Computer Supported Design of Logistic Production Technology

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Abstract **– The work deals with the experimental verification of production and realization of the innovative shape of the gutter head. The core of the work consists of the design of a cutting tool, a drawing tool and a cutting tool for cutting the yield. The experimental pulling tool was designed as a welded structure. The pulling of the yield was realized on the hydraulic press BEZ 100. Part of the work are structural technological calculations and the technological process of production. The experimental material was used in hardwood - galvanized DC 01 from Dunaferr.**

Keywords **– logistics system, cutting, drawing, forming of forming tools**

1. Introduction

Forming technology is one of the industries that are constantly developing, not only in the field of molding tools. The most important role played by molding technology is in industrial production, as evidenced by the rapid development in recent years. In addition to mechanical engineering, heavy use also includes metallurgy, construction and the chemical industry.

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Designing is associated with the high-technology technological process of production of engineering and other products. It is an excellent technology for making simple and shape-complex products at a high percentile utilization of the starting blanks. The reduction in production costs has contributed to reducing material consumption and labour productivity.

At present, molding technology is used to make simple as well as complex shapes. This technology also produces components for the construction industry such as gutters. Gutter faces are most often made of galvanized sheet metal which is essentially the most widely used and the most famous material due to its low purchase price. A major drawback of this material is its shorter lifetime due to corrosion compared to other materials such as copper and titanium zinc. Surface protection is needed in this case which brings a higher price.

There are several materials that are affordable. The advantage of the galvanized sheet metal hot-dip galvanizing system is higher quality and longer life without maintenance [1].

In addition to the coated sheet, galvanized sheets with a plastic coating, coloured plastic and coloured aluminium are also used. Glide systems made with such advanced technologies achieve not only high quality and colour durability but also a lifetime of up to 40 years.

2. Analysis of tension - deformation states during dragging

Pulling cylindrical extracts without wall tapering

The plastic deformation in the first pulling operation when pulling the cylindrical yield from a planar blank (circular blank), is produced by drawing the middle parts, i.e. parts of the force transfer. From the tension in the flange in case of neglect $\sigma 2$, it is obvious that the planar voltage scheme is decisive. Draw and strain diagrams in the drawing process are changed at the same place in the extraction material (except bottom).

A critical point in this pulling operation, in which the thickness of the material greatly prolongs and thickens and thus often cracks and breaks, is the rounding between the bottom and the yielding wall. At this point, the uniaxed voltage scheme (tensile force *σ1*) acting in the cylindrical part of the output changes to a three-axis majority of the tension traction scheme [2]. The yield material bends at this point and moves along the rounded edge of the trailer. The criticality of this pulling position also results from the influence of the stress on material ductility. The flow of logarithmic deformations in drawing cylindrical extracts without wall tapering is shown in Figure 1.

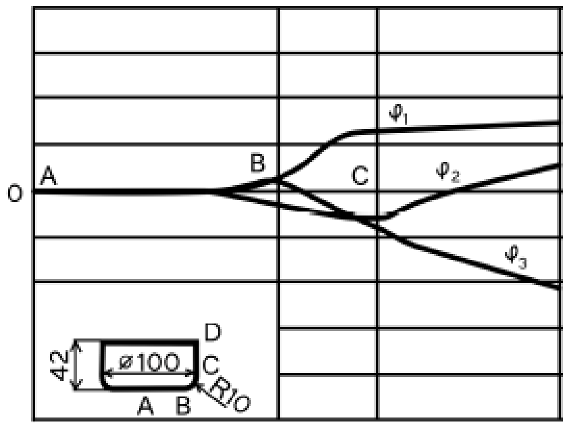


Figure 1. Scheme of the course of logarithmic deformations in drawing cylinders
φ1 – deformation in the radial direction (*σ1*)
φ2 – deformation in the axial direction (*σ2*)
φ3 – deformation in the tangential direction (*σ3*)

If the tension *σ3* in the flange exceeds the strength of the material on the strut, the flange is then curled. Corrugation can be avoided by retaining the material during dragging by the retainer. When pulling on two or more pulling operations, the blank is a cylindrical yield. The schematic of the second and other pulling operations, as well as the voltage - deformation schemes, are shown in Figure 2.

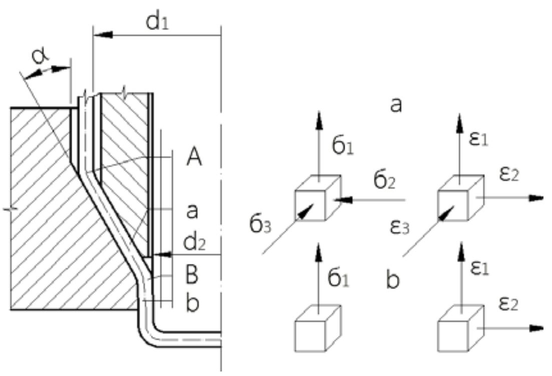


Figure 2. Draw and deformation schemes for drawing cylinders for second and other pulling operations
a – pulling cone, b – cylindrical part

The diameter of the cylindrical yield *d1* is changed to *d2* by pulling in the conical part of the ejector α. The yield material is spatially bent at point A. The deformation process takes place in the region I (conical part of the extractor). If a hold-down is used in the second and other pulling operations, then a three-axis stress occurs at this point, with the tension *σ1* being tensile, *σ2* and *σ3* being pressure. In place B, the spatial bend runs again. In the cylindrical part of the output with the diameter *d2*, one-axis stress (tension *σ1*) is generated. On the day of extraction and on the edge, the voltage schemes are the same as in the first pulling operation [2, 3].

Draw square extracts – During the drawing of the angular yields, the scheme of the main stresses and deformations of the material is like the drawing of the yields with a diameter corresponding to the double radius of curvature. One-axis bending and pulling are formed on straight sections of the voltage scheme (Figure 3.). The change in tension between the rounded section and the straight wall is fluid. The large deformation is the result of the voltage difference between the voltage scheme and the stresses in the corners and the walls, so it is important to consider designing the shapes and dimensions of the forming forces and the starting material [3, 5].

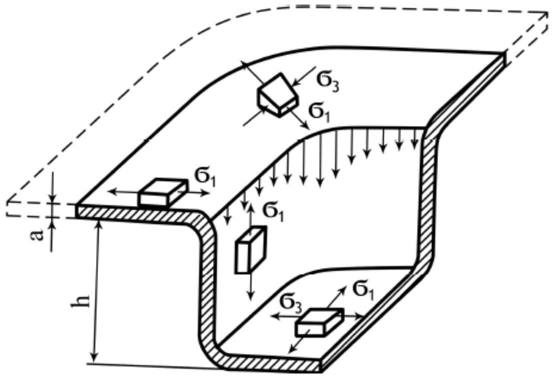


Figure 3. Draw schemes for drawing squares

3. Technology of extracts

The choice of material and the construction of the yield are the basis for determining the yield technology. With the increasing number of yields, the cost of material increases as compared to total production costs. In bulk and large-scale production, the technology of the material is larger than other energy sources. For deep drawing are used materials with suitable chemical composition, with uniform mechanical properties, distribution of structural components, without previous aging and reinforcement tendency. An unavoidable requirement is a clean, skinless surface and a suitable microgeometry.

The tolerance of the thickness of the tiles used for drawing should be as small as possible. Swings can result in great inaccuracies both in size and in the form of yield, thus greatly varying the pulling force. The dimensional accuracy of yields without instrument accuracy and geometric characteristics is limited by certain imperfections (conical casing, surface roughness in large deformations, wall thickness changes, material hardening, etc.). Imperfections are mitigated (dragging with wall thinning, finer graduations, etc.). A more expensive tool or additional operations is important [4].

Recommended principles of technology for the construction of extracts:

- Do not prescribe the tolerance of the wall thickness of the yield.
- The increase in pulling operations is often caused by an unnecessary increase in extraction height.
- Do not splinter the extraction flange unnecessarily. Observe the least flange width rule.

$$D = d + 12.a_0 \quad (1)$$

- Do not unnecessarily reduce the rounding of crossings between the floor and the wall, wall and flange, in the case of angular extractions between the walls (calibration).
- The inappropriateness of more accurate yields than can be achieved in a conventional mill. As a rule, extracts made for more operations are more accurate than one extraction operation.
- The number of drag operations affects the shape of the yield. The most preferred form is a flat, cylindrical, straight flange without a flange [5, 7].

4. Experimental molding tools

Attachment tool – The tool design for the cutting tool is shown in Figure 4. and the 3D model of the tool is shown in Figure 5.

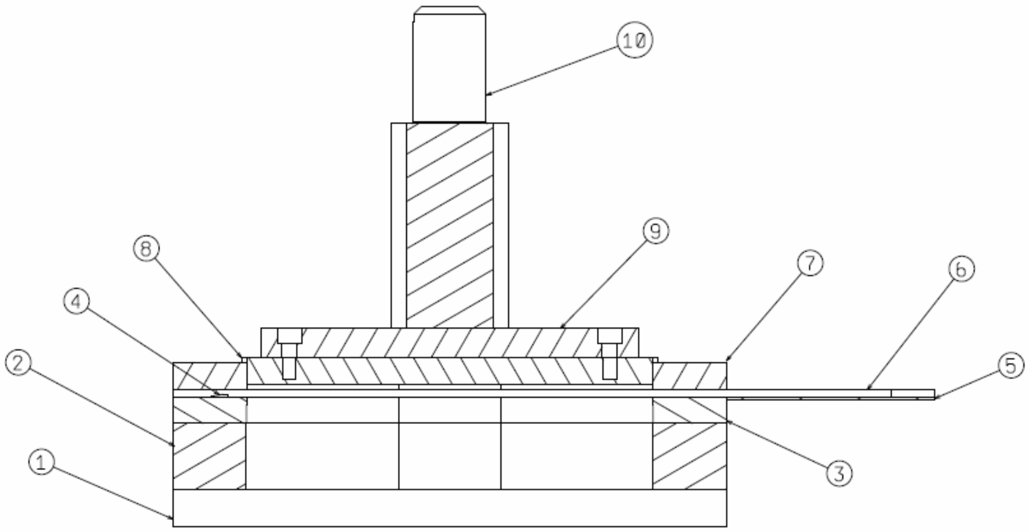


Figure 4. Construction system for the cutting tool

1 – joist, 2 – base plate, 3 – cutter, 4 –backstop, 5 – sheet, 6 – guide rails, 7 – guide plate, 8 – cutter, 9 – clamping plate, 10 – stop

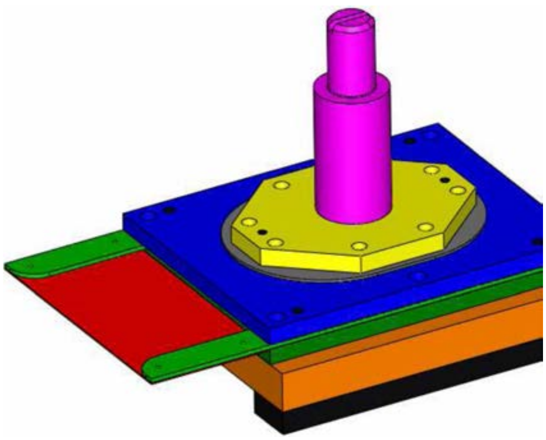


Figure 5. 3D model of cutting tool

Towing tool – The construction system is shown in Figure 5. As an experimental molding tool, a pulling tool with a simpler design was used, consisting of a trailer and a retainer [5]. The yield is carried out on one stroke in which the yield is drawn from the blank. As a lubricant, a micropenic bag was used.

Figure 6. Tensioning tool for deep pulling

The galvanized sheet of galvanized steel, which complies with EN 10130, has been used for the gutter made by ordinary pulling. This sheet is used for deep drawing or for the production of special deep-drawing parts. The chemical composition and mechanical properties are shown in Tables 1. and 2. From the table below, I recommend using Dunaferr steel sheet 01 for the production of the gutter [6].

Table 1. Chemical properties

Category EN 10130	**Chemical properties**			
	C	**P**	**S**	**Mn**
DC 01	0,12	0,045	0,045	0,60
DC 02	0,10	0,035	0,035	0,45
DC 03	0,08	0,030	0,030	0,40
DC 04	0,06	0,025	0,025	0,35

Table 2. Mechanical properties

Category EN 10130	Mechanical properties				
	Re max* (N/mm^2)	Rm (N/mm^2)	A80 min.* (%)	r_{90} min.	N_{90} min.
DC 01	280	270 - 410	28	-	-
DC 02	240	270 - 370	28	1,3	-
DC 03	210	270-350	38	1,6	0,180
DC 04	180	270-330	40	1,9	0,200

5. Design of a gutter production technology

The front gutters are manufactured in various designs which are high in their production and assembly. Experimental verification of the technology of producing the innovative shape of the gutter head has a design that corresponds to a shallow oval yield, which will be divided by cutting into two parts and then adjusted to the final shape of the forehead. The proposed technology is for the annual production of 1000 pieces.

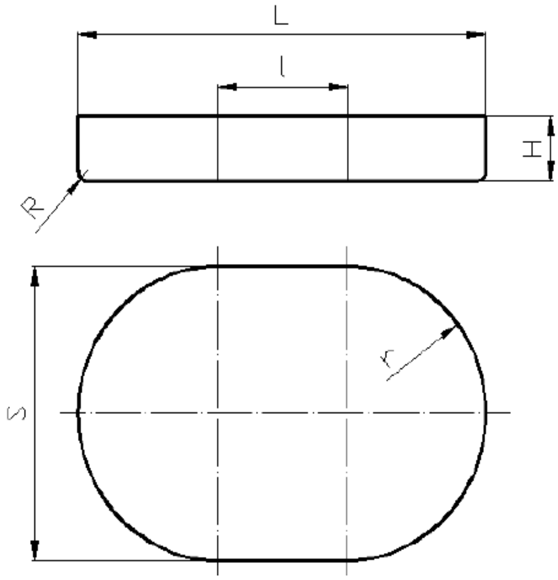


Figure 7. Basic dimension of extract
L = 220 mm, l = 70 mm, R = 3 mm, r = 75 mm, H = 30 mm, S = 150 mm,
Wall thickness a_0 = 0,6 mm

Table 3. Technological process of production

Number of operation	**Job description**	**Machine**	**Tool**
1	Shaping of sheets to the required strip width	-	Sheet scissors
2	Cutting of blank	Lis LEN 63C	Cutting tool
3	Pulling	Lis BZE 100 - 8.4.2	Towing tool
4	Cutting the yield to two part	Lis LEN 63C	Cutting tool
5	Cutting in corners	Hand workstation	Sheet metal scissors
6	Left bend and bend right side	Hand workstation	Bending tool
7	Bending of the front	Hand workstation	Bending tool
8	Size and quality control product, embossing of a company brands	Hand workstation	Stamp

In production of the extract, it is necessary to know the dimensions of the cut out from which the yield will be produced. There are 3 ways to determine the size of the trim:

a) Calculation of the area of the molding from elementary surfaces.
b) Calculation using a formula.
c) Calculation using CAD software.

For the given yield, option (C) was selected, i.e. SolidWorks appendix calculation, as this option proved to be the most effective and accurate way for CATIA. We calculate the device using mathematical formulas for volume and area calculation [4, 8]. In order to calculate the volume, it is necessary to modulate the specific yield in the program SolidWorks (Figure 8.). SolidWorks allows a simple calculation of yield volume (Figure 9.).

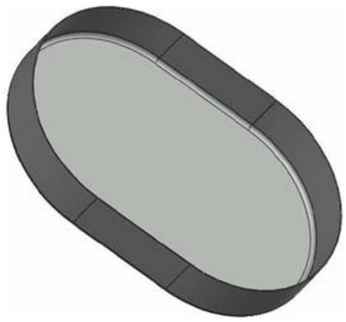
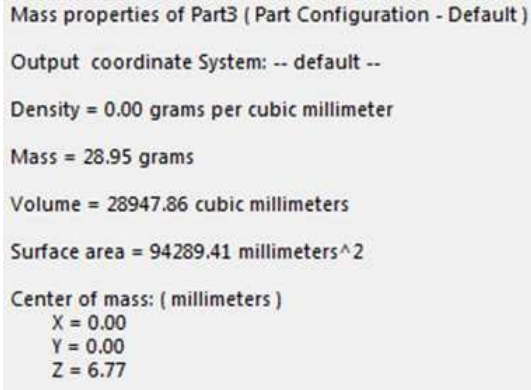


Figure 8. SolidWorks Extract Model



Mass properties of Part3 (Part Configuration - Default)

Output coordinate System: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 28.95 grams

Volume = 28947.86 cubic millimeters

Surface area = 94289.41 millimeters^2

Center of mass: (millimeters)
X = 0.00
Y = 0.00
Z = 6.77

Figure 9. SolidWorks Desktop Calculation

Calculated volume of yield using Solidworks software:

$$V = 28947{,}86\ mm^2$$

Desktop Calculation S:

$$S = \frac{V}{a_0} \quad (2)$$

$$S = \frac{28947{,}86}{0{,}6}$$

$$S = 48246{,}43\ mm^2$$

Calculation of overhead:

$$D_0 = \sqrt{\frac{\pi}{4}.S} \quad (3)$$

$$D_0 = \sqrt{\frac{\pi}{4}.48246{,}86}$$

$$D_0 = 247{,}85 = 248\ mm$$

With regard to the calculation, we choose the average of the minimum *Φ*248 mm.

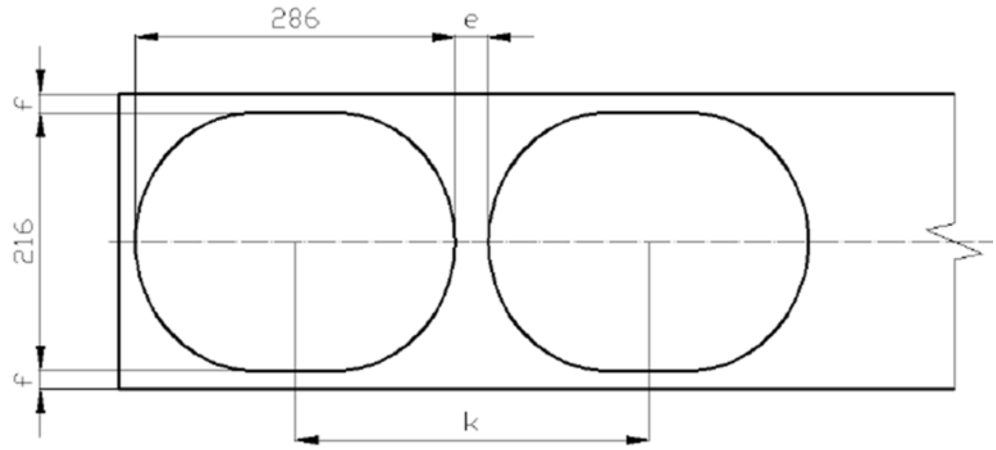


Figure 10. Cutting plan

Minimum strip width:
$f = 1{,}8\ mm$
$B_{min} = D + 2f$ (4)
$$B_{min} = 216 + 2.1{,}8$$
$$B_{min} = 219{,}6\ mm$$

Delivery step:
$e = 1{,}5\ mm$
$k = b + e$ (5)
$k = 286 + 1{,}5$
$$k = 287{,}5\ mm$$

Usability of material:
- we choose the size sheet: 0,6 x 1100 x 2500

Calculating the number of strips from one sheet of metal:
$m = \frac{width}{B_{min}}$ (6)
$$m = \frac{1100}{219{,}6}\ pieces$$
$$m = 5{,}009 = 5\ pieces$$

Calculate the number of cuts from one strip:
$n = \frac{l}{k}$ (7)
$$n = \frac{2500}{287{,}5}$$
$$n = 8{,}7 = 8\ pieces$$

Calculation of strip utilization:
$\tau_{strip} = \frac{n.S}{B_{min}.l}.100$ (8)
$$\tau_{strip} = \frac{8.48246{,}43}{219{,}6.2500}.100$$
$$\tau_{strip} = 703{,}04\%$$

Calculate the number of clippings:
$N = m.n$ (9)
$$N = 5.8$$
$$N = 40\ pieces$$

Calculate the number of tables:
$P_{tab} = \frac{set}{N}$ (10)
$$P_{tab} = \frac{1005}{40}$$
$$P_{tab} = 25{,}125 = 26\ tables$$

Calculating the use of the board:
$\tau_{tab} = \frac{N.s}{w.l}100$ (11)
$$\tau_{tab} = \frac{40.48246{,}43}{1100.2500}100$$
$$\tau_{tab} = 70{,}17\%$$

$\tau_{total} = \frac{set.S}{P_{tab}.w.l}.100$ (12)
$$\tau_{total} = \frac{1005.48246{,}43}{26.1100.2500}.100$$
$$\tau_{total} = 67{,}81\%$$

Calculation of total material consumption:
$H = V.\rho.set$ (13)
$$H = 0{,}037881.10 - 3.7850.1005$$
$$H = 298{,}9kg = 0{,}23\ t$$

$V = B.a_0.k$ (14)
$V = 219{,}6\ .\ 0{,}6\ .\ 287{,}5$
$V = 37881\ mm^3$
$$V = 0{,}037881.10^{-3}m^3$$

Calculate the distance between the guide bars:
$A = B_{min} + \Delta B + Z$ (15)
$A = 219{,}6 + 0{,}2 + 0{,}006$
$A = 219{,}86mm$

- We choose bandwidth tolerance from IT 12
$\Delta B = 0{,}2mm$
$Z = 0{,}1\ .\ a_0$
$$Z = 0{,}06mm$$

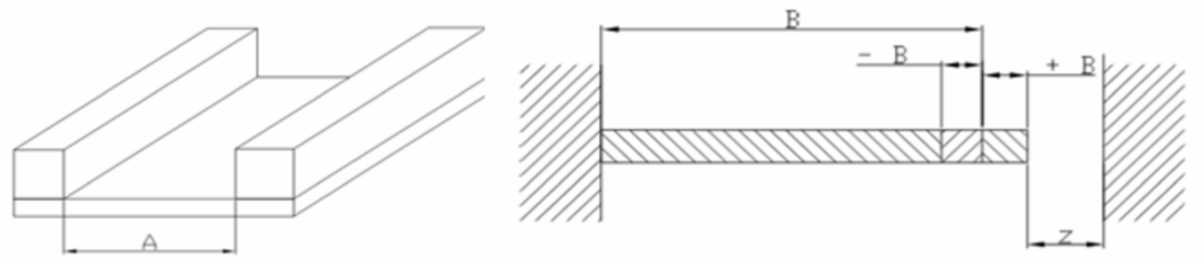


Figure 11. Distance between guide bars

Calculation of the shear force:

n – dulling factor of the tool n = (1,15 – 1,55) => we choose 1,45
$R_m = 300\ MPa$

$$F_S = n\ .S.\tau_{PS} \qquad (16)$$
$$F_S = 1{,}45\ .750{,}35\ .278$$
$$F_S = 302{,}47kN$$

$$\tau_{PS} = 110 + 0{,}56.R_M \qquad (17)$$
$$\tau_{PS} = 110 + 0{,}56.300$$
$$\tau_{PS} = 278\ MPa$$

$$S = a_0.l_S \qquad (18)$$
$$S = 0{,}6.1250{,}58$$
$$S = 750{,}35\ mm^2$$

Where:
S – surface of cut material
l_s – length of cut line
a_0 – thickness of material
τ_{PS} – the shear strength limit

Calculation of cutting work:

$$A_S = F_S \cdot \chi \cdot a_{0.} \cdot \frac{\pi}{4} \qquad (19)$$

$$A_S = 302470 \cdot 0{,}2 \cdot 0{,}6 \cdot \frac{\pi}{4}$$

$$A_S = 28507{,}13\ J$$

Where:
X – the coefficient of dependence on the type and thickness of the material (0,2 – 0,4):
0,2 – steel of higher strength
0,4 – low carbon steel

Calculation of wiping force and work:

$$F = k_u\ .F_S \qquad (20)$$
$$F\ \ = 0{,}12\ .302{,}47$$
$$F\ \ = 36{,}29kN$$

Where:
k_u - coefficient of steel (0,1 - 0,13), we choose 0,12

$$A_U = F_U\ .(a_0 + v) \qquad (21)$$
$$A_U = 36296\ .(0{,}6 + 0{,}3)$$
$$A_U = 32666\ J$$

Where:
$v = 0{,}5.a_0 = 0{,}3$ the speed of penetration of the clip into the clipper

Calculation of power and work needed to extrude cutouts:

$$F_V = k_V\ .\ F_S\ .n_1 \qquad (22)$$
$$F_V = 0{,}05\ .302{,}47.5$$
$$F_V = 75{,}62\ kN$$

Where:
K_v – coefficient of steel (0,05)
n_1 - number of extruded prints (5 - 10), we choose 5

If the sheet thickness is greater than 1.5 mm than we choose 10 pieces. If the sheet thickness is less than 1.5 than we choose 5 pieces. n1 = 5 pieces.

Work on pushing:

$$A_V = F_V\ .a_0 \qquad (23)$$
$$A_V = 75617{,}5\ .0{,}6$$
$$A_V = 45370{,}5\ J$$

Total cutting power and work:

$$F_C = F_S + F_U + F_V \qquad (24)$$
$$F_C = 302{,}47 + 36{,}29 + 75{,}62$$
$$F_C = 414{,}38\ kN$$

The guide plate serves as a wiper, then:

$$F_C = F_S + F_V \qquad (25)$$
$$F_C = 302{,}47 + 75{,}62$$
$$F_C = 378{,}09\ kN$$

Calculation of total work:

$$A_C = A_S + A_U + A_V \qquad (26)$$
$$A_C = 28507{,}13 + 32666 + 45370{,}5$$
$$A_C = 106543{,}63\ J$$

Calculation of shear clearance:

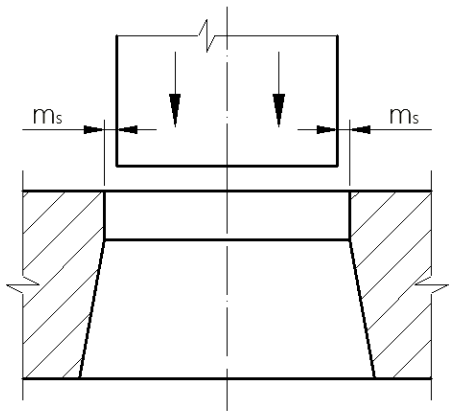


Figure 12. Striving will

$$v = 2\ .m_S \qquad (27)$$
$$v = 2\ .m0{,}0332$$
$$v = 0{,}0664\ mm = 0{,}066\ mm$$

$$m_S = c \, . \, a_0 \, . \sqrt{\frac{\tau_{PS}}{10}} \qquad (28)$$

$$m_S = 0{,}01 \, . \, 0{,}6 \, . \sqrt{\frac{278}{10}}$$

$$m_S = 0{,}0316 \, mm = 0{,}032 \, mm$$

Where:
c – mathematical constant 0,005 – 0,035,
we choose c for normal production accuracy
c =0,01.
m_s– slash gap

6. Calculations for dragging

For cylindrical yields in the 1st stroke, the need to use the retainer is decided by calculating the coefficient *kp* according to the relationship:

$$k_P = 50 \, . \, (Z - \frac{\sqrt{a_0}}{\sqrt[3]{D_0}}) \qquad (29)$$

$$k_P = 50 \, . \, (1{,}9 - \frac{\sqrt{0{,}6}}{\sqrt[3]{248}})$$

$$k_P = 88{,}84$$

When
$k_P \geq \frac{100.d_k}{D}$ → a retainer must be used
$k_P < \frac{100.d_k}{D}$ → pull without retainer

$$\frac{100 \, . \, 150}{258} = 60{,}48$$

$88{,}84 \geq 60{,}48$ → we have to use a retainer

Where:
Z – material constant
(1,90 – steel deep-plate; 1,95 – brass plate; 2 – aluminium plate)
a_0 – nominal sheet thickness
D_0 – diameter of the cut
D_k – diameter of the trap

The towing force between the drawbar and the fork is determined by the reduction of the friction between the drawbar and the sheet. The roughing of the edge of the blank and the unevenness of the sheet thickness is important to count when designing the pitch. Because of the difference in shape, accuracy, technical conditions of yields, it is not easy to establish a uniform pulling wish.

When dragging small yields with a calibrated wall thickness, the size of the toe clearance must be less than that of ordinary pulling without calibration. In the first case, with the increasing number of strokes, the towing force diminishes, on the contrary, in the latter case, it increases [1, 9]. The increase in tension in the dangerous cross section is a result of a small pulling force, the tensile force increases and the limitation of the deformation (the limiting drag coefficient increases). The effect of the toe pulls on the pulling force size at the deep pull is shown in the diagram of Figure 13. Referring to Figure 13. shows that the tensile force decreases to about the value with increasing drag $v = 1{,}2.a_0$.

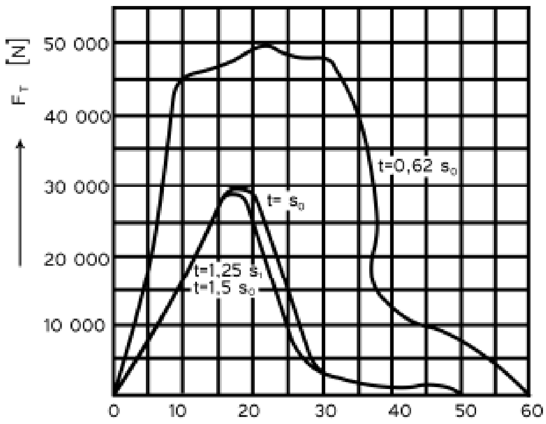


Figure 13. Diagram of the toe pulls

According to this relationship, it is recommended to choose the size of the traction gap.

$$T_m = 1{,}2 \, . \, a_0 \qquad (30)$$

$$T_m = 1{,}2 \, . \, 0{,}6$$

$$T_m = 0{,}72 \, mm$$

Where:
a_0 – nominal sheet thickness
Draw the gap t_m = 0,72 mm.

7. Economic calculations

Cost appraisal applies to the traction tool, and only semi-finished and labour costs are included in the calculations.

Table 4. Economic evaluation of the pulling tool

Component	Material	Net weight [kg]	Weight of workpiece [kg]	Price for 1 kg of material [€]	Price of workpiece [€]	Price of production [€]	Total price [€]
Punch	11 523.1	28,72	7,1	0,60	4,62	30	34,26
Towing box	11 523.1	58,88	89,86	0,60	56,92	70	123,92
Retainer	11 523.1	18,93	37,73	0,60	22,64	6,5	29,14
				Total:	**80,82**	**106,5**	**187,32**

The total cost of the tool is N_n = 187,32 € and this value is only indicative.

a) Material cost

$$N_{mat} = S_{mat} \,.\, C_m \,.\, n \tag{31}$$
$$N_{mat} = 0{,}3 \,.\, 0{,}81 \,.\, 1005$$
$$N_{mat} = 244{,}22\ €$$

Where:
S_{mat} – consumption of material [kg/pieces]
C_m – price of material [€/kg]
n – number of pieces

b) Labour costs

$$N_{labour} = (t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7) \,.\, M_t \,.\, n$$
$$N_{labour} = 147{,}05\ € \tag{32}$$

Where:
t_1 – the time required to divide the boards [hours]
t_2 – the time needed to cut [hours]
t_3– time needed for dragging [hours]
t_4 – the time required to cut the extract [hours]
t_5 – the time needed for cutting in the corner [hours]
t_6 – the time required to roll [hours]
t_7 – the time required to bend the front [hours]
M_t – hourly wage [€/hours]

$$N = N_{mat} + N_{labour} \tag{33}$$
$$N = 244{,}22 + 147{,}05$$
$$N = 391{,}27\ €$$

Total cost of production of 1005 pieces
$$N_c = N + N_n \tag{34}$$
$$N_c = 391{,}27 + 187{,}32$$
$$N_c = 578{,}58\ €$$

Conclusion

In the experimental part is verified the technological progress of the production of the innovative shape of the gutter head. The construction and technological documentation of the individual forming tools is made for the realization of the production, namely: a cutting tool for shaping the blank, a pulling tool for pulling the twin of the gutter face and a cutting tool for cutting the yield. The extruded sheet metal - hot-dip galvanized, which complies with EN 10130, was used for the experiment.

The sheet is used for deep drawing or the production of special deep-drawing parts. Performed technological and construction calculations, the force required to extract the required shape of the component, work and the size of the trim was determined. There are two variants designed to cut the cutout, of which the A variant was more advantageous because of the better usability of the sheet. The yield was carried out on the Fritz Müller BEZ 100 three-stroke hydraulic press.

Acknowledgement

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