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USE OF NUMERICAL SIMULATION AT OPTIMISATION OF TECHNOLOGICAL PROCESSES OF COLD BULK FORMING

VYUŽITÍ NUMERICKÝCH SIMULACÍ PŘI OPTIMALIZACI TECHNOLOGICKÝCH PROCESŮ OBJEMOVÉHO TVÁŘENÍ ZASTUDENA

Abstract
The paper deals with numerical and physical modelling aimed at optimisation of production technology and designing of manufacturing tools with use of finite-element method. For the topic of cold bulk forming a manufacture of pressed insert, used in industry as a component for damping system for passenger cars, was simulated. It is a rotationally symmetric component, which is subjected to high axial load, and strength and fatigue characteristics of which depend substantially on service life and reliability of the whole damping system. This component was subjected to analysis of distribution of flow stress and deformation intensity at combined extrusion from the viewpoint of their load with use of simulating software Simufact.Forming 10.0. The simulation process ran smoothly, without sudden changes of the shape leading to formation of possible internal defects.

Abstrakt
Práce se zabývá numerickým a fyzikálním modelováním za účelem optimalizace výrobní technologie a konstrukce výrobních nástrojů s využitím metody konečných prvků. Pro danou problematiku objemového tváření zastudena byla provedena simulace výroby zálisku využívaného v praxi jako součást tlumícího systému osobních vozů. Jedná se o rotačně symetrickou součást, která je vysoce namáhaná axiálním zatížením a jejíž pevnostní a únavové charakteristiky závisí podstatnou měrou na životnosti a spolehlivosti celého tlumícího systému. U dané součásti byla provedena analýza rozložení deformačního napětí a intenzity deformace při kombinovaném protlačování z hlediska jejich namáhání za pomoci simulačního programu Simufact.Forming 10.0. Vlastní proces simulace probíhal plynule, bez náhlých změn tvaru vedoucích ke vzniku možných vnitřních vad.

1 INTRODUCTION

The component was chosen for optimisation of forming process realised in collaboration with the company J-VST s.r.o. Brno, which specialises on manufacture by of components by cold forming. This component, which is one of elements of damping system for passenger cars, was subjected to analysis of process of combined extrusion, which is used for manufacture of this component.

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Fig. 1 Photo of the component.

Forming technology is applied, with use of which the blank is transformed to bodies of different shape, mostly of circular or symmetric cross-section. Transformation takes place as a result of action of pressure of extruding punch on material, which becomes plastic due to effect of general state of stress, and its particles are displaced without violation of cohesion of its molecular bonds. It is possible to create by extrusion the same shapes that can be obtained by pressing from a sheet, but comparison shows that extrusion is more economic method. Another advantage consists in high precision and surface quality. Production tolerances IT8 to IT7 are achieved and in case of inclusion of another forming operation – sizing – even tolerance IT6 may be achieved (i.e. precision of the order of ±0.05 and toughness Ra=0.8).

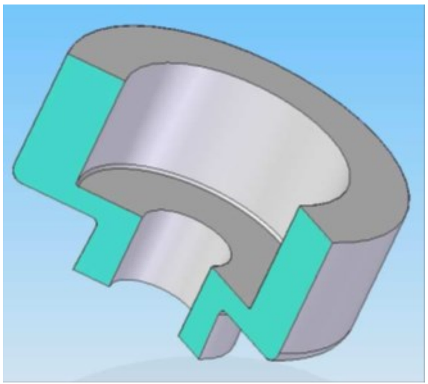

Fig. 2 Required component.

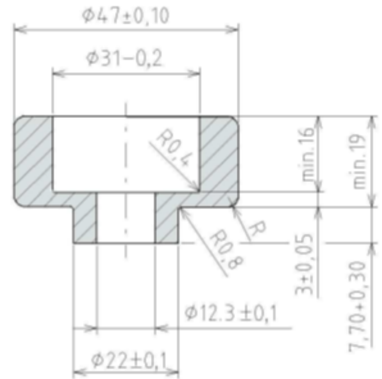

Fig. 3 Schema of the required component.

Technological procedure for manufacture of the component

- cutting of material to dimensions Φ35 h9 x 25,16 (mass 190 g) on cutting tool with use of mechanical press LEPP 100
- soft annealing of blanks
- phosphating of blanks and their coating with soap
- pressing on forming automate TPZK 25
- degreasing
- inspection

Simulation makes it possible to resolve nowadays very complex technological operations, which cannot be resolved or can be resolved only with big difficulties by analytical methods, or in vases where use of analytical solution would be too simplifying. Simulation enables also verification of results obtained by other methods from the viewpoint of experiments or results from practice.

Simulation of technological process makes it possible to investigate behaviour of the formed material in real, accelerated or decelerated time. After creation of geometric model and realisation of simulation calculation it is then possible to simulate in couple of minutes the evolution of the whole technological operation. Already the experience from creation of simulation model may lead to enhancement of geometry of material. The reason is that creation of simulation model is impossible without thorough analysis of investigated problem, which may discover at the very beginning of processing considerable reserves. Simulation offers thorough verification of various variants of solution and comprehensive view of the investigated problem. It thus enables analysis of the whole process on the basis of several criteria, such as design–technological parameters and influence of behaviour of the formed material on formation of possible defect of the product [1].

2 MATHEMATICAL SIMULATION OF EXTRUSION PROCESS

Simulation tool Simufact.Forming was used, which had been developed specially for forming industry. This software was developed by the company Simufact by combination of the programs MSC.SuperForge and MSC.Super.Form from MSC.Software, both additional technologies were integrated in to one efficient product, which can tackle all problems of forming technologies. the software works in a 3D space using finite-element method (FEM) or finite-volumes method (FVM). It is focused on requirements of industry related to forming processes. The program SimufactForming byl was developed for support of all forming applications, which are independent on temperature of process, machine or of processed material. SimufactForming is an integrated simulation environment for optimisation of all forming processes: die forging, extrusion, drawing, upsetting, bending, cutting, free forging, ring rolling, rolling of surfaces, rolling of sections or cold rolling, hot rolling or semi-hot rolling, orbital forming, forming of sheets. It can also perform analysis of tools, analysis of material flow or dielectric analysis. [2]

2.1 Selection of material

For production of the required component for damping system we choose steel marked as 1.1180 (according to the standard ČSN 12 040). It is steel for heat treatment with carbon content C=(0.32-0.39)%. The steel is suitable for shafts of stationary combustion engines and pumps, shafts of mining machines, countershafts and crankshafts, journals, pins, crane hooks, rotors for turbo-generators, machine components for heat treatment, bolts and nuts for high temperatures, etc. [3].

Tab. 1 Chemical composition of material 1.1180.

Designation		**Chemical composition, mass ratio in %**									
Grade	Numerical marking	C	Si_{max}	Mn	P_{max}	S	Cr_{max}	$Mo_{max.}$	Ni_{max}	$V_{max.}$	Cr+Mo+Ni
C35R	1.1180	0.32-0.39	0.4	0.50-0.8	0.04	0.020-0.040	0.4	0.1	0.4	-	0.63

Tab. 2 Mechanical properties of material 1.1180 [4].

Designation		Mechanical properties				
Grade	Numerical marking	$Re_{min.}$ [Mpa]	Rm [Mpa]	$A_{min.}$ [%]	$Z_{min.}$ [%]	KV $_{min.}$ [J]
C35R	11.180	380	600-750	19	45	35

2.2 Characteristic of forming tools

Forming automate TPZK 25 was chosen for cold forming, which is owned by the company. Its another undisputable advantage consists in rapidity of its operation, possibility of four operations on one machine and also compactness as compared with four individual single-operation machines.

The decisive factor for design of the forming tool is played by the proposed technological procedure and used machine ensuing from it. Design solution will differ at use of single-operation press, upsetting automate, or three- or multi-operation forming automate. The tool for cold bulk forming can be divided to functional parts (extrusion punches, extrusion dies, ejectors, stripper plates, etc.), to auxiliary parts (clamping elements, bushings, springs, base plates, etc.).

2.3 Forming tools for follow forming automates

In most cases drawn steel is mostly used as input material for follow forming automates. It can be delivered either in coils or in bars. Design solution of the tool block conforms to that. It contains usually cutting tool, which divides material to block with length corresponding to the required volume.

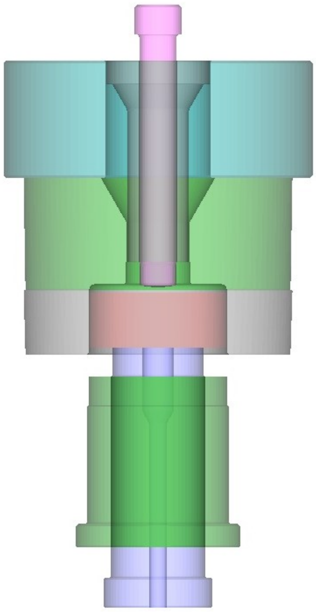

Fig. 4 Schema of set of tools.

We created a set of tools for the mathematical simulation. Figure 4 shows the set of tools in the program Simufact.forming, which was designed and plotted in the 3D program Autodesk Inventor and then imported to the simulation program. Diagram of proposed simulation is created with respect to the most precise interpretation of the forming process according to the working drawings of machine. Appropriate material was assigned to the forming tools from the library of materials of this program, as well as boundary conditions. Material 1.1180 was assigned to the blank (Poisson's number, Strength constant, Strengthening exponent, Young's modulus of elasticity, Density), as well as boundary conditions. At the same time initial temperatures and mesh were assigned to the tools. After this we were able to start creation of the set of given operation, assign contact conditions, movements, kinetic actions and then start the simulation as such.

2.4 Magnitude of deformation – stress state

The results are evaluated in the program Simufact.forming during simulation and after its completion. Material is at spatial forming, as in reality, heterogeneous and its behaviour is not constant along its full cross-section. Intensity of deformation, caused by friction between the tool and the sample, is much higher at the edge of the component. Results of simulation are therefore illustrated graphically at 50 % of the component cross-section.

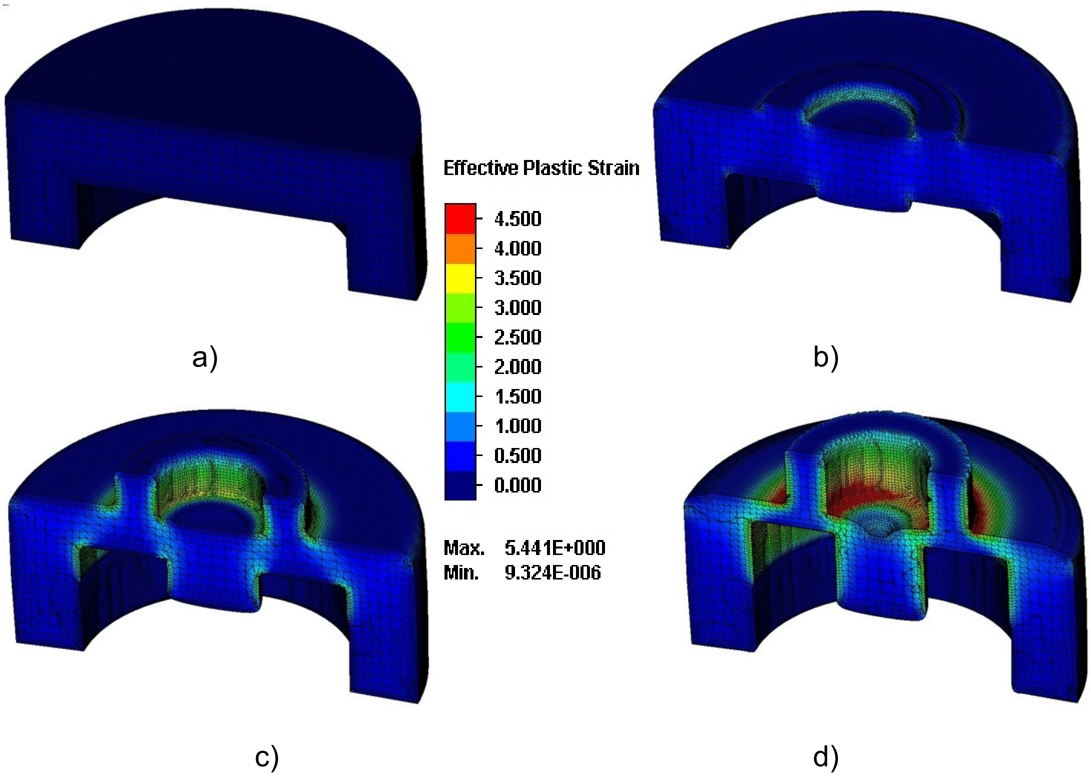

Fig. 5 Course of deformation intensity in the component with displayed mesh of finite elements a) initial state after 1st operation b) at 38% c) at 66% d) final state after combined extrusion.

Magnitude of deformation intensity after extrusion achieves the maximum value $\underline{\varepsilon_i \approx 4.5}$ (see Fig. 5)

Shape of grains changes with the increasing degree of deformation. Initially polyhedral grains get elongated in direction of prevailing deformation, until they become elongated fibres with comparatively small cross-section dimensions. Plastic deformation results also in change of orientation of crystal lattice. Original random orientation changes during plastic deformation to directional orientation.

Deformation of material is accompanied also by deformation strengthening.

Deformation strengthening of metals and alloys is accompanied by change of their mechanical properties. Strength and hardness increase with reduced ductility and contraction. Increase of strength values of the formed materials is in many cases undesirable in technical practice, particularly in multi-operation forming processes. On the other hand it is used comparatively frequently.

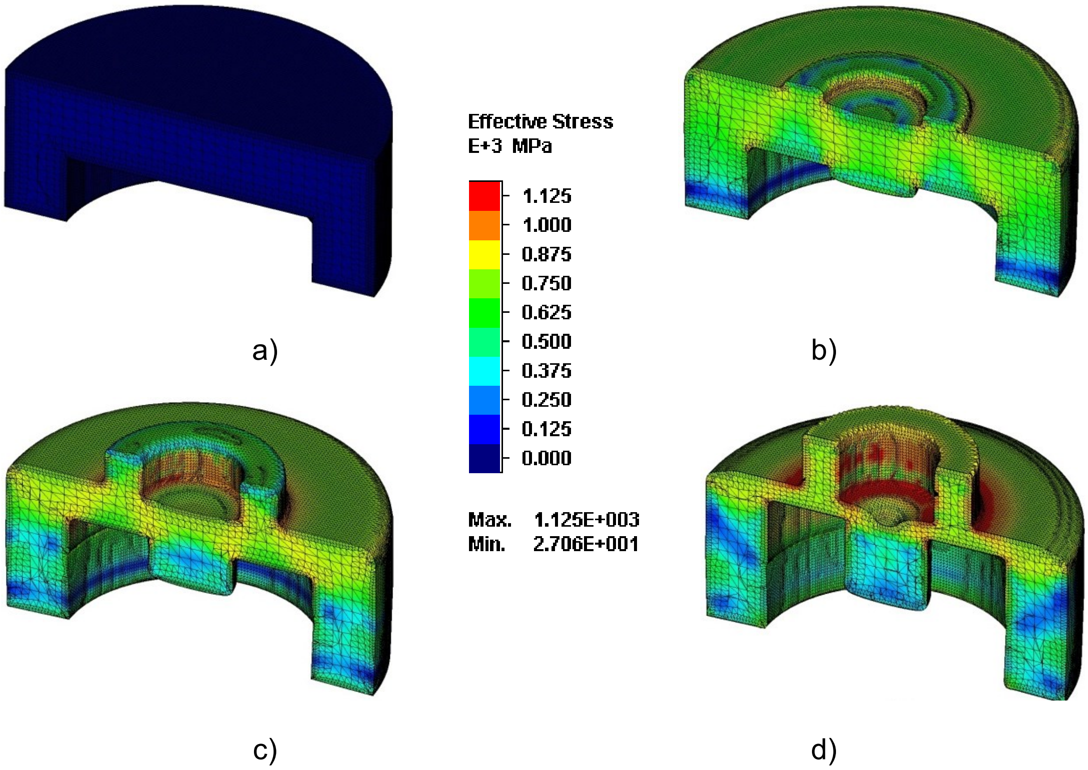

Fig. 6 Courses of flow stress in the component with displayed mesh of finite elements a) initial state after 1st operation b) at 38% c) at 66% d) final state after combined extrusion.

Resulting maximal value of flow stress in the component is $\underline{\sigma_i = 1\,125.5}$ MPa.

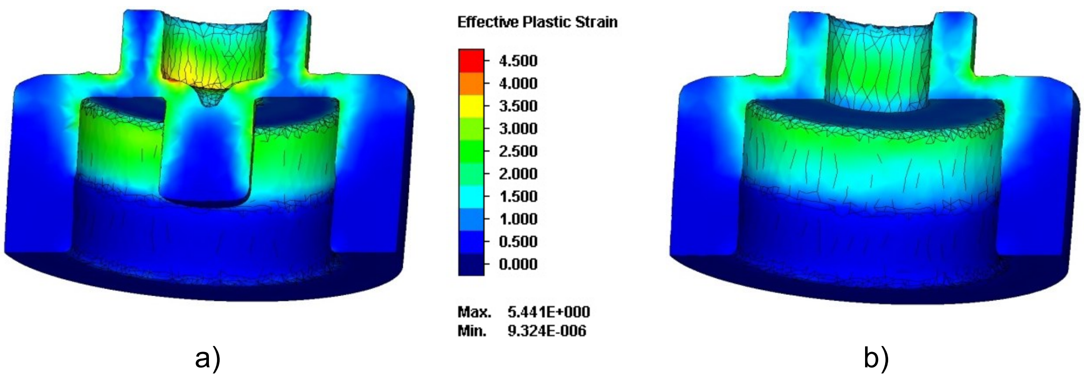

Fig. 7 Cutting of hole a) state after extrusion b) state after cutting through.

Last operation on the TPZK 25 is cutting through of the hole Φ12.5. This cut-off material is afterwards also used technologically.

3 CONCLUSIONS

Analysis of distribution of deformation intensity and flow stress was made for the chosen type of component with use of the program Simufact.Forming 9.0. During simulation of combined extrusion stress gets concentrated and local transformations take place in the component's notch and at transitions of roundings. Comparison of peak values of stress and transformation at the chosen method of modelling and mesh density illustrates the fact, that radius of rounding was chosen correctly and that it is not a root of dangerous defects from the viewpoint of initiation of formation induced failures with subsequent crack formation.

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