Development, Structure and Design of Stamping Tool

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Abstract. Market demand for electrical products by standard electrical products defines the demand for stamping tools. The design of the tool is based on the requirements of easy assembly, disassembly and maintenance. The development of such tools requires the designer to meet complex requirements, some of which are only defined at the beginning, so that the most precise specifications possible are necessary right at the start of the design process. In order to meet the required complex product geometry, product tolerance and the number of products required by the customer, the development of a multi-row punching tool is shown. The tool consists of an upper and a lower part, which are appropriately positioned accordingly and fixed to the stamping machine. The force required to stamp and the force required to detach the guide plate from the sheet metal were determined. The functionality of the developed tool and the stamping process is shown in its entirety, from the entry of the sheet into the tool to the exit of the finished product. The products obtained by stepwise stamping are rotors and stators, which are the basic elements of any electrical device.

Keywords: Stamping tool · Tool development · Tool structure · Stamping

1 Introduction

Stamping is the processing of metals or non-metals without separation of particles. As today's trend is towards large-scale and mass production, this technique is an ideal choice because the machines can be automated, very high productivity is achieved, and the price of the products is drastically reduced the higher the production and the degree of automation. The time of production by punching is very short. It is 7 to 10 times shorter than machining by particle separation, and the manufacturing accuracy is in tolerances of the class IT 11 to IT 9 [1].

Press tools are used to fabricate components in large numbers out of sheet metal. The design of press tool involves common steps to be followed to have an efficient and acceptable outcome. Economy, use of unskilled labour, high degree of precision has made press working indispensable [2].

The term punch refers to tools that separate, reshape, or join material on a press. The punch usually consists of a lower part, which is usually fixed, and an upper part, which is

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movable. It can process metals (steel, aluminum, brass) and non-metals (leather, rubber), usually using strips or individual semi-finished products as preparation depends on the type of processing. They use different motorized presses to achieve the force. Depending on the force needed, the size of the press is chosen. For high volume production, it is common to use the progressive tool shown in Fig. 1 which allows the production of very complex products, complex geometry and dimensions with a small tolerance field. Figure 1 is displaying a progressive tool.

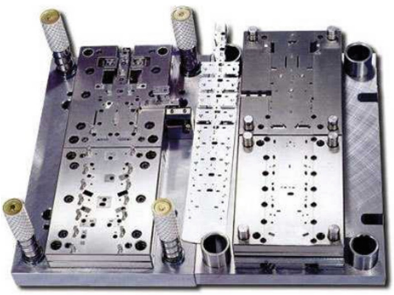

Fig. 1. Progressive tool.

1.1 Progressive Tool

A progressive tool is an alternative tool for the transfer press. With this tool, you can perform a whole series of processing steps with one stroke of the press. Progressive tools are designed for processing strip material. The strip is pushed through the tool with the help of feeder along the tool and a precise strip guide during each stroke.

Progressive tool performs two or more operations at different stages in each stroke. The stock strip is advanced through a series of stations that form one or more distinct press working operations on the strip to get the component [3].

The product is separated from the strip only at the last station. It then usually falls through the opening into the designated tank or the transport system is transporting the product to another control operation.

A progressive press tool has been designed for the purpose. In progressive press tool the final product is obtained by progressing the sheet metal or strip in many stages. In each and every stage the component will get its shape and at the final stage the component is completely ready [4].

Punching waste is also collected and freely disposed of freely in appropriate containers or disposed of via the transport system.

Progressive tools are suitable for continuous production of thin sheets with complex geometry, and the same sheets can be combined into packages. A progressive tool is a highly efficient production tool. It is used to produce very large quantities. However, its reliable operation requires absolutely smooth operation of the production machine, the press.

Stamping tools are mounted and placed on automatic presses. Manual operation is not possible with this type of tool. Common applications of progressive tool are found in the automotive, electronics or household appliance industries. The cost-effective manufacture of complex products in these industries can be partly due to the use of progressive tools (Fig. 2).

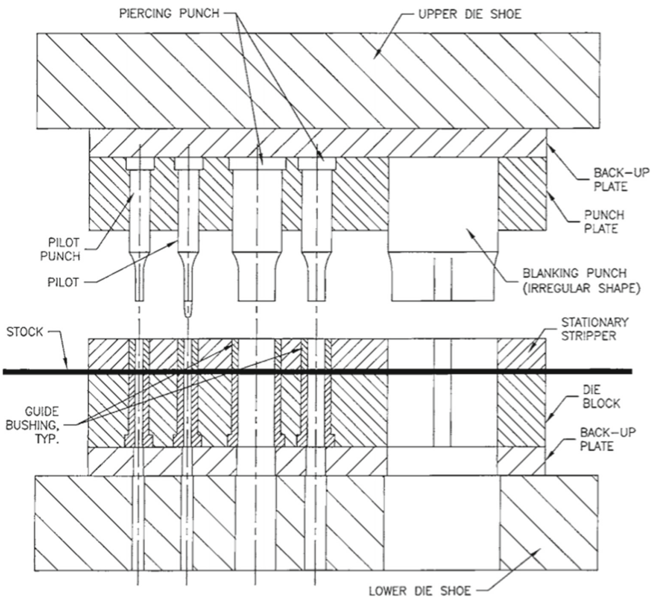

Fig. 2. Standard progressive tool with different elements [5].

2 Development of a Progressive Tool

The first phase of the tool development design process begins with the study of the drawing that design department received from the customer. Detailed analysis is performed to determine the possibility of manufacturing the desired product. The number of tool rows is determined based on the required number of products. If blanks are required due to the complex geometry of the product, the customer is contacted and presented with the stamping product that matches the technological capabilities of the stamping tool. Figure 3 is displaying a product example.

By performing the analysis and confirming the possibility of punching, a layout of strip is developed showing the punching sequences to obtain the desired product. The offset and strip width is chosen so that the usability of the strip is about 90%.

Machining is an operation of forming the desired geometry by performing chip removal over the material. Hence, the appropriate material, tools, and lathes should be used in order to achieve this operation [6].

As every technological process is planned among others also according to the requirements of quality, the quality of machined surface (surface roughness) needs to be also pointed out. The quality of machined surface is directly correlated with the manufacturing process which usually contains various influencing parameters (variables) [7].

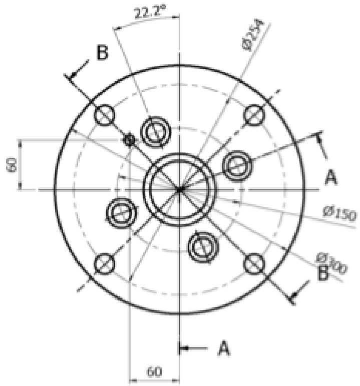

Fig. 3. Product example.

In the process of developing punching stations, the possibilities of the machines (EDM or milling machines) must be taken into account, and experience shows that at least two additional stations are used in the first stages of development. Additional stations are mostly used for additional requirements of the customer for the geometry of the products, which occur in the process of tool development.

When developing stations, the preset offset is taken into account. The offset directly affects the dimensions of the station, as it is necessary to ensure easy assembly, positioning and disassembly of each station.

The Fig. 4 displayed for the two-row toolbar for punching the desired product.

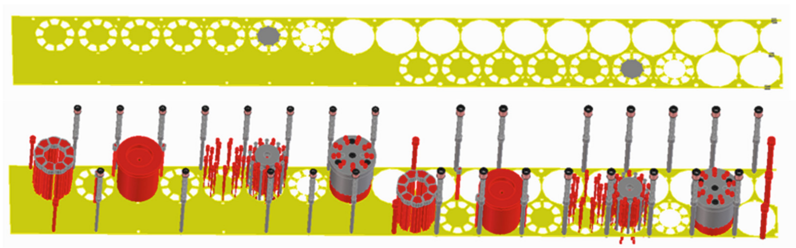

Fig. 4. Layout of strip.

2.1 Layout Strip

According to the defined thickness of the input sheet and the dimensions of the product, the displacement and the width of the input sheet are defined. The rest between the cutting lines of the two stations must be at least two sheet thicknesses.

In the design development of the strip, the first station is drilling holes. The specified hole is later used by the tool to hold the sheet catcher. To ensure the function of the machine operation, it is necessary to provide one of the holes for the catcher with the mechanism. In the case of an unperforated hole, the catcher strikes the solid material and stops the press via a sensor.

The second station is the punching of magnetic holes. The contour is defined by the customer and the puncher and tool matrix inserts are manufactured for the specified station. Matrix inserts are manufactured under the cone and in equal segments. Such design solution ensures easier maintenance and assembly and disassembly as needed.

The third station is punched parts of the outer contour. The showed product contains outer contours with sharp edges. Due to the technological impossibilities of the machines, it is necessary to perform the required work in two stations. One station with pre-punching and the last station with round contour punching. This arrangement ensures a sharp transition from the pre-punching of the parts of the outer contour to the round contour.

The fourth station is the station where the punch core is removed. The process must be predefined by the customer. During the construction process, a uniform contour is taken at the place where the core must be removed. A contour matrix insert should be attached to the lower part of the tool. The cutter presses the contour bar onto the contour stamp via the spring system, thus removing the bar.

The fifth station is empty. Due to the space required for the possibility of positioning and screwing the stations, the fifth station remains empty.

The sixth station is a hole punching station for joining sheets. Depending on the requirements of a certain height, a certain number of sheets connected together, this station performs the function as required. Due to the design of the slider above the sheets, the station can be turned on and off. When the slide mechanism is off, the punching force is not transmitted to the punches and no operation is performed.

The seventh station punches the inner diameter of the product and presses the punches into the strip. Pressing the punches, 2/3 of the thickness of the tool sheet, creates shots that are pressed into each other in the last station. Such a design solution allows the arrangement of tool sheet inside each other to a certain height. By activating the sixth station, the station where the connecting holes are drilled, a series of connected sheets is stopped. Such a construction system ensures that the set height is reached.

The eighth station is empty. Due to the space required for the sheet rotating system during injection, the indicated station is empty.

The ninth station is the station for punching the outer contour of the product, the round part and the system for rotating the tool sheets. The system is realized by an electric motor. The rotation is transmitted through a gearbox, eventually through a belt. The sheets always rotate at the same angle, each in relation to the others. Such a system prevents the influence of uneven flatness of the input sheet, on the verticality of the punched product.

In the case of multi-row tool, a uniform station layout is used for all rows. The last station is the strip cutting station. This completes the stamping process.

2.2 The Structure of the Progressive Tool

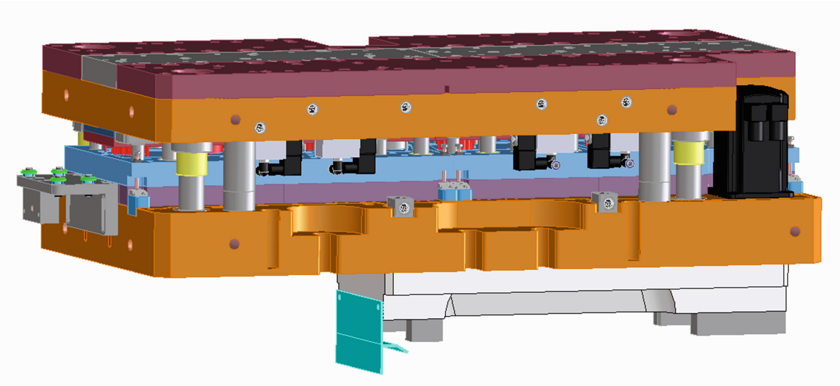

Fig. 5. Progressive tool for stamping.

The tool consists of an upper and a lower part (Figs. 5, 6 and 7).

Tool top:
- cover plate,
- upper plate,
- intermediate plate,
- puncher holding plate,
- guide plate.

Bottom of the tool:
- matrix,
- base plate,
- support plate.

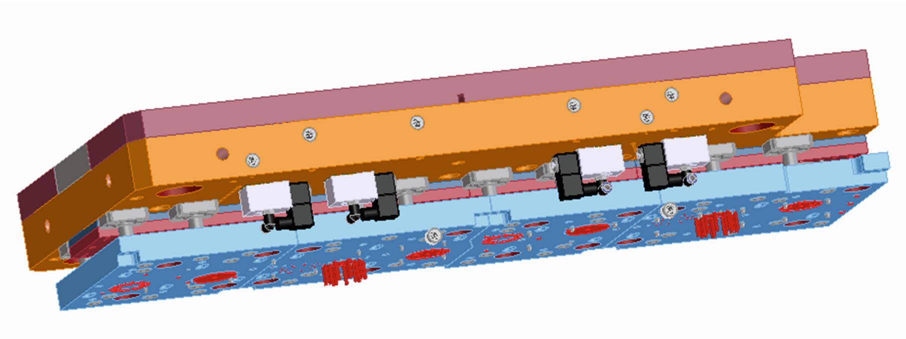

Fig. 6. Tool top.

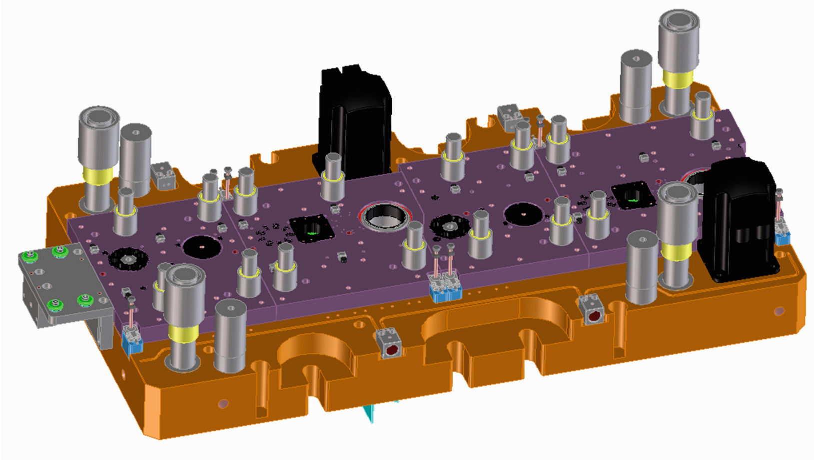

Fig. 7. Bottom of the tool.

Matrix

The matrix or cutting plate is one of the most important parts of the tool, which together with the punch cuts the material. It provides all the contours for the shaping of the work piece and the release for the inserts. The holes of this cutting contour are placed under the cone. The figure shows the possibility of a design cone.

The matrices are cut so that certain stations are built into the same plate for stability. For the need of additional machining, it is necessary to provide two holes Ø10H7 for the possibility of calibration of machining machines. It is obligatory to grind the upper and lower surfaces of the plate to achieve the appropriate parallelism. To facilitate the separation of the matrix from the base plate when all the screws are unscrewed, it is necessary to provide 4 threads M12 that allow to separate the plates through the screw. The screw is screwed into the matrix, thus separating it from the base plate. The M12 thread must be provided in the guide area.

The releases for the inserts on the matrix are made by electro erosion. The choice of this technology ensures the positioning of the insert due to the erosion accuracy. The erosion accuracy is ± 0.005 μm.

To facilitate assembly and disassembly of the tool, the matrix inserts are attached to the base plate from below. Holes are provided on the matrix for guiding elements. The bore tolerances are H5. Such a system ensures that the burning part of the tool is guided downwards.

For multi-row tools, the distribution of stations per matrix should be equal. Such distribution excludes the possibility of differentiation of products by stamping rows.

The figure shows the matrices for a multi-row tool.

The height of the plate on the illustrated matrix is 30 mm. It is determined empirically (Figs. 8 and 9).

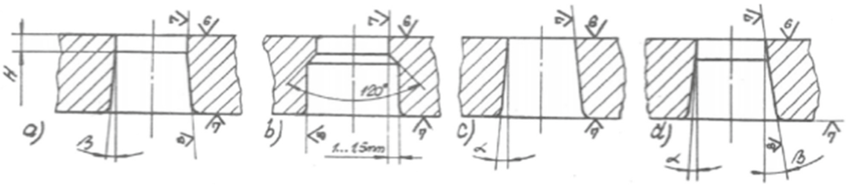

Fig. 8. Possible cone designs.

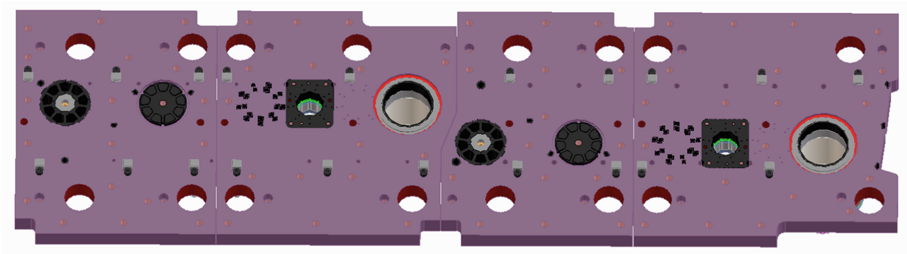

Fig. 9. Matrix.

Base Plate

The base plate has the task of transferring the force from the matrix to the press table and serves as a stable and robust support for the matrix. The openings are slightly larger than those of the matrix due to facilitate the passage of waste. The length of the plate is determined by the lengths of the matrices. Recesses are provided on the base plate for the inserts on which the matrix inserts rest. The inserts are hardened so that they can absorb the cutting force.

It is obligatory to grind the upper and lower surfaces of the plate to achieve the appropriate parallelism. To ensure possible manipulation of the plate, it is necessary to provide at least 4 positions for blind holes with M16 thread for transport during tool assembly.

The height of the base plate is determined empirically depending on the stamping force. It is necessary to know the data on the maximum and minimum height of the inlet for the strip in the press. Each press has defined data for the height of the strip inlet and mounting height.

The base plate has the function of connection and positioning of the tool in the press. According to the calculation of the punching force and based on the center of gravity of the specified force, it is necessary to provide exceptions for the positioning and mounting of tool on the press table.

Holes for large and small guides are provided on the base plate. The bore tolerances are H5. Such a system ensures that the top of the tool is in position with the bottom of the tool (Fig. 10).

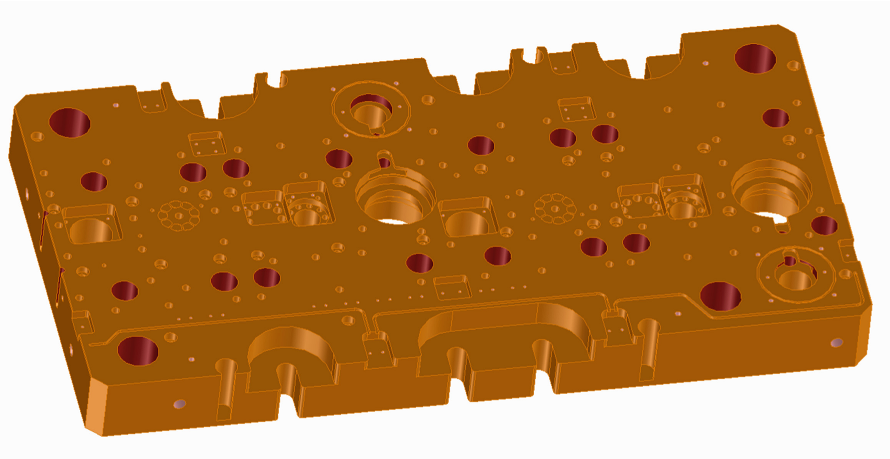

Fig. 10. Base plate.

Guide Plate

The function of the guide plate is to guide the punches and remove the tape from the punches. Holes and contours are made according to the corresponding knives with a certain distance. The holes and contours are made by electro erosion. Due to the technological possibilities of this technology, it is possible to achieve the required clearance. The clearance is determined empirically and is up to µm, depending on the punches. In the direction of faster and easier assembly, it is possible to provide recesses for inserts. This selection facilitates maintenance of the punching stations.

Small guide holes are provided on the guide plate. The hole tolerances are H5. Such a system ensures that the burning part of the tool is guided downwards. A 2 mm deep groove is provided on the upper side, which serves as an accumulation of punches lubricant. When the press is lowered, the lubricant is poured between the punches and the hole, ensuring high-quality passage of the punch and reducing friction.

On the lower surface there are recesses for the guide rails. The inlets are designed so that the guide plate can be lowered to the stop. The stops achieve a distance between the guide plate and the 0.2 mm strip. This ensures better punch guidance.

The guide plate is connected to the base plate by springs. The number of springs, the position and the spring force are determined by calculating the force required to separate the plate from the strip. This connection ensures that the sheet is separated from the punches. When the tool, the punches are lifted above the mounting plate while the guide plate remains in the down position until the force required to lift the guide plate is reached. In this way, the punches are continuously guided during the stroke of the press and the strip is separated from the punches.

For the need of additional machining, it is necessary to provide two holes Ø10H7. The height of the plate is 37 mm (Fig. 11).

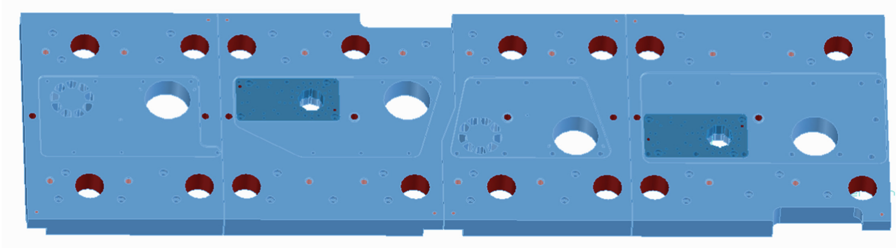

Fig. 11. Guide plate.

Puncher Holding Plate

The function of this plate is to receive, align and pre-position the punchers towards the guide plate. The distance between the plate and the puncher is 0.05 mm per surface. It is fixed to the intermediate plate. The plate is hardened and all holes and recesses for the puncher are made by electro erosion. It is obligatory to grind the upper and lower surfaces to achieve the required parallelism.

It is fixed to the upper plate by M12 screws. For the need of additional machining, it is necessary to provide two holes Ø10H7. The height of the plate is 15 mm (Fig. 12).

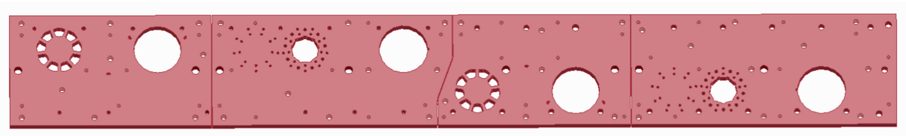

Fig. 12. Puncher holding plate.

Intermediate Plate

The intermediate plate is made to save machining on the belove plate. The punch head rests on the punch holder plate, and there is a release for the punch head in the intermediate plate. The distance between the plate and the punch is 0.5 mm per side.

It is screwed to the holding plate. For the need of additional machining, it is necessary to provide two holes Ø10H7. The intermediate plate is positioned on the mounting plate by means of pins. The height of the plate is 10 mm (Fig. 13).

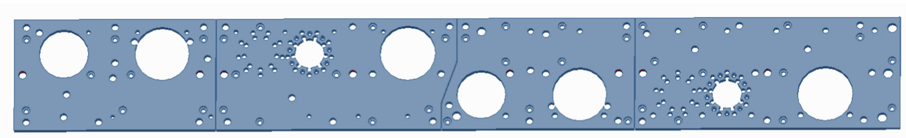

Fig. 13. Intermediate plate.

Upper Plate

The function of the upper plate is to connect the upper part of the tool to the press and transmit the force to the punchers. In punching stations, it is necessary to provide recesses for slide mechanisms.

The slide moves with the cylinder and lands on the surface of the lower slide, transmitting the force to the punchers. Each individual slider should have two capacitive position sensors. Such a system allows maximum control of the puncher under the slider.

The upper plate contains holes and through contours for the supports on the puncher. Such a system facilitates disassembly and assembly of the upper part of the tool. It is possible to pull out the punchers without disassembling the upper part of the tool.

Holes for large and small guides are provided on the upper plate. The hole tolerances are H5. Such a system ensures that the burning part of the tool is guided downwards.

The spring for the guide plate is fixed to the upper plate. It is obligatory to grind the upper and lower surfaces of the plate to achieve the appropriate parallelism. In order to ensure possible manipulation of the plate, at least 4 positions for blind holes with M16 thread for transport must be provided during the tool assembly (Fig. 14).

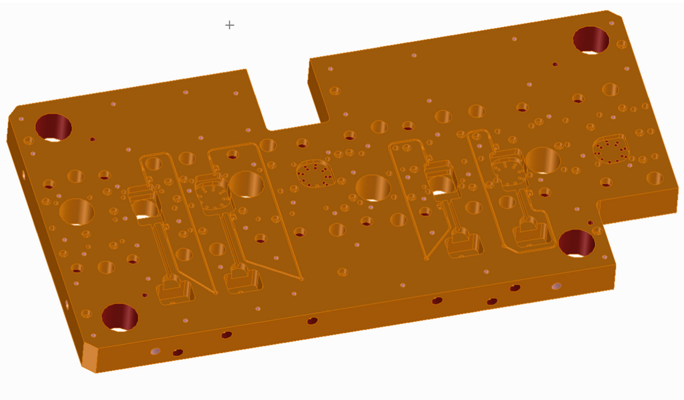

Fig. 14. Upper plate.

Cover Plate

The function of the cover plate is to cover all punchers supports and all sliding mechanisms and cylinders. It prevents the penetration of impurities and thus affects the function of the work.

The dimension is defined by the top plate. Due to the technological limitations of the workbenches of certain machines, it is necessary to divide the cover plate into several parts. Each individual plate must be positioned on the top plate and screwed together.

The plates positioned in the space of the punch support, must be hardened because of the possibility of twisting under the punch shaft during punching. Such distribution of the plates facilitates and speeds up the assembly and disassembly of punchers, and thus the maintenance of the tools. Each plate contains M16 threads with which the plates can be transported (Fig. 15).

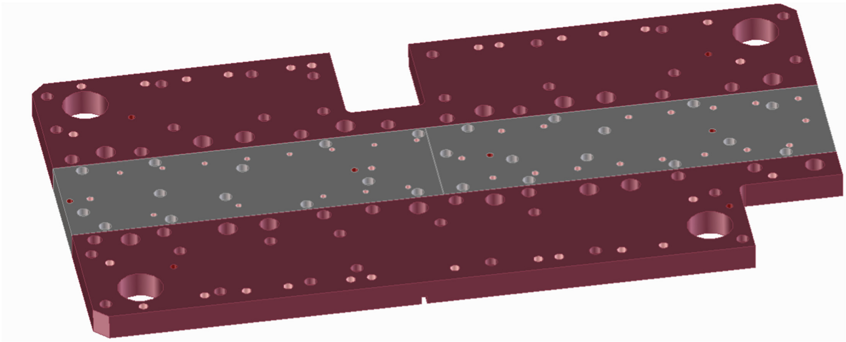

Fig. 15. Cover plate.

Support Plate

The function of the support plate is to absorb some of the force generated by the press. The progressive tool is positioned in the press above the specified plate. The positioning is done after calculating the center of gravity of the required cutting force.

The support plate also drains the products with transport systems, it is necessary to provide drainage channels and lead the punching waste out of the evacuation systems. Said plate also contains threads for handling and transport (Fig. 16).

Fig. 16. Support plate.

Punchers

The basic function of the puncher is to punch the input sheet together with the matrix. Depending on the distribution of punching stations, a certain product is formed. We divide punchers into purchased and made on own demand for the design of a given product.

In case of punches made on demand, it is necessary to form the head of the puncher. The puncher head, like the punch, is made by electro erosion. There must be a clearance of about 0.01 mm between the punch and the head. The puncher is pressed into the head and firmly soldered. The puncher head contains a slot of 1mm. The punches are made of CF-H40S.

For punchers with larger diameters, a bracket is made to save material. The bracket is positioned from CF-H40S and screwed to the part. The puncher head should provide a secure hold in the mounting plate (Fig. 17).

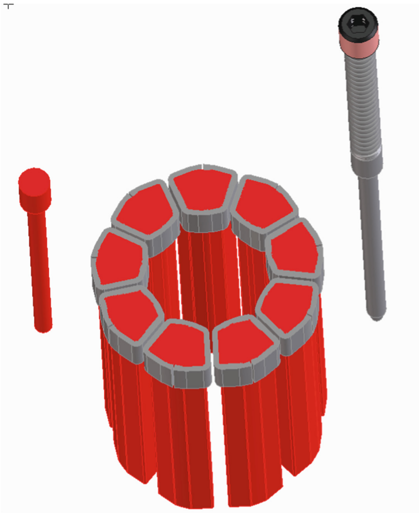

Fig. 17. Punchers.

Matrix Inserts

When designing cutting contours, matrix inserts are selected for easier maintenance and assembly and disassembly. Such selection enables faster disassembly of individual stations and their maintenance.

Positioning and fixing of matrix inserts can be done in several ways of construction. The contour for the inserts and the inserts itself is made by electro erosion. The choice of this technology allows to achieve the necessary tolerances. The insert, which is positioned by the contour, is fixed to the base of the plate with a screw connection. Another design option is the production of a cone on the matrix insert and a contour on the matrix. Selection of this variant ensures positioning by the contour. When selecting a negative cone, the matrix insert is mounted on the bottom side of the matrix and the die is fixed to the base plate.

The cutting contour is determined according to the puncher with a certain distance. The distance depends on the thickness of the sheet to be punched (Fig. 18).

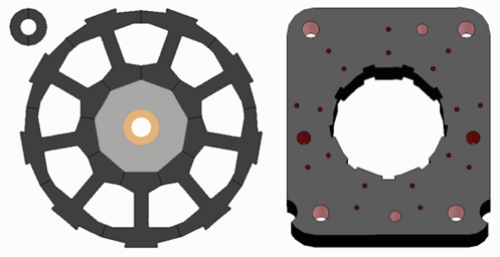

Fig. 18. Matrix inserts.

2.3 Positioning the Progressive Tool in the Press

The positioning of the progressive tool inside the press is done according to the center of gravity of the cut. The calculation of the center of gravity of the cut is processed as the paper progresses. The ideal position of the tool inside the press is when the center of the press coincides with the center of gravity of the cut. After determining the position of the tool inside the press, it is necessary to provide the releases and the through contour for the screws.

The lower part of the tool is screwed to the press table. On the press table are provided grooves for T-segments with thread. Holes for wedges on which the base plate is positioned are also provided on the table. The upper part of the tool is also screwed to the upper table of the press. In this way, the positioning and fastening of the tool to the press is achieved (Figs. 19, 20 and 21).

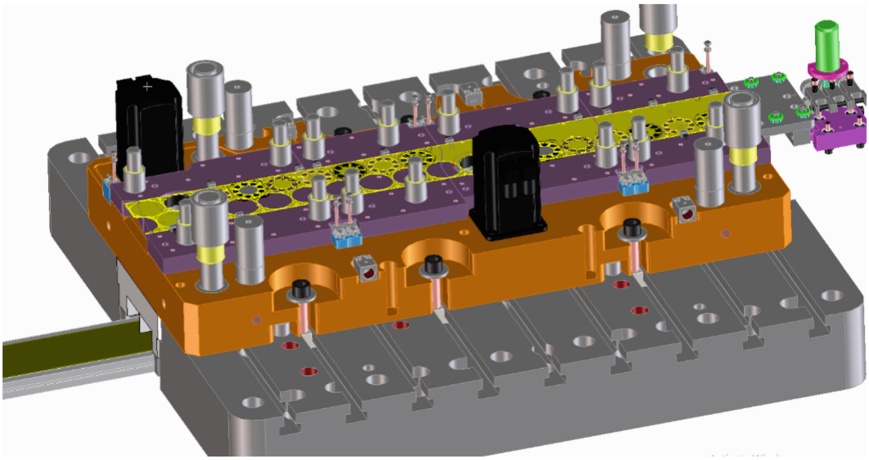

Fig. 19. Screwing and positioning the lower part of the tool.

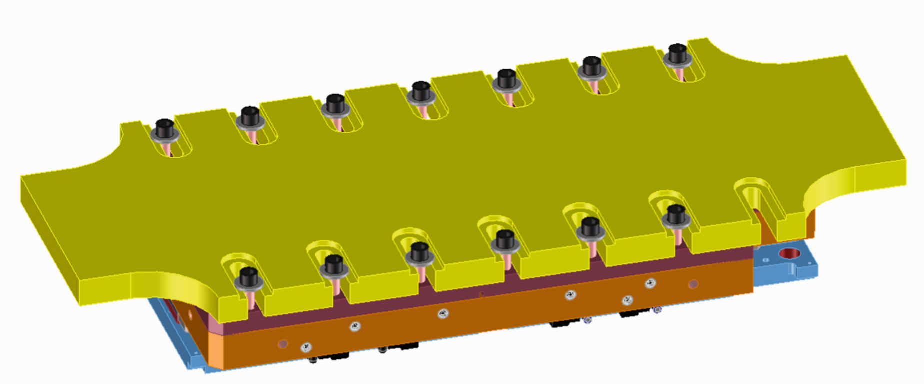

Fig. 20. Screwing the upper part of the tool.

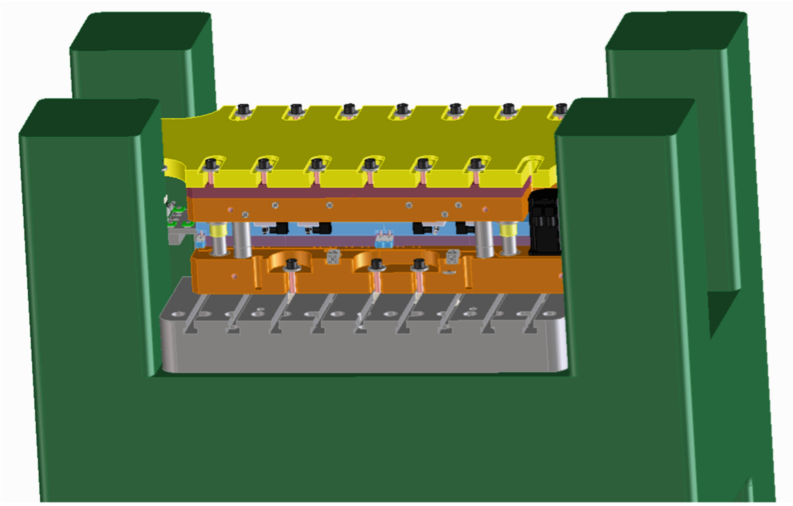

Fig. 21. Progressive tool positioned and attached to the press.

3 Maintain the Progressive Tool

Maintenance is an interdisciplinary activity that brings together experts from the fields of mechanical engineering, electrical engineering, electronics and other professions with the aim of achieving optimal maintenance as well as improving the maintenance of installed equipment [8].

Maintenance is the function of the company entrusted with the constant control of equipment and the performance of certain repairs and inspections, which allows constant functioning and maintenance of production and auxiliary equipment and other devices [8].

Downtime and maintenance costs are interdependent. Reducing maintenance costs, i.e., reducing the number of inspections and maintenance, results in frequent and longer downtimes and thus higher downtime costs. With the other hand, excessive maintenance costs are also not good, as they are an unnecessary expenditure of financial resources [9].

3.1 Preventive Maintenance

Preventive maintenance involves maintenance activities that are performed on a specific schedule before a failure occurs. The condition of the component is assumed to be as good as new after the preventive maintenance is performed [8].

Preventive maintenance can be periodic and preventive, depending on the condition. In periodic preventive maintenance, the maintenance interval can be based on a calendar or on the operating time (service life). In condition-based maintenance, certain variables are measured continuously and action is taken only if the variable is outside certain limits [8].

The advantages of preventive maintenance are the increase in reliability and availability, the ability to plan actions, and the ability to prevent failures. Disadvantages are the impossibility to predict failures, higher costs due to the replacement of parts that could still work [8].

3.2 Corrective Maintenance

Corrective maintenance is the oldest model of machine maintenance and is performed after a failure. No preventive action was taken prior to the failure. Corrective maintenance activities are limited to returning the machine from a state of failure to a state of operation. Today, this approach is used only for auxiliary equipment or in combination with preventive maintenance [8].

The advantages of corrective maintenance are full use of the system's usability and a lower level of technical education. Disadvantages are the possibility of breakdowns and uncontrolled failures [8].

3.3 Maintenance According to Condition

Condition maintenance uses a range of technologies to achieve and maintain optimal operating condition of machinery and individual components. By measuring and determining the trends of physical parameters against known limits or specifications, potential machine problems are identified, analyzed, and corrected before failure occurs. Machine diagnostics is performed to detect faults at the earliest possible stage, to plan machine repair and inspection, and to avoid undesirable consequences for the process [8].

The advantages of maintenance by condition are reduced maintenance costs, increased reliability and availability of the machines. The disadvantages are that it requires good organization and a higher level of knowledge, possession of monitoring equipment and training of personnel [8].

3.4 Maintenance of the Progressive Tool

The progressive tool in theoretical terms can be stamped continuously, 24 h 7 days a week. In a real environment, where the tool is limited in time to one press and depending on the number of products required in a given time, maintenance is as follows.

When the tool does approx. 10000000 strokes, it is disassembled and grinding of the matrix and punches are ground by 0.2 mm. Grinding is performed as long as the cutting elements produce a product with the given dimensions within the tolerance field. The empirical dimension is 10 mm grindability for the matrix and also for the punches. Any grinding above these values will affect the stability of the tool and the product will no longer be within the given tolerances.

Structural elements such as springs are replaced with new elements, bearings are checked and, if necessary, replaced with new ones. The guide plate is cleaned and blown. Punchers are lubricated and the tool is reassembled and set for stamping. An inspection of the cutting elements is performed to determine the consumption condition. Control measurements, height of the matrix and punches are performed and the data is archived in the necessary documentation.

4 Calculating

In this chapter, the calculation for the punching force, the cutting center of gravity, and the usability of the strip are presented. These points should be determined in the initial stage of the design process. The punching force and the center of gravity of the cut must be known at the phases of the design process where the press is selected. The usability of the strip must be determined when defining the tool offset. It is necessary, in terms of punching stability, to ensure a relationship between the usability of the strip and the residue between the punch cuts.

4.1 Punching Force

The stamping force is one of the most important quantities to calculate, since the choice of the type and strength of the press depends on it. The force required is not the same throughout the entire path of penetration of the punch into the material, but changes and consists of phases of elastic and plastic deformation, cutting and fracture of the material.

The punching force depends on the shear strength of the material, the total length of the cut, the thickness of the material, the size of the gap and the condition of the cutting punchers. The size of the gap and the condition of the cutting punchers cannot be expressed by a fixed coefficient. In addition, the cutting punchers gradually become blunt during the operation of the tool, so these coefficients are not taken into account, but the total required force calculated according to the known values increases by 30%.

The required force for punching is calculated according to the expression [1]:

$$F = 1.3 \times L \times s \times \tau_m, \text{N} \tag{1}$$

Where is:

- F – required punching force, N
- 1.3 – coefficient used due to the influence of the clearance between the matrix and the punches and the wear of the cutting edges
- L – total cut length, mm
- s – sheet thickness, mm
- τm – shear strength, N/mm^2.

The total length of the cut is calculated according to the expression

$$L = L_1 + L_2 + \ldots.L_n, \text{mm} \tag{2}$$

Where is:

L_1 – length of the cut at the first station, mm
L_2 – length of the cut at the second station, mm
L_n – length of the cut at each separate station, mm.

Calculation for Tool:

- total length of the cut

$$L = L_1 + L_2 + \ldots L_n$$

$L = 14.14 + (9 \times 42.42) + 14.14 + (2 \times 12.7) + (18 \times 4.1) + (18 \times 4.1) + 119.7 + 188.3 + 20.42 + (9 \times 42.42) + 20.42 + (2 \times 12.7) + (18 \times 4.1) + (18 \times 4.1) + 119.7 + 188.3 = 1820.1$ mm.

- sheet thickness

$$s = 0.5\,\text{mm}$$

- Shear strength (defined on customer's drawing)

$$\tau_m = 400\,\text{N/mm}^2$$

- punching force

$$F = 1.3 \times 1820.1 \times 0.5 \times 400 = 473226\,\text{N}$$

The obtained force is approx. 48 *to* and the press is selected according to this force.

4.2 Center of Gravity of the Cut

The center of gravity of all cutting forces is determined for the purpose of correct positioning of the tool clamp. The tool clamp must be positioned at the center of gravity of all cutting forces, which is especially important for tools with a guide plate. If the center of gravity of such tools is not positioned correctly, incorrect guiding will occur and the cutting edges will be loaded on bending, resulting in shorter tool life and accelerated wear of the sliding surfaces of the press.

The center of gravity of the cut is calculated according to the expression:

$$\mathrm{x} = \frac{\sum \mathrm{L_i} \times \mathrm{a_i}}{\sum \mathrm{L_1}},\ \mathrm{mm} \tag{3}$$

Where is:

x – position of the center of gravity of the shape along the x axis, mm
L_i – length of an individual cutting line, mm
a_i – distance of the center of gravity of an individual cutting line along the x axis from the origin, mm.

Calculation for Tool:

- Center of gravity of the cut

$$x = \frac{908597.4}{1820.1} = 504.2\,\mathrm{mm}$$

4.3 Strip Usability

The degree of utilization of the strip is an important factor and shows what percentage of the material is utilized, and is calculated according to the expression [1]:

$$\eta = \frac{f \times n}{S} \times 100,\ \% \tag{4}$$

Where is:

η – degree of strip usability, %
f – surface of one product, mm^2.
n – number of rows.
S – surface of strip, mm^2.

Calculation for Tool:

- Surface of one product

$$f = 189.9\ \text{mm}^2$$

- Number of rows

$$n = 2$$

- Surface of strip

$$S = 404.1\ \text{mm}^2$$

- degree of strip usability

$$\eta = \frac{189.9 \times 2}{404.1} \times 100 = 93.90\%$$

5 Conclusion

Following the worldwide trend of the development of electric cars and the general development of electric products, the aim of the work was to bring the process of manufacturing stators and rotors of electric motors closer to the general public. Stators and rotors are the basic elements of any electrical device and the process of their production is described in more detail. The technological process for manufacturing these elements is stamping.

The paper presents the constructive development of a progressive tool. The technological process of stamping to obtain the required product is presented, shown by the example of product design. The process of developing punching stations is described in detail, and the layout of strip with punching stations is shown. The design of the progressive tool is shown. Design solutions in terms of easier tool assembly, disassembly and maintenance are also presented. The maintenance procedure of the progressive tool is described. The key positions for the progressive tool are shown and described. The mounting and positioning of the progressive tool in the press was performed and the calculated force for performing the punching operation was determined.

In view of today's trend towards large-scale and mass production, and with the emphasis on quality and economy of products, it is necessary to work continuously on the development of tools and equipment.

References

1. Margić, S., Rebec, B.: Stamping Part I. Sveučilišna naklada Liber, Zagreb (1990)
2. Dinesh, K.V., Madesh, R.: Design and stress analysis of washer tool. Int. J. Appl. Theoret. Sci. Technol. **1**(8), 194–200 (2015)

3. Mastanamma, C., Prasada Rao, K., Venkateswara Rao, M.: Design and analysis of progressive tool. Int. J. Eng. Res. Technol. (IJERT) **1**(1) (2012)
4. Jaya Laxmi, B., Vijaya Kumar, Y.: Design of progressive die using FE analysis. Int. J. Res. Modern Eng. Emerg. Technol. **2**(1) (2014)
5. Suchy, I.: Handbook of Die Design, 2nd edn. McGraw Hill, Michigan (2006)
6. Özdemir, M.: Modelling and prediction of effect of machining parameters on surface roughness in turning operations. Technical Gazette **27**(3), 751–760 (2020). https://doi.org/10.17559/TV-20190320104114
7. Šarić, T., et al.: Modelling and prediction of surface roughness in CNC turning process using neural networks. Technical Gazette **27**(6), 1923–1930 (2020). https://doi.org/10.17559/TV-20200818114207
8. Mijović, B.: Maintenance of Machines and Devices. Veleučilište u Karlovcu, Karlovac (2019)
9. Rejac, E.: Terotechnology-Modern Organization of Maintenance of Funds. Informator, Zagreb (1974)