RAPID TOOLING USE WHEN VERIFYING NUMERICAL SIMULATION OF DEEP DRAWING PROCESS

VYUŽITIE METÓDY RAPID TOOLING PRI VERIFIKÁCII NUMERICKEJ SIMULÁCIE HLBOKÉHO ŤAHANIA

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Abstract

The contribution deals with design of production the gutter corner for rainwater systems. The deep drawing process has been simulated in Pam Stamp 2G software by ESI Group and the part and blank geometry, friction and process parameters have been optimised. Then, those parameters of the deep-drawing process and die geometry were verified by experiment. The Rapid Tooling method based on metal laminated technology was used for production of the punch by applying the laser cutting, assembling and joining. The experiments were done using hot deep galvanized steel sheet DX54D+Z with thickness 0.7 mm.

Key words

numerical simulation, rapid tooling, punch, laser cutting, deep-drawing

Introduction

The development of informatisation and progressive innovation of the information technologies allows applying CA systems to production. In principle, it deals with a full computer support from the design of model to the final product realisation. Consequently, It leads to the production time shortening and saving of costs. Nowadays, the production process of deep-drawn parts is realised by CAE systems based on numerical simulation, such as Pam-Stamp 2G simulation software and it is mainly used in the simulation of forming processes of metals and their alloys. [1, 2].

Numerical simulation uses simulation model created as an artificial object and its behavior under specified conditions is simulated. Numerical simulation of forming processes is based on finite element method, which is considered as the most progressive method of plastic deformation research. In the finite element method, the workpiece is divided into elements. After aplying boundary conditions and process parameters to the elements, based on set of equations, the major and minor stress and strains are calculated to each element and these are visualised as thickness value, thinning etc. [3, 4]

Quick geometrical changes of complex components produced by stamping, based on computer aid by 3D CAD or CAD/CAM software, require new technologies for quick production of stamping dies in order to verify its production by physical modelling. These processes are based on additive and subtractive technologies such as laser cutting, laser welding and CNC milling [5].

The metal sheet lamination technology was developed in 80’s for Rapid Tooling of large car body parts [6]. An automated process for the manufacturing of forming tools (see Fig. 1) was developed by Toyota group and consists from a special machining centre, Nd-YAG laser for cutting and welding and an automated sheet metal loader. [7]. Nowadays, development and improvement of new process chains for manufacturing of large tools is done at the Fraunhofer Institute for Material and Beam Technology. Different technologies for cutting, assembling and joining of metal sheets by the LOM principle are used with regard to reduce the manufacturing time and costs [5].

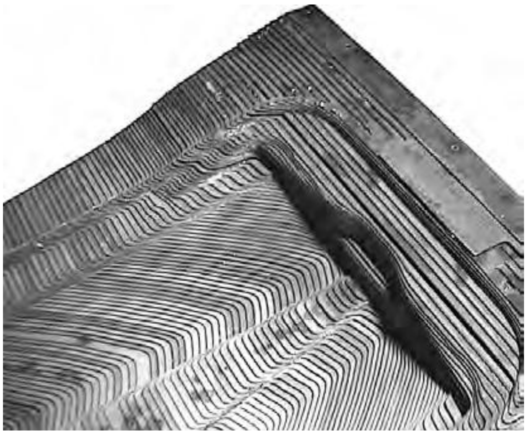


Fig. 1 Laminated die component [5]

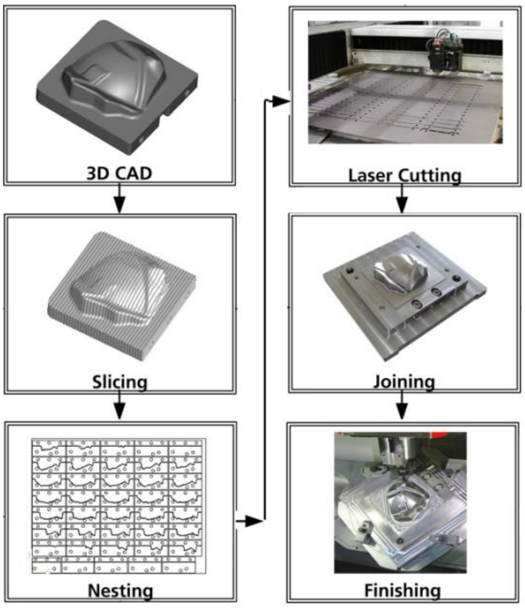


Fig. 2 MELATO® - process chain [8]

The MELATO® (MEtal LAminated TOoling) technology, developed by Fraunhofer IWS together with partners from the industry, allows producing deep drawing-, stamping- and injection molding tools of various sheet metal materials [8]. The process chains of MELATO consist in following steps: [5]

1. Data Preparation – 3D CAD data of the tool to be manufactured are read into the CAD system. The tool is then modified into contour geometry and tool frame. Contour geometry will be manufactured by metal sheet lamination. Tool frame contained no complex shaped surfaces and is easy to manufacture conventionally. Then, tool insert is sliced into single cross sections. After slicing, the single cross sections are arranged on a metal sheet panel.
2. Building process – consists of Laser cutting and Joining. Laser cutting is used to manufacture cross sections free of burs to ensure high accuracy in the slicing direction. The joining method is the key to MELATO. Several technologies might be considered, but the usage of the tool determines the bonding type [5].

Table 1 Joining methods [5]

	Application range
Laser welding	Metal sheet forming tools, core boxes
Diffusion welding	Injection molding tools, pressure die casting tools
Bonding by adhesives	Metal sheet forming tools
Screw, anchors	Metal sheet forming tools, core boxes

3. Post process - Laser Build-up welding and Finishing. For reinforcement of heavily loaded sections, e.g. draw edges of forming tools, laser build-up welding is applied. This welding technique is also considered for the connection of lamellae. Finally, the tool is finished by CNC milling, EDM, polishing and heat treatment. [5, 8]

Methods of experiments

The deep drawing process of gutter corner for rainwater system (see Fig. 3) was proposed, numerically simulated and experimentally verified in the Laboratory of forming processes. The drawpiece is a complicated in shape due to low inside radius R39 and disproportional material plastic flow at straight die parts (high plastic flow) and inside radius (low plastic flow) when produced by deep-drawing. Thus, mentioned causes excessive stretching by tensile radial and tangent stresses at inside radius and cracks may occur when oversize blankholding force or excessive blank are applied.

Fig. 3 The gutter corner for rainwater system

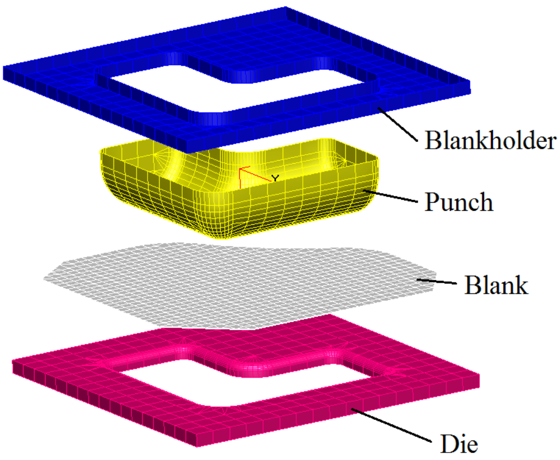
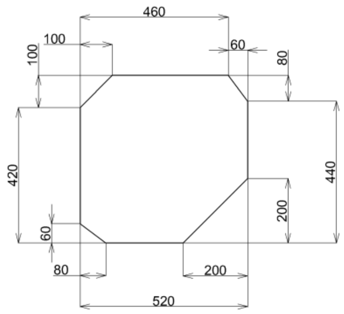


Fig. 4 Experimental drawing die

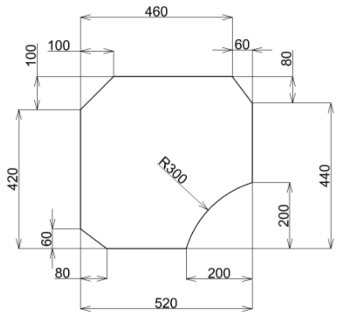
Numerical simulation of the deep-drawing process of the gutter corner was performed before production of the experimental die in order to find out the proces parameters – blankholding force, part and blank geometry, friction. The die setup after meshing 3D CAD model in Pam Stamp 2G is shown in Fig. 4. Following input data were set up in Pam Stamp 2G preprocessor:

- basic material data - density, Young's modulus, Poisson's constant,
- blank thickness – 0.7 mm,
- strain-hardening curve defined by Hollomon's law: $\sigma = 487.\varphi^{0.215}$,
- Lankford's coefficients $r_{0°} = 1.98$, $r_{45°} = 1.04$ and $r_{90°} = 1.59$,
- Yield law defined by Orthotropic Hill 48 model.

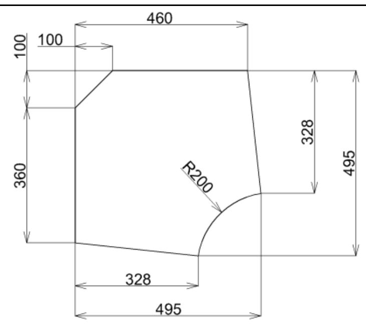
Table 2 Variants of blank shape



1st option



2nd option



3rd option

The blankholding force was set to 220 kN based on the recommended blankholding pressure 2 MPa for drawing quality steel sheets. The friction between blank and blankholder, die as well as punch was set to 0.1 (microten foil) and 0.2 (grease). The blank size and shape tested in numerical simulation are shown in Tab. 2

The experimental drawing die was designed using CAD/CAM system Pro/Engineer Wildfire 5.0 – Fig. 5. The welded box construction of upper (drawing die) and lower (blankholder) die parts as well as punch were created from thick steel sheets. Drawing die and blankholder functional surfaces were cut by plasma.

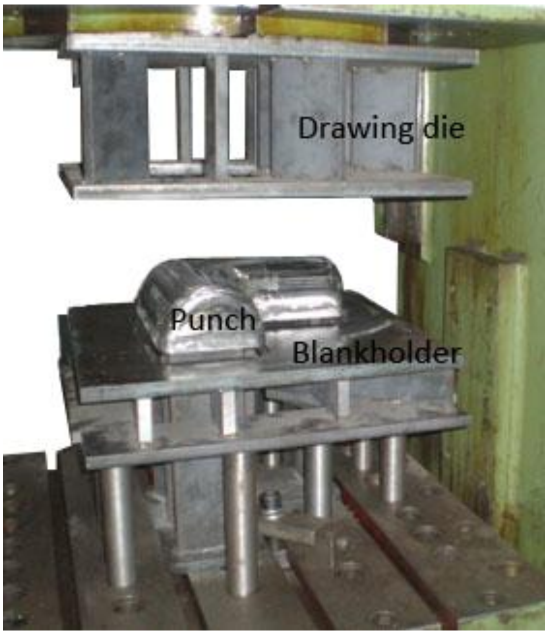


Fig. 5 Experimental drawing die

The most complicated part of the experimental drawing die was punch. The shape of punch was created with two perpendicularly intersected semi-cylinders (Fig. 6). The MELATO method was implemented to produce punch for experiments and it has been adjusted to punch shape, dimensions and required accuracy. The 3D punch model was sliced into single cross sections as it is shown in Fig 7.

The slice direction was taken perpendicular to punch path in order to prevent any movement of the lamellas due to drawing forces. To prevent tangent movement of lamellas pins were used to create mechanical join. The parallel cross sections were created in distance 5 mm. The last four cross sections were created with distance 1 mm in order to refine steps between slices. 17 cross sections were created total. After slicing, the single cross sections were arranged on a metal sheet panels. 13 cross sections were arranged on metal sheet with thickness 5 mm and last four cross sections were arranged on metal sheet with thickness 1 mm – Fig. 8.

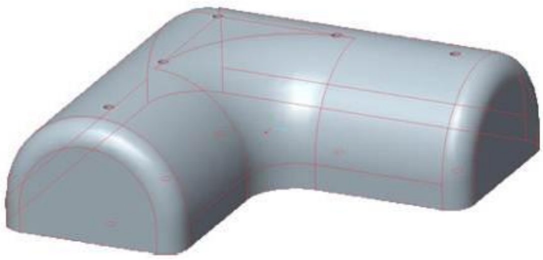


Fig. 6 Shape of the punch

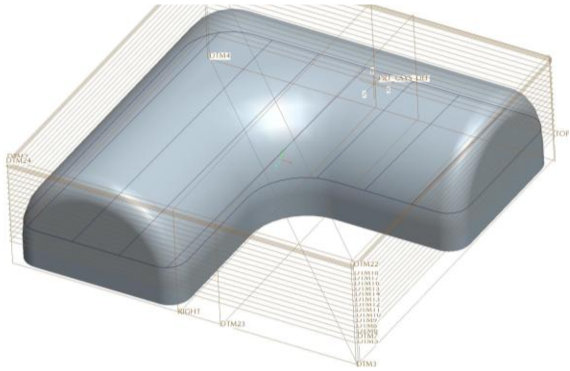


Fig. 7 Slicing of punch to create cross sections

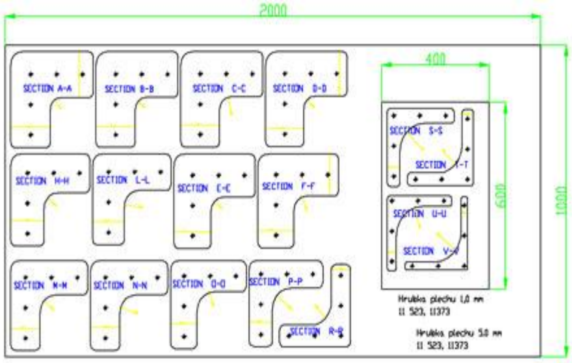


Fig. 8 Nesting of cross sections

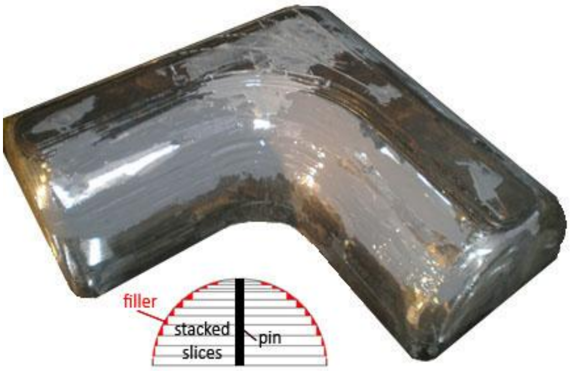


Fig. 9 The punch after bonding and grinding

The main body of punch (the punch body) was cut by plasma from thick steel sheet with thickness 20 mm. Lamellas cut by laser were stacked to the punch body and joined together by pins to fix their position – Fig. 9. To create smooth punch outer surface, two component polyester filler Galvaplast 77 was applied. After filler hardening the punch outer surface was regrind to final shape as it is shown in small sketch in Fig. 9.

Reached results

The critical area of the drawing die was inside radius R 39 and material fracture has been found in simulations for all of tested blank shapes and friction coefficients, as it is shown in Fig. 10 in dark blue colour. Therefore, the inside radius has been changed to R 49 and the simulation was succesfull considering the forming limit diagram when the 3rd option of blank shape and friction coeficient f = 0.1 were set (Fig. 11).

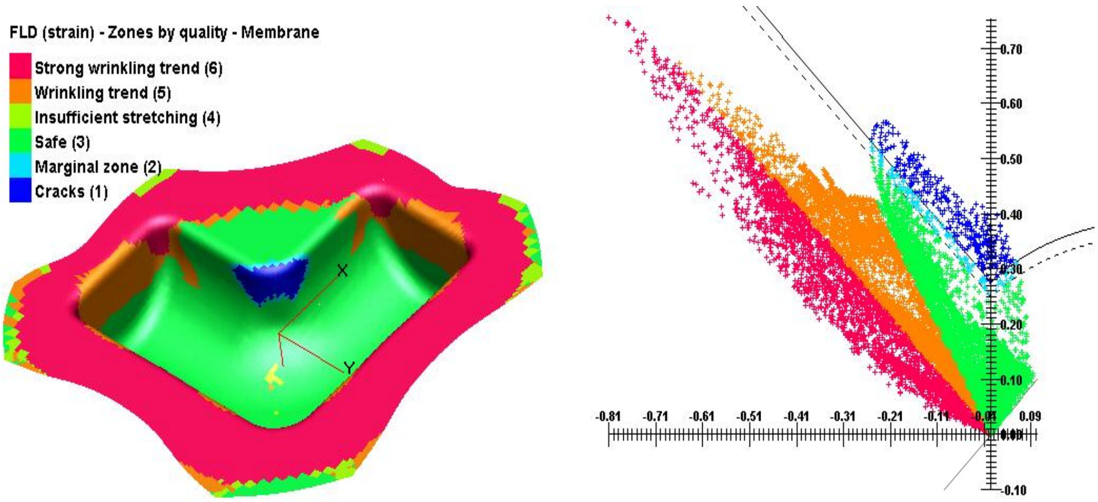


Fig. 10 Simulation result (FLD by quality) for 1st blank shape, friction f = 0.1 and R 39

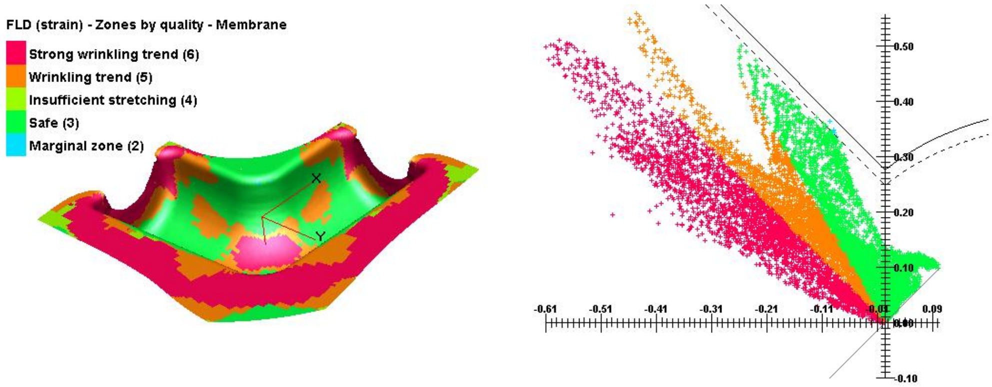
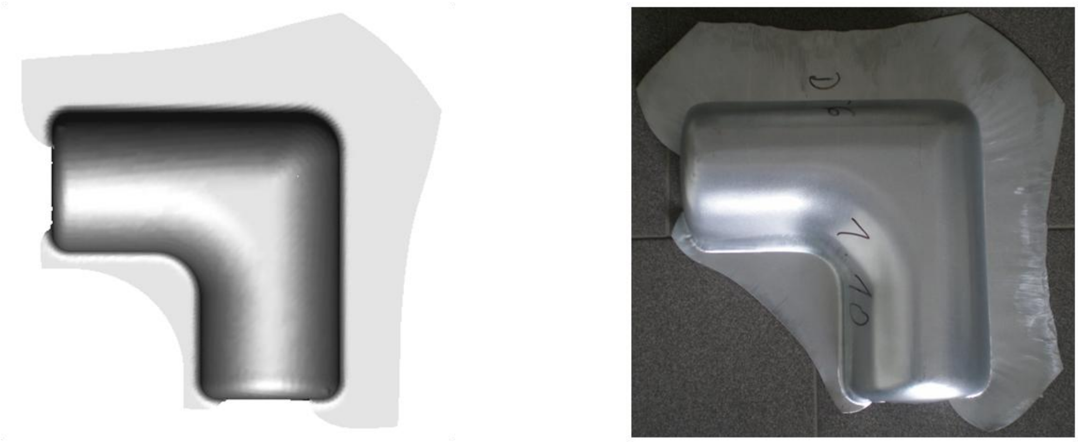


Fig. 11 Simulation result (FLD by quality) for 3rd blank shape, friction f = 0.1 and R 49



a) b)

Fig. 12 Comparison of numerical simulation (a) and experimental drawpiece (b)

Based on results of numerical simulation, the blank shape 3 was deep drawn in experimental drawing die and microten foil was used as lubricant. The final drawn part of the gutter corner is shown in Fig. 12b compared to the shape after numerical simulation Fig. 12a.

Conclusion

The paper presents the rapid way to create and manufacture complicated shape of punch for deep drawing, based on modified MELATO method. The presented method is suitable for large punch sizes and the main advantage is time and cost reduction when different production method are tested and verified in preproduction of new components. Thus, laminated tools can be fabricated and modified in a time a cost effective manner.

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Key words

numerická simulácia, rapid tooling, ťažník, rezanie laserom, hlboké ťahanie

Abstract

Príspevok pojednáva o návrhu výroby rohového žľabu odkvapového systému. Proces hlbokého ťahania rohu žľabu bol simulovaný v softvéri Pam Stamp 2G od firmy ESI Group, kde boli optimalizované rozmery nástroja a prístrihu, trenie a parametre procesu hlbokého ťahania. Následne, boli parametre procesu hlbokého ťahania rohového žľabu verifikované experimentálne. Pri výrobe ťažníka rohového žľabu bola použitá metóda „Rapid Tooling" založená na spájaní kovových lamiel vyrobených rezaním laserom. Ako experimentálny materiál bol použitý žiarovo zinkovaný oceľový plech DX54D+Z o hrúbke 0,7 mm.

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