RESEARCH PAPERS
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA
SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

2009 Number 27

ANALYSIS OF DROP FORGING IN CLOSED DIE USING COMPUTER SIMULATION

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Abstract

This paper is focused on analysis of materials as they function in cavity filling during closed die forging. These analyses were completed using simulation software, SuperForge, during the production of forging with the shape of a toothed wheel determined for the gear box. The numerical simulation allowed for the optimal forging process, especially from the fold creation elimination perspective.

Key words

drop forging, forging without flash, closed die, numerical simulation

Introduction

The computer simulation of the forging process is very important for the forging of demanding die forging and for the application of progressive die forging methods. This simulation enables us to analyse principles of the forging process and to observe plastic flow of materials in the die cavity during its filling. Simulation software has a considerable advantage – they enable the verification of technological parameters and technical preparation of production before making forming tools and beginning the production [1,2,3].

Characteristics of used simulation software

The simulation software MSC.SuperForge was used in the simulation of forging in close computer simulation of 2D and 3D die forging processes with FEM or FVM methods. It is a modern simulation software with easy use that does not demand experience with FEM and enables the insertion of CAD tool geometry in STL format. The working environment of this software is similar to the Windows operating system environment and is clearly arranged for easy use. Simulation of warm forming processes utilizes elastic –

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plastic models of material behaviour. The advantage of this software is a large material database created according to strain hardness, temperature, and deformation velocity. Simulation software MSC.SuperForge enables us to observe the course of material plastic flow in tools and offers coloured depictions of deformation size and velocity, course of stress, temperature fields and contact pressures on tool surfaces during cavity filling.
Numeric simulation of the die forging process consists of these phases:

- Preparatory phase of simulation – creation of geometrical model of workpiece and tools (i.e. AutoCAD, Catia, etc.), choice of process kind, type of depiction 2D/3D, forming temperature, etc.
- Simulation – beginning and course of forming process simulation.

The environment of this software comprises three working windows, two of them serve for entering of input data and creation of the "simulation tree". The third window is used for depiction of the simulation course and results.

Simulation of forging "Wheel" in closed die

Figure 1 depicts a simulated drop forging wheel. This forging when machined is used as a toothed wheel in gear boxes of agricultural and industrial machines. Output material is a rolled bar with circular section ∅ 65 steel 16 220 (16NiCr4). This material is not heat treated, soft annealed, normalized, or hardened. It is proper for carburizing and is easily forged. It is used for over-stressed machine components with carburized surfaces (e.g. toothed wheel for gear boxes, spline shafts, pins, etc.). Chemical composition of mentioned steel is shown in Table 1.

Fig. 1. *Shape of simulated forging Wheel*

CHEMICAL COMPOSITION OF STEEL 16NiCr4 Table 1

Material	**Content of elements**	**Chemical composition (%)**									
		C	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Al**	**Ti**
16NiCr4	min.	0,1	0,7	0,4	0,035	0,035	0,6	0,8	0,10	0,02	0,010
	max.	0,19	1,0				1,0	1,10		0,04	

The drop forging wheel is produced by HKS Forge, s.r.o. in Trnava, with the standard method of forging with flash, in common workmanship. For the purpose of reducing the waste of materials, a new technology of closed die forging was proposed. This technology represents very precise forging production according to STN EN 10243-1. Correct compensation of small material surplus is important for a flawless technological process of forging in closed die cavity. Compensation of surplus material into internal flash was also used for the aforementioned forging wheel. Forging in closed die requires precise preparation

of the workpiece, therefore, a high-powered belt saw was used for the separation of material. This saw guarantees a better quality cut surface. Round bars Ø 65 will be cut into workpieces with batch weight 2,68 ± 0,03 kg. Length of workpiece – 105 mm is only informative.
The technological process of forging in closed die consists of these operations:

- Induction heating of workpiece Ø 65 x 105 on forging temperature 1150 °C;
- Upsetting of heated workpiece on height 40 mm;
- Blocking the shape in blocking die cavity;
- Finishing of drop forging shape in closed die cavity.

Drop forging will be produced by three strokes of crank forging press LZK 2500. The proposed process was verified by simulation software SuperForge. Computer simulation of the forging process relating to the drop forging "Wheel" requires choice of process and input data for simulation of upsetting, blocking, and finally, for the finishing process.

Defined Input Conditions for Simulation of Upsetting and Results

Press 1 – Crank Press LZK 2500
Upper Die – model of tool: CYLINDER1
- material of tool: 19 552 Mat.No.(W. Nr.): 1.2343
- coefficient of friction: 0,25
- temperature of tool: 280 ˚C

Lower Die – model of tool: CYLINDER2
- material of tool: 19 552 Mat.No.(W. Nr.): 1.2343
- coefficient of friction: 0,25
- temperature of tool: 280 ˚C

Workpiece - model of workpiece: CYLINDER Ø65 x 105
- material of workpiece: 16 220 Mat.No.(W. Nr.): 1.5714
- temperature of workpiece: 1150 ˚C

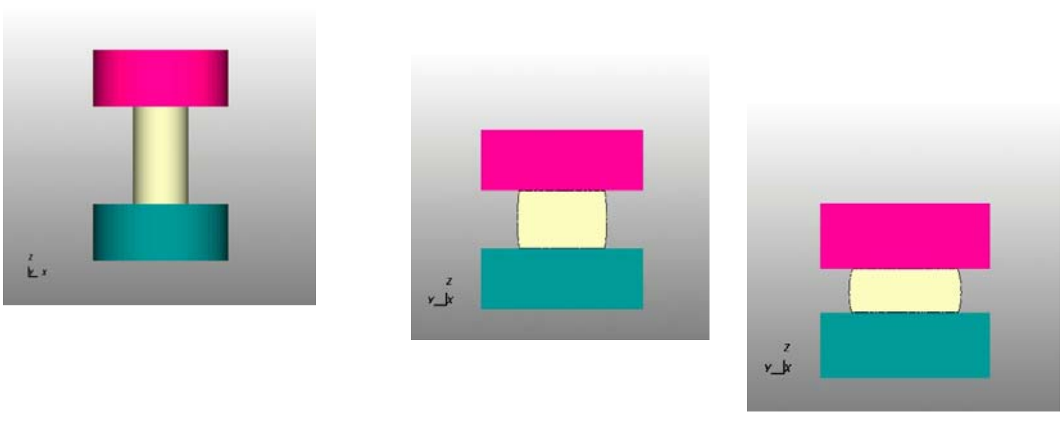
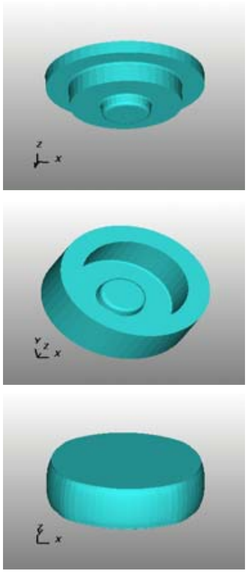


Fig. 2. *Simulation of workpiece upsetting process (on height 40mm)*

Input Conditions for Simulation of Blocking and Results

Process 1 – process of blocking in closed die



Press1 – Crank Press LZK 2500

Upper Die

- model of Upper Die
- material of tool: 19 552 Mat.No.(W. Nr.): 1.2343
- coefficient of friction : 0,25
- temperature of tool: 280 ˚C

Lower Die

- model of Lower Die
- material of tool:19 552 Mat.No.(W. Nr.): 1.2343
- coefficient of friction : 0,25
- temperature of tool: 280 ˚C

Compressed workpiece after upsetting process

- model of workpiece after upsetting
- material of workpiece: 16 220 Mat.No.(W. Nr.): 1.5714

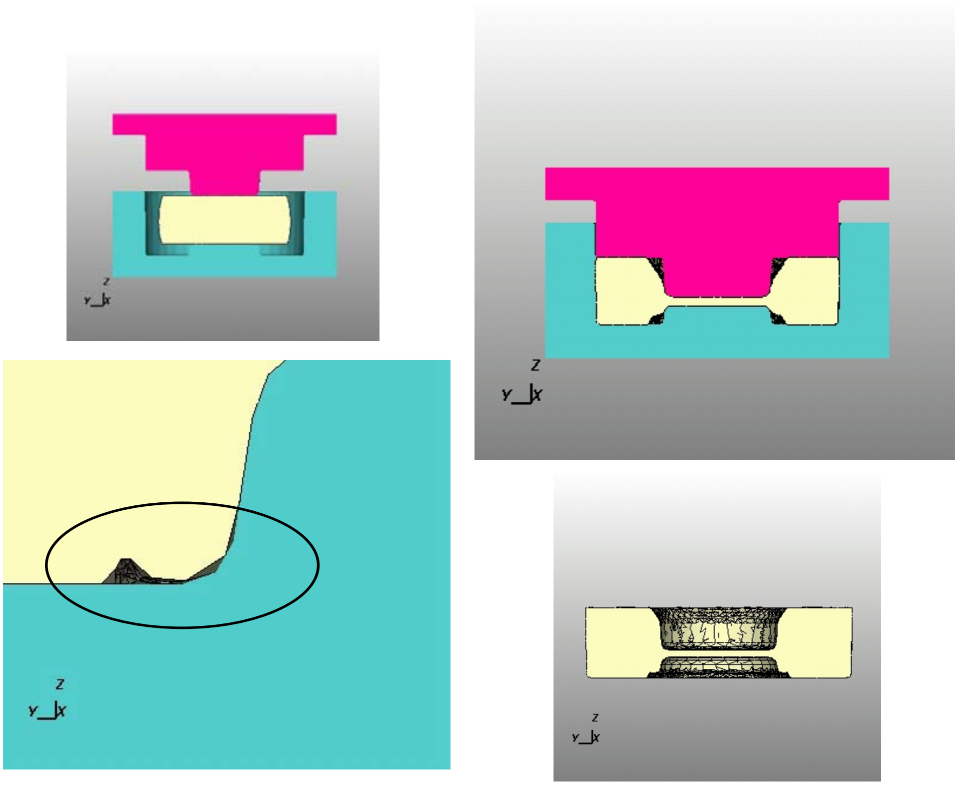


Fig. 3. *Simulation of material flow in die cavity and creation of a fold*

Result of the blocking process simulation in Figure 3 confirmed incorrect plastic flow in the cavity of the blocking die. After locating a wad in the lower part of the forging, a visible fold appeared. The reason for this is the incorrect flow of material. Therefore, a treatment in the shape of the blocking die cavity was made. The wad moved into the middle part of the forging and the radius of fillet increased from R3 to R4.

Numeric simulation allowed for the optimal shape of forging tool to be produced prior to the forging production. The simulation process shown in Figure 4 confirmed the forging cavity changing, as plastic flow of material was without folds [4, 5].

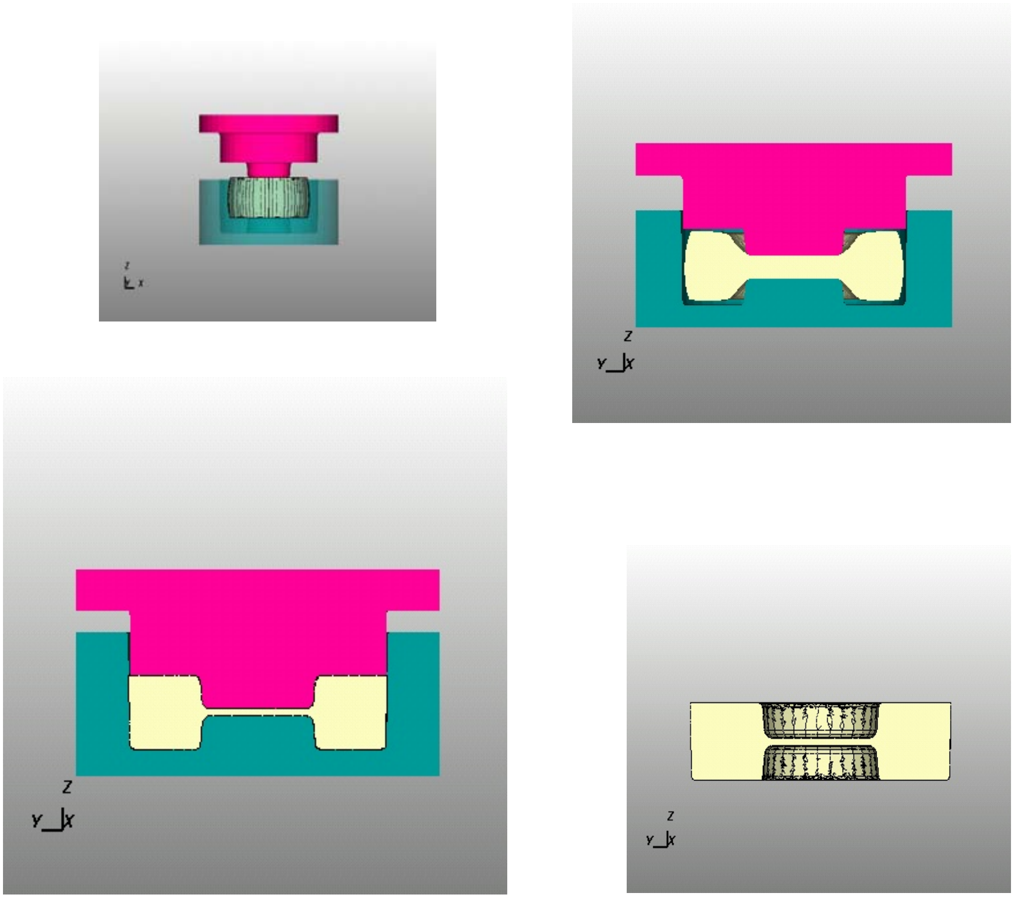
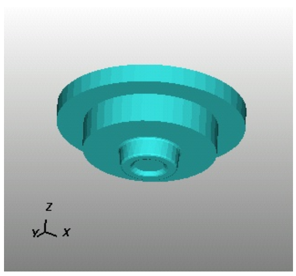


Fig. 4. Simulation of flow in arranged blocking cavity

Input Conditions for Simulation of Finishing the Forging Shape and Results

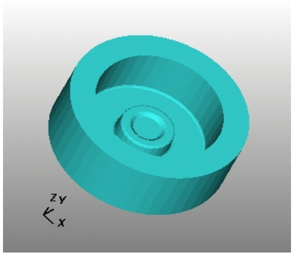
Process 2 – process of finishing in closed die



Press1 – Crank Press LZK 2500
Upper Die
- model of Upper Die
- material of tool: 19 552 Mat.No.(W. Nr.): 1.2343
- coefficient of friction: 0,25
- temperature of tool: 280 ˚C

Lower Die

– model of Lower Die
– material of tool: 19 552 Mat.No.(W. Nr.): 1.2343
– coefficient of friction: 0,25
– temperature of tool: 280 ˚C



Workpiece from blocking process

– model of blank
– material of workpiece:16 220 Mat.No.(W. Nr.): 1.5714

Results of simulation of finishing process in closed die are stated in Figures 5 and 6. Simulation confirms correct flow of material in closed die with complete cavity filling.

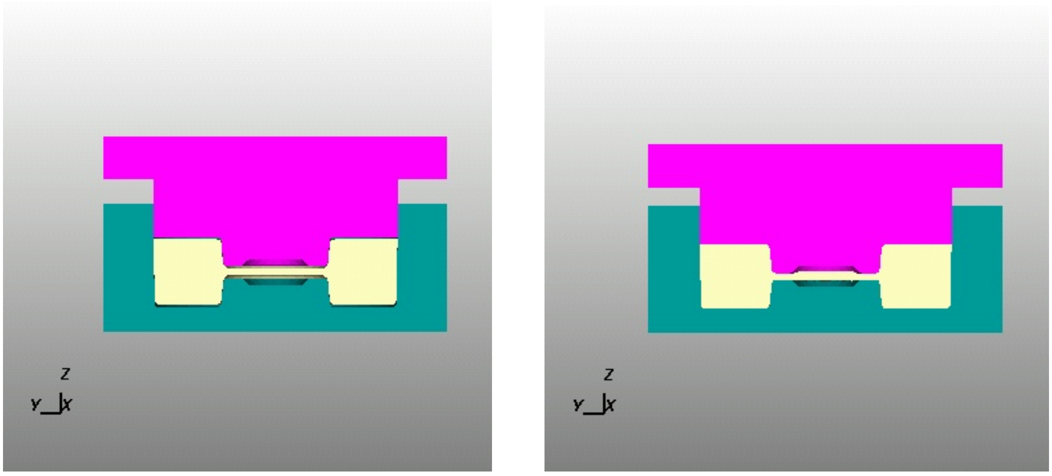


Fig. 5. *The material flow in finishing tool cavity – a small surplus of material is extruded into internal flash*

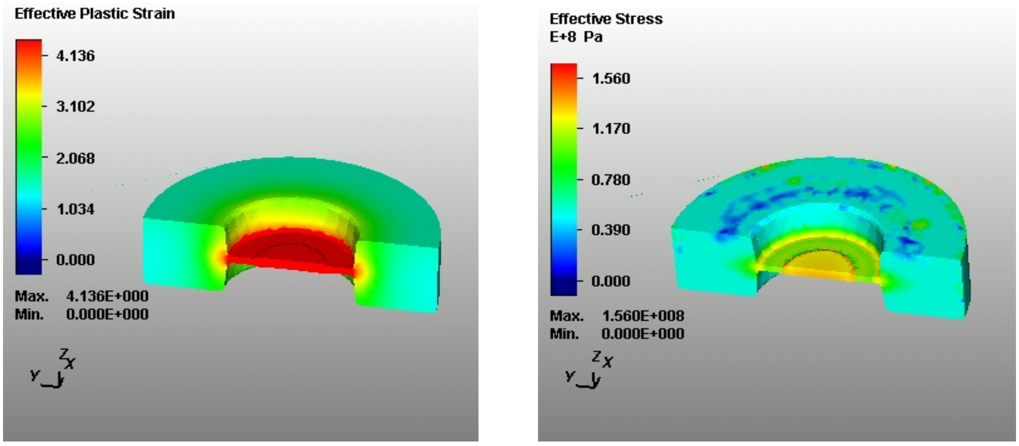


Fig. 6. *Course of deformation and stress in finished forging*

Self-scientific addition

Forging of "Wheel" drop forging in closed die is interesting especially for its cost savings, requiring less materials and machining. Comparison of the common production method using forging with flash and production using forging in closed die is presented in Figure 7. This comparison enables us to see considerable savings of input material. Moreover, production of forging in closed die brings a reduction of forging weight [6]. The batch weight and the weight of scrap is reduced, resulting in lower material costs and overall production costs. Particular material savings are visible in Figure 7 and represent, in this case, a savings of 0,42 kg per one par to the batch weight.

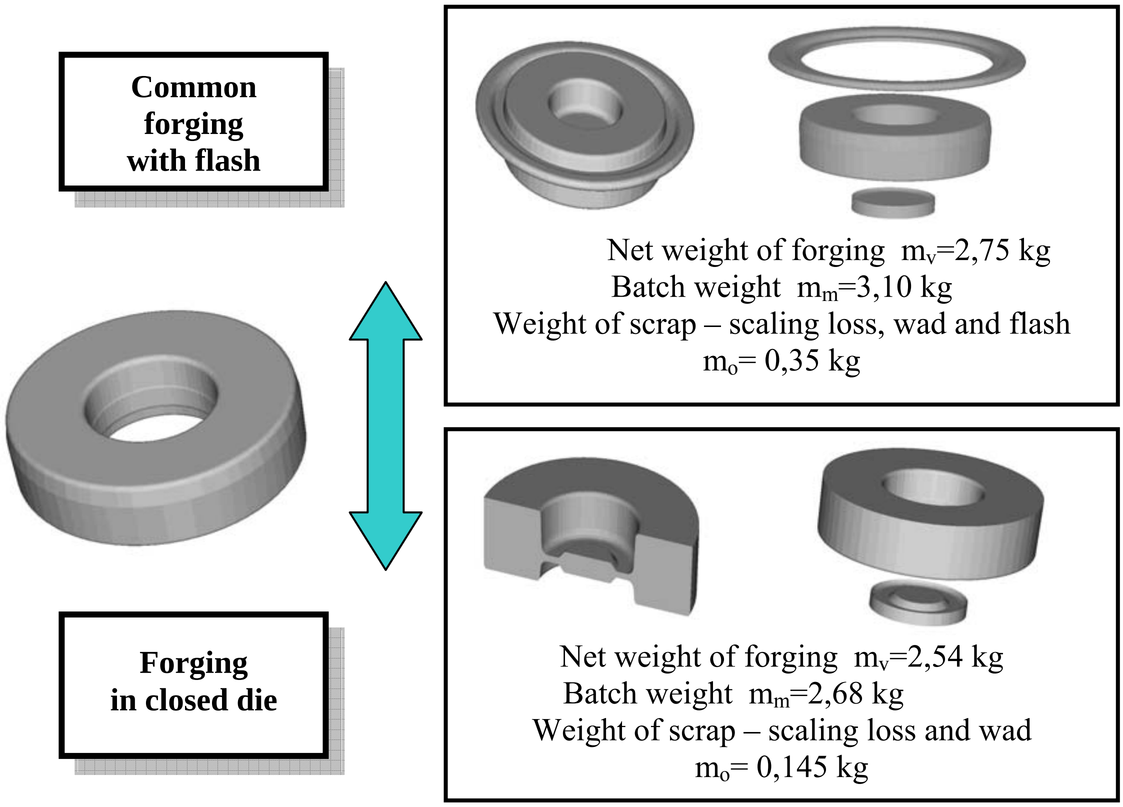


Fig. 7. *Comparison of present and proposed production of forging Wheel*

Conclusion

The aim of this paper was to point out the importance of simulation software for development of die forging technology and for application of new forging methods into production practice, on a particular forging wheel. Computer simulation confirmed the possibility to change the production of this forging from forging in open die to forging in closed die - without flash. New technology assumes reduction of overall production costs [7]. In this case the saving of materials is most significant because of their relatively high costs.

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