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DEVELOPMENT OF A PACKAGE OF DIES FOR THE COVERS OF THE TWIST-OFF SYSTEM

О. Ватренко, Я. Верхівкер, І. Прокопович. **Розробка пакету штампів для кришок системи твіст-оф.** Холодне штампування металів широко використовується в машинобудуванні та інших галузях промисловості для виробництва деталей та виробів з тонколистового прокату. Перевагами цього методу є висока продуктивність обладнання та відносно невеликі витрати енергії. Штампування здійснюється на вертикальних або горизонтальних пресах з використанням змінного штампового оснащення. Світова тенденція у виробництві тари та упаковки спрямована на зменшення товщини пакувальних виробів та питомої частки упаковки в загальній масі упакованої продукції. Однак просто взяти і зменшити товщину жерсті існуючих виробів, наприклад, кришок системи твіст-оф неможливо, оскільки зменшення товщини металу одразу негативно вплине на надійність герметизації затвора. Необхідно вжити запобіжні заходи, які могли б адекватно компенсувати зменшення товщини металу. Ці заходи полягають в обов'язковому внесенні змін в існуючу конструкцію кришок, а отже, й в штампове оснащення. В статті розглянуто проєктування пакету штампів трансферного пресу для виробництва кришок системи твіст-оф для консервної скляної тари. Наводиться технологія виготовлення кришок та описується робота кожного штампу з пакету окремо. Показано конструкції кожного штампу, які входять в пакет, та послідовну розробку технічної документації на штампове оснащення. Наводяться конструкції найважливіших деталей штампів, які зазнали змін при переведенні виробництва кришок на жерсть зниженої товщини. Надається обґрунтування та пояснюються конструктивні зміни найважливіших деталей штампів.
Ключові слова: холодне штампування, жерсть, пакет штампів, пуансон, матриця, згинання

O. Vatrenko, Ya. Verkhivker, I. Prokopovych. **Development of a package of dies for the covers of the twist-off system.** Cold stamping of metals is widely used in mechanical engineering and other industries for the production of parts and products from thin plates. The advantages of this method are high productivity of equipment and relatively low energy consumption. Stamping is carried out on vertical or horizontal presses using interchangeable stamping equipment. However, it is not possible to simply take and reduce the thickness of the tin of existing products, for example, twist-off covers, since reducing the thickness of the metal will immediately negatively affect the reliability of the sealing of the seal. Precautions must be taken that could adequately compensate for the decrease in the thickness of the metal. These measures are mandatory changes to the existing design of the covers, and therefore to the stamping equipment. The article discusses the design of a package of transfer press dies for the production of twist-off system lids for tin glass containers. The technology for manufacturing lids is given and the operation of each stamp from the bag is described separately. The designs of each die included in the package and the sequential development of technical documentation for stamping equipment are shown. The designs of the most important parts of dies are given, which have undergone changes during the transfer of the production of covers to tinplate of reduced thickness. Justification is provided and structural changes in the most important parts of dies are explained.
Keywords: cold stamping, tin, die package, punch, die, bending

1. Introduction

Cold stamping of metals plays a key role in the production of metal packaging. The global trend in the production of packaging for the food industry is aimed at reducing its material consumption. Thus, the issue of reducing the level of consumption of material resources, reducing the cost of packaged products, reducing the harmful impact of used packaging on the external environment is solved. The rapid development of the production and use of packaging products has sharply exacerbated environmental problems. After all, after use, the packaging turns into garbage, which complicates the already difficult environmental situation.

Ukraine, as well as the whole world, faces the task of minimizing packaging. This can be achieved, for example, by reducing the thickness of the material for the manufacture of packaging products, making a change in their design and developing, accordingly, new stamping equipment. The most important and technically complex link in the technological process of production of twist-off (TO) lids is the stage of forming on a multi-position transfer press by cold stamping.

The lids of the twist-off system are mass-produced products and are made of white tin. It is known that metal packaging, along with glass, is the most energy-consuming and leaves a large carbon footprint, in addition, tinplate is not produced in Ukraine at all, but imported from abroad.

Based on the above, the development of stamping equipment designed for the mass production of metal

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products from tinplate of reduced thickness is not an easy and urgent task. The development of such equipment requires the production of high-precision parts of complex configuration and a long process of approbation of capping agents, with appropriate changes in the design of die parts, in the conditions of a real process of capping and subsequent sterilization of products to obtain high quality products.

2. Analysis of literature data and problem statement

Equipment and stamping equipment, as well as technological processes of cold stamping of thin plates are quite well covered in specialized literature [1, 2]. It provides data on the processes of sheet metal formation, classification of these processes, plastic deformation, stress, characteristics of types of presses, analyzes materials for molding. The main processes of sheet stamping, such as felling, bending, deep drawing, and others are described in [3, 4]. The paper [5] thoroughly considers the mechanics of formation processes and the interaction of the properties of metals with the processes of extraction.

The third part of the work [6] provides a methodology for designing and calculating the main parts of dies for the production of products of the most common configurations. In the paper [7], the stamp for the manufacture of hollow products from hard-to-form materials is considered, and in the work [8] the choice of the optimal rounding radius of the punch for the cold drawing process from pre-profiled sheet blanks is investigated.

The problems of forming products from thin-sheet rolled products of low-carbon steel by bending under the condition of a constant decrease in the thickness of rolled products are not sufficiently covered, or are not considered at all.

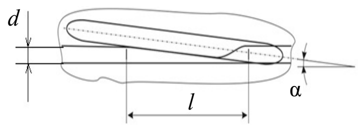

Fig. 1. Threaded gate element. l is the length of the threaded stop, α is the angle of lifting the thread, d is the diameter of the shoulder of the cover rigidity assembly

3. Purpose and objectives of the study

The purpose of this work is to develop stamping equipment for the formation of maintenance system covers from tinplate of reduced thickness. This stamping equipment is a three-position package of dies for a transfer press.

Research objectives.

Design of a package of dies, which consists of dies of the 1st, 2nd and 3rd operations, with their arrangement in one column block.

Production of stamping equipment and testing it on tin of reduced thickness.

Analysis of the resulting products, identification of shortcomings and making changes to the corresponding stamps operationally.

Final completion of the stamping equipment by approbation after making changes with the analysis of the resulting products.

4. Materials and methods of research

The existing stamping equipment for the production of TO-82 covers was designed for tin with a thickness of δ=0.24 and δ=0.25 mm, the length of the threaded stops of which was l=13 mm. However, in order to remain competitive and in accordance with global trends, manufacturers had a need to reduce the thickness of the tin to δ=0.18...0.20 mm. A decrease in the thickness of the tin led to changes in the key geometric parameters of the covers – an increase in the length of their threaded stops to l=18 mm, Fig. 1. All this was the reason for the development of new stamp equipment.

Table 1

Mechanical properties of tin produced by USS Corporation at the plant in Slovakia (Košice)

Degree of hardness, strength class	Annealing	Hardness HR 30 T at tin thickness $\delta \le 0.21$, mm	Yield strength $\sigma_{0.2}$, MPa	Tensile strength $\sigma_в$, MPa
TS260	portioned	56±4	260±50	360±50
TS275	portioned	58±4	275±50	375±50
TH415	continuous	62±4	415±50	435±50
TH435	continuous	65±4	430±50	460±50
TH520	continuous	–	520±50	540±50
TS550	portioned	–	550±50	575±50
TH550	continuous	73±3	550±50	570±50
TH580	continuous	–	580±50	590±50
TH620	continuous	76±3	620±50	625±50

However, the increase in the length of the threaded stops was not enough. It was also necessary to increase the hardness of the tin. Table 1 shows the mechanical properties of white and chrome-plated tin with a thickness of $\delta \le 0.21$ mm of Slovak manufacturers.

Consider the production line of the twist-off system covers, Fig. 2. The production of lids begins with cutting sheets of tin. In most cases, tin sheets are first calibrated on disc scissors. Consider a line with two-row checkerboard cutting of sheets. which is carried out using disc shears *1*, *2*.

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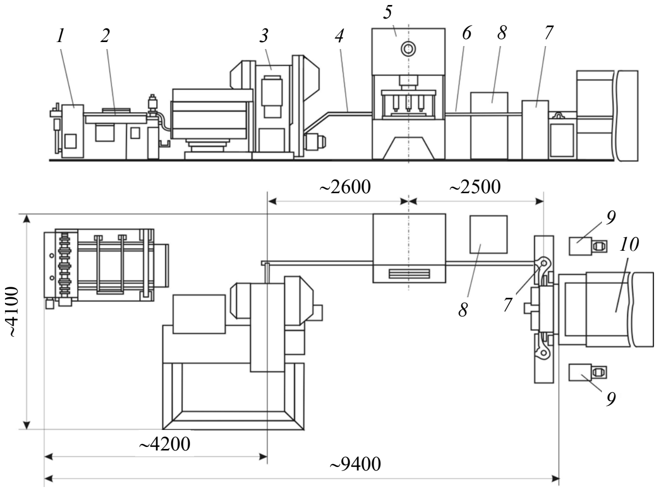

Fig. 2. Positional Cap Production Line: *1*, *2* – disc scissors; *3* – crank press; *4*, *6* – conveyors; *5* – transfer press: *7* – paste-laying machines; *8* – plastisol mixer; *9* – pumps for plastisol; *10* – conveyor oven

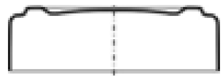

Fig. 3. Blanking the lid after stamping

The next operation is stamping blanks to make lids. The workpieces are stamped on a horizontal crank press machine *3*. Strips of prepared tin are laid in the press shop, from where they are automatically fed for stamping. The press is equipped with a 2-row single-position column die. During stamping, a round workpiece is cut out of the strip and during the same stroke of the slider, a cover blank with a fully formed field relief is stamped, Fig. 3.

Blanks of lids are fed to the transfer press *5* (Fig. 2) using conveyors *4*, which works on the principle of a vertical crank. The peculiarity of this press is that several dies are installed on it in a solid columnar block at once, in this case three, Fig. 4. The lid body is formed from the workpiece in three operations, Fig. 5. Each operation is performed on a separate stamp. The workpiece, moving from position to position, sequentially passes each die of the package and changes its configuration, taking the form of a finished lid body after the third operation.

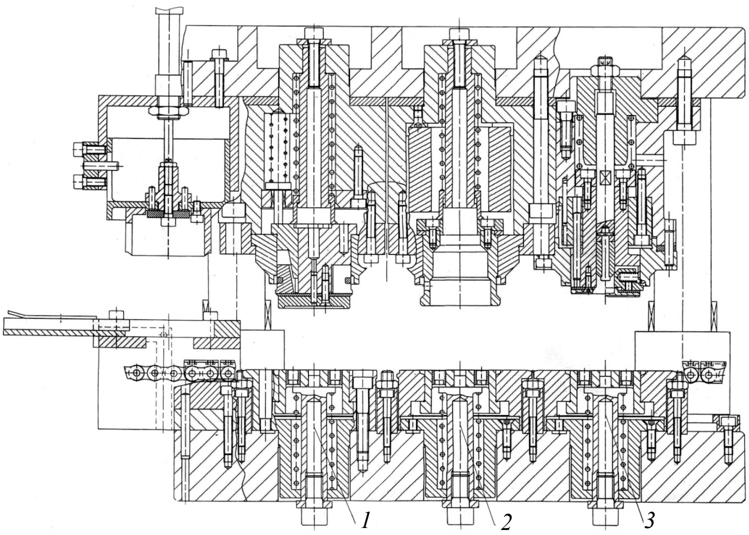

Fig. 4. A package of stamps for the cover of the twist-off system. *1* – stamp of the first operation; *2* – stamp of the second operation; *3* – stamp of the third operation

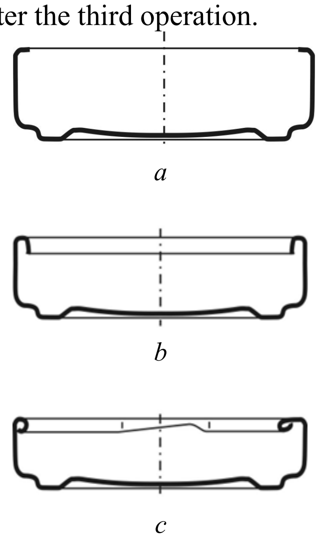

Fig. 5. Operationally forming of the lid body from the workpiece: *a* – the preparation of the first operation; *b* – preparation of the second operation; *c* – finished case

Consider the operation of a stamp package. The workpiece (Fig. 3), with the help of a stepper conveyor, in the “edge up” position, is installed on the spring-loaded Table 1 of the open die of the first operation, Fig. 6, and is fixed on it with magnets *2* and using a vacuum. When the die is closed, the spring-loaded clamp *3* enters the annular channel of the workpiece, centering the latter.

The presser *3* moves the workpiece downwards, until the stop of the table 1 in the glass *4* of the press plate underplate, fixing it in the lowest position. At the same time, the upper part of the die continues to move downwards and six spring-loaded wedges *5*, descending, spread the same number of sectors *6* pulled by a spring *7* from the axis of the die. The edge of the workpiece is fixed between the working surface of the matrix *8* from the outside and the working surfaces of the sectors from the inside and, as a result of their convergence, at the moment of closing the die, is bent to the angle determined by the matrix profile (Fig. 5*a*).

Having reached the lowest position, the die opens and its upper part begins to move upwards, lifting the wedges *5*. In this case, sectors *6* under the action of spring *7* are reduced to the axis of the die, freeing the molded workpiece, and the clamper *3* brings the latter out of the matrix *8*. The workpiece continues to be held by the magnets of the Table 1. Under the action of its spring, the Table 1 rises, setting the workpiece at the level of the upper plane of the lower part of the die package.

The workpiece, with the help of a stepper conveyor, is removed from the die table of the first operation, transferred to the spring-loaded Table 1 of the open die of the second operation, Fig. 7, and is fixed on it with magnets *2* and using a vacuum. When the die is closed, the spring-loaded clamp *3* enters the annular channel of the workpiece, centering the latter.

The clamp *3* moves the workpiece down, until the stop of table 1 in the glass *4* of the press plate under-stamp, fixing it in the lowest position. At the same time, the upper part of the die continues to move downwards and the workpiece is pressed with an edge against the working surface of the matrix *5*. As a result of their axial convergence, the edge of the workpiece is bent to the angle determined by the matrix profile (see Fig. 5*b*).

Having reached the lowest position, the stamp opens and its upper part begins to move upwards. At this time, the spring-loaded clamp *3* removes the workpiece from the matrix, which continues to be held by the magnets of the Table 1. The spring-loaded Table 1 rises, setting the workpiece at the level of the upper plane of the bottom of the die pack.

The workpiece, with the help of a stepper conveyor, is removed from the die table of the second operation, transferred to the spring-loaded table of the open die of the third operation, Fig. 8, and is fixed on it with magnets and using a vacuum. When the die is closed, the spring-loaded clamp *2* enters the annular channel of the workpiece, centering the latter.

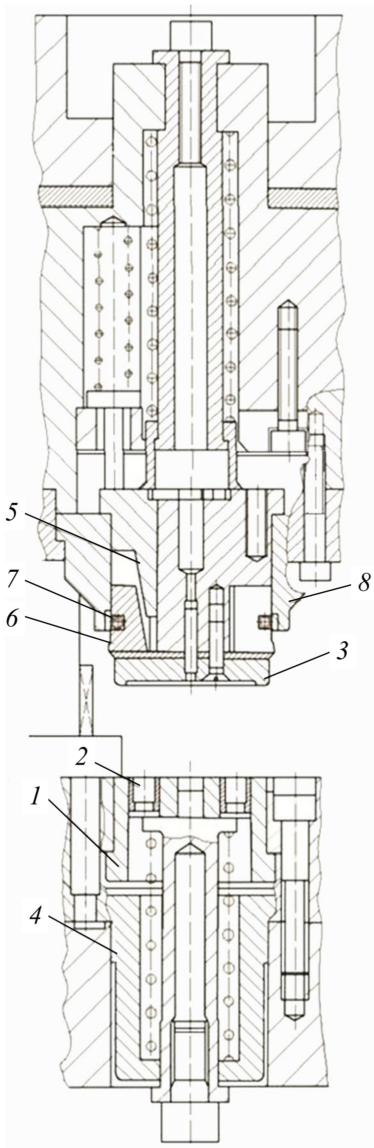

Fig. 6. Stamp of the first operation

The presser *2* moves the workpiece downwards, until the stop of the Table 1 into the glass *3* of the press under-die plate, fixing it in the lowest position.

At the same time, the upper part of the die continues to move downwards, and the pyramid-shaped hexagonal rod *4*, descending, spreads six spring-loaded crackers *5* from the axis of the die (according to the number of threaded stops of the covers). Each cracker with a forming part goes under the edge of the workpiece bent in the middle after the second operation, forming, so to speak, a small anvil.

On the sections of matrix 6 located opposite the crackers, special molding platforms for threaded stops are made. As a result of the axial convergence of the edge of the workpiece with the molding pads of the matrix, with simultaneous support on the forming parts of the crackers, threaded stops are formed. Formation occurs by pushing the bent edge of the workpiece into the gaps between the crackers and the forming pads of the matrix.

At the same time, when the crackers have gone under the bent edge of the workpiece and the threaded stops begin to form, and the upper part of the die continues to move downwards, the sections of the edge located between the stops are pressed against the working surface of the matrix 6. As a result of their axial convergence, the formation of the edge into a torus-shaped ring shoulder is completed. This completes the formation of the lid body (Fig. 5*b*).

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Having reached the lowest position, the die opens and its upper part begins to move upwards, lifting the pyramidal rod *4*. In this case, the crackers *5*, under the action of springs *7*, are reduced to the axis of the die, freeing the molded body. Presser *2* brings the latter out of matrix *6*. The body is held in place by the magnets of the Table 1. Under the action of its spring, the table rises, setting the body at the level of the upper plane of the die package. The body, with the help of a stepper conveyor, is removed from the die table of the third operation and transferred to conveyor 6 (Fig. 2).

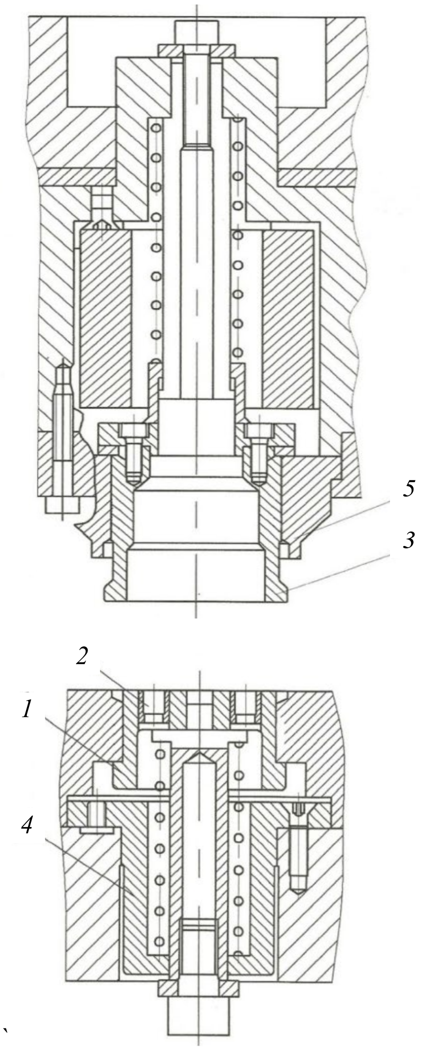

Fig. 7. Stamp of the second operation

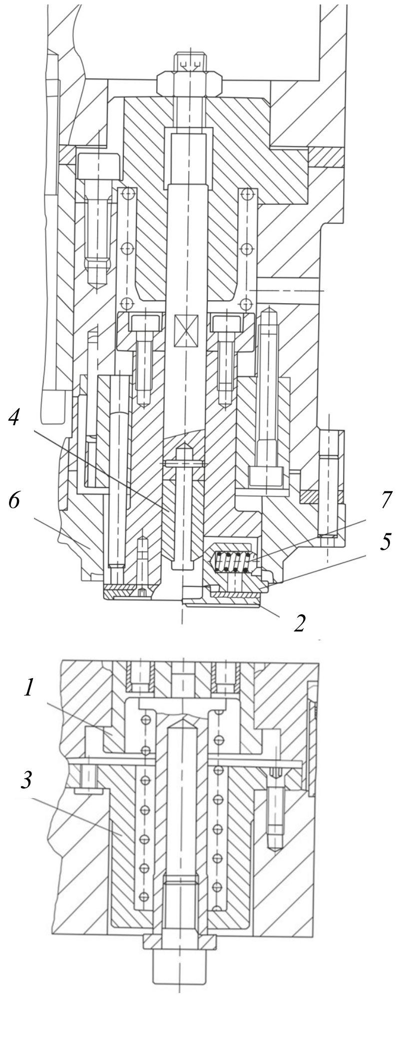

Fig. 8. Stamp of the third operation

5. Development of technical documentation for stamping equipment

On the stamp of the first operation with the transition to tin of reduced thickness, this problem was significantly exacerbated. Sectors *6*, which are involved in the formation of the edge of the workpiece (Fig. 6), are tightened by a coiled spring *7*. Due to the possible unevenness of the pitch of the spring turns *7*, as well as the difference in the contact of the spring with pairs of adjacent sectors in the places of the gaps between them (the spring coil falls into the gap and can cling to the sector, or the gap between the turns falls on the gap between the sectors), some distortion of the sectors may occur.

In this case, the equilibrium of the forces from the spring *7* arising at the points of contact of the spring with the sectors, which acts from the side of a separate sector on a separate wedge *5*, which dilutes this sector, will, passing through the axis of the wedge, be directed not to the axis of the die, but past it. So, when the wedges spread skewed sectors, then when forming a workpiece from thin tin, its edge is deformed unevenly, which leads to a lack of finished products.

It was possible to get rid of this problem by removing six coots *2* mm deep in the places between adjacent sectors, Fig. 9. Now there are no sharp edges of the sectors to which the spring would cling, and the equilibrium of the above-mentioned forces, passing through the axes of the wedges, converge on the axis of the die. As a result, the edge of the workpiece on the die of the first operation is deformed evenly.

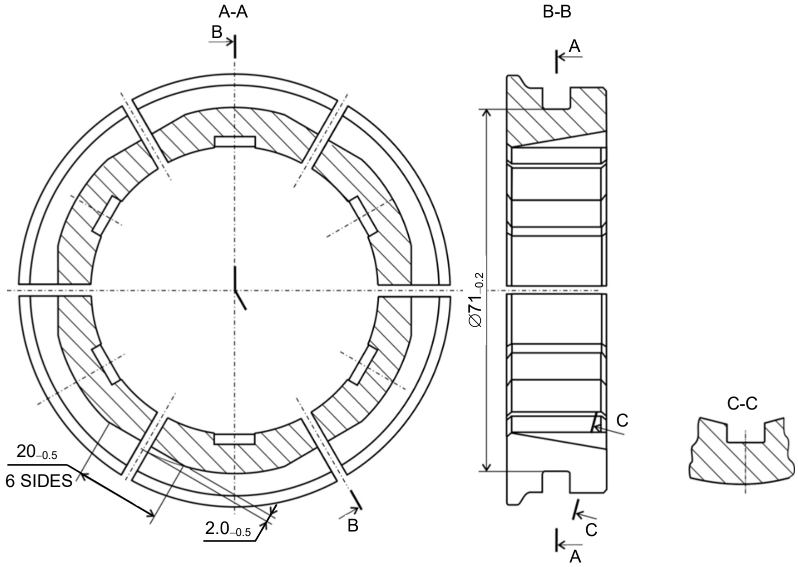

Fig. 9. Sectors of the stamp of the first operation

On the stamp of the second operation with a decrease in the thickness of the tin, two serious problems arose. The first problem was as follows. Since manufacturers use tinplate of increased hardness of the steel base to increase the strength of thin tin covers, it turned out that with an increase in the hardness of the tin, the inner diameter of the lid along the torus-shaped shoulder suddenly began to decrease.

Thus, on the finished workpiece, the diameter of the shoulder *d* (Fig. 1) decreased from the required 1.80 mm to 1.55...1.60 mm. As a result, the bending torque and maximum stresses in the body of the stops increase, which contributes to their plastic deformation during the closure process.

Subsequently, it was concluded that this behavior of the workpiece is a reaction of thin sheets, associated with a decrease in the plasticity of the tin due to an increase in its hardness. To eliminate this problem, changes were made to the die tool of the second operation, since it is in the second operation that the final preparation of the edge of the workpiece for the formation of a torus-shaped shoulder takes place.

On the tin of hardness degrees TS275 and TH415, during the second operation, the side of the lid passed into the edge bent inside the lid cavity along a radius of $R0.6^{+0.05}$ mm. This radius was determined by the radius on the functional surface of the matrix of the second operation, Fig. 10. On the tin of hardness degree TH435 and strength class TH550, due to a decrease in its ductility, the bending radius of the edge decreased. As a result, the diameter of the ring shoulder on the finished workpiece decreased.

To compensate for the decrease in the bending radius of the edge after the second operation, it was decided to bend the entire end part of the side in the edge bending area towards the axis of the workpiece. To do this, the functional surface of the matrix of the second operation was changed. In the existing matrix (Fig. 10*a*), the diameter of the functional surface $\varnothing 85.2^{+0.02}$ mm passed into a radius R of $0.6^{+0.05}$ mm, and then into a chamfer at an angle of 30° to the inner end surface. In the new matrix, Fig. 10*b*, the cylindrical part of the functional surface with a diameter of $\varnothing 85.2^{+0.02}$ mm at a distance of 4.0 mm from its end surface passes first into the conical part, with an angle of inclination of 15°, and then into a radius R of $0.5^{+0.05}$ mm and a chamfer at an angle of 30° to the inner end surface. As a result, the diameter of the ring shoulder increased to the required 1.8 mm and stabilized, and the cantilever of the threaded stops returned to normal.

The second problem was as follows. During the axial convergence of the matrix 5 (Fig. 7) with the edge of the workpiece, the opposite part of the cylindrical side of the workpiece in the step area began to lose stability.

The loss of stability consisted in the fact that from the action on the edge of the axial force F_1 at the place of the step, a reverse annular depression occurred, Fig. 11*a*. This phenomenon was accompa-

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nied by a corresponding loss of high-altitude dimensions of the workpiece, which is unacceptable. To determine the causes of the loss of stability, consider the part of the workpiece that is subjected to axial compression. The cylindrical part of the workpiece from the outside has supports in the form of die parts that support it during compression. Inside, the sidewall of the workpiece has practically no such supports, Fig. 11*b*.

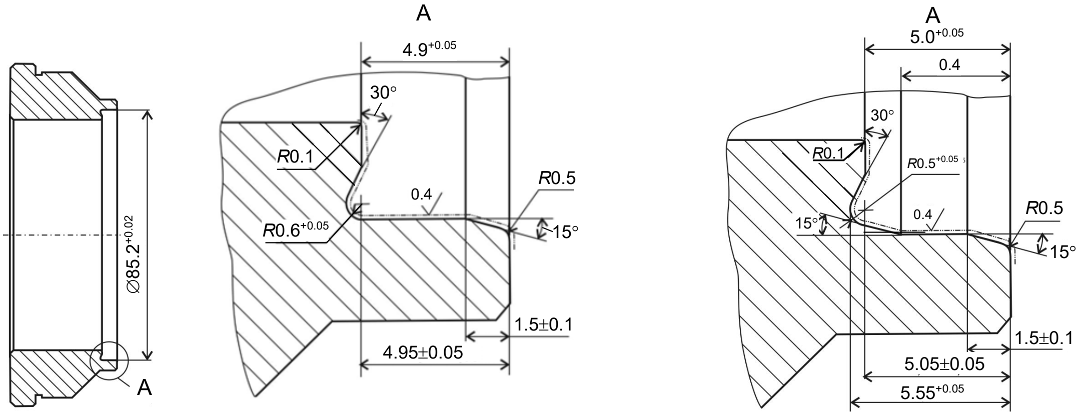

Fig. 10. Die matrix of the second operation: *a* – old matrix; *b* – a new matrix

Let us consider the forces acting on the area where the loss of stability occurs, Fig. 12. The axial force F_1, which acts from the matrix, in the area of the step is transformed into the force F_2 and is directed no longer along the generating cylindrical part of the workpiece, but approximately tangentially to the supporting part, inside which the table moves.

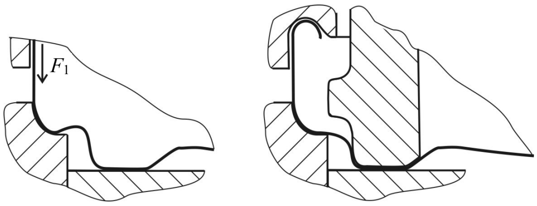

Fig. 11. Loss of stability of the workpiece at the place of the step: *a* – reverse annular recess; *b* – formation blanks of the second operation

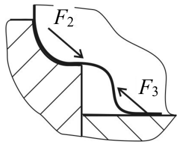

Fig. 12. Forces that cause a loss of stability of the workpiece at the place of the step

At the same time, in the area of the step, at the point of support of the workpiece in the table, an oppositely directed force F_3 acts, caused by the action of the support reaction and a symmetrical force F'_2 from the diametrically opposite side of the workpiece.

These oppositely directed forces compress the step. Structurally, the bend of the step is directed inside the cavity of the workpiece. Therefore, under the influence of two oppositely directed forces, the step bends even more inward, which forms a reverse annular depression.

To prevent loss of stability, it was decided: a support must be introduced at the bend point of the step. For this purpose, the profile of the functional surface of the presser *3* (Fig. 7) was changed. The outer flat annular section of the functional surface was approximated to the end annular section. The distance between them was reduced from 1.5±0.3 mm in the existing design of the clamp, Fig. 13*a*, to $1.0_{-0.1}$ mm in the new, Fig. 13*b*. At the junction of the outer annular section with the outer cylindrical surface of the clamp, instead of a radius of *R*0.8 mm, in the existing design, a chamfer is inserted at an angle of 60° to the axis, in the new one.

Thus, the functional surface of the presser was as close as possible to the inner surface of the bend of the step, creating a support for it. As a result, the loss of stability of the workpiece at the place of the step stopped.

In addition, due to the above-described changes in the design of the edge of the workpiece, associated with an increase in the hardness of the tin of reduced thickness, the width of the inner bend of the edge of the workpiece increased and it began to cling to the clamp when opening the die, so the outer diameter of the clamp was reduced from ∅81.3 mm in the old design (Fig. 13) to ∅81.0 mm in the new one.

Tool mines on the die of the third operation were associated with both the problem of forming covers from tin of reduced thickness, and with a change in the geometric parameters of threaded stops.

In the process of forming threaded stops, the edge of the workpiece is pushed between the forming pads of the matrix *6* and the forming parts of the crackers *5* (Fig. 8), bending inside the cavity of the workpiece. Deformation is carried out in accordance with the configuration of the molding pad of the matrix. However, with a decrease in the thickness of the tin, the cylindrical side of the workpiece in the stop zone began to deform, bending inside the cavity of the workpiece in uncertain places. That is, despite the increase in the hardness of the tin, not only the edge, but also part of the cylindrical side of the lid began to bend.

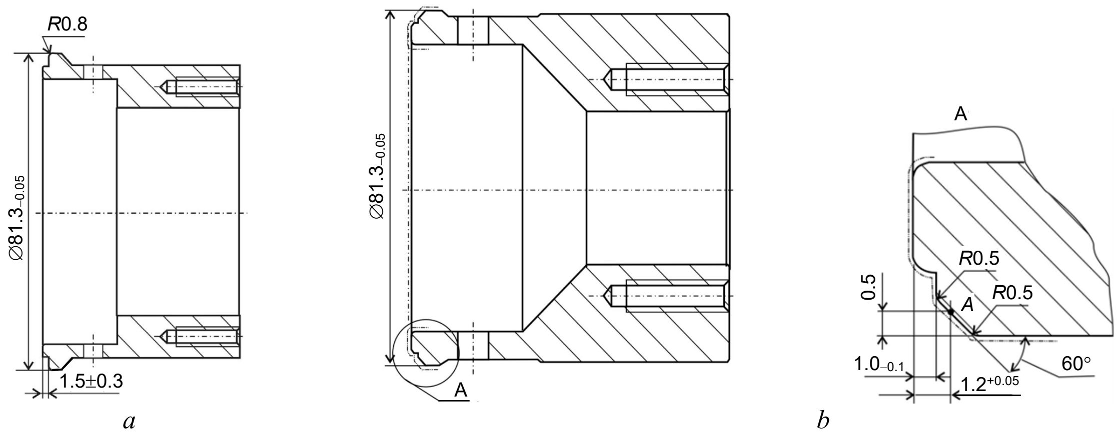

Fig. 13. Stamp clamp of the second operation: *a* – old clamp; *b* – a new clamp.

Since the height of the workpiece after the second operation (Fig. 5*b*) is the same throughout the cylinder, then with unregulated bending of the bead inside the workpiece cavity along the stops, the amount of metal that goes to form the latter begins to increase. As a result, the width of individual stops increases along the radius. This size is controlled in the manufacture of lids. Its increase can lead to a serious problem, which is that the lid may not screw onto the neck of the container.

To overcome this problem, the size of the crackers has been changed. The length of the forming part of the crackers was increased from 21.3 mm in the old design to 25.6 mm in the new one, Fig. 14*b*, which brought it as close as possible to the inner surface of the cylindrical side of the workpiece. As a result, the side of the workpiece from the inside received support and its indefinite deformation stopped. To prevent impacts of the upper end edge of the forming part of the crackers through the workpiece into the molding platform of the matrix, the corresponding chamfers were removed on the forming parts of the crackers, with a value of 1.0±0.1 at 45° (Fig. 14*b*). In addition, due to the change in the geometric parameters of the threaded stops, in order to expand the support during their formation, the width of the forming part of the crackers was increased from 12.0 mm in the old design to 13.0 mm in the new one (Fig. 14).

Increasing the length of the threaded stops was achieved by gradually increasing the radii of rounding of the segments forming the annular channel to form the annular shoulder of the workpiece on the matrix *6* of the die of the third operation (Fig. 8). The distance *L* between the points of junction of the radii of rounding the edges of two adjacent segments with fragments of the annular channel, Fig. 15, determines the length of the threaded stop. stops.

Simultaneously with the increase in the radii of rounding of the segments, the thickness of the tin was gradually reduced and its hardness increased. Then the lids were delivered to processing enterprises of the food industry, where their quality was confirmed in the process of production of canned products.

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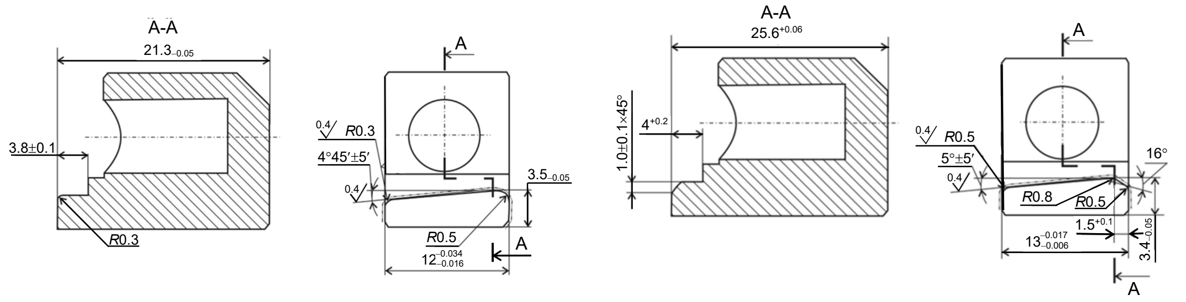

a *b*

Fig. 14. Crackers of the stamp of the third operation: *a* – old; *b* – new

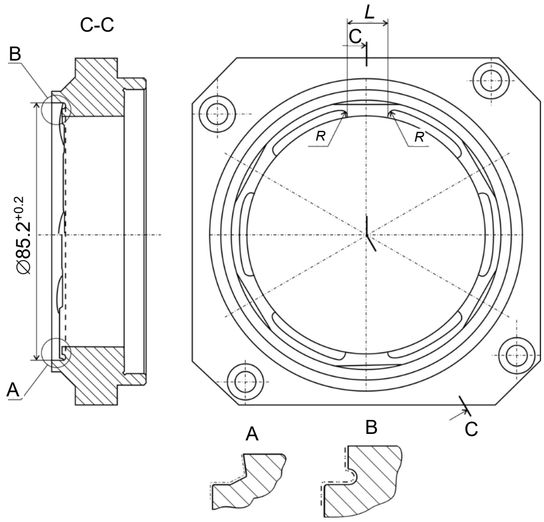

Fig. 15. Die matrix of the third operation

This work turned out to be long-term, in several stages, but it brought a positive result. It has been practically confirmed that the minimum length of the threaded stops of the TO-82 cover with a thickness of 0.20 mm, the degree of hardness of TH415 and TH435 is 18.0 mm. This became the basis for the theoretical design of parametric series of maintenance system covers [10].

The length of the stops from the initial 13.0 mm to the current 18.0 mm was increased by increasing the radii of rounding *R* of the matrix segments, respectively, from *R*0.8 mm, in the existing design, to *R*2.4 mm in the new design (Fig. 15). At the same time, as noted, when making changes to the design of crackers (Fig. 14), the width of the forming parts of the latter was also increased, but in a much smaller proportion – from 12.0 mm to 13.0 mm.

Conclusions

As a result of the development of new technical documentation for the package of dies for the covers of the maintenance system made of tinplate of reduced thickness, the new stamp equipment was manufactured and successfully tested. It has been practically confirmed that the minimum length of the threaded stops of the TO-82 cover made of tin with a thickness of 0.20 mm, the degree of hardness of TH415 and TH435 is 18.0 mm. The length of the stops from the initial 13.0 mm to the current 18.0 mm has been increased by making changes to the dies of each operation. The key changes were the increase in the radii of rounding *R* of the matrix segments, respectively, from R0.8 mm, in the existing design, to *R*2.4 mm in the new one (Fig. 15) and changes to the design of crackers (Fig. 14), the width of the forming parts of the latter was also increased, but in a much smaller proportion – from 12.0 mm to 13.0 mm. A reduction in the weight of the TO-82 lid blank by at least 20% has been achieved, which significantly reduces the cost of lids, saves metal and provides grounds for reducing the weight of lids of other standard sizes.

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