e – the eccentricity of a deforming matrix, h – the depth of slotted recesses, HRC – the hardness of a material by Rockwell; h_l – the height of laps after the formation of slotted recesses, $n_{doub.s}$ – matrix oscillation frequency, n_{sp} – spindle rotation frequency, P – the effort of pressing by a deforming matrix, P_{gen} – generator power, p_{nit} – the pressure of working gas (mixture) in the chamber during nitriding, p_{clean} – the pressure of working gas in the chamber during purification, R – the radius of the deforming matrix, R_a – the arithmetic mean of the profile deviation, S – the feed, T_{nit} – the maximum temperature of the roller's surface during nitriding, t_{nit} – nitriding duration, t_{clean} – purification time, U_{nit} – the potential at nitriding, U_{clean} – the potential at purification.

Our study has registered the maximum level of durability increase for a near-surface layer, which fluctuates in the range of the plane, on which a partially regular microrelief is applied, over 24–29 % of the total plane of the roller's surface. The surface hardness, respectively, increases, on average, by 30–32 %.

Table 2

The parametric system of plastic deformation of the surface of rotating pressing rollers at the ionic nitriding of the formed microrelief

| Part title and initial parameters | Material | Plastic surface deformation | | Ionic nitriding in the plasma of the helicon discharge |
|---|--|---|--|---|
| | | Completely regular microrelief (sampling range) | Partially regular microrelief (sampling range) | |
| Rotating pressing roller $D=65$ mm, $L=80$ mm surface roughness: $R_a=0.17-3.5$ μ m | Steel – 20x Initial hardness HRC 44...46 Preliminary treatment of the roller's surface – polishing | $R=0.5-1$ mm; $P=150-500$ N; $e=0.2-1.0$ mm; $n_{doub.s}=1,000-2,000$ doub.s/min; $S=0.08-12.5$ mm/rev; $n_{sp}=25-2,000$ rpm. | $R=1.5-2.5$ mm $P=75-500$ N $n_{sp}=0-50$ rpm. $S=0.2-7.5$ mm/min, $\alpha=5^\circ...30^\circ$ | Preliminary purification: working gas – argon $p_{clean}=7 \cdot 10^{-3}$ mm Hg. $t_{clean}=5$ min. $U_{clean}=-50...-200$ V $P_{gen}=600$ W Nitriding: working gas – nitrogen or a mixture (argon 30 %, nitrogen 70 %) $p_{nit}=5 \cdot 7 \cdot 10^{-3}$ mm Hg $t_{nit}=30$ min. $U_{nit}:-50...-200$ V, or «floating» $P_{gen}=600$ W, $T_{nit}=330$ °C |

Table 3

The physical-mechanical parameters of the rotating pressing rollers' surface after reinforcing treatment

| Completely regular microrelief | Partially regular micro-relief | Ionic nitriding in the plasma of the helicon discharge |
|---|---|---|
| Completely regular microrelief of hexagonal type (GOST 24773-81) belongs to the class with elements of concave shape; to the group of a new microrelief; to the kind of a mesh type; to the type of a hexagonal shape; to the shape of a concave type | Partly regular microrelief in the form of flat-parallel slotted recesses; $l=2b$ (Fig. 6); $h=0.002...0.0075$ mm; $b=0.25...0.55$ mm; $h_l=0.0002...0.002$ mm | Geometric parameters – unchanged; Microhardness distribution: to a depth of 300μ m – $5,000...4,000$ MPa; from 300μ m to the center of the roller – unchanged |

Such indicators are ensured by forming initially a regular microrelief by a deforming matrix with a radius of $R=0.9$ mm. At the following parametric conditions of the technological process of strengthening: the feed $S_1=0.09$ mm/rev., the matrix indentation effort $P_1=180$ N, the frequency of rotation of the pressing roller $n_{p1}=120$ rpm, the matrix oscillation frequency $n_{doub.s}=1,400$ doub.s/min., the oscillation amplitude $e=0.8$ mm.

The next step of strengthening is the formation of a *partially regular* microrelief, in the form of the flat-parallel slotted recesses cut at angle $\alpha=15^\circ$, by the matrix with a deformation radius of $R=1.8$ mm. The technological process is ensured by the following performance indicators of the equipment: the feed $S_2=0.09$ mm/rev., the matrix indentation effort $P_2=80$ N, the workpiece rotation frequency $n_{p2}=45$ rpm.

The angle $\alpha=15^\circ$ was selected from the sampling range of $5^\circ...30^\circ$ as it ensures the creation of necessary and sufficient guiding efforts to transport a semi-hard cover along the central axis of the folding-gluing line. An experimental study has found that the inclination angles of slotted recesses of up to 15° significantly affect the cover orientation, while the angles exceeding 15° , in proportion to the growth, lead to the deformation of the outer contour of the cover.

The obtained results, shown in Fig. 7, reproduce the dependences of the height of the microreliefs' laps on the matrices' indentation efforts with the fixed dimensions of their radii, where $R1=1.8$ mm – the radius of matrix 1; $R2=2.0$ mm – the radius of matrix 2; $R3=2.5$ mm – the radius of matrix 3.

The experimental array of the indicators of the dependence of the height of the micro-relief's laps on the indentation efforts of deforming matrices was formalized for the construction of graphic dependences in Fig. 7 employing a method of statistical treatment. We have determined the mean arithmetic indicators, for systematization and graphic clarity, in the fixed zones of the applied effort of the indenter pressing, corresponding to the size range of $100-500$ N, with a discrete pitch of 50 N (Fig. 7). Due to the possible unreasonable overload of the current paper with measurement data that required methodological processing, the initial array of experimental parameters is not given.

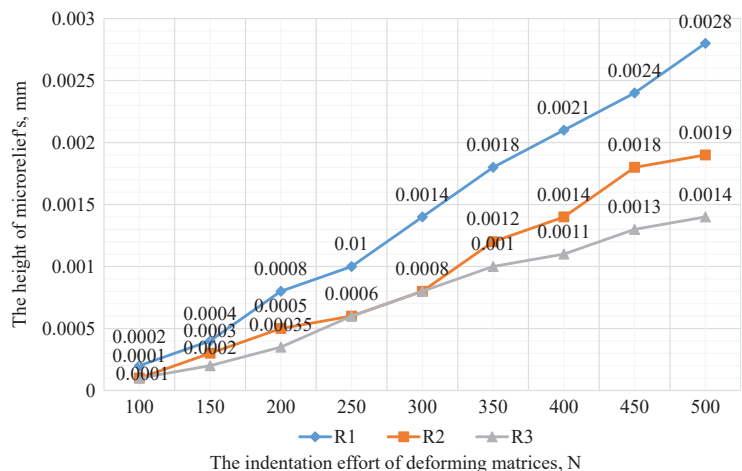


Fig. 7. Dependences of the microrelief's laps height on the indentation efforts of deforming matrices: $R1=1.8$ mm – the radius of matrix 1; $R2=2.0$ mm – the radius of matrix 2; $R3=2.5$ mm – the radius of matrix 3

Graphical results of the obtained indicators demonstrate the effective use of the deforming matrix $R1=1.8$ mm for the formation of a partially regular microrelief that ensures a gradual proportional change in the height of the laps, due to the proportional change in the indentation effort. This, in turn, promotes the formation of credible calculations of surface strength, which could be used in the development of production technology of rollers with the predefined characteristics.

Deforming matrices of radii $R2=2.0$ mm, $R3=2.5$ mm do not provide benefits from using them, due to the heterogeneous discreteness of the formed laps, the compacted near-surface layer of the rollers' material, under the condition of a proportional growth in the indentation efforts.

The improvement of the near-surface layer of rollers is achieved by forming a completely regular micro-relief, a partly regular micro-relief, with the flat-parallel slotted recesses, cut at an angle, and by using the ionic nitriding technology in the plasma of the helicon discharge.

Applying the parametric set of the specified reinforcing technologies contributes to stabilizing the process of the rotating pressing of glued semi-hard covers and their coordinate transportation. Arranging the covers' sweeps during their sequential operational transportation positively affects the quality and circulation stability of manufactured products, as well as the duration of the operational resource of the production folding-gluing line.

7. Discussion of results of studying the technological features in the manufacturing of semi-hard book covers

The results of our study into the technological processes of making semi-hard book covers have shown that in terms of strength and durability the semi-hard covers are an intermediate option between the bindings and the folded covers made from a single part.

This is due to the existing structural differences of covers' sweeps, in the form of edges and flaps, shown in Fig. 2. The edges and flaps after folding and gluing to the main rectangular part of the cover form a double composite structure, in contrast to the spatial double structures examined in study [3].

In some cases, a part of the spine zone, of width t_1 and t_3 (Fig. 1, *a, c*), does not double and remains with the initial single thickness of a binding material. At the same time, due to the double gluing, it is possible to strengthen the contour parts of the covers, in cases shown in Fig. 1, *a, b*, along a continuous parameter, in the case shown in Fig. 1, *c*, with discrete breaks in the spine zone.

Moreover, in the joints of edges and flaps, there are no laps of one part to the other. Therefore, the formed gluing plane acquires a flat shape, convenient for gluing the fly-leaves, without the manifestation of defects related to protruding contours in the joints.

It should be noted that the essential mechanisms for ensuring the high-quality production of semi-hard covers, under industrial conditions, are the mechanisms in a roller-roll assembly. The mechanisms execute the rotating pressing of glued parts of the covers, with their simultaneous coordinated transportation along the central axis of the folding-gluing line.

It is easy to see (Fig. 2, *b*) that after folding and gluing the edges and flaps, the finished semi-hard cover at the top and bottom part should be the same, that is, $B_1=B_{11}$. The cover length in the left and right parts must also be the same, $S_l=S_{1l}$, while all the angular sizes of the cover must be equal to 90° .

The rectangular contours of a book block, of plane $s_b=b_b \times s_b$, which is attached to a semi-hard cover, as well as the coordinate plane of flyleaf gluing $s_f=b_f \times s_f$, ensure the formation of the technologically defined edging $b_1=b_2=b_{11}=b_{12}$ and $s_1=s_2=s_{11}=s_{12}$, which, to the required degree, would promote the quality production of books.

In this sense, failure to comply with the specified conditions for dimensional deviations, given in Table 1, could lead, after connecting a book block to the cover, to the formation of edging with deviations. It should be noted that the above circumstances are in agreement with the practical data reported in works [6, 7, 9], whose authors also stress maintaining the technological stability in the production of glued products under the operating conditions of coordinate-transporting systems.

However, unlike the results of studies [6, 7, 9], the obtained data suggest that after the application of an adhesive, in the process of screw folding, the edges and flaps are attached to the main plane of the cover not at the same time. The attachment occurs gradually as they fold in the folding device, as shown in Fig. 4.

Therefore, the composite structure of the cover, with the edges and flaps, attached by an adhesive layer, is in a shaky spatial state, prone to an easy loss of the rectangular geometry of the outer contour. In turn, it should be noted that the rigidity of the cover, at the beginning of entering the pressing zone, is minimal, and then quickly increases in proportion to the compaction of the composite structure by a roller-roll mechanism, $T > T_1$ and $t_{gl} > t_{1-gl}$ (Fig. 5). It should be noted that the operational polishing of the mechanism's rollers forms a heterogeneous wavy surface, with a slight amplitude of dimensional deviations, which is sufficient for the partial loss of contact with the surface of the covers during coordinate transportation.

Therefore, it is a relevant task to implement modern technology for strengthening the surface layers of cylindrical surfaces, by creating a steady regular microrelief, which would contribute to the prolonged preservation of the operational inhomogeneity of the external dimensions of the rollers.

After the formation of a completely regular microrelief in the near-surface layer of the rollers, a partially regular microrelief is formed, whose technological execution implies the application of flat-parallel recesses in the form of slots shown in Fig. 6, of width b mm and of step $2b$ mm, geometrically coordinated an angle α to the axis of the rollers. The flat-parallel recesses contribute to a change in the amount of residual compression stresses, depending on the structure of the formed partially regular microrelief.

In turn, it follows that during the application of a partially regular microrelief there is complete smoothing and formation of a new micro-relief, instead of that formed previously. The height, shape, and arrangement of such a microrelief are determined not only by the amount of the compression effort but also by the diameter of the deforming matrix, the amplitude of its oscillations, the velocity, feed, and the number of oscillations.

The improvement of the physical and mechanical characteristics, at the final stage of modifying the surface strength of the rollers, implies the use of an ionic nitriding technology in the plasma of the helicon discharge [20]. As a result, those diffusion processes that cause the formation of a new structural-phase state of the surface, different from the core, change the composition of the near-surface area of the rollers' metal.

We have derived indicators of a partially regular microrelief, given in Table 2, for the experimentally developed parametric system, which takes into consideration the type

and shape of micro-relief, as well as the distribution of micro-hardness obtained after ionic nitriding.

Our study has registered the maximum level of durability increase of the near-surface layer, which fluctuates in the range of the plane upon which a partially regular microrelief is applied, by 24–29 % of the total plane of the roller's surface. The surface hardness, respectively, increases, on average, by 30–32 %.

The graphic results, shown in Fig. 7, demonstrate the effective use of a deforming matrix with radius $R1=1.8$ mm for the formation of a partially regular micro-relief that ensures a gradual proportional change in the height of the laps due to a proportional change in the indentation efforts. Accordingly, the derived results of surface hardness are based on the measurement of the dependence of the height of microreliefs laps on the indentation effort of deforming matrices and do not take into consideration the dependence of the width and depth of irregularities on the indentation effort.

Therefore, the above circumstances indicate the existing shortcomings of the proposed parametric system for reinforcing the surface plastic deformation. The area of further research related to their elimination should be aimed at establishing the influence of the decorative-reinforcing treatment by oscillatory smoothing.

Smoothing ensures an increase in the intensity of stresses at the core of the elastic-plastic deformation of the near-surface layer of steel rollers. This would help form credible calculations of surface strength, which could be used in the development of manufacturing technology for rollers with the predefined parametric characteristics.

8. Conclusions

1. We have proposed a list of the required and sufficient technological operations, compliance with which would contribute to the manufacture of covers with the calculated contour and structural design. The specified features in the cover design imply that the structural elements, in the form of edges and flaps, after folding and gluing to the main part, form a solid double composite structure. In the joints of the edges and flaps, there are no laps, so the plane of the inner part of the covers acquires a flat shape, without defective contours.

With this structure of covers, there are new possibilities of their contour strengthening, along a continuous or discrete perimeter, by the creation of the conditional rebars of stiffness, in the preliminary blanked, to fold the edges and flaps, places.

Given this, it can be argued that the parallelism of deviations in the outer contours of semi-hard covers from a rectan-

gular design would not exceed the defined ranges. The dimensional indices of such ranges are 0.4–0.5 mm, 0.3–0.4 mm, 0.2–0.3 mm for the book frames, divided into groups based on qualitative indicators. And this, in turn, makes it possible to limit the skewness of the deviations by book blocks. The attachment of book blocks to semi-hard covers and the formation of edging occur in the ranges of 0.8–1.0 mm, 0.6–0.8 mm, 0.4–0.5 mm for the groups, according to the same qualitative characteristics as for covers.

2. An experimental parametric system for stabilizing the positioning of covers has been devised, at their linear movements in the process of rotating pressing. The strengthening of the cylindrical surface of the pressing roller-roll assembly, obtained at its application, ensures stable conditions for the technological process of manufacturing covers.

The features in the strengthening of the surface imply the use of the means of plastic deformation. The result of the first operating cycle of the deformation is the formed completely regular microrelief of the hexagonal type, convex in shape. The parametric range of the dimensional sampling of the micro-relief from an experimental array is: for the radius of a deforming matrix – 0.5 ± 1.0 mm, for its eccentricity – 0.2 ± 1.0 mm, for the oscillation frequency – $1,000\pm 2,000$ doub./s.

The determining factor in the next operating cycle of plastic deformation is the formation of a partially regular micro-relief, in the form of the flat-parallel slotted recesses, cut at an angle $\alpha=15^\circ$ to the central axis of the roller. The flat-parallel recesses ensure the creation of the required and sufficient guiding efforts for transporting semi-hard covers during the manufacturing process.

The results, derived from the strengthening of the cylindrical surface of the rollers, are presented graphically, thereby demonstrating the effective use of a deforming matrix of radius $R1=1.8$ mm, from the sampling range of 1.5–2.5 mm. The deforming matrix ensures a gradual proportional change in the height of the laps in a partially regular micro-relief, due to a proportionate change in the indentation efforts of the indenter.

We have established the distribution of microhardness of the near-surface layer of rollers after the final technological operation of ionic nitriding in the plasma of the helicon discharge. To a depth of 300 μm , it is 5,000–4,000 MPa, and from 300 μm to the center of the roller – there are no changes. Our study has registered the maximum level of an increase in the durability of the near-surface layer, which fluctuates in a range of the plane upon which a partially regular microrelief is applied, 24–29 % of the total plane of the roller's surface. The surface hardness, respectively, increases, on average, by 30–32 %.

References

1. Tatarinova, L. (2020). Some trends in the development of book printing in the leading countries of the world. Available at: <http://upba.org.ua/index.php/uk/zakonodavstvo/knyzhkova-palata/item/121-deiaki-tendantsii>
2. VAT/GST on Books & E-books. An IPA/FEP Global Special Report (2015). Available at: <https://www.internationalpublishers.org/images/VAT2015.pdf>
3. Martyniuk, M. S., Havenko, S. F., Kulik, L. Y. (1998). Pat. No. 32803 UA. Book-and-magazine cover and method for its manufacture. No. 98042120; declared: 28.04.1998; published: 15.02.2001, Bul. No. 1.
4. Kyrychok, P. O., Paliukh, O. O. (2018). Pat. No. 119418 UA. Prystriy dlia vysikannia rozghortok iz paperu ta kartonu knyzhkovykh obkladynok i paliturok odnogo knyzhkovoho formatu. No. a201805409; declared: 16.05.2018; published: 10.06.2019, Bul. No. 11.
5. Rudawska, A. (2019). Bonding technology. Surface Treatment in Bonding Technology, 7–46. doi: <https://doi.org/10.1016/b978-0-12-817010-6.00002-3>

6. Starchenko, O. P., Marchenko, I. V. (2016). Influence of Heterogeneous Structure of Material Surfaces on Adhesion Quality in Finishing Processes Technology. *Technology and Technique of Typography*, 3 (53), 26–34. doi: [https://doi.org/10.20535/2077-7264.3\(53\).2016.73162](https://doi.org/10.20535/2077-7264.3(53).2016.73162)
7. Chen, K.-N. (2019). Polymer Adhesive Bonding. *Encyclopedia of Packaging Materials, Processes, and Mechanics*, 1–13. doi: https://doi.org/10.1142/9789811209680_0001
8. Kyrychok, P., Paliukh, O. (2020). Simulation of Deformation of the Adhesive Layer of the Spine of the Book Back of the Thread-Stitched Book Block. *Mechanics*, 26 (2), 114–119. doi: <https://doi.org/10.5755/j01.mech.26.2.25854>
9. Havenko, S., Korobchynskiy, M., Yordan, H., Kadyliak, M., Bernatsek, V. (2017). Effect of microwave drying of the spines of book blocks on the quality of printed materials. *Eastern-European Journal of Enterprise Technologies*, 6 (1 (90)), 68–79. doi: <https://doi.org/10.15587/1729-4061.2017.118006>
10. Zaydes, S. A. (2018). New surface plastic deformation techniques in the manufacture of machine parts. *Vestnik of Nosov Magnitogorsk State Technical University*, 16 (3), 129–139. doi: <https://doi.org/10.18503/1995-2732-2018-16-3-129-139>
11. Zaides, S., Nguyen Van, H. (2017). Oscillating burnishing parameters effect on hardened surface roughness. *Proceedings of Irkutsk State Technical University*, 21 (4), 22–29. doi: <https://doi.org/10.21285/1814-3520-2017-4-22-29>
12. Oteniy, Ya. N., Privalov, N. I., Shchegolev, N. G., Murav'ev, O. P., Tkacheva, Yu. O. (2016). Osobennosti formirovaniya glubiny uprochneniya pri obrabotke detaley poverhnostnym plasticheskim deformirovaniem. *Mezhdunarodnyy zhurnal prikladnyh i fundamental'nyh issledovaniy*, 12, 452–455. Available at: <https://applied-research.ru/ru/article/view?id=10860>
13. Kuritsyna, V. V., Martynyuk, A. V., Grachev, M. V. (2014). Directed surface plastic deformation in the system of control of pneumatic hydro-aggregates precision part shape. *Izvestiya Moskovskogo gosudarstvennogo tehnikeskogo universiteta MAMI*, 2 (2 (20)), 55–63.
14. Lihobabina, N. V., Korolev, A. A. (2008). Surfaces hardening by diamond burnishing. *Vestnik Saratovskogo gosudarstvennogo tehnikeskogo universiteta*, 1 (1).
15. Wang, Z. B., Lu, J., Lu, K. (2006). Wear and corrosion properties of a low carbon steel processed by means of SMAT followed by lower temperature chromizing treatment. *Surface and Coatings Technology*, 201 (6), 2796–2801. doi: <https://doi.org/10.1016/j.surfcoat.2006.05.019>
16. Rudenko, E. M., Panarin, V. Y., Kyrychok, P. O., Svavilnyi, M. Y. et. al. (2018). Hardening of a Surface of Steel 45 by the Ion Nitridation in a Helicon Discharge. *Metallofizika i noveishie tekhnologii*, 40 (8), 993–1004. doi: <https://doi.org/10.15407/mfint.40.08.0993>
17. Martyniuk, M. S., Yakutsevych, S. Ya. (2003). Rozroblennia konstruktsiy knyzhkovykh oprav. *Naukovi zapysky*, 6, 65–67.
18. Paliukh, O. O. (2018). Experimental Determination of Technological Features of Production of Semi-Rigid Book-Magazine Cover. *Technology and Technique of Typography*, 2 (60), 22–32. doi: [https://doi.org/10.20535/2077-7264.2\(60\).2018.145378](https://doi.org/10.20535/2077-7264.2(60).2018.145378)
19. Zyhulia, S., Barauskiene, O. (2019). Effect of the integrated treatment on the manufacturing of printing cylinders. *Eastern-European Journal of Enterprise Technologies*, 3 (12 (99)), 22–28. doi: <https://doi.org/10.15587/1729-4061.2019.171808>
20. Rudenko, E. M., Panarin, V. Y., Kyrychok, P. O., Svavilnyi, M. Y., Korotash, I. V., Palyukh, O. O. et. al. (2019). Nitriding in a Helicon Discharge as a Promising Technique for Changing the Surface Properties of Steel Parts. *Uspehi Fiziki Metallov*, 20 (3), 485–501. doi: <https://doi.org/10.15407/ufm.20.03.485>