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Aspects regarding the cutting of the material in the case of certain processing by plastic deformation of thin blank-tape

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Abstract. By this cutting, we consider a maximum efficient use of the surface of the thin blank-tape, which is achieved by a judicious establishment of the relative positions of the pieces on its surface, so that the quantity of resulting waste is minimal. This will reflect on the productivity, the cost of finished pieces and stamping die, as well as the level of exploitation of the presses, knowing that complex presses confer the highest quality. Furthermore, the cutting of strips for the case in which parts are processed by deep drawing is important for a proper sheet metal deformation, thus achieving high-quality results.

1. Introduction

Generally, processing by cutting or deforming various pieces is done from semifinished material in the form of strips, which have been cut from sheets of metal. These sheets can be cut either transversely or longitudinally. The choice between these methods is made based on achieving two criteria: a) minimizing waste metal; b) maximizing productivity.

For efficient use of working materials, there are calculation relationships for the utilization coefficient of the material, both for longitudinal and transverse cutting of the sheet metal. Out of these two options, longitudinal cutting is preferable, as the larger length dimension ensures better continuity of strip processing, while also minimizing waste quantity at the strip ends.

2. The notion of rational cutting

This notion involves fulfilling the following criteria: economical use of material, minimal cost of stamping tools, efficient use of presses, and high productivity in stamping. Only within the context of rational cutting will result in minimal cost in manufacturing parts. This cost will include expenses for raw materials, workmanship, design and construction of devices required for carrying out the technological process.

To highlight the concept of rational cutting, below are presented several possibilities for strip cutting, starting from a specific chosen configuration of a part. (Fig. 1)

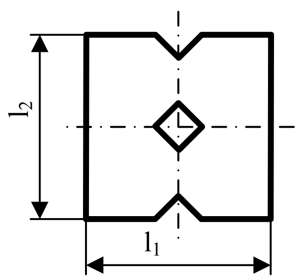
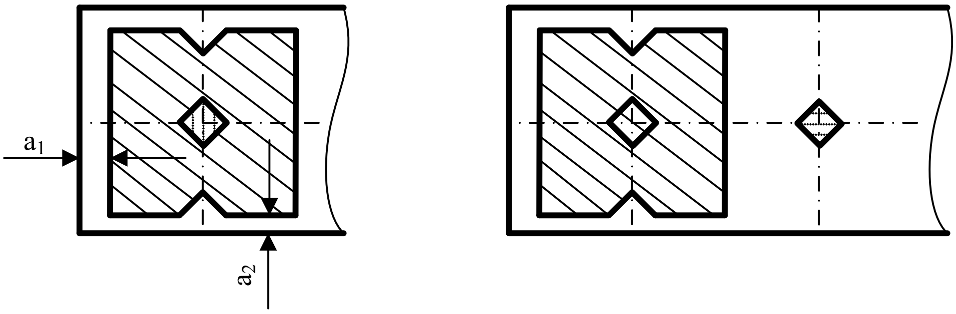


Fig.1 The shape of the stamped piece from the blank-strip

2.1. Stamping with a little bridge around the entire contour of the part

This working method (Fig. 2a) records the highest specific material consumption. According to the scheme in Fig. 2a), it is necessary to use a combination die with simultaneous action. These are expensive, but ensure the highest precision in processing parts.

According to the scheme in Fig. 2b), processing on a combination die with successive action is required. These have a simpler construction and are cheaper compared to those with simultaneous action, but the processing precision of the parts is lower.

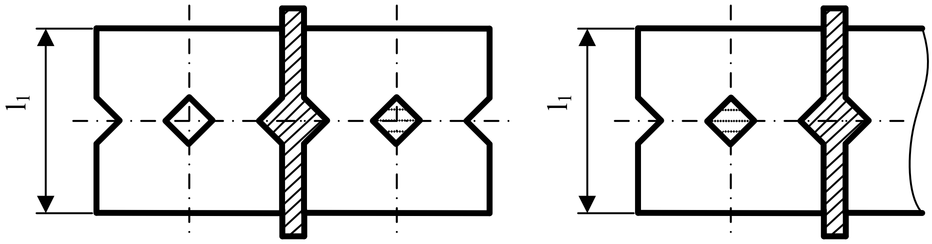


a) b)

Fig. 2 Cutting options with a little bridge around the entire contour of the part

2.2. Stamping with a partial little bridge on the contour of the part

In this technological solution, a lower material consumption is highlighted compared to the variant of cutting with small punch holes along the entire contour of the part. In both situations in Fig. 3 a) and b), the use of combination die with successive action is required, with the mention that the one for the scheme in Fig. 3b) is more compact. In both situations, these dies are simpler than the one used in the scheme in Fig. 2b). The variants in Fig. 3 lead to obtaining parts for which the precision of dimension "l_1" is lower.



a) b)

Fig. 3 Cutting options with a partial little bridge on the contour of the part

2.3. Stamping without a little bridge

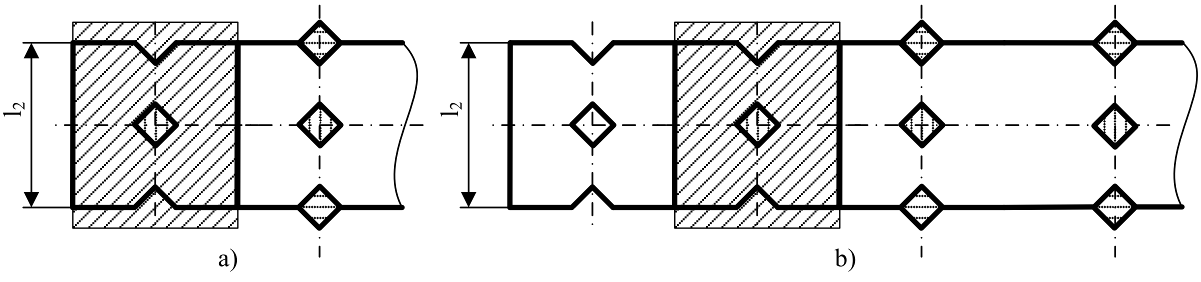


Fig. 4 Cutting options without a little bridge

This technological choice is characterized by the lowest material consumption, but also by the lowest processing precision. In both cases presented in Fig. 4, combination die with successive action are used. In option b), the required die is the largest, but it offers double productivity compared to any of the other options presented in any case.

2.4. Comparative Analysis of Punching Methods

In conclusion, there are two criteria based on which one of the cutting variants is chosen:

• The precision of processing the parts, which varies depending on their intended use;

• The processing productivity.

To achieve minimal consumption of raw materials and ensure high-quality stamped parts, the following criteria are taken into consideration:

- An optimal choice of the relative position of the parts on the semi-finished strip , and if applicable, respecting the position in relation to the direction of the sheet rolling fiber;
- A correct determination of the width of the strip;
- A correct determination of values of the little bridge material stamped (values provided by design) on the surface of the steel strip;
- An use of material waste for the purpose of making other parts.

The size of the little bridge affects the stability of the stamping process, the precision and quality of the cut parts. It must also ensure the rigidity and resistance of the semi-finished strip during advancement through the die, so that it does not get caught in the cutting plate hole, does not generate bits, or cause accidents for the manipulator.

The little bridge size is extremely important when using a low precision semifinished product or imprecise feed of the strip through the stamping die, especially when choosing the option of cutting the piece along the entire contour.

The durability of the stamping die is significantly affected by the little bridge size. Experiments have shown that in the case of stamping without little bridge or with inappropriate little bridge sizes, the durability of the dies is much lower compared to those with normal little bridge. Therefore, a reduction of the normal little bridge size by 30% or 50%, will result in a corresponding decrease in the durability of the die. In the case of stamping without little bridge, the decrease in die durability is already at the level of 60%-70%.

The value of the little bridge width is influenced by the following factors:

- o The little bridge width will be higher for more complex shapes and smaller radii of curvature;
- o The little bridge width will be higher for larger sized parts;
- o The little bridge width will be higher for more plasticity and softer the hardness of blank-tape;
- o The absolute value of the little bridge width will be higher for thickness sheet metal;
- o The side little bridge will be smaller for stamping die equipped with lateral mechanism for sheet metal pressing;
- o The little bridge width between parts will be higher in the case of manual sheet feeding compared to automatic feeding;
- o The little bridge width will be higher when cutting parts using reversed sheet metal, compared to cutting in a single direction (normal direction);
- o The little bridge width will be higher for more precise parts;
- o The little bridge width will be lower for more precise stamping die construction and operation.

The diversity of these factors does not allow for the establishment of calculation relationships for the value of the little bridge. Its values are adopted experimentally, depending on the nature of the strip material, the thickness of the semi-finished material, the type of cutting (normal or using reversed of the strip), the size of the parts (small, medium), the method of advancing the strip through the die, whether a lateral knife or a lateral mechanism for pressing the strip is used, the type of dies and active elements used.

3. Cutting strips for circular parts

Most parts cut from the semi-finished strip are generally of circular shape. If the diameters are larger, then the parts will be distributed linearly, in a single row. (Fig.5).

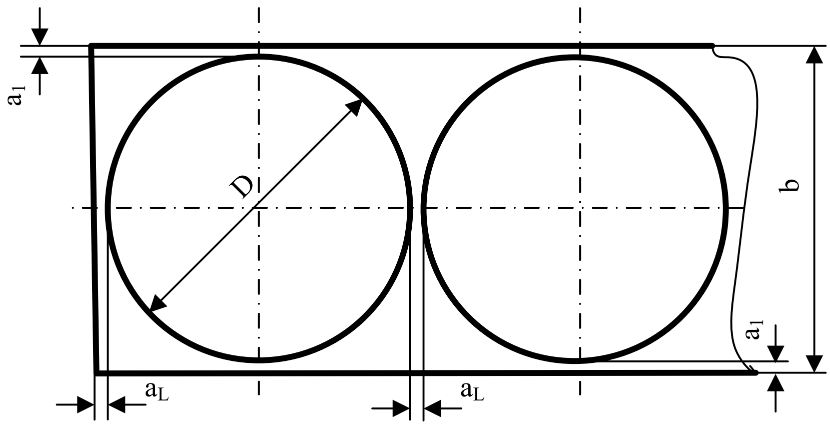


Fig. 5 Arrangement of circular pieces in a row [3]

The width of the strip is calculated using the equation:

$$b = D + 2a_l, \quad (1)$$

where D is the diameter of the piece, a_l is the the side little bridge. In this case, the die is equipped with a lateral pusher.

If the die has a step knife, then the width of the strip is determined using the equation:

$$b = D + 2a_l + c, \quad (2)$$

where c is the width of the strip of material cut by this step knife.

When the pieces are small, they are arranged in multiple rows (up to 9-11 rows), in a zigzag pattern. (Fig.6).

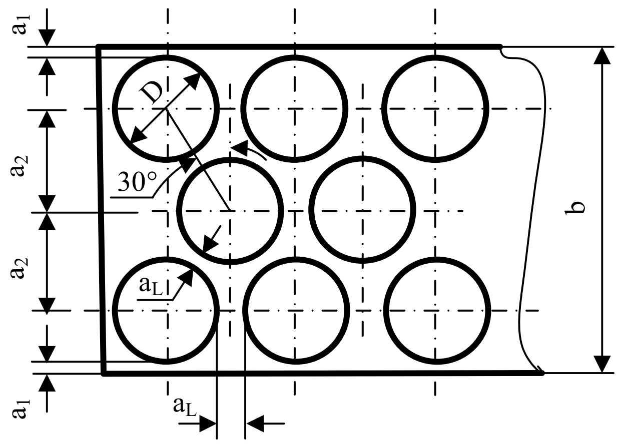


Fig. 6 Arrangement of circular parts on multiple rows, in a zigzag pattern [3]

In this case, the width of the strip is calculated using the equation:

$$b = D + 2a_l + 2a_2, \quad (3)$$

where D is the diameter of the piece, a_l is the lateral punch and a_2 is calculated using the following equation.

$$a_2 = \frac{\sqrt{3}}{2} \cdot (a_1 + D) \quad (4)$$

4. Cutting strips for complex-shaped pieces

Due to the complex contour, the optimal positioning of the parts on the strip is achieved using templates. This choice takes into account both the respect for punch values and the generation of waste in a minimal quantity. In the case of the part model shown in Fig. 7, the option of punches all around the part's contour is preferred. (Fig. 7).

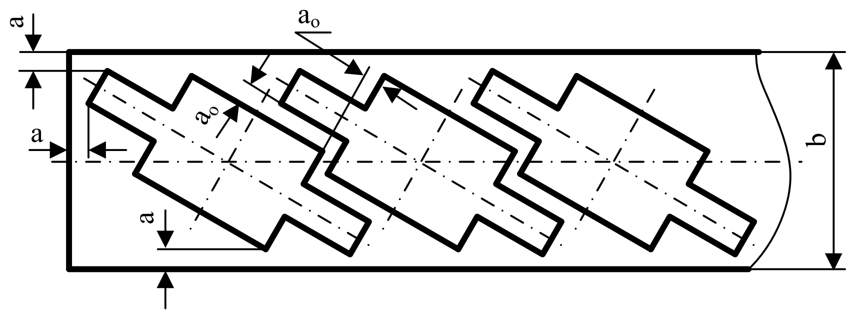


Fig. 7 The graphical method for the rational positioning of parts with complex geometry on a strip-semifinished product [3]

In Fig. 8, for another configuration of the part, various positioning possibilities on the strip surface are proposed, and the extent to which the conditions mentioned above regarding precision and whether the waste can become usable or not are analyzed..

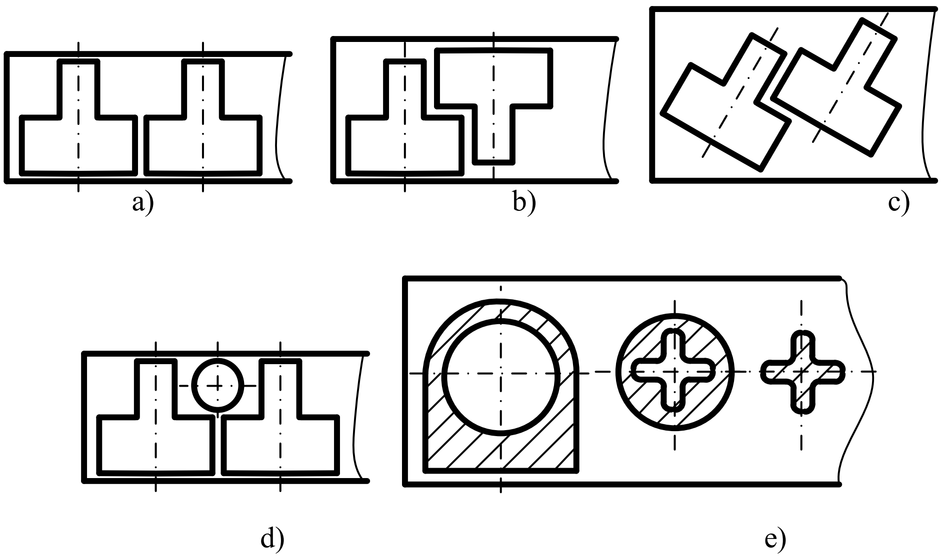


Fig. 8 Variants of cutting a piece with a complex contour [3]

In Fig. 8a) a straight cutting pattern has been proposed, which is not economical in terms of material consumption, although the required die has a simple construction. A better material usage option is presented in Fig. 8b), where the pieces are interleaved on two rows. Two types of dies can be used. In the first option, two punches are required to simultaneously cut both pieces, which would lead to the construction of a large die and would be difficult to ensure the advancement of the strip. In the second variant, the punch has a die for cutting the parts from the second row, and it is necessary to reverse the strip. This leads to the deformation of the strip after cutting the pieces from the first row, which makes it difficult to obtain quality pieces after turning the strip.

In these conditions, from a practical standpoint, the third solution, corresponding to the diagonal cutting from Fig. 8c), is preferable as it allows judicious use of the strip, and the punch has a simple construction.

The disadvantages of the first cutting variant could be compensated by choosing a combined cutting variant (Fig. 8d), which allows obtaining multiple types of parts in successive or simultaneous processing, and which provides a very good material utilization coefficient for the semi-finished strip.

This method is also applicable for obtaining pieces with conjugate contours or dimensions, such as those used in electrical engineering (Fig. 8e).

5. The notching of the semi-finished strip for deep drawing processing

As mentioned initially, there are cases of processing by deformation of semi-finished strips that require the application of notches in order to facilitate the easier drawing of the material into the die.

In the case deep drawing processing from strip, to improve stress and deformation state, strip notching operations are recommended ([4], [5]). When obtaining small cylindrical parts with a flat base and rounding radius to the wall from semi-finished strips with a thickness of 0.3mm, a width of 22mm, made of deep drawing brass and steel, steel brand A3k and A5, a first mode of notching and perforation has been implemented, as shown in Fig. 9 [1].

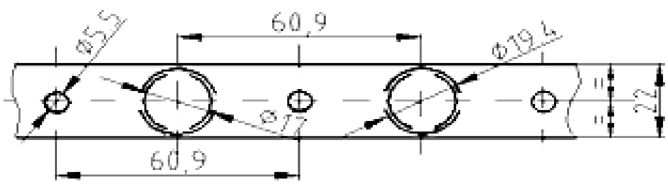


Fig. 9 The strip notching mode [1]

The following operations were performed ([1], [2]):

• punching the strip with a diameter of 5.5 mm, for positioning the semi-finished product in the feed direction;

• notching the strip after two diameters: d_I = 17 mm and d_{II} = 19.4 mm.

In Fig. 10, parts obtained from the A3K strip obtained at Sidex are shown, and the appearance of fractures in the die radius area is observed, due to the fact that the strip was intact and the stress and deformation state exceeded the material's breaking limit.

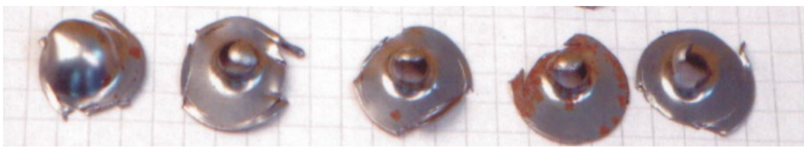


Fig. 10 Pieces obtained from A3K-Sidex strip [1]

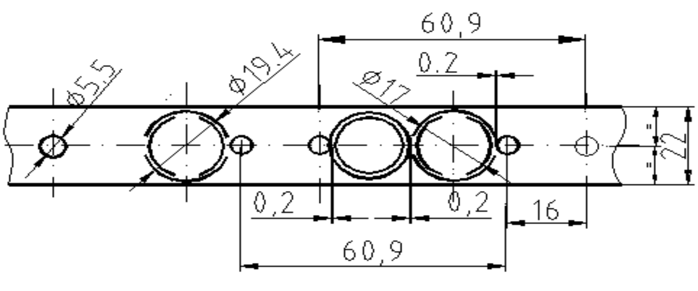


Fig. 11 Notching the strip, for more efficient material usage [1]

For a more efficient use of the strip and to obtain parts that meet the material continuity condition, the number of perforation operations has been doubled, and a notch has been added at each of the two diameters (Fig. 11).

In Fig. 12, the parts obtained following the selection of these work variants are presented. The fractures remain in the same flange connection area.

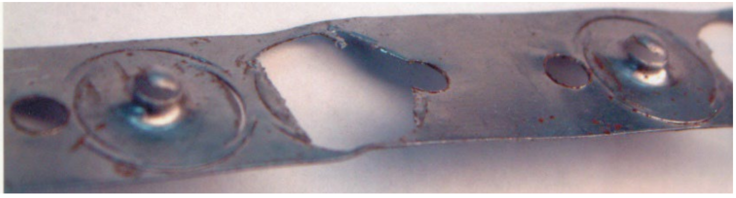


Fig. 12 Parts obtained as a result of increasing notching operations [1]

Finally, the notching mode presented in Fig. 13 was achieved.

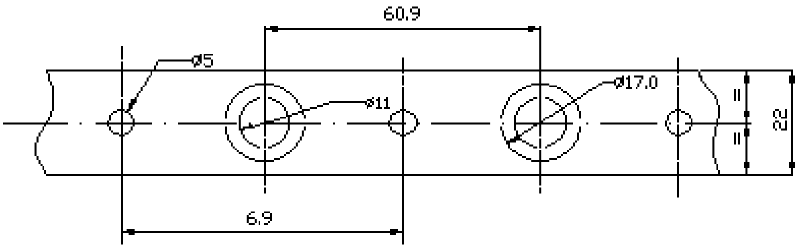


Fig. 13 The final strip notching mode [1]

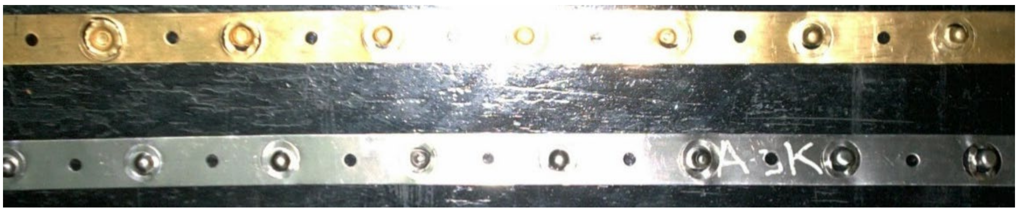


Fig. 14 Pieces obtained from the last variant of the experimental program [1]

Corresponding to the last variant in which the semi-finished strip was notched and cold-formed, the parts showed wall continuity and are presented in Fig. 14.

In this final scenario, some parts exhibited a cylindrical wall, while others did not, but there were no further fractures

6. Conclusions

The cutting operation is extremely important as it influences the efficient use of the thin strip-semifinished surface, recording a minimum amount of waste metal, aspects that reflect on the productivity, quality and cost of the finished parts.

At the same time, for parts obtained through strip deformation processes, depending on the material's plasticity, die dimensions, and final part dimensions, it may be necessary to apply cutting operations to allow better material deformability, with the aim of obtaining integral parts.

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