Journal of Achievements in Materials and Manufacturing Engineering

Volume 64 • Issue 2 • June 2014

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Computer simulation of forging process of axially symmetrical forging with hammer

P. Thomas
Department of Applied Computer Science and Armament Engineering,
Faculty of Mechatronics and Machine Design, Kielce University of Technology,
Al. 1000-lecia 7, 25-314 Kielce, Poland
Corresponding e-mail address: thomas@tu.kielce.pl

Received 21.04.2014; published in revised form 01.06.2014

ABSTRACT

Purpose: The article presents the results of computer simulation of forging process on hammer using a commercial program QFORM 2D.

Design/methodology/approach: Commercial metal forming simulation software allows users to model technologies being designed and implemented. Computer simulation helps, as early as the technology development stage, conduct a multivariate analysis of the forging process to be able to determine the critical process parameters.

Findings: The simulation provides accurate prediction of material flow and filling a cut-out as well as the formation of defects in the form of lapping.

Research limitations/implications: Computer simulation has allowed the selection of such a cut-out shape to eliminate defects without the need of physical modeling.

Originality/value: This paper presents the QFORM2D simulation program applied to die forging of an axisymmetric workpiece, performed in three operations.

Keywords: Metal forming; Numerical simulation; Die forging

Reference to this paper should be given in the following way:

P. Thomas, Computer simulation of forging process of axially symmetrical forging with hammer, Journal of Achievements in Materials and Manufacturing Engineering 64/2 (2014) 85-89.

ANALYSIS AND MODELLING

1. Introduction

Gears are widely applied to all types of drive trains and power transmission systems to provide torque transfer from the active to the passive side. As gear durability strongly affects the service life of trains, gear products have to comply with strict requirements. High performance materials or suitable thermo-chemical treatments are used to enhance the gear strength. The simplest method, however, is forming an effective internal structure of the product through plastic working of the gear half-products [1-3]. Today's market conditions force manufacturers to quickly implement new forging technologies, which due to the complexity of forging processes require that a number of costly experimental studies be carried out beforehand [4,5]. Commercial metal forming simulation software allows users to model technologies being designed and implemented [6-8]. Computer simulation helps, as early as the technology development stage, conduct a multi-variate analysis of the forging process to be able to determine the critical process parameters [9-11]. This paper presents the QFORM2D simulation program applied to die forging of an axisymmetric workpiece, performed in three operations.

2. Numerical analysis of the forging process

The simulation of the forging process for a gear-shaped component was carried out using the commercial finite element-based program QFORM2D, designed for plastic working volume simulations. Material flow calculations were made assuming a viscoplastic model of the deforming body. The mathematical model is described in detail in [12]. Figure 1 shows the gear used for the modelling. Geometry of the forging is not complex but cold shuts tend to occur on the inside surface of the workpiece.

Numerical analysis of the gear forging was made for two impressions. In the first forging stage, the forging stock was upset between the flat dies. In the second stage, the gear half-product was forged. During the simulation, the piercing followed by the upsetting led to the excessive radial flow of the metal. This resulted in a defect, a lap, formed on the inner side surface of the formed material. Figure 2 shows the lap forming mechanism.

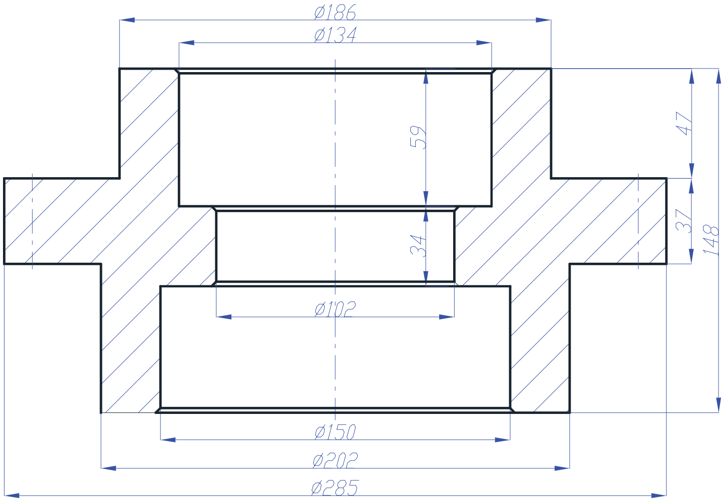

Fig. 1. Gear

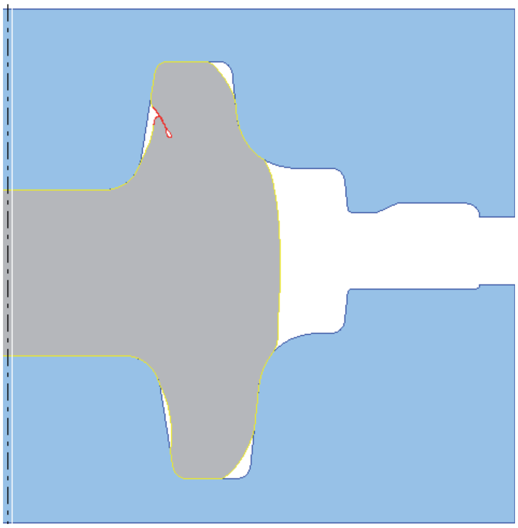

Fig. 2. Location of the lap in the formed material

The depth of the lap at the lap location is larger than the machining allowance. To remove the defect, the shape of the forging was changed by introducing changes in the die radius of curvature, position of the forging bottom and tilts. These changes did not have any significant effect on the material flow kinematics, and failed to eliminate the lap. For that reason the second variant was introduced. The three-die technological variant helped obtain a fully filled, flawless forging. Grade C45 steel bars 135 mm in diameter and 378 mm in length were used as stock. Steel C45 is commonly used for making all types of low stress machine parts such as gears, connecting rods or crankshafts. Table 1 shows the chemical composition of grade C45 steel.

The C45 steel model from the QFORM2D program database was used for numerical calculations. Forging was performed on the air steam hammer MPM 31500B. The stock was heated with induction to a temperature of 1150^{0}C in order to limit the formation of scale. The temperature of the tools was 200^{0}C. In the first stage of forging, the bar was upset using flat dies from the initial height of 378 mm to 240 mm for the purpose of descaling. Forging in the initial impression constituted the second forging stage. The half-product was pierced and upset until the material came in contact with the walls of the die. Piercing mandrels forced in the pre-form caused the metal to be displaced radially, leading to the barrelling effect. In the third stage, the forging half-product took the final form, as in Fig. 3.

During the forming process, the material is first pierced and extruded, and its complete yielding in the final stage results in the fully filled cavity and the formation of flash. Figure 4 shows the stress distribution in the forging being formed, relative to the process advancement in the third and last forming stage.

The material cools quickly in the bottom region of the forging and in the flash land region, increasing the forming resistance. Therefore the largest stresses occur in those regions reaching 240 MPa for the bottom and 340 MPa for the flash land. The bottom and the flash land are trimmed in subsequent operation. Geometric parameters of the forged blank, the deformation and temperature distribution were imported from the final stage of the previous impression simulation. In this way, the history of the deformation in the formed material was retained.

Table 1.
Chemical composition of C45 steel (PN-EN 10083-2:2008)

C	Mn	Si	P	S	Cr	Ni	Mo
0.42-0.5	0.5-0.8	0-0.4	0-0.035	0-0.035	0-0.4	0-0.4	0-0.1

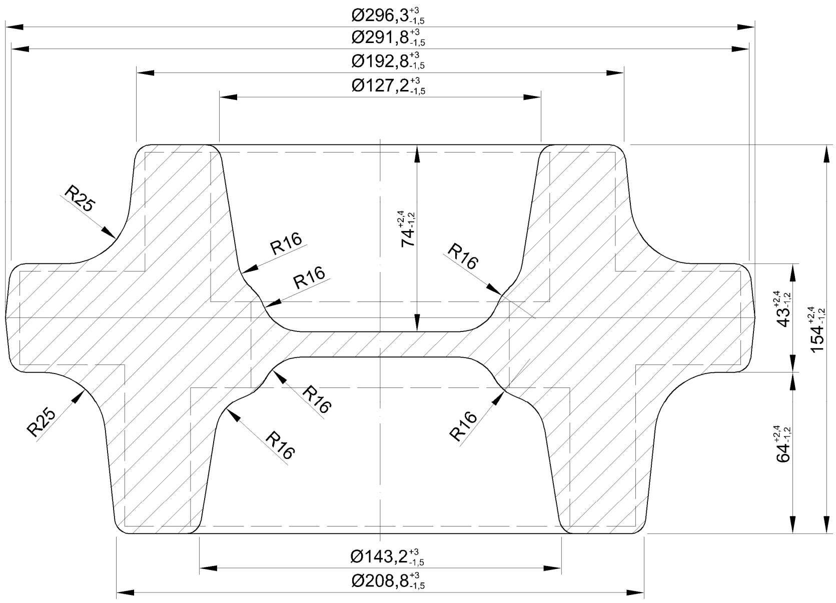

Fig. 3. Forged gear

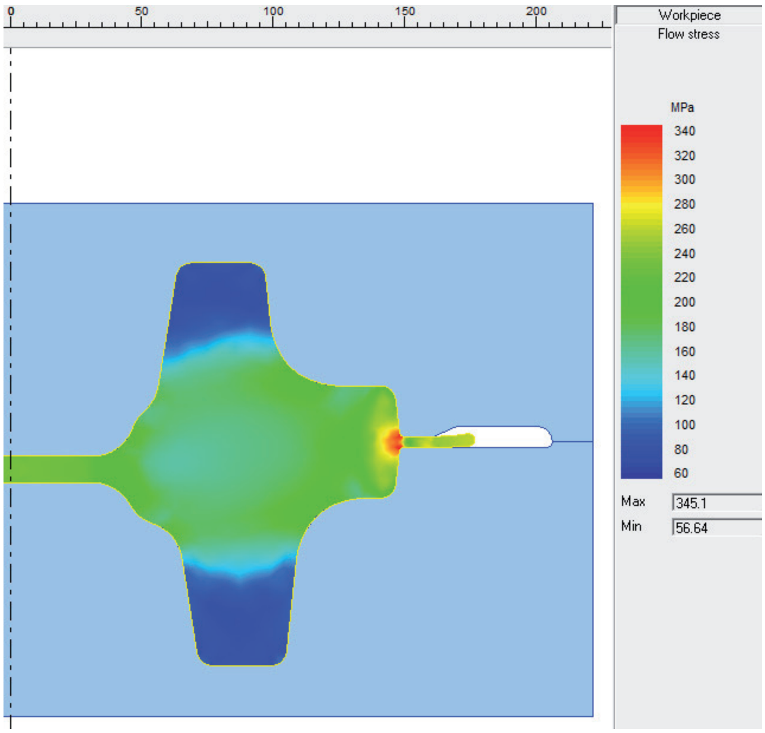

Fig. 4. Stress distribution in the forged part

3. Conclusions

Numerical analysis of the gear forging, carried out using the FE method, has confirmed that gear half-products can be formed with plastic working methods. Considering high costs and labour intensity of experimental studies, FEM modelling appears to be the suitable method to simulate the filling behaviour through the entire deformation cycle as it aids in avoiding mistakes related to inappropriate shape of the starting material or auxiliary impressions. The application of the FE method to determining the temperature, stress and strain distributions in the impressions helps predict and control the properties of the products and develop appropriate design of the dies and instrumentation. The maximum stress values recorded in the simulation process did not exceed 340 MPa, which should not contribute to an accelerated wear of the impressions. The die forging process used in this study helps eliminate defects such as lap and decrease the unit pressure values. The results obtained can be helpful when the gears with this shape are put into production or when the existing technologies are to be designed or optimised.

Literature

[1] J. Tomczak, Z. Pater, Numerical analysis of the bevel gear forging process on crank press, Mechanic 84/2 (2011) 92-98.

[2] J. Tomczak, Z. Pater, Numerical analysis of the bevel gears forging process, Mechanical Overview 7-8 (2011) 31-38.

[3] P. Wasiunyk, Die forging, Warsaw, 1987.

[4] E.N. Czumaczenko, B. Kukuryk, Modelling of the metal flow in the die forging on crank presses, Ores and Non-ferrous Metals 46/11 (2001) 517-520.

[5] E.N. Czumaczenko, B. Kukuryk, Modelling of the die forging process for bearing rings manufacture in presses, Ores and Non-ferrous Metals 49/5 (2004) 233-237.

[6] J. Sińczak, J. Kusiak, W. Madej, Analysis of flow metal of multi forging of symmetrical components, Plastic Forming 1 (1994) 11-15.

[7] E. Jacniacka, Contour impression shape selection basing on computer simulation of the axisymetric die forging process, Metal Forming 9/4 (1998) 5-11.

[8] S. Szczepanik, S. Kalz, Numerical analysis of multi forging with MES method, Metal Forming 3 (1997) 13-18.

[9] B. Kukuryk, The influence of thermomechanical parameters on forging process, Ores and Metals 42/11 (1997) 493-496.
[10] T. Miłek, Computer analysis of forming of round forged parts in mechanical press and hammer, Proceedings of the 22nd International Conference "Metallurgy and Materials" METAL 2013, Ostrava, Czech Republic, 2013, 255-260.
[11] T. Miłek, Experimental research on hydromechanical bulge forming of pipe connections, Proceedings of the Metal Forming Conference 2008, in: Steel Research International 79/1 (2008) 280-287.
[12] Qform 2D/3D. The program for the simulation of metal forming processes, QuantorForm Ltd., 2008.