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RESEARCH OF METAL FLOW IN CLOSED DIE IN PRECISION FORGING

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Abstract

The first part of the article contains the brief characteristics of the precision die forging process. The second part of the article focuses on the design and trials of the press tool for precision die forging of spur gear where aluminum is used as model material. The conclusion gives an evaluation and comparison of material flow in the die cavity, based on the results taken from material experiment and computer simulation.

Key words

precision die forging, spur gear, material experiment, simulation of metal flow

Theoretical part

The process of precision die forging is a separate part of die forging. The technology enables finishing of parts with high dimensional accuracy and high surface quality (near net shape parts) [1].

The main methods of precision die forging which allow for the reduction of material consumption are closed die forging and minimal fillets forging, or forging without fillets. Making cuts in the consumption of material has a serious influence on the final price of the forged piece. This process requires an exact volume of semi-product and exact division of material in the rough forge operations because there is no possibility of displacing surplus material into the flash [3].

There are many factors which have an influence on precision die forging (Fig. 1): the material of the forged piece, tribology, CAD/CAM tools, the forming presses, running, theory

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of plastic simulation. Analysis of these factors is not easy, therefore research in this area is common nowadays [4].

The accuracy and stiffness of the tool, the thermal contraction, the amount of each forging operation, and the parameters give accuracy in forgings. Nowadays these characteristics can be researched with the help of computers (numerical simulation) where technological parameters can be changed, and the optimal conditions of forging and shape of forged pieces can be achieved.

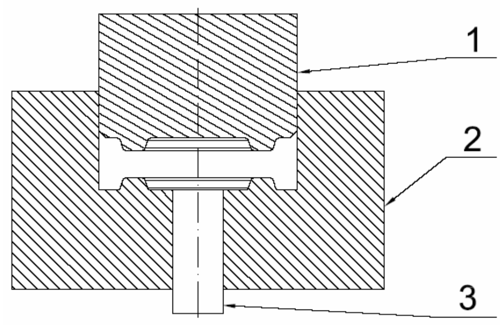


Fig. 1. *Precision die forging with slot aperture compensation of material surplus [2]*
1 – upper die, 2 – lower die, 3 – tool ejector

Utilization of the process of simulation

In the experiment the process of material flow simulation in cavity dies was used. This method was based on the division the forged piece into small elements where the path of material flow and the position neutral axis or plane can be defined. Proper characteristics, such as temperature, coefficient of friction, speed of plastic strain, etc., were given to the element. The course of stress and proper force for the element can be obtained by the method of basic equations of equilibrium.

Experimental part

This part of the article focuses on the design and trials with the tool for precision die forging of the spur gear (Fig. 2) and evaluation and comparison of material flow in the cavity die which is based on the results obtained from material experiment and computer simulation.

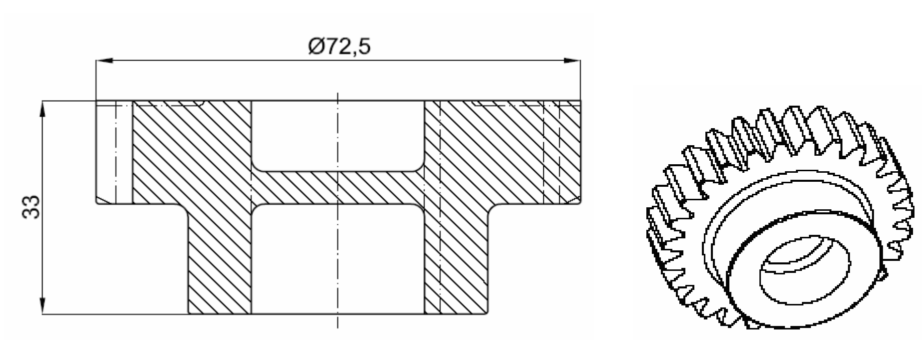


Fig. 2. *Forged piece – spur gear*

Aluminum was used as the material of the forged piece in order to save on experiment costs and energy. The process of the precision die forging was completed by cold forging.

The designed press tool (Fig. 3) was tested on the hydraulic press PYE 160 S under laboratory conditions.

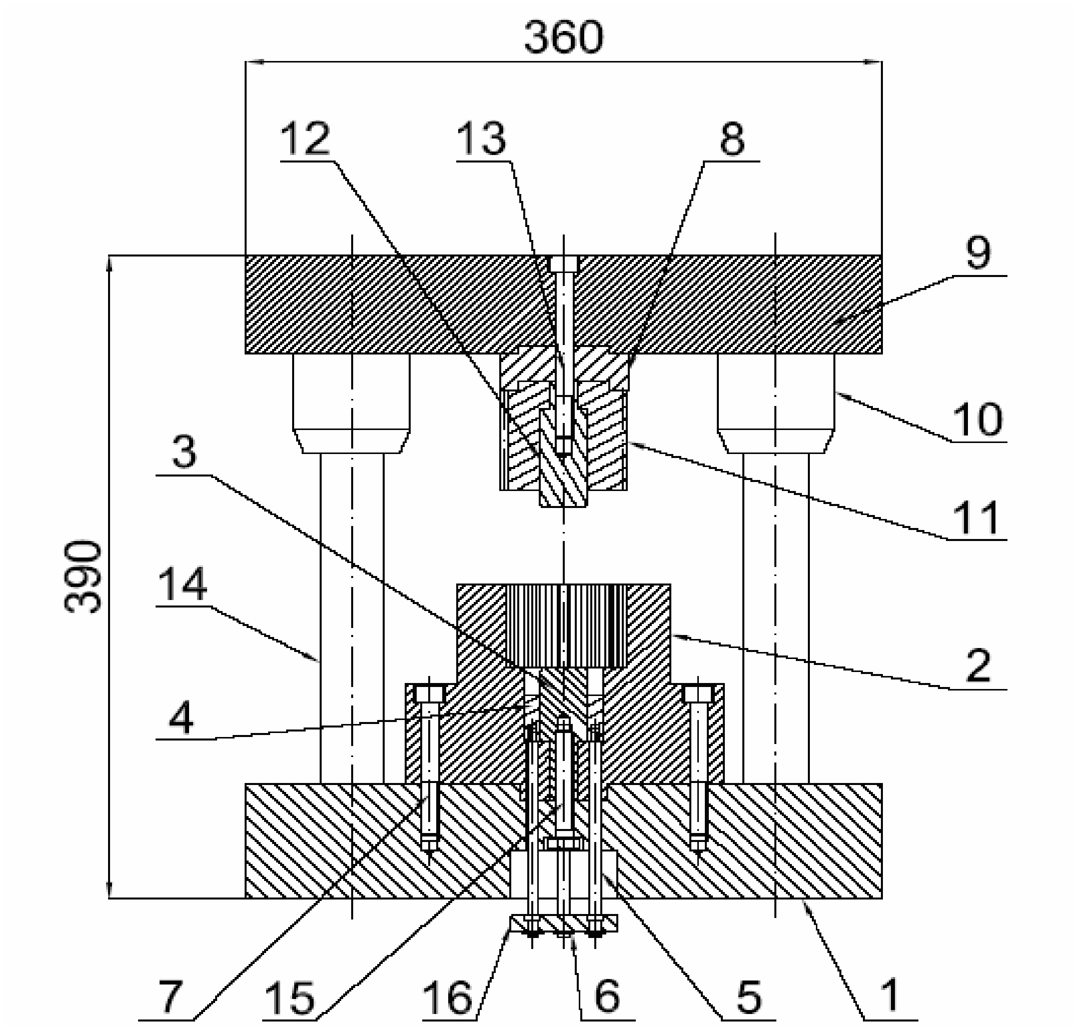


Fig. 3. *Designed precision die forging tool [4]*
1 – die holder, 2 – die, 3 – lower punch, 4 – ring, 5 – pin of spring ejector,
6 – bullet, 7, 13, 15 – screws, 8 – support plate, 9 – fixing plate, 10 – bushing guide,
11 – punch, 12 – upper punch, 14 – guidepost, 16 – ringled

Material flow of metal in the cavity die in the lower part of the forging die, in connection with the travel of the upper punch, was observed during the material experiment and the course of press force F_L was obtained.

Note: The forged piece was taken out of the press tool during the process of forging under different values of press force and its dimensions were measured.

Realisation of precision die forging simulation

The precision die forging simulation was performed by using the simulation programme MSC.SuperForge [6]. The simulation consisted of one operation – precision die forging of a cylindric aluminum semi-product sized Ø60 x 25 mm and manufactured by lathe.

The process of entering the input data necessary for starting the simulation:

- forming process: closed die forging, in cold forging, 3D, FVM,
- geometry of the tool and semi-product: designed in Inventor (CAD program) and imported into the programme,
- material of semi-product: DIN AA_1100 (T = 18°C) – equivalent of aluminum material for cold forming,
- material of the tool: H-13 – equivalent to material 19 554,
- forming press: hydraulic press PYE 160 S (v = 0,2 m/s),
- coefficient of friction: 0,3 (plastic shear friction),
- start temperature of semi-product and temperature of the tool and ambient: 18° C,
- length of the stroke: 20 mm,
- size of the element used in simulation: 1,
- start of simulation,
- evaluation of the results: many quantities such as division of the temperature, effective stress, plastic strain, ***material flow***, etc. were observed in different stages of the forming process [2].

An example of visualization of the results in the MSC.SuperForge programme is given in Fig. 4.

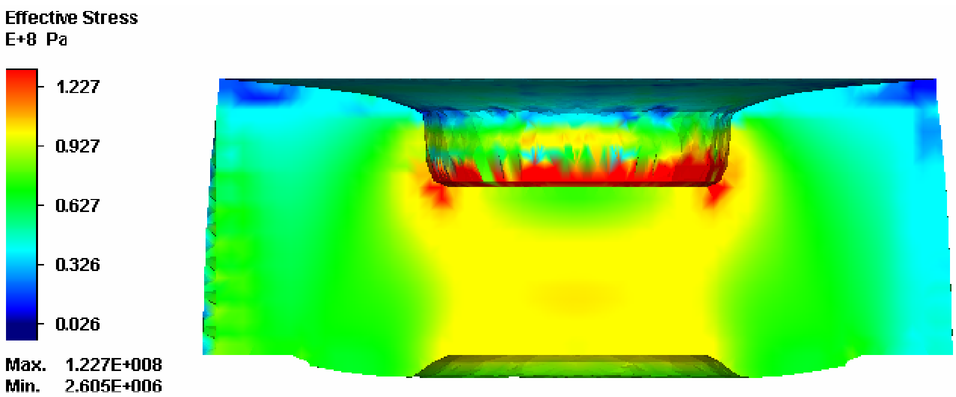


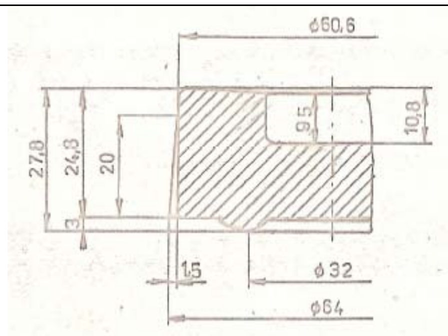
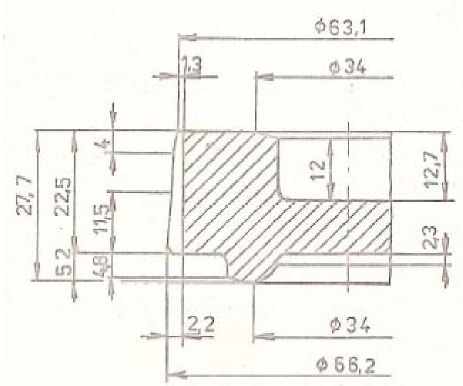
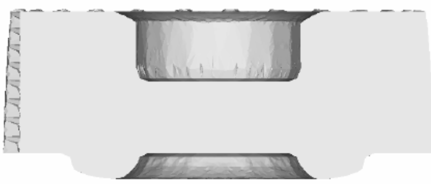
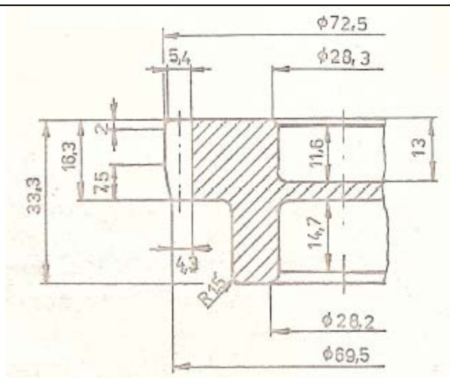
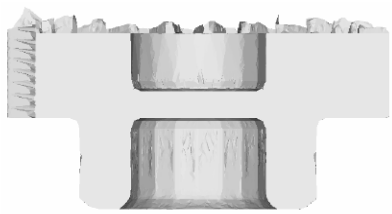
Fig. 4. *The division of effective stress under stroke z = 10 mm*

Evaluation of the results showed that the highest effective stress is on the places where the upper tool is in contact with the semi-product. The lowest intensity is in the upper part of the gearing.

Comparison of material experiment and computer simulation

The material experiment, based on the tests of metal flow in precision die forging of spur gear in a closed die with a fixed lower die, showed that the process of material flow of a cavity die can be divided into two stages (Tab. 1).

COMPARISON OF METAL FLOW OF THE DIE IMPRESSION Table 1

Press Force	Metal flow of the cavity die	
F_L [kN]	Material experiment	Computer simulation
	Stage 1	
460		
880		
	Stage 2	
1180		

In the first stage the metal (Al) started to flow into tooth spaces of the internal gearing of the die in its lower part, and at the same time the metal started to flow into the hub. After further loading, the metal flowed into the hub and at the same time it started to flow on the whole width of the gearing, while the lower part of the gearing was faster than the upper part.

In the second stage the flow material in the lower part of the tooth spaces was reduced. After further loading the metal filled the radius of the hub and almost the whole width of the gearing, while the tooth spaces were filled with the metal as a result of the friction effect on the contact surfaces of the semi-product and the die. Further loading caused the total filling of the tooth spaces, the radius of the hub, and the radius of the upper punch.

With the ***computer experiment*** (simulation) of cavity die material, the flow was very similar to the material experiment. The only difference was the following: after the filling of the lower part of the tooth spaces they started to be filled on the whole width. The results of the cavity die filling were influenced by many factors (the entry friction coefficient, the material of the semi-product, the forming press, the tool used, the size of the element used in simulation, etc.).

Scientific asset

The verification of the function of the designed forming tool for precision die forging of a spur gear in the experiment showed that the MSC. Super Forge simulation program can be used for simulation of precision die forging, and it can replace material experiments.

Conclusion

The comparison of the material experiment and the computer simulation of material flow in the cavity die proved that the results of a physical experiment in real conditions are equal to a theoretical – mathematic model of die forging simulation.

References:

[1] NASTALI, W. F. Exploring the Options in Net and Near-net shapes. In *Manufacturing Engineering,* 1986, No. 4, pp. 34-38.
[2] KRAVÁRIK, Ľ. *Možnosti simulácie technologických procesov tvárnenia. Diplomová práca*. MTF STU Trnava, 2009, 86 p.
[3] ČERMÁK, J. Presné zápustkové kování. *In Form 2000*. Brno: TU, 2000, pp. 43 – 46.
[4] VAJO, P. Aktuálnosť a predpoklady presného zápustkového kovania. In *Strojné Inžinierstvo 1998*. Bratislava: STU, 1998, pp. 651 – 655.
[5] ULÍK, A. Analysis of Material Deformation by FEA Program Antares. In *METAL 2000*. Ostrava: Tanger, 2000, No. 210.
[6] KOPŘIVA, M. *Počítačová podpora technológie.* Brno: VÚT, 2002.

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