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Radek ČADA[*], Petr TILLER[**]

TUNING OF INTRICATE SHAPE STAMPING SHAPE AND DIMENSIONS WITH THE USE OF DRAWING PROCESS SIMULATIONS

LADĚNÍ TVARU A ROZMĚRŮ VÝTAŽKU NEPRAVIDELNÉHO TVARU POMOCÍ SIMULACÍ PROCESU TAŽENÍ

Abstract

The paper deals with the process of creation of model of intricate shape stamping from thin sheet-metal – internal reinforcement of car bodyshell B-pillar for flat forming simulations and subsequently with the procedure of its critical dimensions tuning in order to keep the dimensions and tolerances of stamping after drawing process which are given in production drawing. The dimensions of stamping after drawing were evaluated by simulations of drawing process in CAE software Dynaform 5.7 which uses finite elements method. At this software the results of drawing process simulation achieved in comparison with the real process satisfactory results. In the paper the simulation of drawing process of car bodyshell B-pillar stamping is described, the procedure of transformation of given model in digital form and evaluation of drawing results by Dynaform 5.7 software. Also the procedure of the real stamping proportions evaluation compared with the simulated drawing process with the use of CAD software and reciprocal transfer of datas between them. In the end of the paper the procedure of stamping dimensions tuning by corrections of drawing tool parts for fulfilment of all tolerances which are specified in the product drawing is described.

Abstrakt

Článek se zabývá postupem tvorby modelu výtažku nepravidelného tvaru z tenkého plechu – vnitřní výztuha B-sloupku karosérie automobilu pro simulace plošného tváření a následně postupem ladění jeho kritických rozměrů za účelem dodržení rozměrů a tolerancí výtažku po procesu tažení, které jsou předepsány na výrobním výkresu. Rozměry výtažku po tažení byly zjišťovány pomocí simulací procesu tažení CAE programem Dynaform 5.7, který využívá metodu konečných prvků. U tohoto programu výsledky simulace procesu tažení dosahují v porovnání s reálným procesem uspokojivé shody. V článku je popsána simulace procesu tváření výtažku B-sloupku karosérie automobilu, postup transformace zadaného modelu v digitální podobě a vyhodnocení výsledků tažení pomocí software Dynaform 5.7. Dále je popsán postup vyhodnocování skutečných rozměrů výtažku v porovnání se simulovaným procesem tažení při použití CAD programů a vzájemným převodem vytvořených dat mezi nimi. Na konci článku je uveden postup ladění rozměrů výtažku korekcí částí tažného nástroje pro splnění všech tolerancí, které jsou předepsány na výrobním výkresu.

INTRODUCTION

Mechanical engineering, especially car industry is one of the most important sectors. This sector is subject to the newest trends, innovations and modern technologies in effort to compete in the

[*] prof. Ing. Radek ČADA, CSc., VŠB – Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Mechanical Technology, 17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, tel.: +420 59 7323289, fax: +420 59 6916490, e-mail: radek.cada@vsb.cz
[**] Ing. Petr TiLler, VŠB – Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Mechanical Technology, 17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, tel.: +420 59 7323289, fax: +420 59 6916490, e-mail: tillerpetr@yahoo.com

market and be one step ahead of competition. Thanks to these trends comes the continued progress in fields such as material engineering, welding materials, construction of individual parts, assemblies and forming process metals. In forming of metals parts must meet the requirements for mechanical properties, safety requirements. Design of components and welded parts is also important based on sheet metal forming technology. a specific problem is the price of materials and cost of production parts.

Novel materials used in construction of cars bring entirely new or additional requirements for technology drawing of stamping because they have different values of spring-back, other forces of deformation and deformation capability. For their assessment are not suitable standard absolute values of the material but their relative values related to the density of material used. Car bodyshell of concept are based by technological possibilities. These factors have an important role for producers in considering the technology used of production parts. There are high demands for shortening the time of preparation tools, technological processes and material savings by selecting a suitable location on the semi-product blanks, etc. Tuning tool dimensions for production intricate shape of stamping with the prescribed dimensions and tolerances on the production drawing is very elaborate and time-consuming process. This is especially of the shape variations arising after drawing or multiple drawing, into which operations are usually included as a cut out hole, bending at progressive drawing tool that must be individually fine tune according to specific conditions of the technological process of drawing.

For this reason car industry using advanced technology. Currently, the standard has already considered the use of simulation software that can simulate of forming process on the basis of finite element method (FEM). Based on the results of simulations CAE (Computer-Aided Engineering) software can shorten the time preparation of tools, the technological process production stamping. The principle method of FEM is described in the distribution of objects (complex intricate shape) on a small area (elements) that are described mathematically easily. There are more layout options for elements of the body they can often be triangular, rectangular and octagonal shape. For calculations by finite element method in CAE software applies that the stamping is distributed the number of nodes increases too and thereby accuracy and objectivity output increase too, of course.

In this paper the model of irregular shape stamping – internal reinforcements of car bodyshell B-pillar was created using of software CATIA V5 R19. To modify a model of stamping to drawing process simulation was used Solid Works 2008 programme. Both above mentioned programs are among the many 3D CAD product of Dassault Systémes. From CAE software for quick verification of model modifications stamping the drawing process, software EasyBlank of company Autoform was used. For calculations and intricate shape stamping drawing process simulation – internal reinforcements of car bodyshell B-pillar software was used Dynaform 5.7 of company ETA (Engineering Technology Associates, Inc.).

1 INTERNAL REINFORCEMENTS OF CAR BODYSHELL B-PILLAR

The specified part of internal reinforcements of car bodyshell B-pillar (see Fig. 1) is located in the inner part of car bodyshell. This is irregular shape stamping for a new type of car. Surfacing for drawing of sheet-metal with zinc is performed. On material of stamping are high demands – they must meet the required strength and ductility simultaneously, including the requirements on the safety part. Due to compliance of contractual arrangement between the manufacturer of stamping and car factory more detailed description of the stamping, dimensional data, etc. is concealed to protect the know-how from competition.

Fig. 1 Internal reinforcement of car bodyshell B-pillar.

In the paper as the starting model is stamping digital format CAT Part that client was created in the software CATIA V5 R19 (see Fig. 2). This model fully describes its shape and dimensional characteristics including accuracy where the shape of tolerance ±0.5 mm. Together with the model were supplied required material properties and manufacturing drawings including specified RSP points for measuring complex shapes that they are not otherwise measurable. For tuning of critical stamping dimensions and related dimensions of drawing tool parts with them and for further testing drawing real of stamping were selected two kinds of materials – strip steel HX220YD and DX56D, both thickness of 0.65 mm.

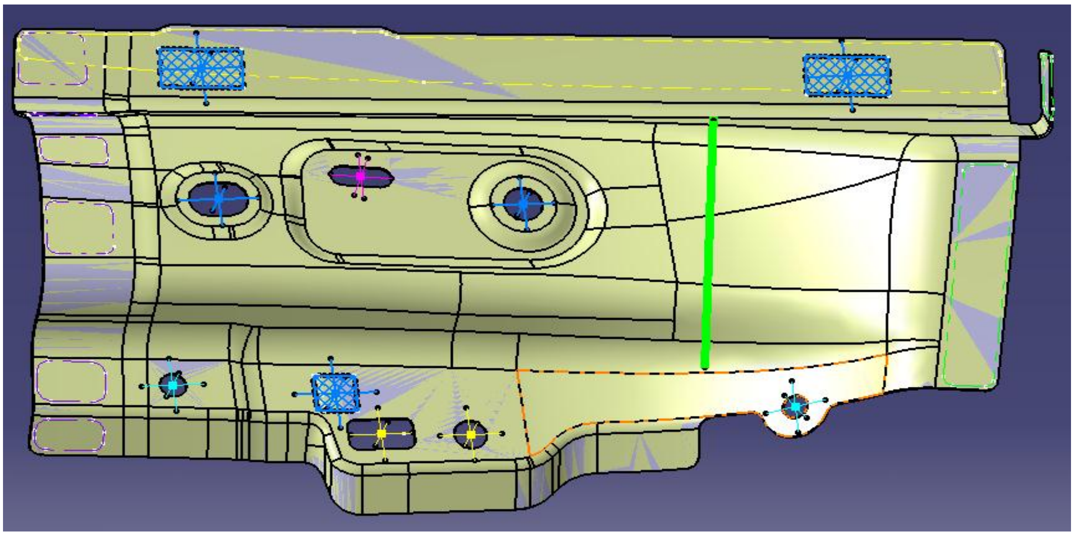


Fig. 2 Model of internal reinforcement of car bodyshell B-pillar in digital format CAT Part Catia V5 R19 software with marked RPS points (three blue rectangles) and location of the holes defined in part.

The required material for production of internal reinforcement of car bodyshell according to the client is strip from steel HX220YD according to ČSN EN 10346. This strip steel is not a typical material that is the best and most commonly used for deep drawing. This strip steel for cold forming is with higher yield strength. Steel is well weldable. The coating layer consists of steel layer a minimum of 99 % zinc. The usual coating has a metallic sheen without zinc flower. The surface is quality of B (improved coating) that reaches mild cold rolling. The coating is good and smooth with surface roughness $R_a = (0.6 \div 1.9)\ \mu m$. Sheet-metal coating is oiled unless otherwise agreed. Oiled layer must be removed with an alkaline solution. Strip steels can be supplied in the annealed state and heat treatment conditions. Chemical composition (see Tab. 1), mechanical properties (see Tab. 2) are specified the standard ČSN EN 10346.

Strip steel DX56D for tuning critical dimensions in the manufacture parts of the drawing tool and follow testing operation progressive drawing tool was used by client. It is a low-carbon deep drawing steel specially determined for deep drawing of cold. Steel is well weldable. The coating layer consists of steel layer a minimum of 99 % zinc. Other features are very similar to material HX220YD.

Required the values for drawing process simulation, i. e. the coefficients of the plastic anisotropy, the values of weighted average of plastic strain ratio and degree of planar anisotropy of plastic strain ratio of strip steel DX56D are listed in Tab. 3 and Tab. 5. For strip form steel HX220YD these values are listed in Tab. 4 and Tab. 6.

Tab. 1 Demands on chemical composition of strips from steels HX220YD and DX56D for cold forming according to ČSN EN 10346.

Steel types		Chemical composition (weight %)							
Steel mark	Numeric marking	C max.	Si max.	Mn max.	P max.	S max.	Al_{whole}	Nb max.	Ti max.
HX220YD	1.0923	0.01	0.20	0.90	0.08	0.025	≤0.1	0.09	0.12
DX56D	1.0306	0.12	0.50	0.60	0.10	0.045	-	-	0.30

Each steel strips are available with types of coatings +Z, +ZF, +ZA, +AZ, +AS. Client required for requested material the surface finish Z200 (see Tab. 2) that ranges from a thickness (10 ÷ 20) μm and a density surface finish layer of zinc 7.1 $g \cdot cm^{-3}$.

Tab. 2 Mechanical properties of strips from steels HX220YD and DX56D for cold forming according to ČSN EN 10346.

Steel types			Mechanical properties				
Steel mark	Numeric marking	Surface finishing	R_e (MPa)	R_m (MPa)	A_{80} (%)	r_{90} (-)	n_{90} (-)
HX220YD	1.0923	+Z200	220 ÷ 280	340 ÷ 420	32	1.5	0.17
DX56D	1.0306	+Z200	120 ÷ 220	260 ÷ 350	36	1.6	0.18

Tab. 3 The values of the plastic strain ratio r_x in direction of 0°, 45° and 90° towards sheet-metal rolling direction, the values of weighted average of plastic strain ratio, degree of planar anisotropy of plastic strain ratio of strip from steel DX56D.

r_0 (-)	r_{45} (-)	r_{90} (-)	$\bar{r}$ (-)	Δr (-)
2.22	1.82	2.6	2.12	0.59

Tab. 4 The values of the plastic strain ratio r_x in direction of 0°, 45° and 90° towards sheet-metal rolling direction, the values of weighted average of plastic strain ratio, degree of planar anisotropy of plastic strain ratio of strip from steel HX220YD.

r_0 (-)	r_{45} (-)	r_{90} (-)	$\bar{r}$ (-)	Δr (-)
1.41	1.35	1.72	1.46	0.22

Tab. 5 The values of the strain hardening exponent n_x in directions of 0°, 45°and 90° towards sheet-metal rolling direction, the strain hardening exponent mean value n_m, the planar anisotropy degree of strain hardening exponent Δn of strip from steel DX56D.

n_0 (-)	n_{45} (-)	n_{90} (-)	n_m (-)	Δn (-)
0.19	0.23	0.22	0.21	-0.03

Tab. 6 Values of the strain hardening exponent n_x in directions of 0°, 45°and 90° towards sheet-metal rolling direction, the strain hardening exponent mean value n_m, the planar anisotropy degree of strain hardening exponent Δn of strip from steel HX220YD.

n_0 (-)	n_{45} (-)	n_{90} (-)	n_m (-)	Δn (-)
0.19	0.17	0.20	0.18	0.03

Steel strips are supplied in coils. Strip length is determined by weight of the coil. For the elaboration of a given stamping in progress drawing tool is supplied for roll of sizes (0,65x600) mm according to EN 10346 which corresponds to ČSN EN 10346 (42 0110) with the name: *Continuously hot-dip coated steel flat products – Technical delivery conditions.* The standard specifies requirements for flat products thicknesses from 0.35 mm to 3 mm.

Coils suppliers are steel producers ThyssenKrupp Steel AG, Europe and Voestalpine AG who guarantee the chemical composition and mechanical properties. Properties of these materials (see Tab. 1 and Tab. 2) correspond to the requirements in the automotive industry. Drawing of stamping is performed on a hydraulic transfer press Schuler 250.

2 PREPARING OF INTRICATE SHAPE STAMPING MODEL FOR DRAWING PROCES SIMULATION

For stamping with complex shape transition areas a uniform and symmetrical forming sheet-metal is necessary to provide. It is important to eliminate created by wrinkling, ripple, cracks and other defects that during sheet-metal forming stamping of complex intricate shape occur. The result of intricate shape stamping drawing process simulation is to get information on the process of forming drawability stamping, use of stock plasticity, thinning of the sheet-metal, the occurrence of wrinkling. These properties are critical factor that influences the total quality of stamping, its applicability and durability.

2.1 Creation of stamping model for drawing process simulation

For the creation model to drawing process simulation as the default stamping model was used that client made in software CATIA V5 R19. The file format has been transformed from format *.CAT Part (Computer Aided Translation) into the format *.step (exchange format 3D CAD data). All modifications to the shape of the model die were created in module *Surfaces* from specified stamping in software Solid Works 2008. There have been blinded by all the holes and shape of the model was pulled such a way that there were no operations for bending (see Fig. 3). Operation cut-out holes and bending the side walls (see Fig. 2) is done after completion of stamping drawing operations in the progressive drawing tool.

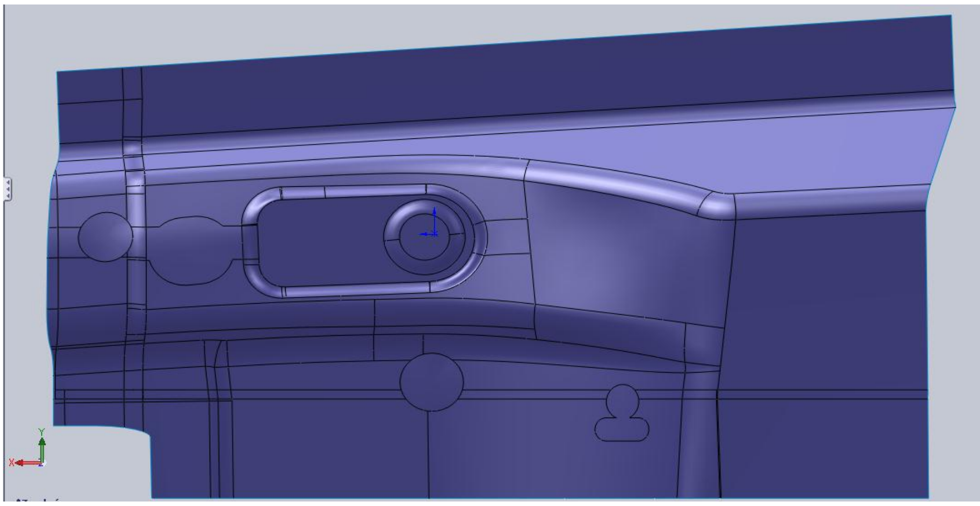


Fig. 3 Shape of initial stamping internal reinforcement of car bodyshell B-pillar after treatment blinding holes and surfaces extension in software Solid Works 2008 before adjusting for the creation of die model.

There is a fixed system known The Global Coordinate System (GCS) that for creation drawings is used that in terms of a need to create a 3D model of stamping is not needed. The default model was turn in the coordinate system that corresponded to location of the part on car body. For this reason it was done centering of the stamping using *Reference Triad* to the user coordinate system (UCS) that was chosen in a negative Z-axis direction of the drawing. This eliminates time-consuming alignment axial of blanks (*"BLANK"*) generated in the BSE module of Dynaform 5.7 software towards to model die (*"DIE"*) because this software has defined the direction of drawing in the negative direction of axis Z.

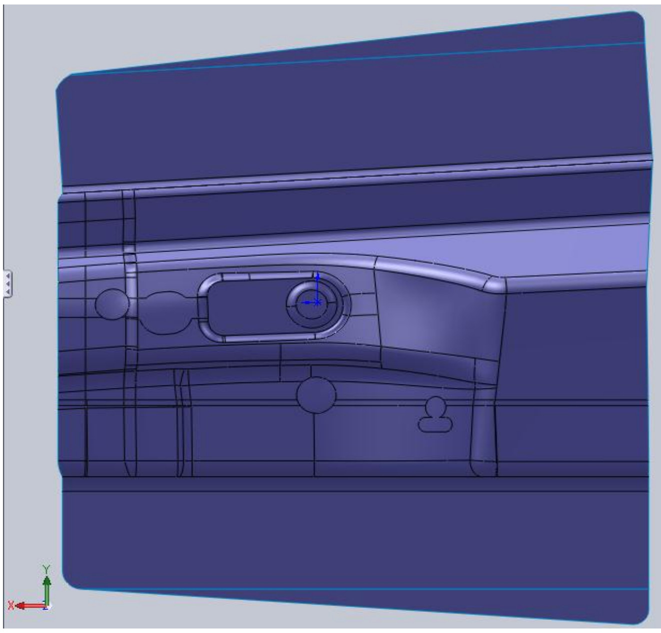
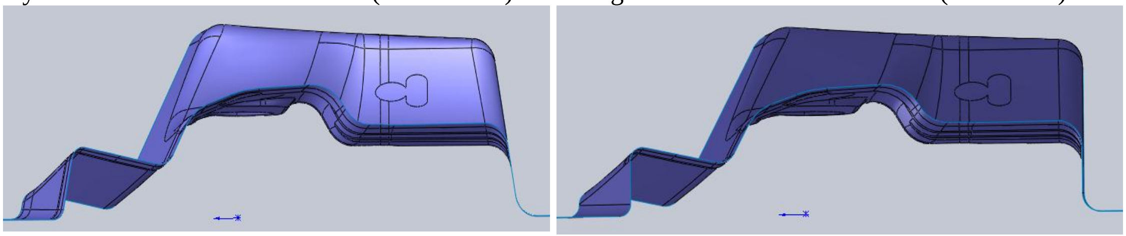


Fig. 4 Modified shape of model die(*"DIE"*) in software Solid Works 2008 for drawing process simulation in software Dynaform 5.7.

After setting in the coordinate system by using module *Surfaces* of software Solid Works 2008 were modified elongation of model with side walls (see Fig. 4) and straight side wall (see Fig. 5) by reason die model where it was observed deformation of the material during forming and to generate binder in software Dynaform 5.7. The rule is for simulate in simulation software Dynaform 5.7 that the binder area (*"BINDER"*) must be greater than the area of blanks (*"BLANK"*).

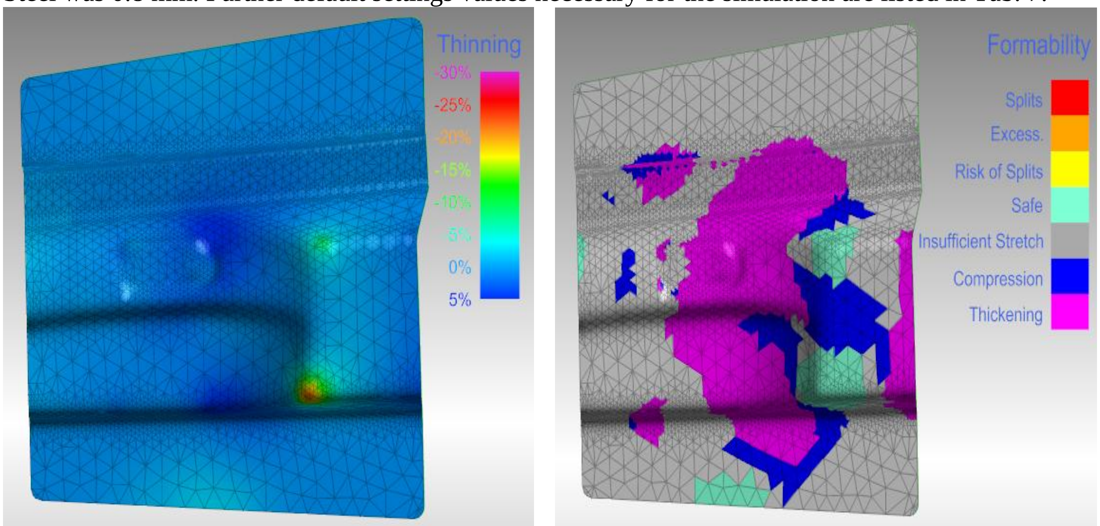


a) b)

Fig. 5 Modified shape of die model (*"DIE"*) in software Solid Works 2008 for drawing process simulation of stamping of internal reinforcement of car bodyshell B-pillar in software Dynaform 5.7 (a – sloping side wall, b – straight side wall).

2.2 Tuning of dimensions and quick verification of drawability generated stamping model for drawing process simulation

For quick verification of the suitability generated model, whose shape was modified in the software Solid Works 2008, of irregular shape stamping for drawing simulation software EasyBlank was used. EasyBlank is software developed by AUTOFORM Engineering that uses solver AUTOFORM-one-step model for meshing stamping, estimating the shape of blanks and a suitable location on semi-product sheet-metal. The calculation allows using default setting values by program, including setting triangle mesh, quick verification bottlenecks in stamping and tuning suitable shape stamping for drawing process simulation (see Fig. 6). The calculation carried out within a few minutes under the simplified default set of parameters. Types materials identified as Mild Steel, High Strength Steel, Dual Phase Steel, etc. are on selection. The specified geometry stamping is calculated thickness of material medium. Nearest default setting for the material thickness of High Strength Steel was 0.8 mm. Further default settings values necessary for the simulation are listed in Tab. 7.



a) b)

Fig. 6 Analysis of drawability of stamping of internal reinforcement of car bodyshell B-pillar using EasyBlank software (a – analysis of material thinning at drawing, b – analysis of drawability).

Tab. 7 Default setting values of EasyBlank software.

Thickness (mm)	E (MPa)	R_e (MPa)	R_m (MPa)	A_{80} (%)	$\bar{r}$ (-)
0.8	210000	168	304	25	1.65

3 DRAWING PROCESS SIMULATION AND DEFINITION OF CRITICAL AREAS OF DEFORMATION

Simulation drawing of intricate shape stamping – internal reinforcement of a car bodyshell was performed in software Dynaform 5.7. This program belongs to a group of computer programs and operating based on FEM (Finite Element Method – an abbreviation of *"FEM"*). For drawing process simulation in this simulation program must be defined many input parameters that are described below.

The software works with the 3D model of stamping and blanks that were imported in *.igs (Initial Graphics Exchange Specification). The optimal shape of blanks in module BSE (Blank Size Engineering) software Dynaform 5.7 was created from supplied of electronic model. The optimal shape of die was modified in the software Solid Works 2008. Both the models of die (see Fig. 5) and blanks were matched in the software EasyBlank (see Fig. 6). Computer network blank are generated in the environment of graphic pre-processor along with the necessary boundary conditions solution. Accuracy result is given based on the shape, boundary conditions and type of analysis. Size and shape of individual elements are predefined by default and necessary can be modified, if needed to refine the results of simulation.

Correct definition of input parameters to drawing process simulation and strain rate parameter settings, size of force binder, lubrication has a decisive influence for tuning of model stamping in progressive tool.

3.1 Definition of blank material

The next step after importing of the models die and blank into simulation program material properties is to define that must be entered before calculation. Selection is made from material database programs or material can be added according to the test results and thereby improve the simulation results.

For defining of material Lankford´s coefficients r_0, r_{45} and r_{90} (or anisotropy coefficients) towards sheet rolling direction α were used that is determined by formula:

$$r_\alpha = \frac{\varepsilon_w(\alpha)}{\varepsilon_t(\alpha)} \ (-), \qquad (1)$$

where are ε_w – width strain and ε_t – thickness strain.

Definition of blanks for the size of lattice elements (*"Radii"*) with the "*Radii = 3"* with regard to size of blanks were carried. The material properties of strip steel DX56D and HX220YD with material thickness 0.65 mm were entered for blanks. Values were used that listed in the Tab. 2 to Tab. 6.

3.2 Definition of drawing tool parts and their appointment to the auto position

For surfaces discretization in finite element network created meshing element of size 5 mm on parts of the drawing tools was chosen given the size of the stamping. Consequently, it is necessary assign positions to each area of the tool part in forming process. The menu *"Define Tools"* in defining parts of drawing tool to different parts of the models were assigned already preset tools for parts of the drawing tool (*"DIE, PUNCH, BINDER"*).

The punch movement speed is according to recommendation of the technical literature in range between 0.4 ÷ 0.6 m s^{-1}. This speed is suitable for smaller presses. The speed of 0.4 m s^{-1} was chosen.

The binder was made from the model of die („*DIE*“). The value of the holding force F_{p1} for intricate shape stamping with straight wall is listed in Tab. 8. Tab. 9 lists holding force F_{p2} for intricate shape stamping with sloping side wall. Specific pressure of binder ranges $p_p = (1.8 \div 2.8)$ MPa as recommended in the technical literature. The pressure of $p_p = 2.6$ MPa (see Tab. 3 and Tab. 4) was chosen. The size of holding force F_p can be calculated from the relationship:

$$F_p = 0{,}1 \cdot \left(1 - \frac{18 \cdot M \cdot h_0}{(M-1) \cdot 2 \cdot b_0}\right) M^2 \cdot F_{0\max} \text{ (N)}, \tag{2}$$

where are b_0 – the radius of initial blank (m), h_0 – blank thickness (m), M – drawing coefficient (–), $F_{0\max}$ – deformation force at the beginning of drawing (N).

Deformation force at the beginning of drawing $F_{0\max}$ which is necessary to calculate the pressing force F_p in equation (2) can be determined:

$$F_{0\max} = 2 \cdot \pi \cdot a \cdot h_0 \cdot \sigma_{r\max} \text{ (N)}, \tag{3}$$

where are a – stamping finite radius (m), h_0 – blank thickness (m), $\sigma_{r\,\max}$ – maximum radial tensile stress (Pa).

Tab. 8 Holding forces for blank of intricate shape stamping with straight side wall.

Blank	Area of Blank S_i (mm^2)	Effective Area of Binder (mm^2)	Specific Pressure p_p (MPa)	Holding Force F_{p1} (N)
BSE Modul	84690.9	52460.8	2.14	83800

Tab. 9 Holding forces for blank of intricate shape stamping with straight side wall.

Blank	Area of Blank S_i (mm^2)	Effective Area of Binder (mm^2)	Specific Pressure p_p (MPa)	Holding Force F_{p2} (N)
BSE Modul	84690.9	34115.5	2.6	74460

4 EVALUATION OF DRAWING PROCESS SIMULATION AND TUNING OF INTRICATE SHAPE STAMPING DIMENSIONS

The drawability analysis of stamping (see Fig. 7) shows colormap of strain stamping with estimated size and occurrence of wrinkling. Effort is to achieve at stamping the highest possible degree of strain by compliance with other conditions simulation, i. e. low value risk of failure, sheet-metal thinning and the occurrence of wrinkling. Deformed edge of stamping is less likely to spring-back. Due to the local material thicking arises wrinkling at stamping, both the model with straight side wall and a in the model with a sloping side wall, and usage compared both materials DX56D and HX220YD. In this case of secondary wrinkles occurs on stamping stroke length and the bottom side wall of stamping where the influence of tangential stress leads material thicking. Fig. 8 shows the drawability analysis of stamping by using the forming limit diagram where all states of deformation detected in the stamping located in safe area from the perspective stamping risk of crack. Minimum thickness of stamping in the critical point is 0.49 mm and maximum thickness of stamping influence thicking the material is 0.77 mm. Further, the forming limit diagram shows the maximum and minimum values of deviations from safe thicking strain given of stamping. The largest deviations from safe areas of strain are characterized by compressing *“WRINKLE TENDENCY”* (blue area) and thicking *“WRINKLE”* (purple area) of the material. These critical areas were also considered in evaluating the simulation results and tuning real results.

The risk analysis fracture of stamping is given a numeric value that represents the highest use stock of plasticity in the place of stamping. If the result gets to value of 1, it means that the deformation lies on the limit deformation curve in forming limit diagram and the limit sate is reached that is tensile strength, or local thinning or failure sheet-metal.

From results of simulation intricate shape stamping – internal reinforcement of car bodyshell B-pillar follow that the secondary wrinkles during drawing leads in wall of stamping. For reasons unsuitability use of draw beads follow that drawing must be made more draws so as wrinkling of side walls removed and compliance outline contours of stamping with tolerances and stamping deviations from the nominal dimension, according to prescribed values on the production drawing. According to the regulation in production drawing the 70 % tolerance is possible to use.

Series test of stamping were made drawing after functional alignment of progressive drawing tool for more draws. These stampings were measured on control product. During measurements deviation of outlines, location and holes dimensions, shape deviations were observed. Tolerance monitored parameters are specified on the production drawing of stamping. The stamping was placed on the RPS surface (see Fig. 2) and centered on the RPS holes at gauging fixture. The RPS points and auxiliary areas are points of reference that they are used for set up of stamping to same measuring system. The system of RPS points defines measuring base from that other dimensions are measured. On several reports are based to correct dimensions and from them to calculate average values of deviations.

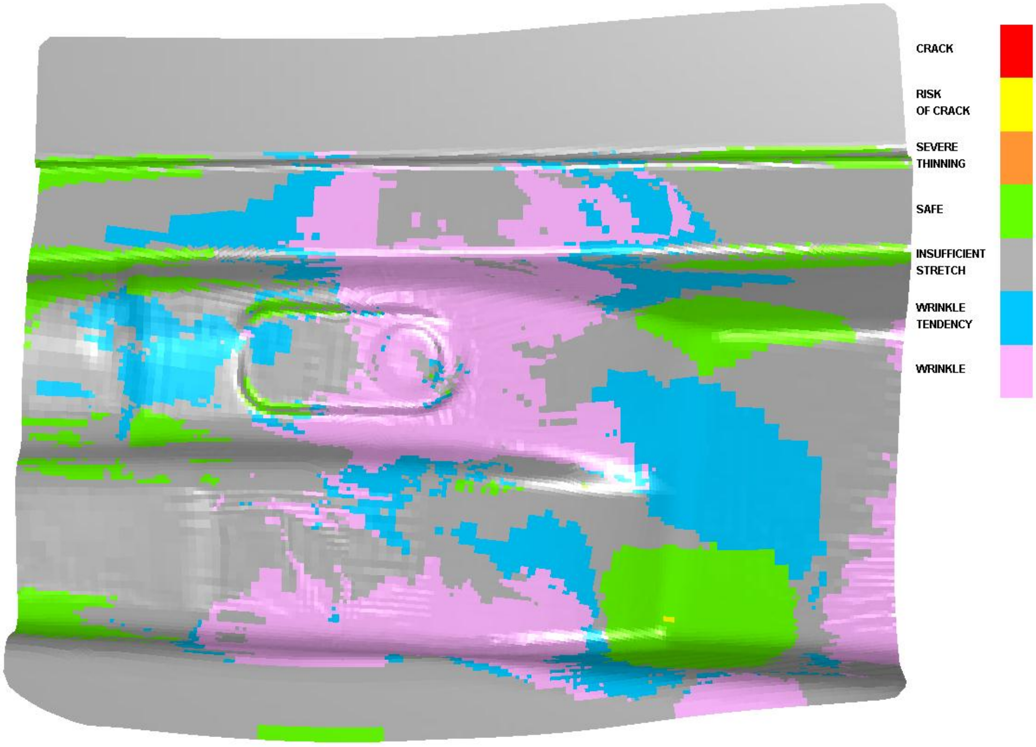


Fig. 7 Results of drawing simulation of stamping of internal reinforcement of car bodyshell B-pillar with straight side wall from material DX54D.

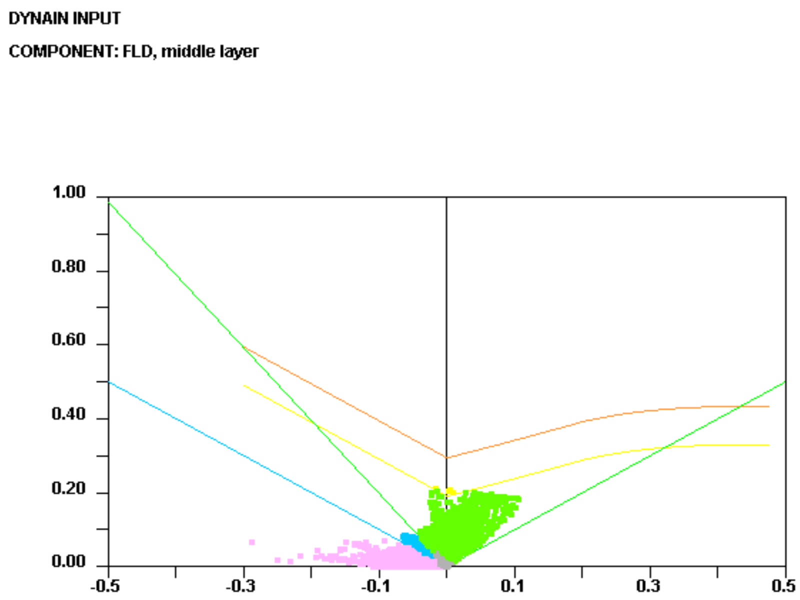


Fig. 8 Drawability analysis of stamping of internal reinforcement of car bodyshell B-pillar with straight side wall of material DX54D using the forming limit diagram where all states of strain detected at stamping lies safe in terms of the risk of the stamping crack.

Dimensional measurement using RPS points of stamping at the control product on the 3D measuring device Wenzel was performed, measuring range (800 x 700 x 700) mm with accuracy of 0.003 mm measuring device length on 300 mm. The results of measurement show measured points on stamping and their dimensional values. These values are showing deviations from the actual dimensions. Values are marked in green that meet the prescribed tolerance, yellow values are borderline (Fig. 9). Off-size values are marked in red that are over the border prescribed values on the production drawing and they must be repaired modifying of drawing tool parts. The modification is done by changing shape of drawing tool parts and for positive deviations milling and grinding of the tool, for negative deviations by overlaying of weld bead, followed by milling and regrinding of drawing tool.

By measuring shape deviations first set of stamping and how it for using material DX56D specified to test the drawing tool as well as using material HX220YD was found, that unsatisfactory deviations from prescribed dimensions of manufacturing drawing is actually occur in critical areas of wrinkles, that correspond to areas on the basis of process simulation. Furthermore, in several areas there were to breach of protective layer zinc surface of stamping progressive drawing tool. For this reason, corrections were made adjustment of tools as described above.

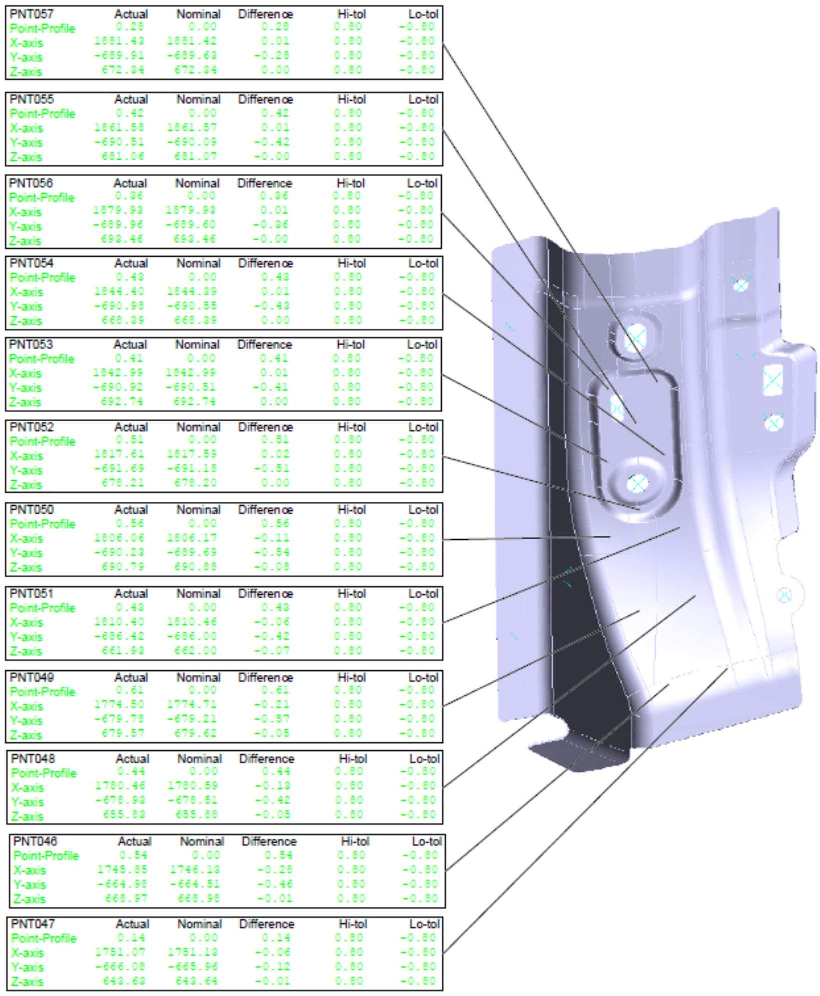


Fig. 9 Results of deviations shape measurements of stamping of internal reinforcement of car bodyshell B-pillar with straight side wall of material DX54D after correction of drawing tool parts.

5 CONCLUSIONS

At intricate shape stampings with large shaped transitions and deep drawing the spring-back comes after drawing process that by their size can cause that the stamping after drawing need not conform to tolerances specified on production drawing. For this reason, it is important to determine the areas where material of stamping is excessively thinned – in these places is risk of cracks or the places most influence the shape of drawing tool parts. The priority is to prevent this state and correct the drawing tools parts in such way as to stamping remained after drawing in tolerance fields prescribed at the manufacturing drawing.

At internal reinforcement of car bodyshell B-pillar by drawability analysis of stamping from drawing simulation of stamping using software Dynaform 5.7 the critical areas were identified. At simulations the stamping with sloping wall of stamping showed better results than the stamping with straight wall. When using material DX56D the stamping did not show any signs of cracks, excessive thinning of wall, material thickness was almost uniform throughout stamping. Due to local material thicking in the side walls and stamping stroke length in transition, however, secondary wrinkling of stamping arises. This secondary wrinkling cannot be removed nor suitable angle of slope side wall, nor fitting transition radius. When using material HX220YD the thinning of wall occur in critical place on wall thickness of 0.45 mm, but secondary wrinkling in the walls of material stamping in comparison with material DX56D are lower. The wrinkle occurs in critical areas when using both materials. According to thickness of own stamping, that is 0.65 mm, it is not useful to use the draw beads which was verified by drawing process simulation. The reason for inappropriateness of draw beads was excessive thinning of wall stamping, which has led to the emergence of cracks in walls of stamping during drawing due to local braking of material. Because the permissible wrinkles were exceeded during drawing, as shown by Fig. 8, the more operational drawing in progress tool was chosen. By this the wrinkling in side walls and in stamping stroke length in tolerance prescribed for production drawing decreased.

Critical areas identified by stamping drawing simulations were compared with the actual measurement set of stampings. Measurements of shape deviations areas location and size of holes to stamping were taken at the measuring product using RPS points. By comparison it was evaluated, that the critical areas, in which deviations are unsatisfactory from dimensions specified at production drawing actually occurs in critical areas of wrinkling that correspond to areas identified by drawing process simulations and compared for both materials. At intricate shape stampings these critical areas cannot be avoided but by suitably chosen number of moves it is possible positively influence the final dimension accuracy of stamping.

REFERENCES

[1] ČADA, R. *Tvářitelnost materiálů a nekonvenční metody tváření: Plošná tvářitelnost: návody do cvičení: skriptum.* 1. vyd. Ostrava: VŠB – TU Ostrava, 2002. 148 s. ISBN 80-248-0019-5.

[2] ČADA, R. *Tvářitelnost ocelových plechů: odborná knižní monografie.* Lektorovali: L. Pollák a P. Rumíšek. 1. vyd. Ostrava: REPRONIS, 2001. 346 s. ISBN 80-86122-77-8.

[3] ČADA, R. *Plošná tvářitelnost kovových materiálů.* 1. vyd. Ostrava: VŠB – TU Ostrava, 1998. 90 s. ISBN 80-7078-577-8.

[4] TIŠNOVSKÝ, M. a MÁDLE, L. *Hluboké tažení plechu na lisech.* 1. vyd. Praha: SNTL, 1990. 200 s. ISBN 80-30-00221-4.

[5] KOTOUČ, J. *Nástroje pro tváření za studena.* 2. vyd. Praha: České vysoké učení technické v Praze, 1982. 158 s. (bez ISBN).

[6] PRIMUS, F. *Teorie tváření plechu a trubek: skriptum.* 2. vyd. Praha: České vysoké učení technické V Praze, 1980. 235 s. (bez ISBN).

[7] EVIN, E., HRIVŇÁK, A. a KMEC, J. Získavanie materiálových údajov pre numerickú simuláciu. In: *Zborník prednášok 7. medzinárodnej konferencie TECHNOLÓGIA 2001: I. diel.* Bratislava: Slovenská technická univerzita v Bratislavě, 2001, s. 281-284. ISBN 80-227-1567-0.

[8] EVIN, E., et al. CAE podpora pri navrhovaní výroby výliskov. *Transfer inovácií* [online]. 2006 [cit. 2009-04-24], s. 73-76. Dostupný z: <http://www.sjf.tuke.sk/transferinovacii/pages/archiv/transfer/9-2006/pdf/73-76.pdf>.

[9] AUDY, J. a EVIN, E. Exploring efficiency of tool coating via deep drawing of cylindrical cups. *MM Science Journal* [online]. 2008 [cit. 2008-06-20], s. 20-23. Dostupný z: <http://www.mmscience.eu/archives/mmsj_2008_06_audy.pdf>.

[10] ETA, Inc. *Eta/DYNAFORM User's Manual: Version 5.7.3.* Michigan: ETA, Inc., 2010. 730 s.

[11] ČSN EN 10346 (42 0110) *Kontinuálně žárově ponorem povlakované ocelové ploché výrobky – Technické dodací podmínky.* Praha: Český normalizační institut, 2009. 30 s.

[12] ČSN EN 10325 (42 0343) *Ocel – Stanovení přírůstků výrazné meze kluzu vyvolaného tepelným zpracováním (index Bake-Hardening).* Praha: Český normalizační institut, 2007. 8 s.

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