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THE INCREASE OF EFFICIENCY OF METAL FITTINGS INSTALLING OPERATION IN LIGHT INDUSTRY PRODUCTS

Summary: Nowadays there is a large assortment of metal fittings for light industry products: grommets, shoe blades and hooks, buttons, rivets, jeans buttons, etc. Qualitative installation of metal fittings in light industry products is a significant problem and depends on various factors. Therefore, theoretical and experimental researches in this field are important and relevant nowadays.
The most popular types of metal fittings used in the sewing, footwear, leather and haberdashery industries are blocks and grommets. While grommets installing in a traditional way, unreasonable losses between the two operations occur.
One of the ways to increase labor productivity is to combine the technological operations of holes punching in the grommets and their fastening in the material. This installation method can be applied to fittings which have a cylindrical hollow shape and a sharp incisive edge.
To investigate the operation of metal grommets installation in light industry products, an experimental installation was developed and experimental studies were carried out.
The experimental studies confirmed the possibility of utilization of the grommet cutting edge as a working tool for the punch, which in turn allowed the punching and fitting operation to be combined, reduce the number of working tools, and increase the productivity of the equipment.

Key words: light industry, metal fittings, grommets, material, press for fitting installation

1. THE RESEARCH TASK AND URGENCY

Nowadays there is a large assortment of metal fittings for light industry products: grommets, shoe blades and hooks, buttons, rivets, jeans buttons, etc. [3]. Almost all kinds of clothes are decorated with metal fittings, and some are generally hard to be imagined without it, for example, denim clothing, which must necessarily be with rivets, jeans buttons, buttons, grommets, etc. The use of quality fittings can decorate any clothing and shoes, increase the convenience and their working term, etc.

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The offer of the metal fittings market is very large today; it is represented by both cheap and expensive various kinds of metal fittings of various quality. The same statement can be said about the tools and equipment for its installation. Quite often, manufacturers of clothing and footwear, using the method of "test and error", are looking for an optimal combination of price and quality when installing the fittings. These attempts are successful not always; consequently, it often causes consumers to suffer because of buying products with poorly installed fittings that are quickly about to be spoiled, broken and need to be replaced.

Qualitative installation of metal fittings in light industry products is a significant problem and depends on various factors. Therefore, theoretical and experimental researches in this field are important and relevant nowadays.

In many cases, the task of a theoretical study is simplified by assumed assumptions in order to determine the basic values that describe the technological process. Experimental studies that are carried out to confirm the adequacy of theoretical statements show how significant the error of the results is due to the assumed assumption and, accordingly, in which direction the theoretical studies should be corrected.

Experimental studies of the process of the metal fittings installation need to be conducted in order to identify patterns of interest in terms of existing theoretical studies and their application.

2. THE RESEARCH METHODOLOGY

The most popular types of metal fittings used in the sewing, footwear, leather and haberdashery industries are blocks and grommets.

The blocks are shaped sleeves which have a circlet on one side. They are intended to strengthen the edges of the openings of sewing, footwear, leather and haberdashery products [3].

The grommets, as a rule, consist of two elements: blocks and rings (pucks), which lead to the connection of increased strength.

The installation of metal fittings in clothing, footwear, leather and haberdashery products at light industry enterprises is carried out according to the traditional technology, which consists of two stages: punching of the opening in the material; metal fittings fastening.

For several decades, the mechanisms implementing the workflow are stable and not subjects to any noticeable changes in their design [2]. Such fittings are installed manually (with hand tools or presses with a manual or foot type of drive) or by special working units of the equipment (in automatic presses with electric, electromagnetic and pneumatic type of drive) into a pre-pierced opening in the material of the product, and then fastened by splitting or beading.

Such working tool as a punch-cutting board is used for holes punching; for fixing of metal fittings, working tool called a die holder is used (Fig. 1).

The process of grommets installation in the traditional way is as follows. The punch-cutting board is mounted on the frame of the press in the die holder. A puncher is attached to the puncher of the press. The puncher with a punch goes down and pierces the opening of the required diameter in the material. Metal fittings are installed into the pierced hole. The puncher is removed from the press puncher, and a punch is installed in that place. The matrix is mounted on the frame of the press in the die holder. The grommet that is in the material is inserted into the matrix. The puncher with a punch goes down and performs the operation of grommet fastening in the material.

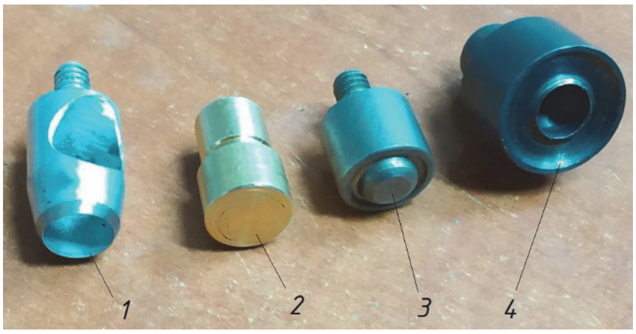


Fig. 1. Working tools: 1 – punch; 2 – punch-cutting board; 3 – punch; 4 – matrix

Thus, unreasonable time losses between the two operations associated with the necessary replacement of working tools occur. Two presses can be used; one with a punch, the second with a punch. The installation time will be lower, but two operations must be performed.

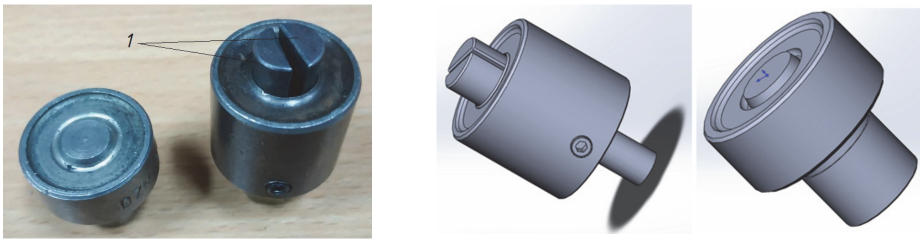
One of the ways how to increase labor productivity is to combine technological operations. The hole punching for the metal fittings and its fastening in the material should occur without intermediate replacement of working tools; it should occur in one operation on the press and impact equipment with the help of the metal fittings themselves and the special design of the puncher and matrix.

This installation method can be applied to fittings which have a cylindrical hollow shape and a sharp incisive edge. Such fittings include special blocks and grommets, which appeared relatively recently, but quickly have gained strong positions in the printing and advertising industries; they are used for holes strengthening in various materials (cardboard, plastic, etc.) and outdoor advertising: banners, stretch marks, etc. Such grommets and sharp-edged blocks can be recommended for use in clothing, footwear, leather and haberdashery goods industries, mainly for dense materials (various types of leather, leather substitutes and textiles).

This method of installation has limitations for highly elastic synthetic materials. If the grommet's edge is not sharp enough, then the material will stretch while beading, it will also get into the gap between the grommet and the puck, and it will be crumbled; hence, the qualitative installation of the grommet is impossible [2].

Further, in the course of experimental studies, such grommets will be used, that is, blocks with reinforcing pucks, which are most common in light industry.

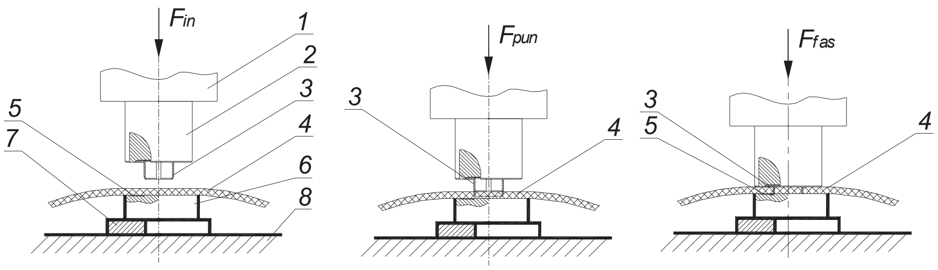
To perform the installation of metal fittings we propose to use the punch design by Micron Group Inc. The general look of the working tools made in the Solid Works software environment is shown on Figure 2.



a) b) c) d)

Fig. 2. General look of working tools: a) punch; b) matrix; c–d) model in the Solid Works software environment; 1 – holder

The scheme of the implementation of the technological operation of installing the grommets by the proposed method is shown on Figure 3.



a) b) c)

Fig. 3. The scheme of the implementation of the technological operation of installing the grommets by the proposed method: a) puncher movement towards the material; b) cutting an opening in the material; c) grommet fixing on the material; 1 – puncher; 2 – punch; 3 – grommets; 4 – material; 5 – puck; 6 – matrix; 7 – die holder; 8 – base

The proposed working tool works as follows. The punch 2 is fixed to the puncher of the press 1. The matrix 6 is fixed to the 7 die holder. Firstly, a puck 5 for strengthening is fixed to the matrix 6. The punch 2 in its design has two spring-loaded holders 1. On the holder 1 of the punch 2, a metal grommet 3 is installed. The material 4 is fixed on the matrix 6 in a certain side. The puncher with a punch and the grommet begins to move towards the material. The grommet, reaching the material, with the help of its sharp part begins to cut the material, plunging into it. The complete cutting of the opening with the sharp part of the fittings and its immersion into the material occurs. This corresponds to the first stage of metal fittings installation in a traditional way. After the material cutting, the grommet, with further displacement, begins to contact with frontal surface of the matrix. Due to the conical protrusion on the matrix, distribution of the grommet manhole occurs. When the edge of the grommet reaches the ring-shaped hollow, a further stripping of the distributed part of the grommet manhole is carried out. Thus, an integral combination is obtained: the grommet- the material – the puck.

Due to the use of this punch design, it was possible to combine the two stages of the metal fittings installation in a traditional way, and we got one proposed method. And this, in turn, leads to a significant reduction of execution time of this technological operation. In this way, we can significantly increase the machine's productivity.

Reducing the time of metal fittings installation, in turn, will lead to the reducing of energy consumption while using the equipment with electric motors.

Another way of reducing energy consumption when using the proposed methods of metal fittings installation can be the use of high-speed modes of operation. Many scientists have proved that during high-speed implementation of the operation, the technological effort in metals decreases. Therefore, when fixing metal grommet with the help of high-speed modes, less work is spent. Thereby, this reduces the energy consumption of the press equipment. But to confirm this, it is necessary to conduct experimental researches.

The disadvantage of high-speed performance of the operation may be the quality of grommet fixing on the material. It also requires experimental researches.

The interaction of the grommet edge with clammy-elastic material and, subsequently, with the matrix, in the process of its installation, is defined to be extremely complex process mainly due to the physical phenomena that are not subject to a clear analytical description. Only a combination of theoretical grounds with experimental studies will give an understanding of the true physical picture of this process and will make important conclusions.

When performing the technological operation of metal fittings installation in light industry products, the proposed method will contain two technological efforts: the efforts of the grommet punching F_{pun} and the effort of grommet fastening F_{fas} in the material. When setting up the press to install metal fittings for maximum effort in the production environment, you will need to know what effort to choose as the maximum for calculations. Therefore, it is necessary to conduct experimental studies to determine the dependence of the technological effort of performing of the metal fittings installing operation from the motion of a punch for a certain diameter of the grommet. On the received diagrams it is possible to determine the maximum values of efforts and compare them. Moreover, we can also compare the obtained values with the results of experimental studies on the installation of metal fittings in the traditional way, which are given in papers [4, 5]. The authors of this work determined the technological efforts of cutting the holes for metal fittings in various materials and the metal bushes strengthening in the materials.

3. THE RESULTS OF THE RESEARCH

To investigate the operation of metal grommets installation in light industry products by the proposed method in a static mode, an experimental installation was developed. The structure of the experimental installation includes: a device for performing the operation of metal grommets installation in the products of light industry; unit of measuring equipment; a computer. The device for performing the operation of grommets installation (Fig. 4) consists of: frame 1, pair of screws to create a load 2, a punch 3, and the material with grommet 4.

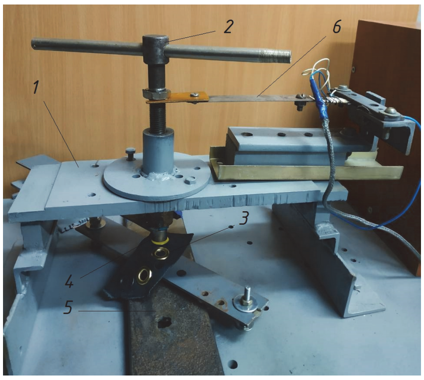


Fig. 4. The device for performing the operation of metal fittings installation: 1 – holster; 2 – a pair of screws for loading; 3 – material with the grommet; 4 – working tools (punch and matrix); 5 – strain gauge for measuring the installation effort; 6 – strain gauge for measuring the value of the punch movement

The block of measuring equipment consists of strain gauge for measuring the installation effort 5, strain gauge for measuring the magnitude of the displacement of puncher 6, an amplifier, an analog-to-digital converter (ADC) and computer.

The setting for the study of the operation of metal grommets installing in static mode works as follows. The ring for strengthening and the material are placed on the matrix fixed in the die holder (Fig. 2). The die holder is in turn placed on the strain gauge. With the help of the pair of screws 2, the necessary effort is made to install the metal fittings in the material 3. The sharp edge of the grommet immerses in material 3 and cuts it. In the further immersion, the distribution of the cylindrical part of the grommet occurs due to the conical part of the matrix. When the distributed part of the grommet falls into the canal on the matrix, its flanging, bending in the form of a ring and fastening on the puck occur.

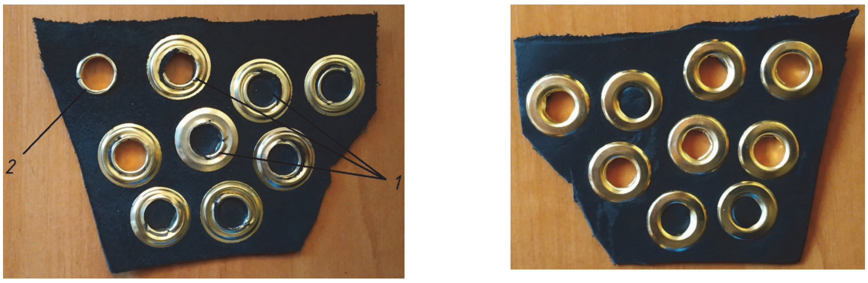
In this way, an inseparable compound is formed: the grommet – the material – the puck.

Analog signals originating in the strain gauges 5 and 6 are amplified with the help of an amplifier, and then they convert to digital with the help of ADC and enter the computer. With the help of the developed software installed on the computer, the dependence between the technological installation effort F_{in} and the value of the punch movement h_p is obtained. Based on the obtained dependencies, the parameters of the process of the metal fittings installation into the material can be determined in the future.

As a material for the grommet installation, natural leather from the top of the shoe was selected (its thickness is 1.6 mm) [8].

For the experimental researches, metal grommets of three different firms "Liuversy" [6], "Alvi" [7] and "Shyjemo razom" [1] were used. The grommets differed in the brand of steel from which they were made and the geometric shape of the puck and had the following dimensions: the inner diameter of the block is 10 mm; the stalk height of the block is 4.8 mm [2].

In the course of experimental research on the installation of the grommets of the company "Liuversy" in the material, we did not manage to perform this operation qualitatively. A torn ring was formed from the flanged metal; there was a lack of leather for the hole (Figure 5a); and the cringing of the outer side of the grommet occurred (Figure 5b).



a) b)

Fig. 5. The installation the grommet in the material by the proposed method: a) the inner side; b) outer side; 1 – defects of installation while using the grommets made from soft material and with dented cutting edge; 2 – defects of installing the grommets when the geometrical shape and size are not measured

Not qualitative performance of the operation can be explained by the softness of the material from which the grommet was made, and the fact that the cutting edge was not sharp enough. As a result of beading, the cylindrical part of the grommet stalk was pulled out, fell into the gap between the grommets and the puck, and cringed.

While installing the grommets of the company "Alvi", it was impossible at all to fix a puck on the material. After measuring the geometric parameters of the outer diameter of block stalk and the inner diameter of the puck, it turned out that the gap between them was very small. The puck was very tight on the cylindrical stalk. That is, they fitted each other very tightly. Furthermore, the shape of the puck did not repeat the shape of the matrix. The splashing of the volumetric shape of the puck took place. The ring from the flanged material was formed on the material itself (Figure 5b).

The installation of fittings of the first two companies with the help of traditional method was carried out qualitatively without breakage, with the formation of an appropriate ring from the flanged metal on the puck. This can be explained by the fact that there was no need to cut the material with the grommet. It was installed in already prepared hole.

The best indicators were shown by the company's "Shyjemo razom" grommets. The block material was stiffer and had a sharp cutting edge. The puck completely repeated the contours of the matrix, and the gap between outer diameter of block stalk and the inner diameter of the puck was sufficient.

When performing the first stage of the operation, the hole punching occurred full and clear, with a clean frontal surface of the hole cutting with the sharp edge of the fittings (Figure 6a). Then there was a qualitative grommet fastening in the material.

a) b) c)

Fig. 6. Stages of grommets installation by the proposed method: a) a sample of cut material for the hole of the grommet; b) grommet fastening on the material (inner side); c) grommet fastening on the material (outer side)

While conducting the experiment, the values of the dependence between the technological installation effort F_{in} and the value of the punch movement h_p were measured; and they determined the nature of the operation, the maximum punching effort $F_{pun \cdot max}$. and the maximum installation effort $F_{in \cdot max}$.

Figure 7 shows the graph of the dependence between the technological installation effort F_{in} and the value of the punch movement h_p. The analysis of the given graph allowed allocating six stages that the grommet passes in the process of its installation in the material. At the first stage (I) the cutting of material with sharp part of the grommet takes place. The maximum technological punching $F_{pun \cdot max}$. occurs when the punch passes through the entire thickness of the material. At the second stage (II) there is a sudden drop of effort due to the certain gap between the material and the conical part of the matrix. During the contact with the conical part of the matrix, the technological effort begins to increase again (Stage III). The process of distribution of the cylindrical part of the grommet occurs. Subsequently, due to the ring-shaped slot on the matrix, the process of flanging the distributed part of the grommet (Stage IV) with subsequent bending in the form of a ring (Stage V) on the fastening washer that is on the material is carried out. At the sixth stage there is further contact of the material with a fixed grommet. By the quantity of the material compression it is possible to evaluate the quality of the installation.

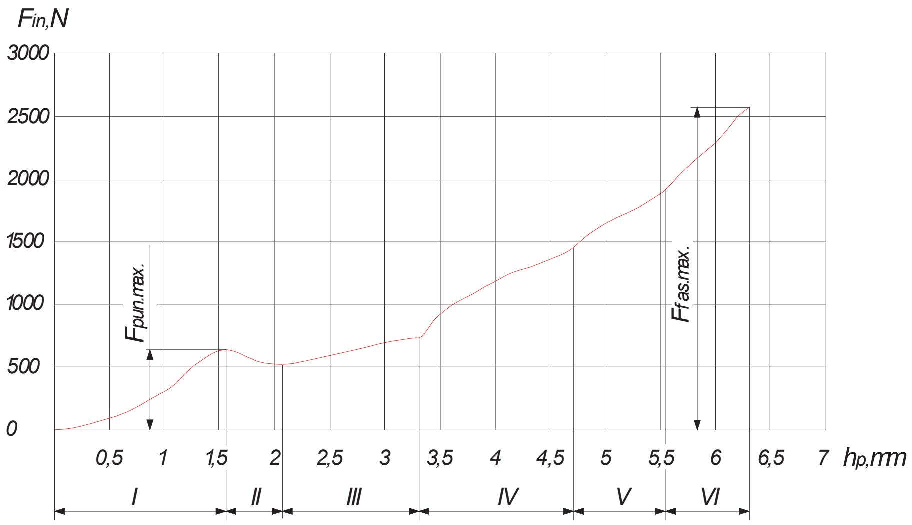


Fig. 7. The graph of the dependence between the technological installation effort F_{in} and the value of the punch movement h_p: $F_{pun\cdot max\cdot}$ – the maximum punching effort; $F_{in\cdot max\cdot}$ – the maximum installation effort

Having analyzed the received schedule, one can conclude that for the fastening of the grommet in material it is necessary to apply much more effort than to cut the punching hole for the fittings. Therefore, the effort of grommet installing F_{in} will be equal:

$$F_{in} = F_{fas} \tag{1}$$

Thus, when calculating the maximum technological effort for the press during the grommet installation of a certain diameter $F_{in\cdot max\cdot}$, it is necessary to take the maximum effort of fastening $F_{fas\cdot max}$.

In the work [4] a study of holes punching for the metal fitting with the angle of aggravation of 25° was conducted, and we obtained the value of maximum punching effort. The comparison of obtained maximum technological efforts of holes punching with the angle of aggravation of 25° and the grommet with a cutting edge (Fig. 7) discovered that the use of the grommet as a cutting tool leads to a significant reduction in the punching effort F_{pun}, and to the reduction of the cutting work and energy costs of the press.

The reduction of the punching effort F_{pun} can be explained by the fact the angle of aggravation of the cutting edge is about 5–10° in the grommets used in the experiment. The blunt blade is absent at all. The sharp edge of the grommet does one-time cutting of the material, and it does not affect the process of its wear. At a smaller angle there are less frictional forces on the cutting edge.

Accordingly, the reduction of the cutting angle and the coefficient of frictional forces lead to a significant reduction in the cutting effort, which was confirmed experimentally.

In order to find out the optimum maximum technological effort in which the quality of the installation will be satisfactory, the following experiment was conducted. The essence of the experiment was as follows. Gradually increasing the installation effort, the height of the fastened grommet was measured with the calipers and we also evaluated the quality of the fixation in the material. The conducted experiment made it possible to discover the following things. A necessary ring of fastening from the flanged part of the grommet was formed at a higher eminence (Experiment 1). The grommet was fixed on the material, but there was a gap between the material and the puck. Accordingly, the grommet scrolled on the material. With increasing effort, the thickness of the fastened grommet diminished. So, the grommet fitted tighter d to the material. When the load became larger the thickness of the grommet reduced to a certain limit. Further, the thickness of the grommet did not change but the effort increased. This can be explained by the geometric parameters of the matrix and the punch. During the collision of their frontal surfaces, the grommet volume was formed only at the expense of their forms. A further increase in force results only in the deformation of the strain gauge beam in an experimental setting. Under the real conditions, an increase in force will lead to the deformation of the equipment for the fittings fixing and the energy consumption will increase as well. In some cases the leather was cut by fittings due to the more compression. These factors should also be taken into account.

On the basis of obtained experimental data we have created a graph of the dependence between the height of the fixed grommet in the material $B_{f.g.}$ and the maximum installation effort F_{in}, as it is shown in Figure 8.

The optimal option that satisfies the quality of the grommet installation in the material is the conditions where the height of the fixed grommet $B_{f.g.}$ is 3.85 mm, and the installation effort F_{in} is 2500 N.

The approximation of the obtained experimental polynomial of the 1st degree made it possible to obtain the equation:

$$F_{in}=-162.79B_{f.g}+868.68 \quad (2)$$

The obtained equation can be used to determine the installation effort at the required height of grommet fastening in the material.

In order to study the effect of speed on the quality of the installation, a design of a press with a pneumatic drive and a design of a press with an electromagnetic drive were developed. This press equipment is shown on Figure 9.

We carried out the operations of metal fitting installation on this press equipment at different speeds.

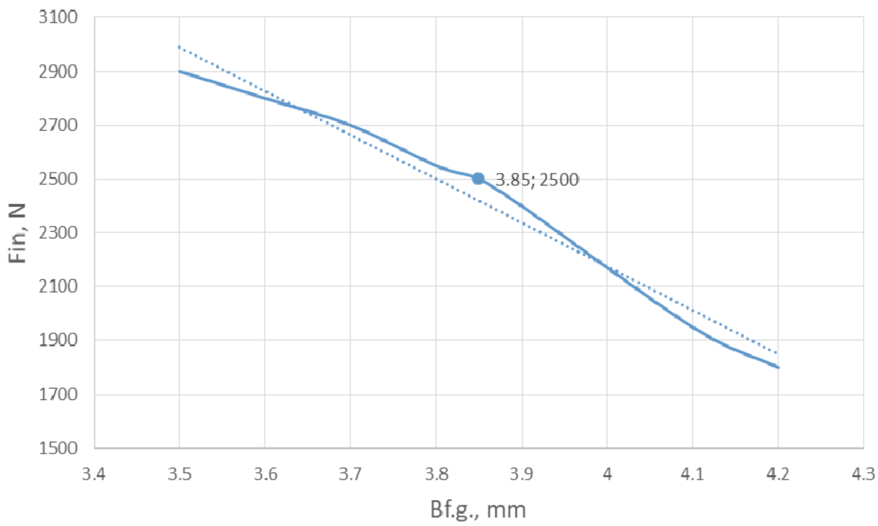
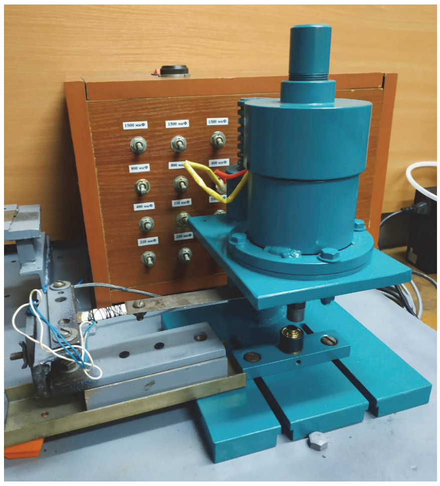


Fig. 8. The graph of the dependence between the height of the fixed grommet $B_{f.g.}$ and the maximum installation effort F_{in}

a)



b)

Fig. 9. Equipment for the grommet installation in a dynamic mode: a) press with pneumatic drive; b) press with electromagnetic drive

Figure 10 demonstrates a sample of the material (natural leather from the top of the footwear; its thickness is 1 mm) with the installed grommets with the help of the manual press, press with pneumatic and electromagnetic drives in a dynamic mode. To install grommets on a manual press, a pneumatic cylinder rod from the press was detached (Figure 9) for transformation into a manual press.

The analysis of the quality of the grommet installation in the material has shown that the grommets are fitted tightly to the material and firmly fixed in it. The outer side of the grommet has no mechanical defects. An equable ring from flanged metal is formed from the inner side of the material.

a) b)

Fig. 10. The natural leather with the installed grommets in a dynamic mode: a) inner side, b) outer side

Later on, the experiment was conducted to determine the productivity of various press equipment types for the grommet installation: manual press and presses with pneumatic and electromagnetic drive (Figure 9). The list of necessary operations for the grommet installation with the help of traditional and proposed methods was identified for this purpose.

The analysis of the operations has demonstrated that in order to install a grommet in the traditional way it is necessary to perform 15 operations, while when using the proposed method their number decreases to 7.

The comparative diagrams of the grommet installation on manual press and presses with pneumatic and electromagnetic drive in traditional and proposed ways are shown on Figure 11.

The analysis of the results has showed that the productivity of the operation of grommets installation on the press with a manual drive increases in 3.4 times, on the press with a pneumatic drive in 4.9 times, and on the press with an electromagnetic drive in 5.3 times.

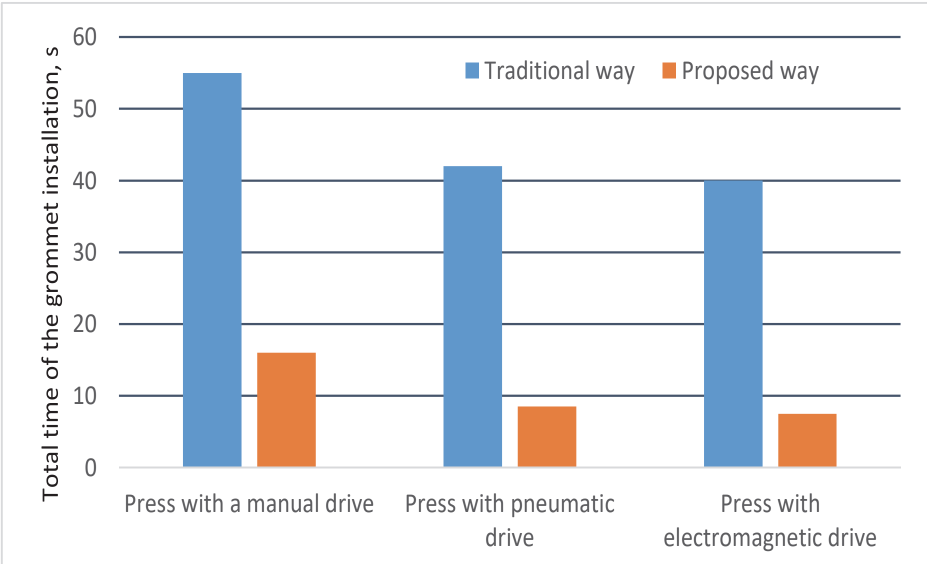


Fig. 11. The comparative diagrams of the grommet installation on manual press, and presses with pneumatic and electromagnetic drive in traditional and proposed ways

4. CONCLUSIONS AND RECOMMENDATION

1. The experimental studies, which were carried out, confirmed the possibility of using the cutting edge of the grommet as a working tool for the punch, which in turn made it possible to combine punching and fixing of the fittings and reduce the number of working tools.
2. The conducted experimental studies have shown that not all grommets can be used for installing into the material by the proposed method. It is necessary to use more rigid grommets with sharp cutting edge. This should be taken into account when choosing the grommets for installation by the proposed method.
3. Reducing the angle of aggravation leads to a significant reduction in the cutting effort, which in turn reduces the cutting performance.
4. The obtained results have shown that during performing the operation of metal fittings installation by the proposed method, the maximum technological effort arises at the end of the puncher move. As a result, when calculating the theoretical effort, it is necessary to use a formula for measuring the maximum fixing effort.
5. There are optimal modes of metal fittings installation where the wasted energy is spent to perform the useful installation work. Increased efforts have a negative effect on the press equipment and can lead to the rapid failure of the equipment and faults in the grommet material and the material in which it is installed.

6. The installation of grommets by the proposed method in high-speed modes does not lead to deterioration of the quality of its attachment to the material.
7. The use of the proposed method for installing a grommet in the material leads to a significant increase in the productivity of the equipment. the productivity of the operation of grommets installation on the press with a manual drive increases in 3.4 times, on the press with a pneumatic drive in 4.9 times, and on the press with an electromagnetic drive in 5.3 times.

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ZWIĘKSZENIE WYDAJNOŚCI MONTAŻU ODZIEŻOWYCH ELEMENTÓW METALOWYCH W PRZEMYŚLE LEKKIM

Streszczenie: Obecnie istnieje duży asortyment metalowych dodatków odzieżo–wych dla przemysłu lekkiego: oczka, klamry do butów, guziki, nity itp. Jakościowa instalacja metalowych kształtek w produktach przemysłu lekkiego jest poważnym problemem i zależy od różnych czynników. Dlatego teoretyczne i eksperymentalne badania w tej dziedzinie są ważne i aktualne w dzisiejszych czasach.

Najpopularniejszymi rodzajami metalowych dodatków stosowanych w przemyśle krawieckim, obuwniczym, skórzanym i galanteryjnym są oczka metalowe i zapięcia. Podczas instalowania tych elementów w tradycyjny sposób dochodzi do nieuzasadnionych strat czasowych pomiędzy tymi operacjami.

Jednym ze sposobów zwiększenia wydajności pracy jest połączenie operacji technologicznych wykrawania otworów w pierścieniach i ich mocowania w materiale. Tę metodę instalacji można zastosować do kształtek o cylindrycznej formie i ostrych krawędziach.
Aby zbadać działanie instalacji metalowych pierścieni w produktach przemysłu lekkiego, opracowano metodę instalacji i przeprowadzono badania eksperymentalne.
Badania eksperymentalne potwierdziły możliwość wykorzystania krawędzi tnącej oczka metalowego jako narzędzia roboczego dla stempla, co z kolei pozwoliło połączyć operacje wykrawania i montażu, zmniejszyć liczbę narzędzi roboczych i zwiększyć wydajność.

Słowa kluczowe: przemysł lekki, metalowe dodatki, przelotki, prasa do montażu