Stamping by using a virtual pressing tools

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Abstrakt

Článek představuje projekt analýzy vlivu okrajových podmínek na proces hlubokého tažení částí automobilových karosérií. Vliv okrajových podmínek se zjišťuje s využitím simulačního softwaru PamStamp 2G s daty reálných 3D oskenovaných nástrojů. V článku je popsána první fáze celého projektu, stavba výpočetní úlohy a verifikace výsledků simulace s reálným systémem.

Klíčová slova

Plošné tváření, Numerické simulace, 3D skenování nástrojů

1. Characteristic of automotive industry in metal sheet forming

Contemporary and modern automotive industry is characterized by increasing quality of manufactured cars and their components at the same time with decreasing of costs. These tendencies are apparent in production of car bodies. The car body is carrying part of the whole car and it has an influence on competitiveness and marketability.

There are high requirements in manufacturing of car bodies from the point of view of the quality on the one hand and of the productivity on the other hand. In the present we are on production-possibility frontier. Deep drawing process of large and shape complicated parts is very complex. There are many boundary conditions, which influence whole process. Those can result in significant scatter of part's quality. This complication of manufacturing process is leading to origin defects like cracks, limit thinning, waviness, mechanical damage of surface, etc. These defects can be limited during modifications of boundary conditions. As things stand it can lead to decrease of production and increase productions cost. [1]

Firstly it is necessary to specify boundary conditions, which have an influence on deep drawing process and possibility to control it. Generally it is material, its thickness and quality, parameters of tools (shape, draw beats), parameters of a machine (kinematics of a process, blank holder forces), tribological properties (surfaces layers, type of lubricating oil), shape of blank. As we can see, the optimization of process is very complex issue and requires knowledge and experiences from many technical areas.

1.1. Using a numerical simulations of the metal sheet forming in the automotive industry

For many years are used with high acceptance in present and modern engineering industry computer systems for basic design and optimizing of manufacturing process. It is design CAD programs on the one hand and simulations programs based on mechanics of pliable body, thus FEM (Final Elements Method) on the other hand. Using of simulations software can be viewed from two aspects. The first one is in basic design of new manufactured blank sheet forming process. The target is to define number of operation, design of stamping tools, optimize blank shape and control of the processing. [2]

The second view is in situation, when goes serious process and we want to optimize it. It is an effect of continual press on decreasing manufacturing costs. Often we change a quality of stamping material, lubricating oil, etc. Because of it we need a virtual pressing process, that is similar to real situation and with its help we can verify an impact of these changes.

Using of numerical simulations leads many of problems. The first one is alone design of computation task and verification with real manufactured systems. Generally we ignore some of boundary conditions and scattering of natural magnitudes, as a mechanical property, blank holder force scattering, friction coefficient etc. But the main problem is in CAD data of a stamping tool. Nowadays we use a data, that we obtain from design programs, such as CATIA, AutoCAD, Inventor Professional. These data are different from real tools, because real tools have to be incorporate, finished after machining. These shape differences cause deviations in results. Other problems are with definitions of boundary conditions and software settings, such as choice of material models, contact model, penetration model between networks of stamping material and tools, models of friction, etc.

2. Design of numerical simulation with 3D scanned data of tools

2.1. Import tools data

Generally we are using CAD data, which are output from design software. Practical experiences show us, that these data are different from real data. Forming tools have to be adjusted for real forming process. It follows, that they are shape grinding. There are shape modifications, such as local coarsening of active areas, modification of draw radiuses and draw beats. Changes are mostly realized only on based of experiences of team tool setters. These modifications we are not able to record in documentations. This is the reason, why we need scanned real data of forming tools for design a numerical simulation. In the figure 1 we can observe differences between CAD data and 3D scanned data of a right frame door of a car Skoda Roomster. We can see that maximal deviation is around 2 millimetres. It can have a great influence on final results of virtual stamping.

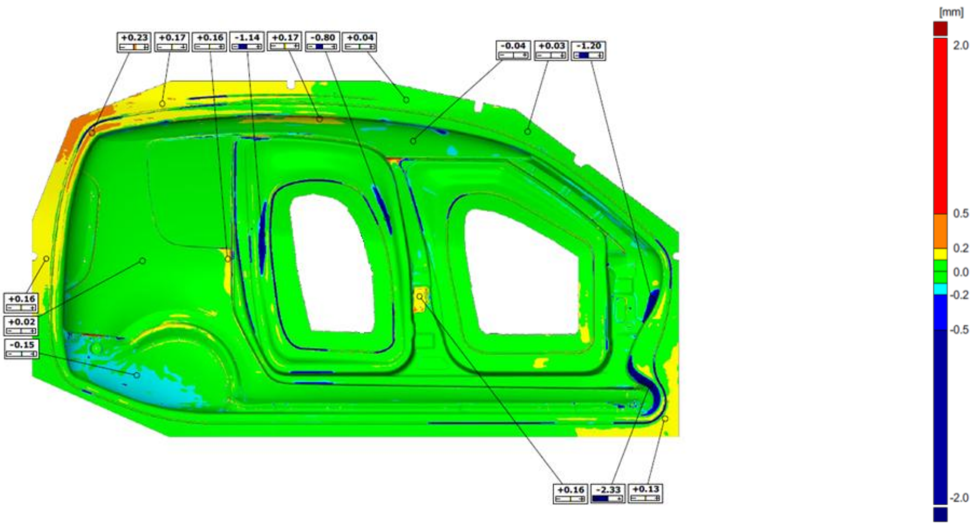

Fig. 1. *Deviaton between CAD data and 3D scanned data of a right frame door of Skoda model Roomster*

Nowadays there are two contactless methods of scanning a 3D digitization. In principal we can divide these methods into – lasers and optical.

Laser scanner uses a property of laser ray. Laser ray is dispatched against the object. Then it reflects and comes back to scanning device. Time data tells us information about distance between objects and scanner. Angle of ray shows us information about curvature of surface. With connecting both information is computer able to localized position of point in the space. Scanner is placed on robotic head that makes a movement around the object.

Optical systems are based on principal triangulation (digital reconstructions of shapes, dimensions and locations in the space) and photogrammetric (finding coordinates in space, and trigonometric calculations). Scanned object is labelled with an optical (references) labels and then is taken photos from the different position of a space. Computing systems will specify position of labels in space. The result is "a cloud of points", which represents scanned objects.

Work with these data brings many specific problems. There are problems with contact definition. We have to adapt finite-element networks, in the next we have to delete areas, that aren´t active in stamping process. Finally we have to extrapolate missing parts of the forming tools. In the figure 2 we can see two examples of specific problems with scanned tools. We can see part of tools, which is badly scanned during optical interferences. On the right side of the figure, we can see the part of tool, which isn't active in the process and we have to delete it.

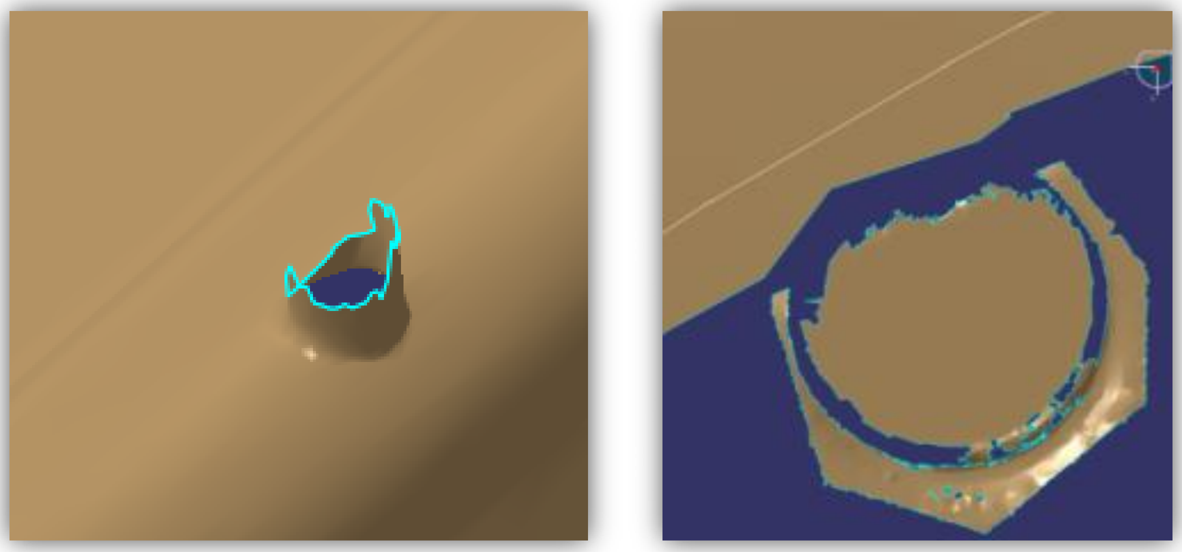

Fig. 2. *Examples of problems with scanning tools. On the left side is a deformation of network on active part of a tool and on the right side is a part of network, which has to be deleted, because it isn't active part of a tool.*

When we are finished with extrapolating missing parts, and deleting non-active parts of forming tools, we have to adjust finite-element network for using in numerical simulation program. This adjusting we can see in the figure 3. Networks have to describe exactly deep drawing process. It follows, that the networks on sharp radiuses have to have smaller elements, than in plane of stamping.

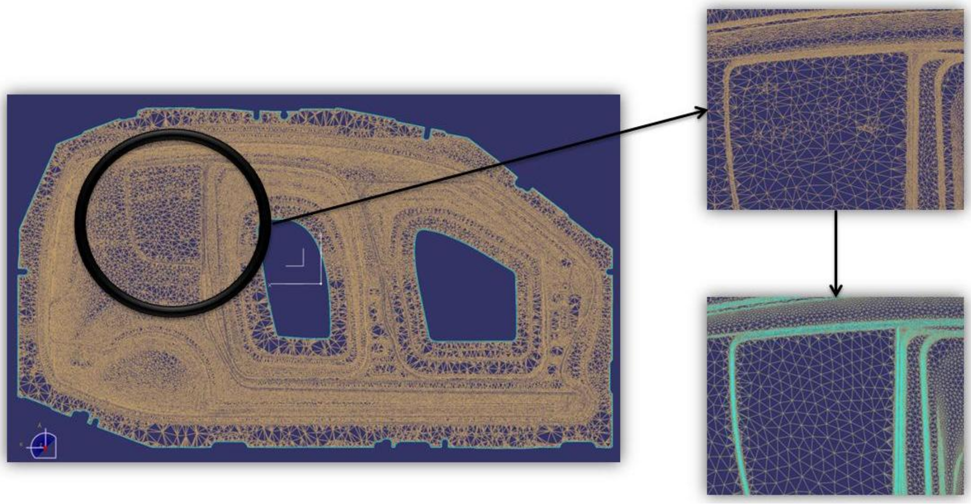

Fig. 3. *Finite element network has to be adjusted for using in simulation software.*

The huge problem is with definition of contacts of penetration between networks of tools and blank. Software PamStamp 2G allows us in framework of default setting two types of contacts – Accurate contact and penalty contact. Accurate contact is used for ideal networks, by there aren´t failures in connections and aren´t deformed. [3]

2.2. Additional input boundary conditions

It is very important to define exactly boundary conditions, which are influencing deep drawing process. These boundary conditions include mechanical data of a material, material model and model of lubrication, kinematics of stamping process, distribution and magnitude of blank holder force.

- *Mechanical properties of stamping material*

Frame doors are stamping from DC06 steel. The material and mechanical properties of the DC06 steel has been specified in the standard EN 10152 (Electrolytically zinc coated cold rolled steel flat products for cold forming). It is alloy, high-grade, low-carbon, ferritic steel micro-alloyed with titanium (the standard requires the maximum amount of 0.3 mass %), which serves as a carbonitride stabilizer cleaning the ferrite from interstitially dissolved carbon and nitrogen. By reducing the presence of these elements, it increases the value of normal anisotropy and improves the deep-drawing properties. Titanium, carbon and nitrogen mix to form TiCN which can be seen under a microscope as yellow sharp-edge in clusions in the material. [4]

Mechnical properties were observed with a simply tensile strength test. Deformation curve has been approximated by a Krupkowsky law for using in Pamstamp 2G software.

$$\boldsymbol{\sigma = K \cdot (\varepsilon_0 + \varepsilon_p)^n} \tag{1}$$

Mechanical properties shows table 1.

Tabel 1. *– Material input data*

K $[\boldsymbol{N \cdot mm^{-2}}]$	0,4934
n [-]	0,237
$\boldsymbol{\varepsilon_0}$ $[-]$	0,00466
$\boldsymbol{r_0}$**[-]**	1,87
$\boldsymbol{r_{45}}$**[-]**	1,76
$\boldsymbol{r_{90}}$**[-]**	2,42
E $[\boldsymbol{GPa}]$	210
$\boldsymbol{\vartheta}[-]$	0,3
ρ$[\boldsymbol{kg \cdot mm^{-3}}]$	$\boldsymbol{7,8 \cdot 10^{-6}}$

- *Blank holder force*

Blank holder is divided into four segments individually adjustable for blank holder force. Input data for simulations were determined from real stamping process and values show figure 4.

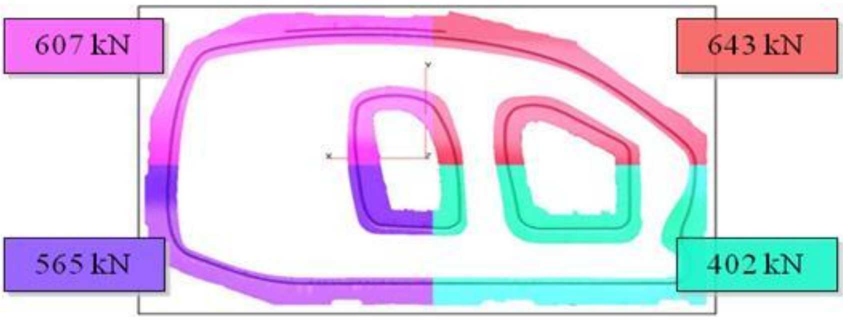

Fig. 4. *Blank holder forces in real deep drawing process of a right frame door of Skoda Roomster.*

- *Lubrication*

Metal sheet blank before the forming goes through the washing and lubricating rollers. Drawing oil is applied to specific locations as needed.

In the case of setting the task it was taken some simplification of the tribological properties between materials and tools. On the contact surfaces was set the friction coefficient to 0.15.

3. Virtual deep drawing

The effect of numerical simulation is in generally transform properties of material to the digital form. This transformation allows us to make a virtual manufacturing of these material, to observe closely how process going on and looking for some optimal conditions. Numerical simulations are based on finite elements method. Objects are represented by finite element network. It follows a geometric deviation, especially in areas of sharp radiuses and curvatures. We have to adjust finite element network as needed. In problem areas we need to have denser network. In this case is important to decide about element size. If the network element is thinner, computation will take a long time and custom properties of the model will be limited. If the element size is denser, it will be better for users, but it will bring a dangerous in problematic areas of a part. It is very important to decide of optimal element size in each area of blank.

Deep drawing process reflects the real situation. In the first stage is blank deformed only by gravity force and adapts on tools shape. The effect of gravity force is shown in the figure 5. In the second stage is blank closed around with blank holder force and finally is deformed by force of male die. The process ends with contact male and female die. Blank is deformed into the required shape. Whole process is shown in the figure 5.

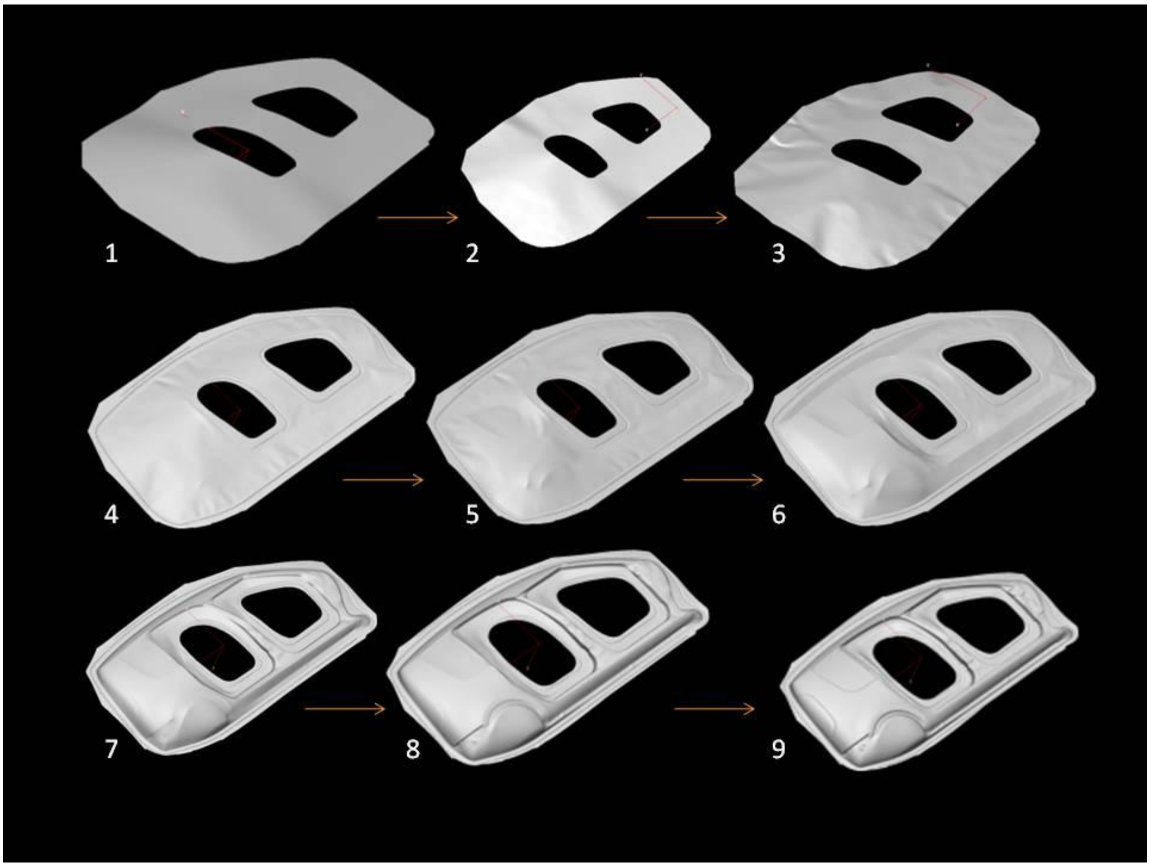

Fig. 5. *Stages of stamping. Stages 1 to 4 show the effect of gravitation and closing blank holders. Stages 5 to 9 show a shapes changes in process of closing female die.*

4. Verification of simulation process

Results from simulation have to be compared with real situation and state. Verification was based on comparing results from simulation program and optical forming analyzes with system Argus 3D.

4.1. Argus GOM 3D

Argus is optical system for measuring the strain and thickness reduction in sheet metal forming caused by stamping, to detect critical areas in forming process. This system was developed for Renault Company, bud now it is widely used in many research centres all over the world and in automotive industry. Measuring system consists of CCD cameras, computer station and components for calibration (calibration stones and rods)

Measuring is based on several steps:

- Application of strain network on blank sheet
- Deep drawing in real dies with real boundary conditions
- Fixing measuring rods and stones in the measured area
- Scanning by CCD cameras
- Evaluation in software Argus

Network is electrolytic etched on blank sheet. Generally is used a network with circle or point elements with pitch 1 to 6 millimetres. In this research project was used a network of pointed elements with a diameter 1 and pitch 2 millimetres.

Blank sheet was stamped with the network in real situation. Network is deformed with a blank. Points were changed their position and this distortion of network reflects the deformation behaviour of material.

Finally was network labelled with calibration rods and stoned, as shows the figure 6 and scanned with a CCD camera. Thanks calibrations rods and stones computer station can define the position of points in space and compute the strains from lateral distortion of points.

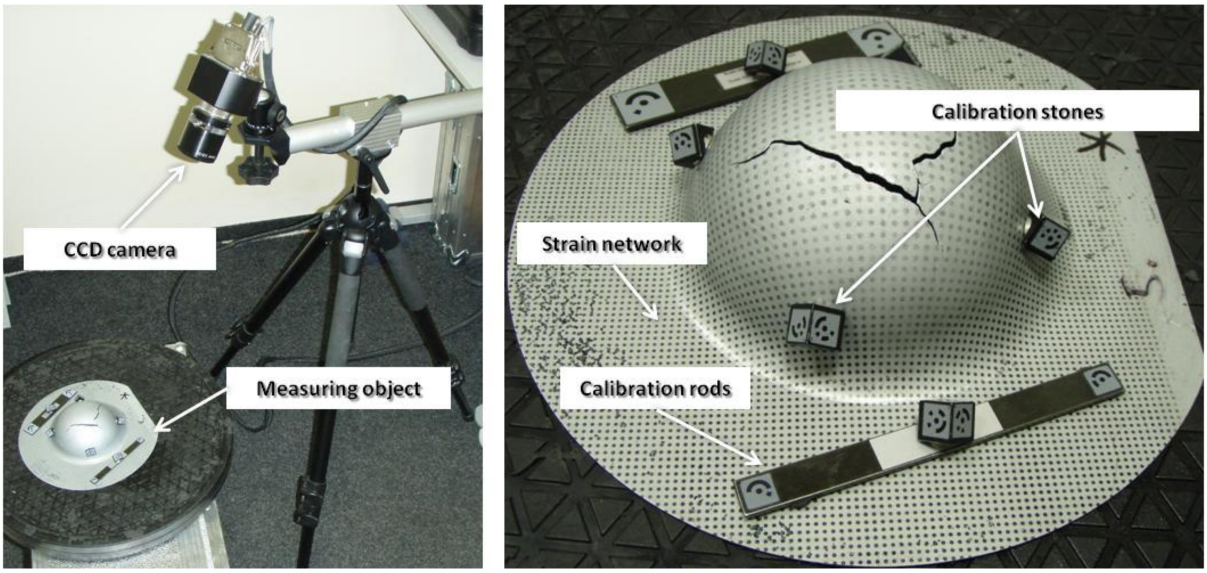

Fig. 6. *Optical measuring system for strain analyzes GOM ARGUS 3D.*

4.2. Validation of simulation results

Results from simulation and from deform analysis were compared during values of thinning and distribution of major and minor strain. Verification was realized in global view and in specific and critical areas. These areas can be find in roof radius “B” column, “A” column, frame door threshold. Deviation is moved in range 10%.

In the figure 6 is shown comparison between simulation and strain analyzes in values of thinning. On the non-critical zones of object there is a quite accurate consensus. In critical parts of drawn shell like “B” column there is higher deviation. This difference can be caused by inaccuracy of boundary conditions, which are input in simulation task.

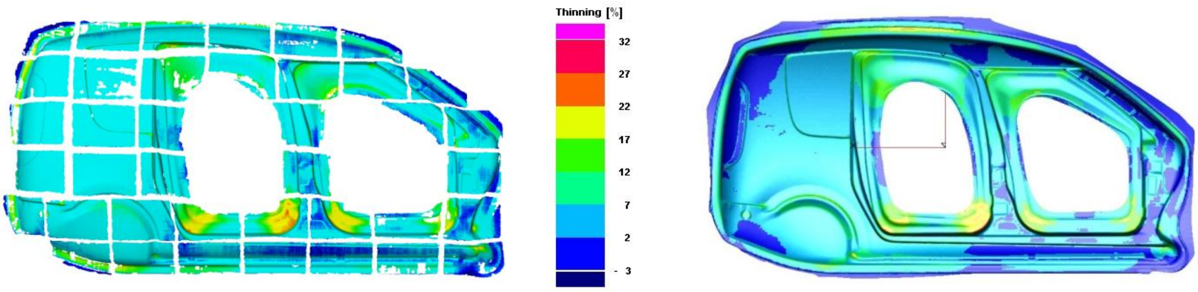

Fig. 6. *Comparison of thinning between simulation and strain optical analyzes*

5. Conclusion

The project aims to have a numerical simulation, which is a very similar to real situation in deep drawing process and works with real data of tools. This simulation can help us with monitoring effects of optimize decisions. We can observe effects of changing of material quality, its thickness, mechanical properties, surface quality. We are able to optimize a blank shape to decrease costs while maintaining stability of process. We can define boundary conditions and their influence on stamping process.

Problem is with definitions of input data, especially with 3D scanned tools, with their preparation and processing for needs of numerical simulation software. We have to have knowledge and experiences from many technical branches.

This article introduces the first stage of whole projects, which is realized with Skoda Car Company, with the department of technical supports of stamping and welding. In another stages will be used these reference simulation to observe influencing of boundary conditions to stamping process.

6. References

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