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RESEARCH ON PRECISION DIE FORGING USING SIMULATION

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ABSTRACT: *Precision die forging can be defined as a production of drop forgings whose shape is not very different from the shape of source part at the optimization of production costs and times. This paper deals with precision die forging of gear wheels in closed dies. The process has been realized on one forming operation in heat from ring billet. In comparison with open die forging, costs for forged material have been evaluated. Material flow in die cavity and effective plastic strain of the designed forging process has been realized with the help of computer simulation.*
KEYWORDS: *precision die forging, computer simulation, gear wheel, closed die, material flow*

INTRODUCTION

Manufacturing processes as well as products in the area of the production of drop forgings must be still analyzed and improved to meet all customers' requirements, environmental legislation and international competition. It's necessary to provide high precision of drop forgings and low usage of forming material at the lowest production times and production costs. Therefore, production of drop forgings by conventional die forging with open die in heat is not very proper. It is due to high costs of the forming material and lower available dimensional accuracy of drop forgings. With this, production of drop forgings by the precision die forging is the main area of research and development within the frame of advanced methods of the production of drop forgings.

EXPERIMENTAL PART

Research on the precision die forging in closed dies has been applied on spur gears with a hub. Shape of the spur gear is shown in Figure 1. Spur gears are enhanced especially in machine industry – for example as a part of machines and gear boxes.

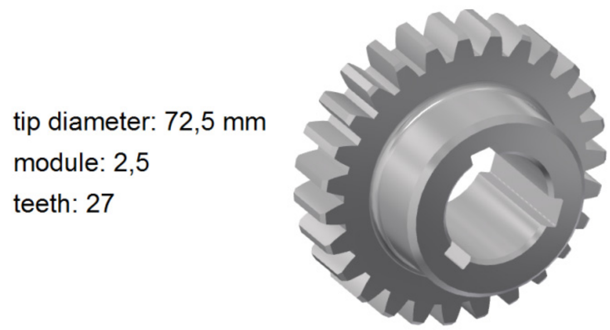

Figure 1. Spur gear with a hub

As a material for drop forging was chosen case hardening steel STN 41 4220 (16MnCr5). The best results within the frame of research on precision die forging of gear wheels in closed dies were achieved by using of this steel. Chemical composition of steel STN 41 4220 is shown in Table 1.

Table 1. Chemical composition of steel STN 41 4220

	Chemical composition [percent by weight]					
	C	Mn	Si	Cr	P	S
in	0,14	1,1	0,17	0,8		
max	0,19	1,4	0,37	1,1	0,035	0,035

PRESENT FORGING METHOD

At the present time gear wheels are manufactured by conventional die forging with flash in heat. Shape of this type of drop forging is illustrated in Figure 2. Manufacturing of given type of drop forging by forging in open dies usually consists of three forming operations: upsetting, rough forging and final forging. The result is increase of production times, tooling costs and machine costs. Low efficiency of charging semi-product is the next insufficiency of the conventional die forging. The result is the creation of flash and a web.

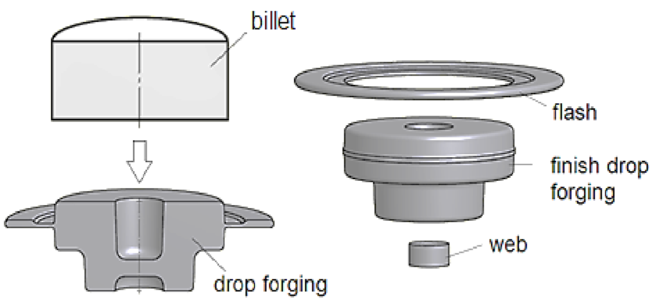

Figure 2. Drop forging with flash and a web

DESIGNED FORGING METHOD

The limitations of present die forging are eliminated by the use of precision die forging in closed dies. Manufacturing of drop forging of gear wheel will consist of one forming operation – precision die forging in closed die in heat from ring billet. Principle of forging tool design and final shape of drop forging is illustrated in Figure 3.

Drop forging of gear wheel will be provided by required minimal material allowance per flank and material allowance for machining of bore hole and slots (shown in Figure 3). Face areas of toothed ring and outside cylindrical surface of a hub will be made net-shape. Cutting operations of the fillets from toothed ring into the hub is unnecessary, too.

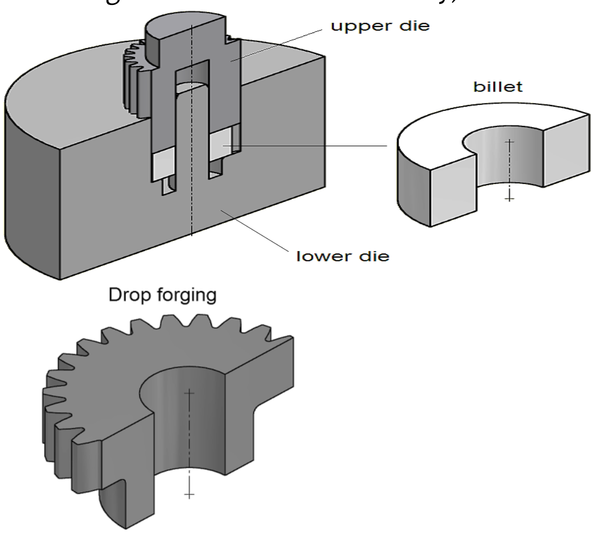

Figure 3. Tool design for precision die forging

COMPUTER SIMULATION

Computer simulation is useful solution for prediction of the course of process and material behavior in die cavity. In this way, it is possible to optimize the tool shape and design technological process and by that considerably reduce financial costs of preproduction stages and production itself. Utilization of computer simulation at the forging processes allows also increase in quality of drop forgings and tool life. Computer simulation was realized by Simufact.forming simulation program which uses final element method (FEM) and finite volume method (FVM).

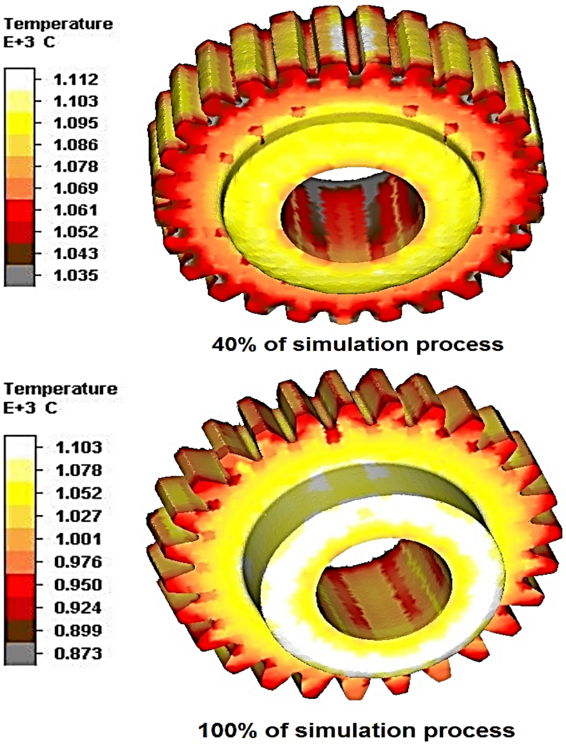

Figure 4a. Results of computer simulation at the various stages of simulation process

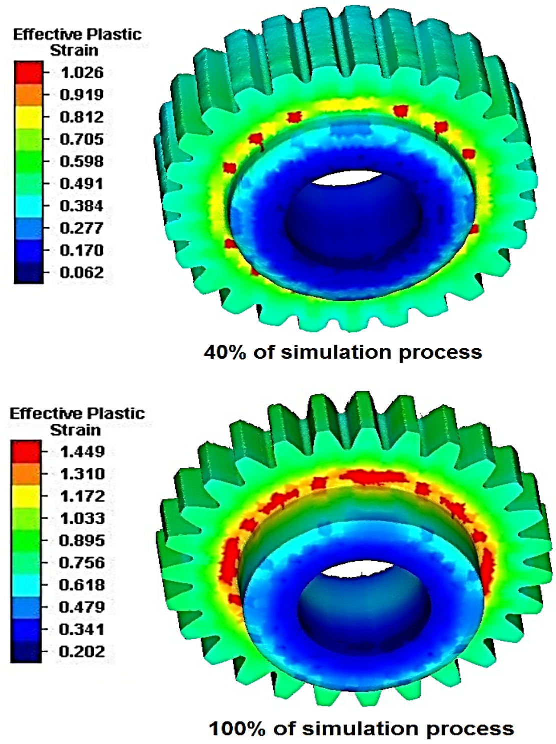

Figure 4b. Results of computer simulation at the various stages of simulation process

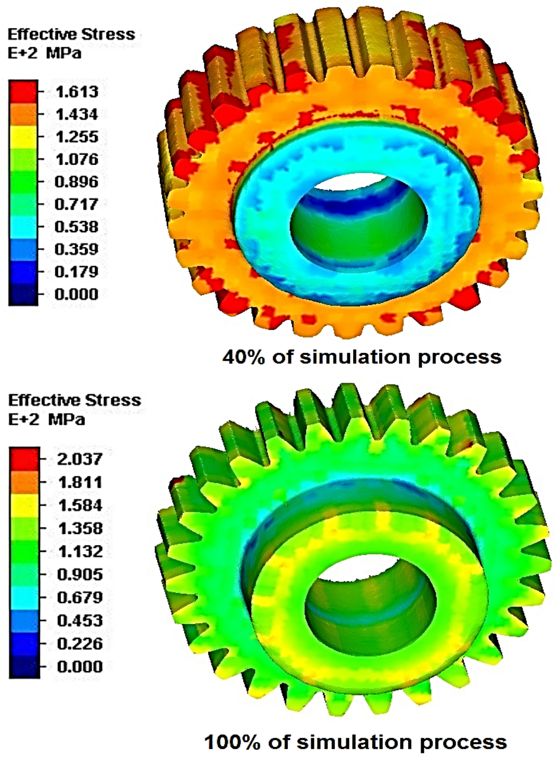

Figure 4c. Results of computer simulation at the various stages of simulation process

The program is suitable for simulation of bulk forming processes in heat, warm or cold. For starting the simulation it is necessary to properly define the input data. For starting a simulation of gear wheel these necessary input data were defined:

- process - closed die forging in heat
- material of billet - DIN 17210 (1.7131)
- material of the tool - ASTM A 681 (H13)
- temperature of billet - 1100 °C
- temperature of the tool - 250 °C.

Results of computer simulation at the various stages of simulation process are shown in the Figure 4.

EXPERIMENT EVALUATION

In comparison with present die forging, production of the given drop forging by precision die forging is more suitable, especially because of the highest material savings. Comparison of charging weight between present and designed forging method of drop forging of gear wheel is shown in Table 2.

Table 2. Comparison of charging weight m_C of drop forging

Method	m_F [kg]	m_C [kg]
Present die forging	0,89	**1,07**
Precision die forging	0,55	**0,57**

$$m_C = m_F + m_{FLASH} + m_{WEB} + m_S \quad [kg] \qquad (1)$$

where: m_F – weight of finish drop forging [kg],
m_{FLASH} – weight of flash [kg],
m_{WEB} – weight of web [kg],
m_S – weight of scale [kg]

Comparison of material costs for present and precision die forging of drop forging of gear wheel is illustrated in Figure 5.

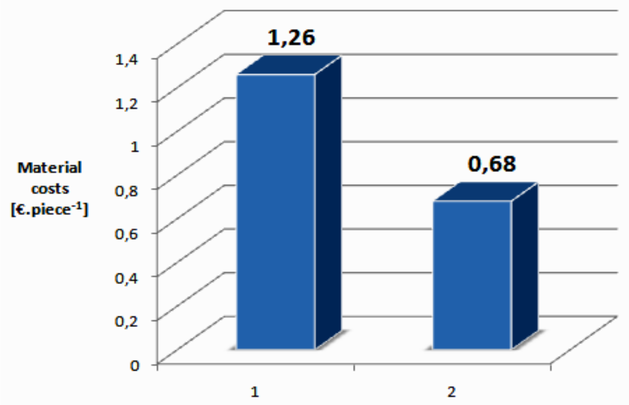

Figure 5. Comparison of material costs for drop forging
1 – present die forging; 2 – precision die forging

CONCLUSIONS

Precision die forging in closed dies represents lucrative method of drop forging production. In comparison with conventional die forging of gear wheels with flash in heat, by precision die forging in closed dies it is possible to reach savings of material costs more than 40 percent, reduction of cutting operations and reduction of production times more than 60 percent. The final filling in die cavity was ended when the fillets on the bottom of a hub were filled. Evaluation of the further results showed that the highest effective plastic strains were in the area of the fillets from toothed ring into the hub. The lowest effective plastic strain was in the area near the bore hole of the drop forging. Evaluation of the results of effective stress showed that the highest values were in the area of the tooting and in the lower part of a hub. To meet all requirements on drop forgings of international competition, producers should have utilized this forging method.

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