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Selection of a technological block scheme for EH forming of various types of sheet metal parts

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The work analyzes the range of typical large-sized sheet metal parts that are typical for sheet metal stamping production in China. These group of parts includes bottoms, box-shaped parts, stiffening panels. Such productions produce sheet metal bottoms with overall dimensions of more than 1.0 m and a thickness of 0.5…2.5 mm, which are used in the construction of aviation equipment, spacecraft for various purposes and special products. Due to the special conditions of their use, strict requirements are imposed on them regarding the accuracy of shape, dimensions and distribution of thinning deformations along the surface of the part. A complicating factor in their manufacture is the small batches of their release - from prototypes to small series.

A typical example of box-shaped parts are covers and pallets of electric batteries of various operating principles. A feature of their manufacturing processes is small batches of parts with frequent changes in configuration and dimensions.

Quite complex in shape and size are various stiffening panels, which are used in the aviation, automotive industries, as well as in the manufacture of machines and devices for food production.

Analysis of the technological features of their manufacture with the specified technical requirements allows us to conclude that it is necessary to use various stamping schemes for their shaping - stamping-extraction of the flange and stamping-forming. This allowed us to determine the main requirements for the design schemes of technological blocks.

The known and proposed designs of technological blocks of EH-presses were analyzed. A conclusion was made about the rationality of their architecture - vertical architecture with powerful hydraulic cylinders for carrying out stamping-extraction processes. At the same time, the possibility of equipping them with multi-electrode discharge blocks to control the place of the desired loading of the part was considered.

For stamping-forming operations, it is proposed to use designs that are similar to horizontal architecture presses with a short-stroke mechanism for pressing the part flanges. They should be equipped with multi-electrode discharge units that allow the realization of a large amount of stored energy (up to 2.5…3.0 MJ). Such installations allow the realization of simultaneous stamping of several parts. Examples of such processes are given.

In conclusion, reasonable conclusions are made.

Key words: electrohydraulic forming, sheet metal parts, technological press blocks, multi-electrode discharge blocks.

Introduction

In modern conditions, China has a need to manufacture a fairly extensive range of large-sized sheet metal parts that have increased technical requirements. The materials for such parts are high-strength aluminum and titanium alloys, strain-hardened steels and other materials with rather unusual technological properties. The manufacture of such parts by traditional methods and means is quite difficult, while the economic efficiency of production decreases, the complexity of technological preparation of production increases. This is due to a complex of reasons: an unconventional combination of the required quality of parts and complex technological properties of the materials being processed, often small batches of parts, large expenditures of all types of resources for prototype and small-scale production.

This requires the search for new methods and ways of technological

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transformations in sheet metal stamping production.

In the work of the authors [1], an attempt is made to generalize some of the experience of using the method of electrohydraulic forming (EHF) of large-sized sheet metal parts on EH-presses, which can control the load on the part in space and time. Several positive results are shown. They were obtained on an experimental industrial EH-press, which remained in a single copy.

The **goal** of this work is to justify the choice of the scheme of the technological block, which is the basic part of any electrohydraulic installation. With the help of this block, it is possible to rationally realize the potential capabilities of the EHF method.

When performing the work, systems analysis methods were used, which allowed a comprehensive consideration of various features of sheet metal stamping technologies depending on the types of parts being manufactured.

Review of existing information on the status of the issue under consideration

In the world scientific literature, which is devoted to relatively new processes for processing sheet blanks, much attention is paid to EHF (in English-language sources the expression and acronym EHF is used). Such articles consider the forming processes; the influence of high loading rates and, as a consequence, high deformation rates on increasing the plasticity of many materials; reducing the influence of the elastic aftereffect of deformation on the accuracy of the obtained parts; the use of EHF for the manufacture of various parts with different technical requirements.

In this large list, it is possible to single out several large articles with fairly thorough reviews.

In a very voluminous article by Avrillaud G. with co-authors [2] of the BMAX company, an overview of the work on EHF processes is given, as well as photos of the technological unit of the EHF installation (Fig. 1).

In this figure, it can be determined that a vertical hydraulic press with a gap between the columns of more than 800 mm and an upper location of the discharge chamber is used as a power unit. The work also provides photos of a number of stamped parts, including those made of low-plastic materials. Their high quality is noted, which, in many cases, is explained by the high rate of deformation. The absence of wrinkles on the flange is evidence of the correct choice of the flange pressing force and sufficient rigidity of the technological unit.

The successful use of hydraulic presses as technological units of EHF installations is given in the book by Yu. E. Shamarin and co-authors [3]. This work describes the use of large presses for EHF parts with overall dimensions of more than 1.0 m. These presses are equipped with discharge chambers with one or two pairs of electrodes. Such ПЕГ brand presses allow storing and releasing up to 150 kJ of energy in one pulse.

The article by S. F. Golovashenko [4] describes the results of research and modeling of EHF processes of car body parts. The work was carried out using a discharge chamber with one pair of working electrodes (single-discharge gap) and a stamping scheme using liquid ejection. A simple EP-press is used as a technological unit. Positive and promising results were obtained.

More detailed information about the discharge chambers of the installation for EHF of car body parts is given in the work of A. V. Mamutov, S. F. Golovashchenko [5] (Fig. 2). It contains a 3D model and a photo of an experimental discharge chamber for stamping a body panel (Fig. 3). One electrode pair is installed in the discharge chamber of a prismatic shape with a rectangular base.

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Fig. 1. Technological installation area for EHF
and formed part on the female die [2]

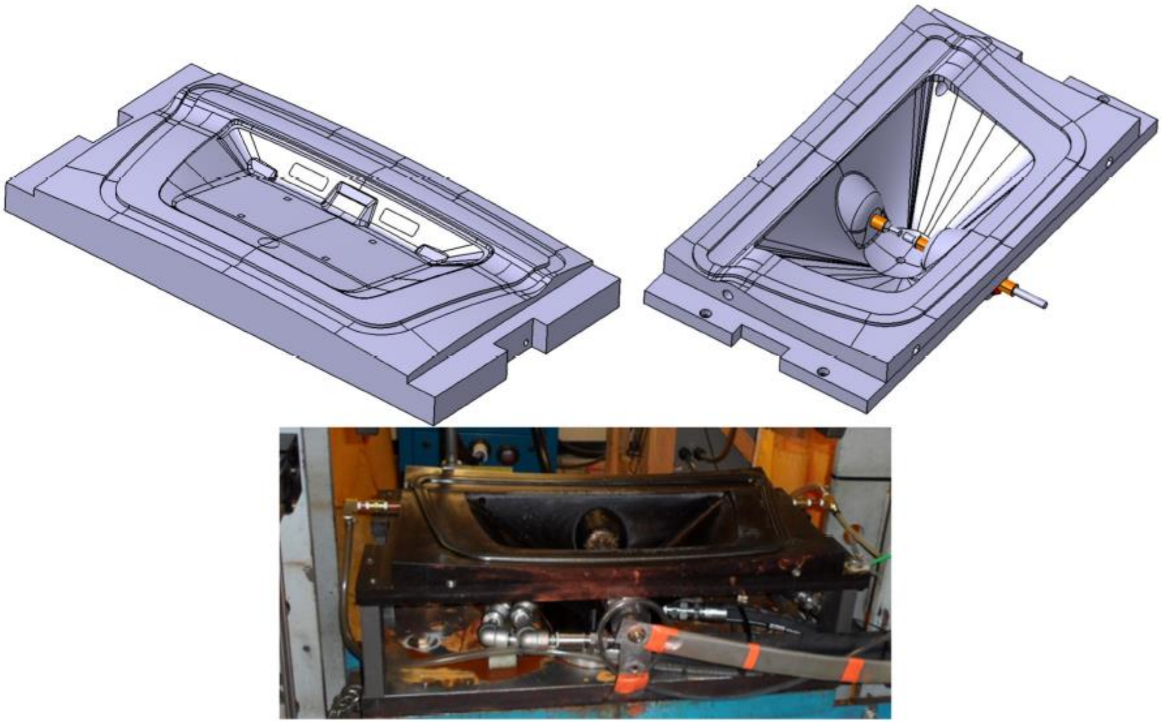

Fig. 2. 3D-model of female die and discharge chamber, picture
of discharge chamber used in the experiments [5]

Experiments were conducted with a number of grades of aluminum alloys and strain-hardened steels. The charging voltage was within 8…13 kV, the capacity of the capacitor battery was 200 μF. The discharge energy was within 6.4…16.9 kJ.

These are low values of the stored energy, but it was enough to manufacture an experimental batch of parts.

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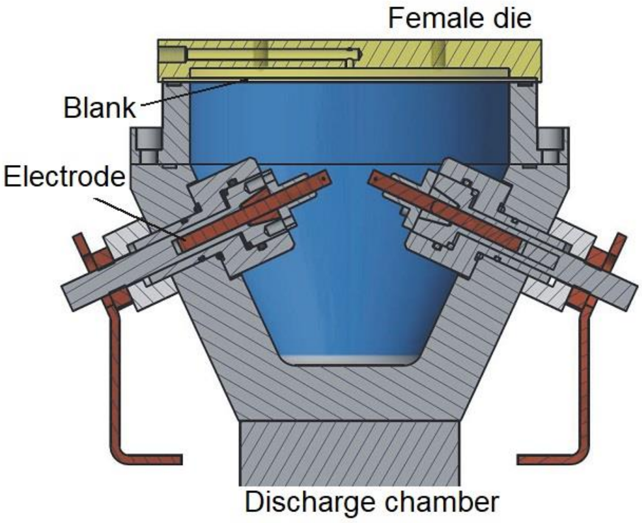
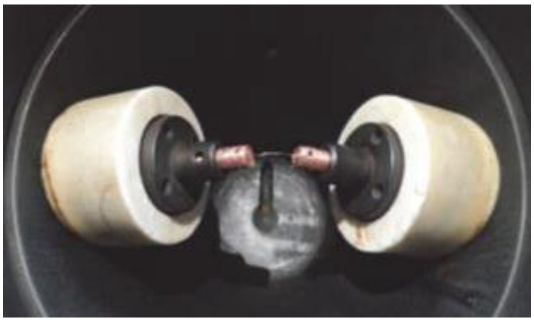
The article by Shim J.-Y and Kang B.-Y [6] shows the schemes of the discharge chambers, the experimental setup and a photo of the electrode system (Fig. 4). Experimental studies on this setup were conducted to study the possible increase in the plasticity of the A5052-N32 alloy under conditions of high-speed deformation for forming parts with high curvature. The authors claim that under the experimental conditions the plasticity increased by two times.

Fig. 3. Experimental part. The circle indicates the most problematic area [5]



a



b

Fig. 4. Discharge chamber scheme (a) and electrode system (b) [6]

A large number of publications are devoted to the results of research on individual issues of the influence of high loading rates on the plastic properties of various alloys, the influence of the geometry of the discharge chamber and electrodes, and energy release modes on the stamping results. Here it is worth noting the works [7-9]. In these and many other works, several conclusions can be drawn:

– there are not enough recommendations for technological support for the EHF of large sheet metal parts;

– the successful use of the EHF is slowed down without full-fledged mathematical modeling of the processes of rational energy release and the dynamics of the behavior of the part.

In this regard, it is necessary to note the cycle of papers by M. Woo and co-

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authors [10-13], which are devoted to the mathematical modeling of the forming process.

In the papers of the creative team of authors V. S. Mamutov, A. V. Mamutov and S. F. Golovashchenko, for example [5], the possibilities of using the LS Dyna software product are assessed and the wide possibilities of its use for modeling various conditions of part loading are shown. The possibilities of sequential deformation of the part are not considered.

The above review of the world scientific and technical literature has shown that the applied issues of EHF do not receive enough attention. The issues of optimal designs of EH-installations that consider the technological features of the processes are not considered. At the same time, many publications emphasize the positive effect of using EHF on various factors. Based on this, it is possible to consider the topic of this work as relevant.

Main part

The range of large-sized sheet metal parts required in the Chinese markets is quite diverse. These include bottoms of various general shapes and surface combination geometries. These bottoms are used in the manufacture of aviation and space structures, sheet panels for cars and special structures; covers and housings of electric batteries and other units. They can be made from a wide range of modern structural materials: carbon steels, including strain-hardened; alloys based on Fe-Cr-Ni; aluminum alloys; alloys based on Ti, Cu, Mg and others. The thickness of such parts is within 0.5…3.0 mm. The technical requirements for such parts are quite diverse:

– high accuracy of the shape of individual surfaces or places of connection with other parts;

– strict requirements for the distribution of thinning deformations along the surface of the part;

– requirements for the manufacturability of the structure for certain types of production.

The large overall dimensions of the parts complicate the possibilities of their manufacture and significantly affect the economics of sheet metal stamping production.

Some typical types of large-sized sheet metal parts are shown in Fig. 5, 6, 7.

Analysis of this range of sheet metal parts from a technological point of view demonstrates various features of their manufacture.

The formation of axially symmetrical bottoms is possible according to the stamping-extraction scheme of the flange. This assumes that the pressing of the flange to the drawing surface of the matrix is carried out with a certain and rather large force. Such pressing is necessary to prevent the formation of wrinkles on the flange part of the part and, thus, complicates the plastic flow of the flange material to the matrix cavity. The need to press the flange of the part requires the presence of pressing mechanisms (most often hydraulic) in the technological block of installations (presses). Large values of the area of the flanges of large-sized bottoms necessitate the application of large pressing forces, of the order of hundreds of tons.

The forming of shallow box-shaped parts (such as covers and battery trays) is possible according to the forming scheme, i.e. without drawing the flanges of the part or with a small degree of drawing in the corner zones. This does not require significant clamping forces, but it is necessary to apply uniform pressure to a part, which is

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distributed over the surface of the part to clearly form the relief on the surface.

The shaping of cladding or protective panels of transport equipment requires a more complex load field. Areas of the surface of the part with a large curvature require a more intense load than areas of small curvature. The difference in the required pressure values can differ by several times. In the work [1], this is clearly shown on a separate example.

Lower bottom Upper bottom

Fig. 5. Typical types of sheet bottoms. Overall dimensions: diameters 600…1800 mm, height 80…200 mm, thickness 0.5…2.0 mm

Fig. 6. Typical types of box-shaped parts are covers and pallets of electric batteries. Materials: steel, aluminum alloys. Overall dimensions: 500x500…600x1600 mm, depth 30…60 mm

Fig. 7. Typical panels of transport equipment. Overall dimensions: 350x600…800 mm. Materials – alloys of Al, Mg, Ti, Nb

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Аналіз показаної номенклатури деталей дозволяє стверджувати, що для скорочення часу технологічного процесу (ТП) формоутворення навантажувати заготовку необхідно одночасно за всією поверхнею з різною за величиною інтенсивністю навантаження. При штампуванні великогабаритних деталей необхідно використовувати багатоелектродні системи ЕГ-розрядів.

Features of possible designs of technological blocks

The technological block (TB) is a power structure in which a force effect is created on the part that is deformed. It also contains auxiliary elements that simplify the technological process. TB consists of a rigid power frame, a universal discharge chamber with electrodes or a multi-electrode discharge block and a power locking mechanism for technological equipment. TB includes: hydraulic cylinders for pressing and moving the worktable, a water and pneumatic equipment system, devices for installing the part and removing the part and other auxiliary devices.

The main requirements for the design of the frames and the entire power circuit of the technological block are as follows.

1. The presence of sufficient strength, rigidity and resistance to impulse loads. This requirement is somewhat lower than the requirements for mechanical, hydraulic presses and especially forging presses, which is explained by the greater inertia of the equipment and the discharge chamber. The required resistance to impulse loads should ensure the absence of loosening and loosening of threaded connections and the compact arrangement of structural masses.

2. Ease of installation of the part and removal of the part from the fixture, proper control of stamping operations, timely replacement of electrodes and elastic diaphragms (if available).

3. General technical requirements of minimum sufficient metal capacity, ease of maintenance and repair. Rigid fastening of various types of electromechanical devices and mechanisms, the performance of which can be impaired by vibrational loads, is not recommended to the frames of EH-presses.

Some schematic designs of technological blocks are shown in Fig. 8.

Such designs of technological blocks are used in operating electrohydraulic presses of the ПЕГ-25, ПЕГ-100, ПЕГ-250, Т1220, Т1226В brands, as well as PEG-XAI-500 with stored energy up to 500 kJ and a worktable measuring 1130x1680 mm [14]. In the SHT-45 press of the Japanese company “SHYMADZU” for stamping parts from tubular blanks, a horizontal architecture of the technological block is used (Fig. 8, d).

The press bed is usually of the column type. The stationary traverses (transverse plates) are pulled together by four columns. Presses with a C-shaped bed have limited application, mainly for the manufacture of small-sized or long parts. Vertical presses are equipped with sliding tables to simplify tooling changes, as well as installing blanks and removing stamped parts.

The location of the discharge chamber is possible in two variants: with attachment to the upper traverse (Fig. 8, a, c) and installation on a movable traverse (Fig. 8, b). In this case, the stamping scheme is implemented by throwing the medium. Such a scheme is less preferable in most variants of the stamping process, as it leads to localization of deformation in places of interaction of the liquid flow with the part, for example, in the center. In the variant of the lower location of the discharge chamber, great difficulties arise in removing air or a vapor-gas medium from the cavity of the semi-finished product, which is partially deformed. The advantage of this variant is a

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very simple removal of the remains of the vapor-gas bubble and the liquid saturated with gas from the electrode system, which prevents cavitation wear of the electrodes. In general, the scheme with the lower location of the discharge chamber is used quite rarely.

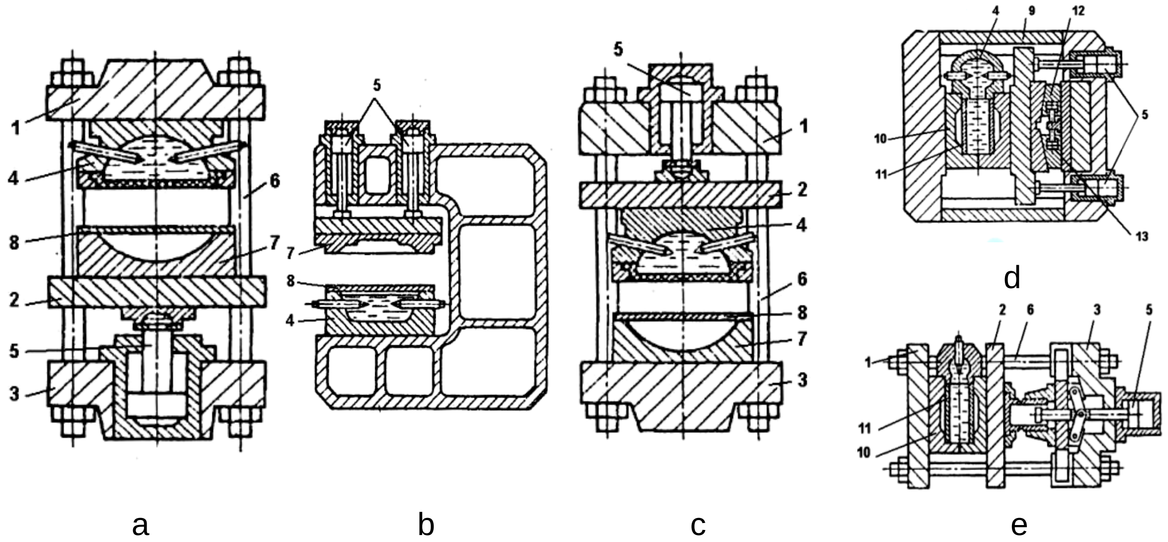

Fig. 8. Designs of technological blocks of EH-presses:
a – vertical column-type press with an upper location of the discharge chamber and a lower location of the power hydraulic cylinder; b – vertical press with a C-shaped frame, a lower location of the discharge chamber and an upper location of the power hydraulic cylinders; c – vertical column-type press with a movable discharge chamber and an upper location of the power hydraulic cylinder; d, e – horizontal press with a frame-type frame and a wedge-shaped mechanism for force-locking the equipment; 1, 2, 3 – upper, movable and lower traverses; 4 – discharge chamber with electrodes; 5 – hydraulic cylinder; 6 – columns; 7 – equipment;
8 – flat part; 9 – frame; 10 – half-matrix; 11 – tubular part; 12 – wedge mechanism;
13 – hydraulic wedge lever mechanism

In most technological blocks designed for stamping parts from flat blanks with dimensions of more than 350 mm of various configurations, an elastic (rubber) diaphragm is used, which separates the blank from the liquid medium. This eliminates the need for seals, protects the blank from corrosion, allows stamping blanks with holes and cutouts, and also reduces the duration of the TP by incomplete drainage of the medium when opening the tooling. Elastic diaphragms are made of sheet rubber or polyurethane with a thickness of 5...6 mm. With such a thickness, the diaphragm practically does not affect the deformation process, but simply allows the use of various kinds of elastic linings, attached masses and other technological techniques. The use of additional technological techniques significantly expands the technological capabilities of the TP, especially in the manufacture of thin large-sized parts.

The required pressure for pressing the flanges during impulse stamping is higher than during traditional stamping, and is within 0.8...2.5 MPa.

To press the flange parts of the part and the “matrix-pressing plate” set to the discharge chamber, hydraulic cylinders 5 (Fig. 8, a, b, c), wedge 12 or wedge-lever mechanisms 13 are used. The latter are mainly used in presses with low energy. They have higher rigidity compared to purely hydraulic pressing mechanisms.

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To close the equipment with the discharge chamber in large presses, powerful hydraulic cylinders (one, two or four) with forces of 1200, 1500, 3000 kN are used. They are more reliable in operation and do not allow the possibility of jamming the press. The lower location of the clamping device (see Fig. 8, a) is more convenient compared to the upper one (see Fig. 8, b, c). This requires the use of various types of pits or special foundations, which are one way or another necessary for laying communications of pneumatic, vacuum and electrical systems.

EH-presses with a closed discharge chamber have a significantly higher efficiency of the process of converting electrical energy into mechanical work of plastic deformation compared to presses with an open discharge cavity.

EH-presses of column type and vertical architecture are more universal, they allow stamping parts according to the stamping-extraction of the flange and stamping-forming schemes. They require a slightly longer duration of the stamping process due to the need for a longer switching path of the technological equipment for pressing the part.

To reduce the duration of the stamping-forming cycle of shallow parts, a simplified TB scheme is proposed (Fig. 9) [14].

Such an EH-installation is designed for stamping large-sized relatively shallow parts or simultaneous stamping of several parts. It consists of two plates: discharge 1 and guide 2. The discharge plate has cavities in which electrodes are fixed. Several dozen electrodes are located along the perimeter of the plate, which are connected by tensioning elements and can be installed in a row or checkerboard pattern. Under these plates is a working table with technological equipment installed on it. The force locking of the table and plates is carried out by a set of plate-frames 11.

Sets of wedges 7 are used for pressing. To install the part and remove the part, the stamping equipment is moved to an auxiliary position in a direction perpendicular to the drawing plane using traction mechanisms.

It is quite realistic to use such a design for stamping parts with overall dimensions up to 2x6 m. In this case, the number of electrode systems can reach several hundred, and the energy released per discharge is 2000...3000 kJ.

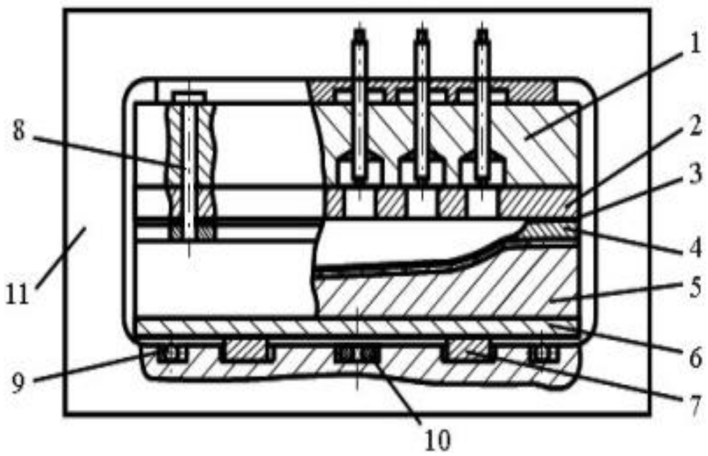

Fig. 9. Structural diagram of the technological block of the EG installation with a multi-electrode discharge block:
1 – discharge plate of the block; 2 – guide plate;
3 – rubber diaphragm;
4 – pressure plate; 5 – female die; 6 – movable table;
7 – pressing wedges;
8 – pin; 9 – bearing;
10 – rods of the table movement mechanism;
11 – plate-frame

The given TB scheme allows to reduce the metal content of the block, to shorten the duration of the TP, to abandon the use of large-sized hydraulic cylinders, replacing them with a set of small hydraulic cylinders for moving wedges.

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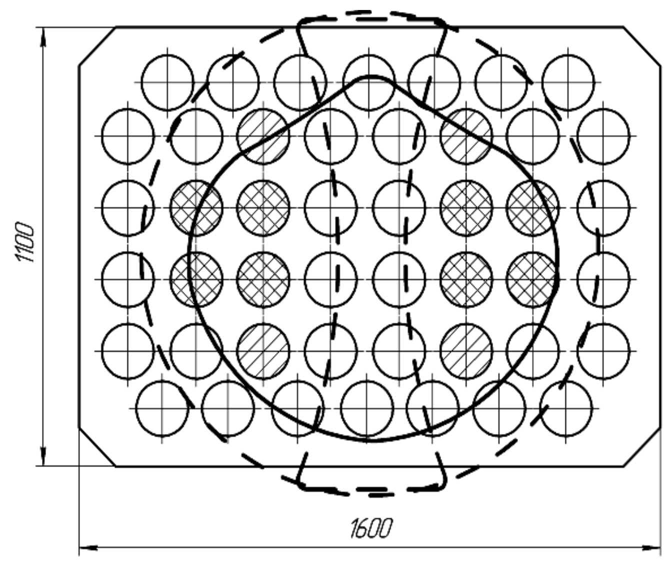
The use of multi-circuit switching schemes of the current pulse generator in EHF installations and peculiar TB schemes allows to control the load field above the part for large-sized parts. Thus, a typical example of the organization of the stamping process of parts that have a shape in plan in the form of a sector layer and have a small deflection is shown in [14]. Such parts are similar to the parts shown in Fig. 10.

In Fig. 10, a, against the background of the projection of the multi-electrode discharge block, the location of the matrix cavities for stamping two parts is shown. Discharge cavities are located above the inner contour of the matrix cavities, which correspond to the most difficultly deformed parts of the part (rigidity crack). A double portion of energy is released in these cavities (cross-shaped hatching). A single dose of energy is released in cavities with oblique hatching. The light projections of the cavities are inactive. EH-discharges in all active cavities (2 pcs) are carried out simultaneously.



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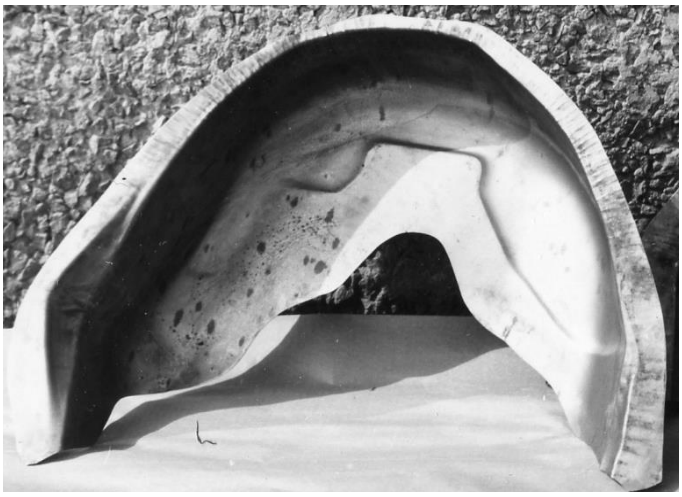

b

Fig. 10. Part "inner arc" VAZ-2101. Material - steel 08Ю, thickness 0.8 mm:
a – diagram of the mutual arrangement of active electrode systems relative to the female die opening of the equipment (solid line - contour of the female die opening; dotted line - contour of the flat blank);
b – view of parts stamped from separate blanks

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Fig. 10, b, c show: one stamped part and the matrix cavity for stamping two parts.

The use of a multi-discharge scheme allows you to sharply reduce the duration of the stamping cycle and the time for manufacturing stamping equipment. This reduces the consumption of stamping material, energy consumption and other resources for the implementation of the TP.

Conclusions

1. A study of the world scientific and technical literature showed a limited number of publications on the issue of rational designs of technological blocks used for EHF installations. Crank-rod, lever, eccentric and other types of presses are not used for them. The most suitable are hydraulic presses of vertical architecture and column type.

2. Analysis of the designs of technological blocks showed that the most rational for use as technological blocks of EHF installations are hydraulic type with the lower location of the hydraulic cylinder and installation on the upper traverse of the discharge chamber or multi-electrode discharge block. Such a scheme is the most universal - it allows the technological process to be carried out according to the stamping-extraction and stamping-forming scheme, has sufficient rigidity of the power structure and is more maintainable.

The use of multi-electrode discharge blocks for stamping large-sized parts provides several advantages.

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Вибір схеми технологічного блоку для ЕГ-штампування різнотипних листових деталей

У роботі проаналізовано номенклатуру типових великогабаритних листових деталей, які характерні для листоштампувальних виробництв Китаю. До них відносяться: днища, коробчасті деталі, панелі жорсткості. На таких виробництвах виготовляються листові днища з габаритними розмірами більш ніж 1,0 м та товщиною 0,5…2,5 мм, які використовуються у конструкціях авіаційної техніки, космічних апаратах різного призначення та спеціальних виробах. У зв’язку з особливими умовами їх використання до них висуваються жорсткі вимоги щодо точності форми, розмірів та розподілу деформацій стоншення вздовж поверхні деталі . Ускладнюючим фактором їх виготовлення є невеликі партії їх випуску – від прототипних до малосерійних.

Характерним прикладом коробчастих деталей є кришки та піддони електричних батарей різного принципу функціонування. Особливістю техпроцесів їх виготовлення є малі партії випуску деталей з частою зміною конфігурації та розмірів.

Достатньо складними за формою та розмірами є різноманітні панелі жорсткості, які використовуються у авіаційній, автомобільній промисловостях, а

також при виготовленні машин та апаратів для харчових виробництв.

Аналіз технологічних особливостей їх виготовлення із заданими технічними вимогами дозволяють зробити висновок про необхідність використання для їх формоутворення різних схем штампування – штампування-витягування фланцю та штампування-формування. Це дозволило визначити основні вимоги до конструктивних схем технологічних блоків.

Проаналізовано відомі та запропоновано конструкції технологічних блоків ЕГ-пресів. Зроблено висновок про раціональність їх архітектури – вертикальній архітектурі з потужними гідроциліндрами для проведення процесів штампування-витягування. При цьому враховувалася можливість їх оснащення багатоелектродними розрядними блоками для керування місцем потрібного навантаження заготовки.

Для операцій штампування-формування запропоновано використовувати конструкції, які схожі на преси горизонтальної архітектури з короткоходовим механізмом притискання фланців заготовки. Вони повинні бути оснащені багатоелектродними розрядними блоками то дозволяють реалізовувати велику кількість енергії, що запасена (до 2,5…3,0 МДж). Такі установки дозволяють реалізувати одночасне штампування декількох деталей. Приведено приклади таких процесів.

На закінчення зроблено обґрунтовані висновки.

Ключові слова: електрогідравлічне штампування, листові деталі, технологічні блоки пресів, багатоелектродні розрядні блоки.

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