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OPTIMIZATION OF FLAT FORMING WITH THE USE OF DRAW BEADS AND FINITE ELEMENTS METHOD

OPTIMALIZACE PLOŠNÉHO TVÁŘENÍ POMOCÍ BRZDICÍCH ŽEBER A METODY KONEČNÝCH PRVKŮ

Abstract

Paper concerns shape and properties choice of draw beads in flange area at stamping drawing to achieve stamping dimensions according to drawing. In paper the simulation of stamping drawing process with various variants of draw beads is described together with evaluation of drawing results with the use of analyses of stamping drawability. For calculations and simulations the programmes of AutoForm 4.06 and PAM-STAMP 2G TM using finite elements method were used. The choice of shape and properties of draw beads to be used in serial production is described. In the end of paper the comparison of dimensions of stamping gained by simulations with the dimensions of real stamping which were gained by 3D measurement is carried out.

Abstrakt

Článek se zabývá volbou tvaru a vlastností brzdicích žeber v oblasti příruby při tažení výtažku tak, aby byly docíleny rozměry výtažku dle výkresu. V článku je popsána simulace procesu tažení výtažku s různými variantami brzdicích žeber, včetně vyhodnocení výsledků tažení pomocí analýz lisovatelnosti výtažku. Pro výpočty a simulace byly použity programy AutoForm 4.06 a PAM-STAMP 2G TM využívající metodu konečných prvků. Je popsáno ladění tvaru a vlastností brzdicích žeber tak, aby mohly být použity v sériové výrobě. V závěru článku je provedeno porovnání rozměrů výtažku získaného simulacemi s rozměry skutečného výtažku, které byly získány 3D měřením.

INTRODUCTION

In practice, the customer requires high quality of the final part (maintaining the geometry of the stamping) at the lowest possible price of the instrument. To maintain the geometry of the stamping you must have an ideally designed technology for pressing the stamping, but because the slightest saving of material mass production means considerable cost savings for the customer, we also try to choose the lowest possible allowances on the trimming of the part.

When designing the technology for a part with a complex shape, the most important step is designing a suitable pressing operation. If the given part is well made already in the pressing operation, then difficult and often very toilsome procedures in other operations, whose goal is to achieve the form prescribed on the production drawing, are eliminated.

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There are many procedures for achieving the correctly deformed surfaces of the part, i.e. without wrinkling and buckling due to suspension. One of these procedures is using braking ribs, which increase the radial tension in the chosen area, when pressing the sheet. This procedure can reduce or eliminate tangent tension in the given place and thus a greater and better deformation of the final part can be achieved.

When designing technologies for parts with complex shapes, software using the finite element method is very useful. It helps deal with the variations of the location or shape of braking ribs. Two of the most-used programs, used primarily in the automobile industry, are AutoForm 4.06, and PAM-STAMP 2G ^{TM}. With this software the tool factory can define the molding process, which it is able to implement in practice, and thus guarantee the manufacturability of the part to the customer. With each design of a technology for the stamping we must deal with specific issues arising from the complexity of the stamping.

This article deals with the design of a pressing operation using braking ribs in order to create the best possible form of the stamping. It then deals with the adjustment of this operation in order to save material to reduce the cost for the customer, while maintaining the optimal state of deformation.

The software CATIA V5R19 was used for creating the stamping model and other auxiliary sheets used in the programs that use the finite element method.

1 MATERIALS USED BY CAR FACTORIES

Materials used in the automobile industry differ with regard to the functionality of the given part, its complexity, safety requirements, and according to internal standards of individual car factories. Along with the functionality, the latest trend of car factories is to reduce the weight of the automobiles, which is associated with other attributes, such as consumption, interior space, safety, etc. Therefore, strength and high-strength (HC) materials, and materials of varying thicknesses are used more. The mechanical properties (measure of shear and ductility) of individual types of materials in the automobile industry are schematically depicted in Figure 1.

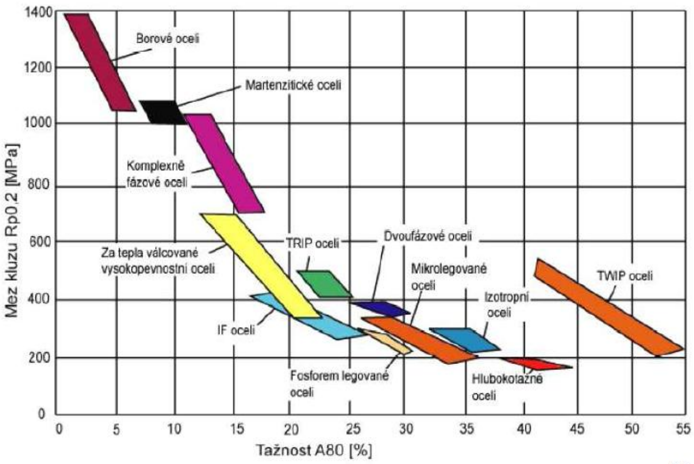


Fig. 1 Mechanical properties (measure of shear and ductility) of individual types of materials in the automobile industry.

Figure 1 shows strength materials, deep-drawing sheets of steels alleviated with aluminum, micro-alloyed steels, sheets of IF steels (interstitial free) – they are used for fenders, door surfaces and other complex shaped parts, sheets of IF steels with BH effect (the BH effect represents the increase of the value $R_p0.2$ by 30÷80 MPa during the paint burning, which is carried out at the temperature 170 °C for 20 min.), high-strength materials, sheets of DP steel – dual phase steel, sheets of TRIP steel – steel with transformation induced plasticity, sheets of TWIP steel – it is characterized by extreme values of stretchability (80÷100 %), sheets of CP steel – characterized by high strength, high deformation hardening, and the ability to absorb energy, and sheets of MS steel – martensitic steel.

2 STAMPING FROM THE CAR BODY BRACE PILLAR

A car body brace pillar (Figure 2) is a complex shaped stamping of an irregular shape, which must be sufficiently accurate in order to be assembled with other parts of the car body (Figure 3). The technology was designed in the joint-stock company PWO Unitools CZ. The material of the stamping together with the definition of the shape was chosen by the customer.

For the stamping, the customer requested the material HX220YD according to EN 10292:2000 with a thickness of 1 mm (H – cold-rolled sheets of high-strength steels designed for cold forming, Y – no inclusions, D – for hot-dip galvanizing).

This is a micro-alloyed continuously hot-dip coated sheet of steel with higher shear measure, high strength, and good formability. The material is suitable for cold forming. It is used in the automobile industry for internal and external components of car bodies, especially because of its good formability, weldability, and good results in crash tests. The properties of this material (Figure 4) meet the requirements for the safety of automobile passengers, according to the internal standards of the car factory.

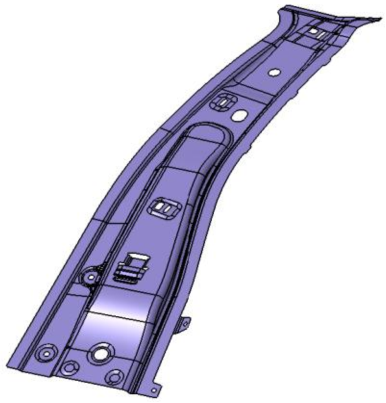


Fig. 2 Car body brace pillar shown in CAD data supplied by the customer.

Fig. 3 Schematic placement of the car body brace pillar in the body of the vehicle.

The material must meet the requirements for strength, but also for stretchability. More detailed information revealing the exact dimensions, mounting method, and a more detailed description are kept secret due to competition in the automobile industry. This article is therefore based on a computerized image of the stamping of the car body brace pillar in the form of CAD data, which fully describe its shape and dimensional properties.

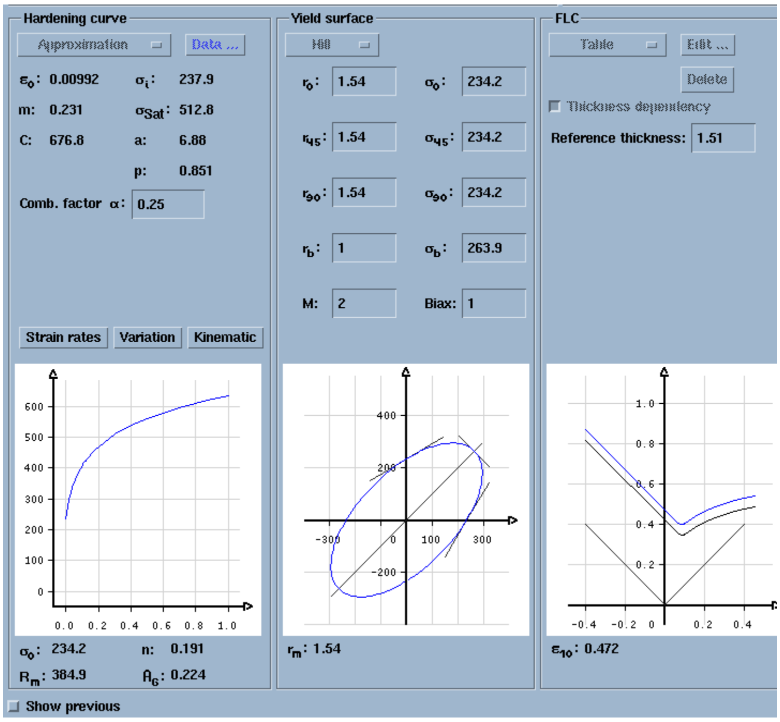


Fig. 4 Mechanical properties of the material HX220YD as material data in the software Autoform 4.06.

Material data needed the software using the finite element method is obtained by testing materials, which include the uniaxial tensile test (ČSN EN 10002-1) and the Erichsen cupping test (ČSN EN ISO 20482).

Tab. 1 Requirements for the mechanical properties of the material HX220YD according to EN 10292:2000.

R_m [MPa] min.-max.	$R_{p0,2}$ [MPa] min.-max.	A_{80} [%] min.	r_{90} [–] min.	n_{90} [–] min.
340-410	220-280	32	1.50	0.170

Tab. 2 Chemical composition of the material HX220YD according to EN 10292:2000.

C_{max} [%]	Mn_{max} [%]	Si_{max} [%]	Al_{max} [%]	P_{max} [%]	S_{max} [%]	Ti_{max} [%]
0.01	0.90	0.10	0.02	0.08	0.025	0.12

3 EFFECT OF THE BRAKING RIBS ON THE PROCESS OF PRESSING STAMPINGS OF IRREGULAR SHAPES

The braking ribs are used primarily with irregular, large, and complex stampings, such as car bodies, where the conditions for forming are much more complex in comparison with regular stampings. In order to improve the conditions of the forming process, unlike with regular stampings, during the pressing of irregular (complex) stampings, the resistance of the formed material in the flange increases. This is achieved thanks to the braking ribs, which slow the flow of the material, channel the transfer of the formed material in the corners and corner parts of the presser, and contribute to the stabilization of the pressing process.

By braking the braking ribs the tensile radial tension can be increased to the extent needed. A braking rib is a protrusion created in the presser and retainer (Figure 5) for slackening the formed material. It is only placed in locations where it is desirable to increase the slowing down of the sheet, and thus achieving a greater deformation of the material.

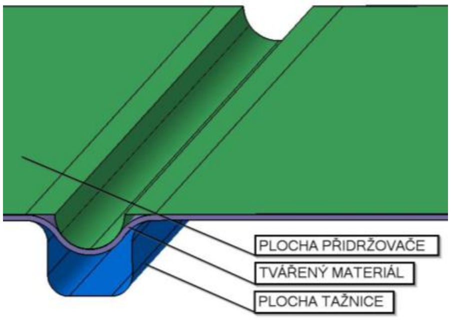


Fig. 5 Schematic representation of the rib; there is a relief in the presser surface.

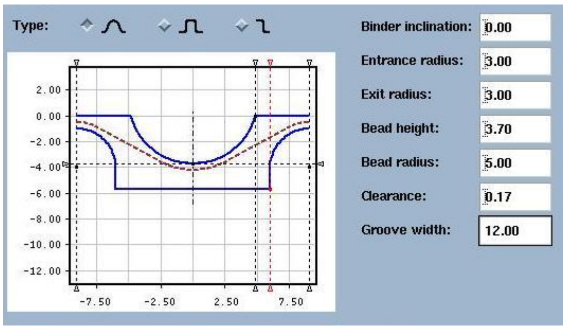


Fig. 6 Defining the geometry of braking ribs in the program Autoform 4.06.

The use of braking ribs enables:

- enlargement of the flange grip of the molded semi product, and thus an increase in the slowing of the material flow during pressing,
- an increase in the allowable range of gripper pressure (brake factor control),
- directing the transfer of the molded semi product in curved and straight areas of the drawing edge of the presser,
- deliberately increasing the slowing of the transferred material at individual locations using a number of braking ribs,
- in some cases, reducing the quality of the machined surface of the presser and the gripper of the pressing tool,
- the stabilization of the pressing of large irregular stampings, and eliminate the formation of waves,
- minimization of tool wear (of the gripper and presser),
- reduction or limitation of the suspension of the stamping resulting after the pressing of the stamping.

Suitable placement of ribs in the retainer depends on the material of the stamping, and it is carried out according to experience. Literature states the optimal distance of braking ribs is 20 mm to 30 mm from the drawing edge of the presser; if there is a larger number of braking ribs in a row, then the distance 25 mm to 35 mm is used. The optimal placement of the ribs is in the plane of the contour of the drawing edge. The braking ribs are usually 5 mm to 10 mm wide, and 1.2 mm to 5 mm tall, depending on the size, the shape of the stamping and the thickness of the pressed sheet, and on the size of the desired braking factor. With complex shaped stampings the ribs are placed in critical locations approx. 15 mm from the tensile edge of the presser, also for the reason of saving the size of the trimming.

For the effect of the ribs to be most efficient, the most suitable geometric profile and dimension of the rib must be found. The intensity of the braking of the sheet in the area of the gripper depends on many parameters such as:

- the radius of the rib itself, and the radius between the vertical wall of the rib and the presser,

- the total angle of the wrap (arching of the rib, radius between the vertical wall of the rib and the presser, arching of the drawing edge), all depending on the geometry of the rib,
- the thickness and mechanical properties of the pressed material,
- the position of the braking ribs depending on the pressed material.
- number of braking ribs.

With an inappropriate choice of geometry of the braking rib profile (radius, height, etc.) and placement of the braking rib, the pressability of the stamping is significantly worsened. The tractive tension can suddenly increase, which causes the sheet to rapture near the drawing edge. The braking rib cannot be too high so the metal doesn't harden too much during the cold deformation. a high rib can cause the material to ripple when impressing it into a flat blank; this cannot be removed. It is therefore better to use a number of low braking ribs in a row, than one high one.

The ribs must always be arranged so that the resulting stamping is as deformed as possible. In practice this means that the final part should ideally show a minimum of 70 % deformation (Figure 7 and Figure 8). In this case, the cushioning effect will be limited to a minimum after pressing. The optimal deformation is achieved by appropriate placement of braking ribs, and a good choice of gripping strength of the molded sheet.

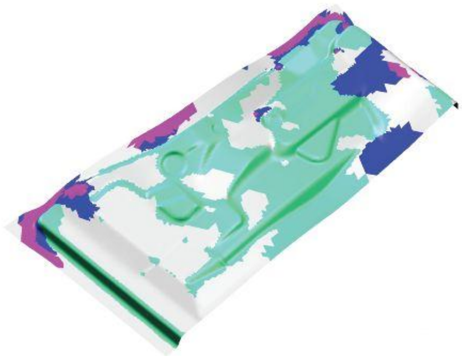


Fig. 7 An inadequately deformed part in terms of deformation analysis – software PAM-STAMP 2G.

Fig. 8 An ideally deformed part in terms of deformation analysis – software PAM-STAMP 2G.

For parts with complex shaped sheets it is necessary, in order to ensure uniform and symmetrical molding, to aim for a brake that creates a uniform stamping. By using braking ribs we can eliminate the formation of waves, wrinkles, cracks, and other defects that occur during sheet molding of complex shaped stampings. Breaking ribs; their shape and gripping strength are an important boundary condition, which must be entered in the software, and the final state of the stamping depends on it.

Generally a number of versions of braking ribs are designed, where the geometry of the rib is the same in each version, and only the values of the strength of the grip and the ribs vary. a rib has its specific geometry, and it can change its cross section a number of times throughout its length. This regulates the gripping force in individual areas of the stamping. For each version of the braking rib shapes a simulation of the pressing process is carried out with the same entered values of the material and pressing process; then the results are evaluated. The comparing individual simulations leads to the selection of a technology that is most optimal in terms of pressability of the stamping, thus eliminating defects, and adhering to the prescribed shape on the stamping drawing.

When choosing the location and type of braking ribs (gripping force) we must also take into account the type of material.

Scientific literature describes the basic distribution of braking ribs in dependence on the material of the stamping (Figure 9) as follows:

a) when pressing stampings of steel of common grades, we must place the direct braking ribs along the perimeter of the stamping, and, where necessary, increase the intensity of deformation of the stamping,
b) with strength and high-strength materials the ribs cannot interfere with the edges; an open structure of braking ribs is used,
c) for docile materials with high stretchability suitable for deep tractions, the so-called locked position of braking ribs (braking bar) is used.

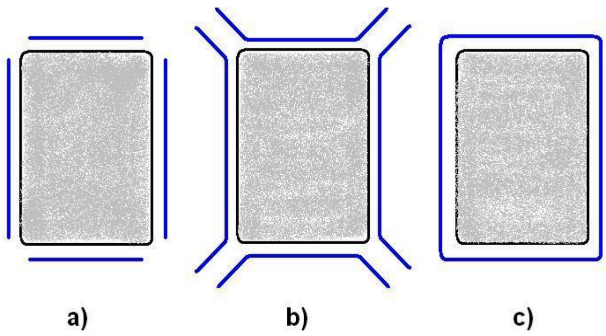


Fig. 9 Schematic distribution of the braking ribs in dependence on the material of the stamping (a – sheet of common quality, b – high-strength material, c – docile material).

4 DESIGNING A TECHNOLOGY FOR THE STAMPING OF A CAR BODY BRACE PILLAR

The stamping of a car body brace pillar is mirror-symmetric, a pair stamping of complex shape. For the molding technology, which shows signs of large-scale (mass) production, it is therefore preferable to press both pieces simultaneously. The advantage is that with one lifting of the tool both (left and right) parts are formed simultaneously. Another advantage is that one tool will be used for both parts, and only one time to test and install the tool into operation, which leads to financial savings. Saving with the selection of this technology is due to the elimination of allowances for the size of the trimming, which would be bigger if the tool was divided into two, especially for the right and left parts. The disadvantage of this technology is that a tool for producing two pieces simultaneously will be more complicated, but the total savings are significantly higher than when two separate tools are used.

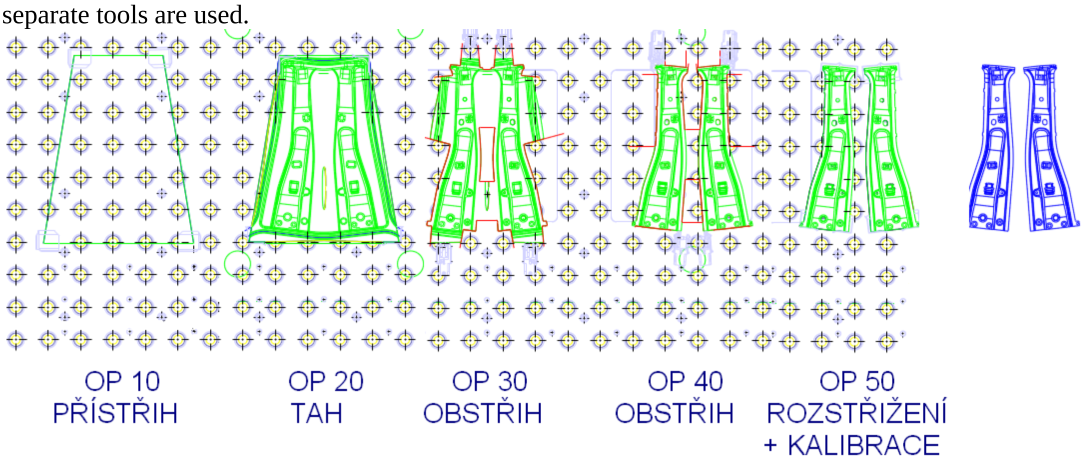


Fig. 10 Designing a production technology for two pieces of car body pillar stampings.

The production technology for a car body pillar stamping was therefore designed in a way (Figure 10) that in the first operation a trapezoidal blank is slit from the sheet. In the second operation both stampings are pressed simultaneously. In the third and fourth operations the contour of the stamping is cut. In the fifth operation both stampings are separated and calibrated in order to comply with the geometric tolerances specified in the drawing.

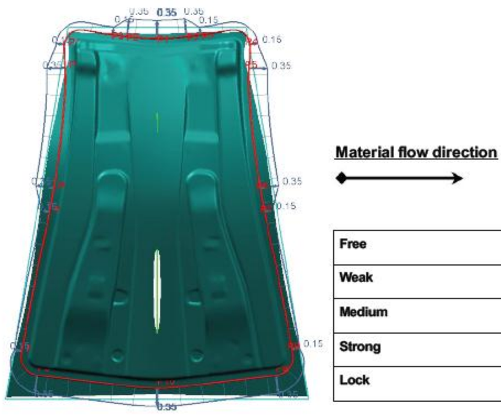
5 DESIGNING A MOLDING PROCESS AND DISTRIBUTING THE BRAKING RIBS

First, the two car body brace pillar stampings were set against each other, to ensure their optimal position to the direction of the pressing. Both parts most be opened in the axis of the traction to ensure their easy removal from the tool. The stampings must be offset from each other at a distance that will ensure the passage of cutting tools needed to slit both stampings (see 4).

The location of the stamping with regard to the direction of the rolling of the sheet is also important, that is why it was chosen with the car body brace pillar in a way that the high margins and sharp transitions are perpendicular to the direction of rolling. This location of the stampings results in less suspension of the stamping after pressing.

The location of the braking ribs was designed with regard to the size of the cut and the desired deformation of the material as close as possible to the tractive radius, i.e., close to the tractive edge of the presser (see 3).

The braking ribs were placed continuously around the whole perimeter of the stamping – the so-called locked position of braking ribs (braking bar), at a distance of 15 mm from the tractive edge of the presser. The braking factor was subsequently entered as a variable value on the braking ribs, from a slightly braked material with the value 0,15 [–], to a medium braked material with the value 0,35 [–]. In areas of sharp radii or assumed high ridging of material, the braking factor is higher, as well as in areas where low deformation of the material is expected (Figure 11).



Free	0
Weak	0,15
Medium	0,35
Strong	0,9
Lock	2

Fig. 11 Designing the location of braking ribs and the intensity of the braking factor.

After entering other boundary conditions of the presser, gripper, type of material, and its thickness, the task was ready for calculation.

The result of the calculation is a set of analyses evaluating the expected state of the stamping of two car body brace pillars after the pressing. This is an analysis of deformations in the stamping, and their comparison with the curve of the boundary deformations in the diagram of boundary deformations of the used sheet; through this the pressability of the stamping, the analysis of the thinning of the sheet after pressing, and the analysis of the risk of rippling is determined. Ideally, the stamping must meet all the analyses of its pressability, and be adequately deformed (see 3), in order to best eliminate the suspension of the stamping after pressing. The proposed technology was overall assessed as unsuitable (Figure 12). The analysis of the pressability shows values exceeding the safe range; this means that the stamping will crack in locations with small radii (Figure 13 and 14). The analyses of the thinning of the sheet and rippling of the stamping are in the tolerances that are set by the customer as satisfactory. The thinning value is ±30 % of the material's thickness 1 mm (see 2.1). The highest permissible rippling values are: for rippling on straight surfaces 0.03 [–], for rippling on bent, inclined, and curved 0.05 [–]. The analysis of the risk of violation is also unsatisfactory, because it exceeds the limit value 1, which means that in some parts of the stamping the plasticity was depleted, and the material ruptured in these places (see 7).

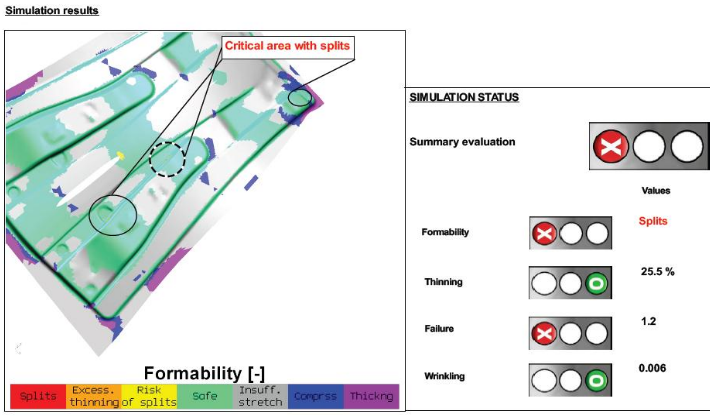


Fig. 12 Analyses of the pressability of the car body brace pillar stamping when using the proposed braking ribs.

The analysis of the level of deformation of the resulting sheet is also unsatisfactory; the stamping is evidently only deformed in peripheral areas, and areas of large shape changes and transitions.

With the current unsatisfactory conditions there are two solutions. The first solution is to seek the critical points in simulation, and find the cause of their formation. In this case we may file a proposal to the customer to modify the part; the critical points around the radii would improve with respect to the pressability analysis. Therefore, the radii would be enlarged in high-risk areas, decreasing the deformation. The radii would be enlarged until the simulations and analysis was satisfactory.

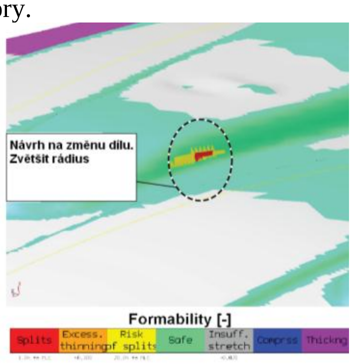


Fig. 13 Rupturing of the car body brace pillar stamping when proposed braking ribs are used.

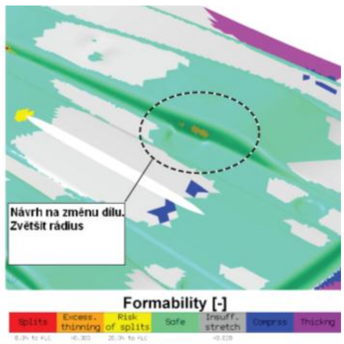


Fig. 14 Risk of other permanent defects of the car body brace pillar stamping when proposed braking ribs are used.

The second solution is to set the molding process differently, in a way that would prevent the defects arising from the current pressing conditions (see 6).

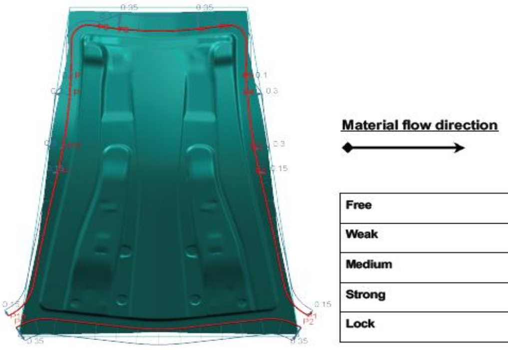
It is always better to try all the testing options of the process by changing the boundary conditions, the shape of the braking ribs, or their brake factor. Only when all the calculation adjustment options have been exhausted and violation still occurs is a proposal for adjusting the geometry of the stamping made to the customer. He must check the relationships of the geometry of the part to the surrounding components in the assembly, the location in the automobile, take into account the rigidity of the part, the functionality, and decide whether he will allow the change or not.

6 OPTIMIZATION OF THE MOLDING PROCESS AND LAYOUT OF BRAKING RIBS

Optimization of the molding process is based on previous calculations. The calculations (see 5) had a number of critical points on the edges of the car body brace pillar stamping, which can be affected by the shape of the braking ribs, and adjustment of brake factors. We must also take into account the material of the sheet, and the fact that it is a strength sheet, so distribution of braking ribs with open corners might be more suitable (see 3, Figure 9b).

The orientation of the car body brace pillar is the same, i.e., in the direction of the rolling of the sheet. The location of the braking ribs is also the same as in the previous case; at a 15 mm distance from the tractive edge of the presser. The brake factor is also variable (Figure 15).

A change took place only at the lower corners of the stamping (Figure 15), which were opened so that the geometry tangently followed the radius of the stamping. An opening of the braking ribs was used in the lower part of the stamping because the critical points were forming mostly in the lower parts of the stamping. Along with this definition also the brake factors were reduced in places, where previous calculations showed a possibility of defect occurrence.



Free	0
Weak	0,15
Medium	0,35
Strong	0,9
Lock	2

Fig. 15 Placing optimized braking ribs, and the intensity of the brake factor of the car body brace pillar stamping.

The overall assessment of the optimized technology is described as satisfactory (Figure 16). All analyses such as pressability, thinning, infringement, and wrinkling are satisfactory according to prescribed criteria. The pressability was evaluated as satisfactory, where the maximum value observed in simulation is well below the limit of boundary deformations (see 7, Figure 18). Thinning gains the maximum value of -0.14 %, which signifies cramming of the material, at a tolerance of ±30 %; therefore, this analysis is also satisfactory. The analysis of the risk of violation is also satisfactory, because the limit value here is 1 [–], and the highest observed value is 0.64 [–].

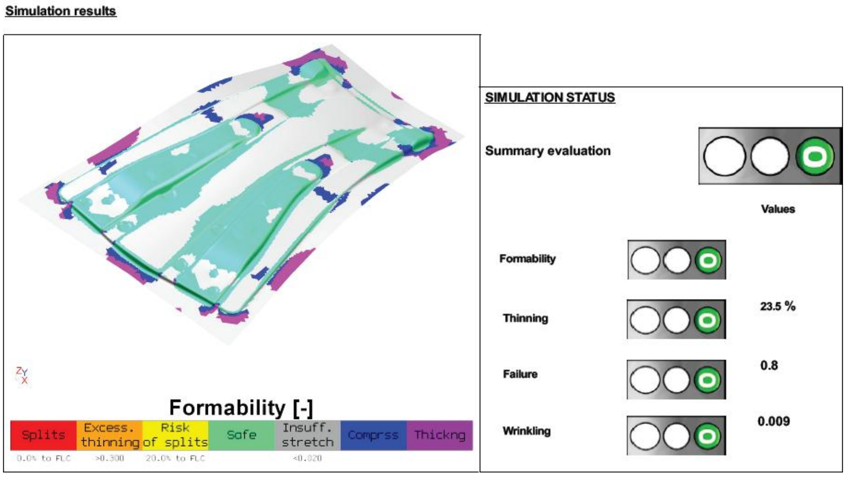
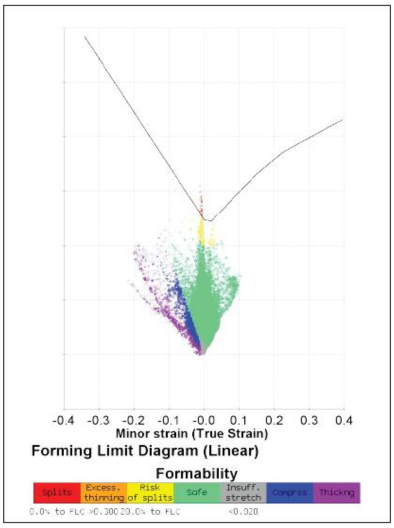


Fig. 16 Analyses of the pressability of the stamping of the car body brace stamping after optimization of the placement and geometry of braking ribs.

The stamping of the car body brace pillar stamping also shows favorable deformation along the whole perimeter of its shape, so it can be assumed that it will be satisfactory in terms of suspension even after trimming. In order to achieve even better conditions we could carry out further optimization, but when all the results are satisfactory and within the tolerances, it would be unnecessary to optimize the whole process again.

7 COMPARING THE PLANS OF MOLDING PROCESSES

By comparing the original production technology designed for the car body brace pillar and the technology after optimization of the placement and geometry of braking ribs, it is clear that thanks to the change in the geometry of the braking rib significantly better results are achieved. The improvement in pressability is evident from the comparison of the distribution of stamping deformation in the diagram of marginal deformations. From the comparison of both technologies (Figure 17 and 18) the difference in the use of the material's plasticity during pressing is evident. In the originally designed technology the stamping showed violation, which is represented by points exceeding the limit of deformation (Figure 17), i.e. in these areas of the stamping the plasticity reserves of the material were depleted, and the material subsequently ruptured. On the contrary, in the optimized technology the deformations of the whole stamping are well below the deformation limit curve, which shows the stability of the pressing process. Because the deformations of the stamping are well below the deformation limit curve, a large reserve of formability is ensured; this is advantageous because during the adjustment of the tool and inevitable external influences, further deformation of the stamping may occur.



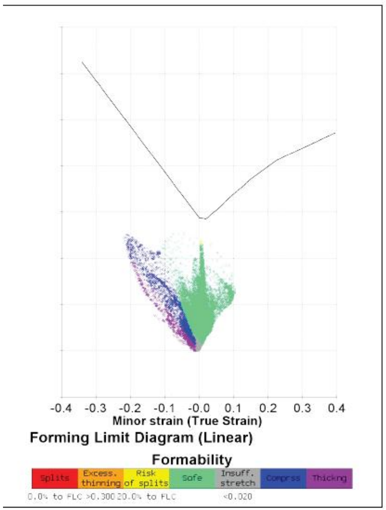


Fig. 17 Diagram of limit deformations for the proposed placement of braking ribs.

Fig. 18 Diagram of limit deformations after optimization of braking ribs.

8 MEASURING THE DIMENSIONS OF THE ACTUAL STAMPING AFTER PRESSING

The measuring of deviations of the produced car body brace pillar stamping dimensions was performed on the 3D CNC measuring machine that is designed for 3D dimensional control in production. Deviations of shape, the position of openings, the sizes of openings, and deviations of contours are measured this way. The values of allowed deviations are prescribed on the production drawing of components. The establishment of the stamping is chosen so as to ensure the reproducibility of the measuring. Constituent points are elected for the establishment (Figure 19). These points are chosen for the technological base of the presswork so as to ensure the same setup of all other controlled stampings. The set of RPS points defines the technological base from which other dimensions are measured. It is always based on a number of measured protocols, and average deviation values are included.

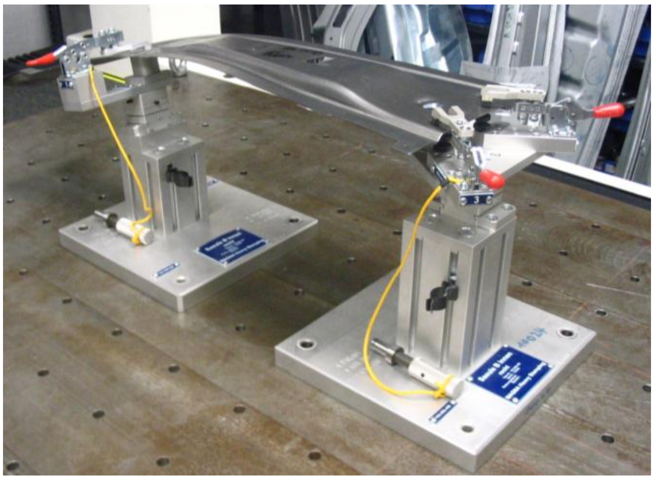


Fig. 19 Measuring the actual state of the stamping of the car body brace pillar stamping after pressing which is carried out on the 3D CNC measuring machine.

The result of the measurement is a synoptical form, which shows the measured areas on the stamping, and their dimensional values. These values are marked with colored symbols and a numeric value indicating the deviation from actual dimensions. Values that meet the prescribed tolerance are marked in green; yellow values are borderline. Unsatisfactory values are marked in red, and they must be fixed by adjusting the tool. The deviations did not have great values, because the suspension was recognized before the stampings were made thanks to the simulations. Nevertheless, some areas showed deviations moving beyond the limit of the values set on the drawing; it was still necessary to adjust the tool. The adjustment is done by changing the shape of the tool; by milling and grinding the tool for positive deviations, and, for negative deviations, by burning in the welding bead with special carbide electrodes and subsequent milling and regrinding of the pressing tool.

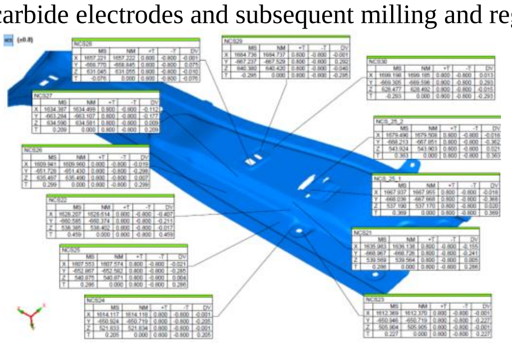


Fig. 20 Revisal of the shape deviation measurement on the surfaces of the car body brace pillar stamping.

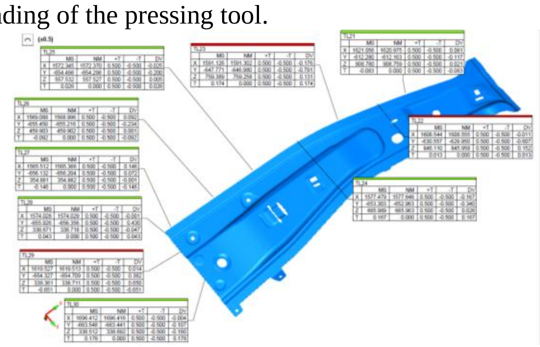


Fig. 21 Revisal of the shape deviation measurement of the car body brace pillar stamping.

9 CONCLUSIONS

From the results of computer simulations it is clear that there are many ways leading to the final design of braking ribs for pressing the stamping. In the case of the car body brace pillar stamping a production technology was designed (see 4), for which pressing simulations with various placements and geometries of braking ribs were performed (see 5).

By using a software that uses the finite element method, such as AutoForm 4.06 a PAM-STAMP 2G (see 5), the pressing tool can be revised already in the electronic form of the model, so that the subsequently produced stamping is within the tolerances prescribed in the production drawing (see 8). This way we can avoid the lengthy process of testing the actual tool. An investment in testing the pressing technology and parameters already in the stage of the designing of the technology is much smaller and much more convenient than subsequent part repairs (see 5) or tool corrections.

Based on the simulations of the pressing process it was found that various shaped of braking ribs are suitable for various stamping materials. When pressing stampings that are made of strength and high-strength materials (see 1) we cannot profitably use braking ribs that are located along the whole perimeter of the stamping; instead, braking ribs with a geometry that enable the pressing of the material in the corners of the stamping (see 3) ensures minimal compression of the metal, and the flow of the material is released in the direction of the pressing.

Resulting analyses of pressability also show that better results, in terms of violation risk analysis, pressability, thinning, and the risk of wrinkling, can be achieved with materials with higher rigidity, by entering a variable brake factor in the braking ribs. For materials with higher rigidity the ribs must have a lower brake factor that is a lower intensity of braking, in areas of sharp transitions (stamping corners, etc.); in flat areas, the brake factor can be higher to ensure sufficient deformation of the stamping, and limit subsequent suspension.

After the first pressing of the set of stampings it is appropriate to measure this set on a 3D measuring machine (see 8); if the tolerances prescribed in the production drawing have been exceeded, the problem should be solved with an instant adjustment of the tool directly in production. The 3D measuring machine detected shape deviations of the car body brace pillar stamping from the prescribed values on the production drawing; these deviations were corrected and adjusted. Deviations from the shape of the contour of the stamping were adjusted in trimming operations by altering the trimming tools (see 4).

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