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Modelling of non-symmetrical side-extrusion in preparation of steering knuckle preform

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ABSTRACT

Purpose: The conventional forging of steering knuckle makes many problems such as: creation of material defects, high force of process, low charge yield. The aim of research was optimization of preform shape for extrusion of steering knuckle.

Design/methodology/approach: Problem was analyzed using Qform3D code based on the finite element method.

Findings: As results of calculations the distributions of stress, strain, strain intensity and temperature were obtained. Besides, the total force of process was calculated.

Research limitations/implications: In future the verification of numerical results should be performed by technological tests.

Practical implications: The numerical investigations were made for real automotive part. The results can be used in real production process.

Originality/value: The new technology of production of steering knuckle was proposed.

Keywords: Numerical modelling; Extrusion; Die-forging; Steering knuckle; Automotive parts

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METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

The extrusion process is used for production of forgings having different shape: cylindrical and conical, smooth and with joggles, full and drilled. This method can be used for very complex forgings and different profiles of cross-section. Analysis of product range indicates that many forgings can be made by extrusion. In automotive industry a lot of die forgings can be made by this method. This process has many advantages. One of them is three-axial state of compression stresses which causes increase of metal plasticity. It allows for deformation of steels with lower plasticity. Extrusion eliminates the metal losses in form of flash and excessive machining allowances [1-4]. In addition, it increases the precision of forgings, productivity and decreases the labour consumption. Advantage of this process is easy automation. The disadvantages of extrusion are: larger unit pressure and energy consumption and lower durability of tools [5,6]. Extrusion process is realized on presses or hammer presses.

The extrusion is very precise process but application of materials having higher strength is necessary. For proper designing of technological process, many forging trials are needed, particularly in the case of multi-treatment forging. Due to expensive technological tests the numerical modelling is used [7-14].

One can distinguish the following methods of extrusion: direct, indirect, side and mixed. In this work the side-extrusion process will be presented on example of extrusion for open-die forging. It is preform of steering knuckle with four non-symmetrically arranged arms (Fig. 1).

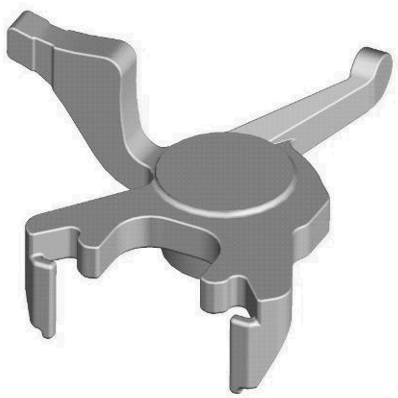


Fig. 1. The steering knuckle with four arms

2. Numerical modelling

In the forging process of final forging having shape showed in Figure 1 the susceptibility to forging laps formation in base of arms is observed [15]. For elimination of forging laps the proper designing of arms shape is necessary. Besides, the distribution of mass of preform stock in area of steering knuckle body must be proper. Large diversification of arms mass, variation of cross-section (Fig. 2a) and non-symmetrical arrangement (Fig. 2b) make an additional problem. About 80% of mass is concentrated in half of circuit of steering knuckle body. It must be taken into account in forging die construction in the aim of obtaining the simultaneous full filling of all die impressions.

a) b)

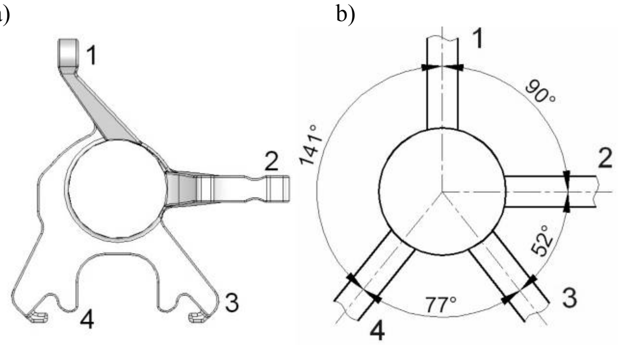


Fig. 2. Arrangement of steering knuckle arms

a)

b)

c)

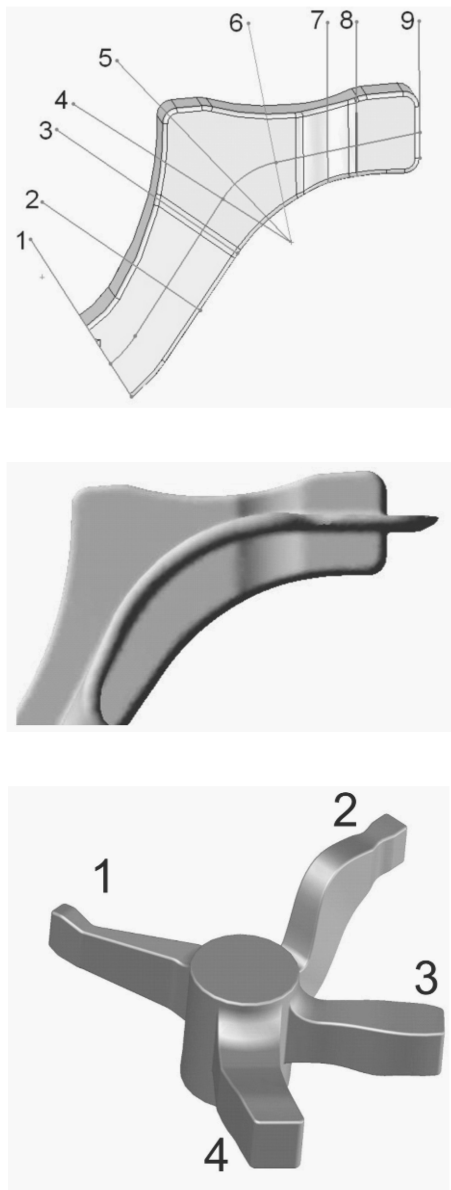
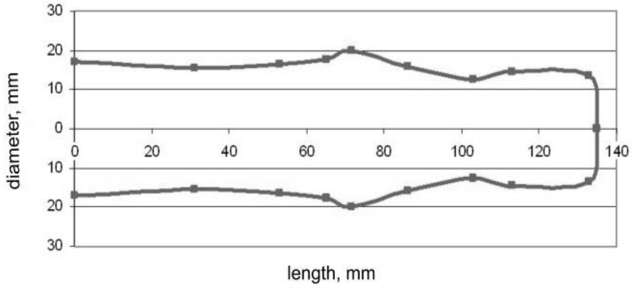


Fig. 3. Second arm of steering knuckle: a) characteristic cross-sections from 1 to 9, b) calculated shape of forging with flash, c) preform of steering knuckle with indicated arms

For providing the proper course of extrusion process, construction of dimensions of shaping side joggles was based on ideal preform principle which is used in analysis of long forgings [16]. Example of construction of cross dimensions shows Figure 3 (based on shape and dimensions of arm no.2 from Fig. 2).

The cross-sections in characteristic places are calculated for each arm with flash (because the final forging is realized in opened dies). The relations of cross-sections and diameters on whole length of second arm are showed in Figure 4. The same method was used for next arms. Based on plots of ideal preforms of arms (Fig. 3a) the model of preform of steering knuckle was performed.

a)



b)

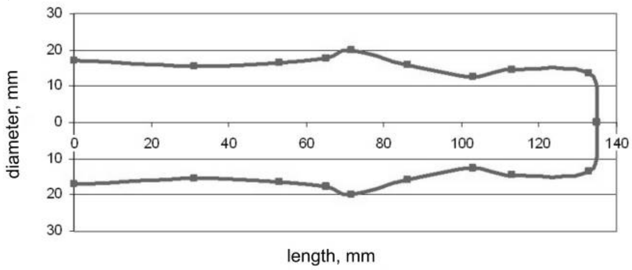


Fig. 4. Characteristics of second arm of steering knuckle: a) plot of cross-sections, b) plot of diameters

The numerical calculations were carried out using QForm3D finite element code [17]. Following boundary conditions were assumed: carbon steel – 0.2% C, stock temperature - 1150°C, friction coefficient – 0.4, velocity of toll – 10 mm/s, tools temperature - 300°C, cylindrical stock having diameter equal to cylindrical part of steering knuckle body and length which provides obtaining the shape of preform showed in Figure 3c.

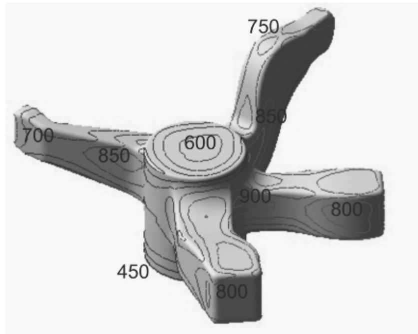
3. Analysis of results

The side-extrusion process in case of analysed product shape is very complex with respect to flow kinematics. Because of difference between temperature of tools and stock the strong decrease of temperature of deformed steel is observed. In last stage the temperature near base of cylindrical part of steering knuckle body is about 450°C (Fig. 5a). High temperature gradient influences on strain distribution. Figure 5b shows high strain intensity gradient: from 8.4 in arm no.1 to 6 in arms no. 3 and 4.

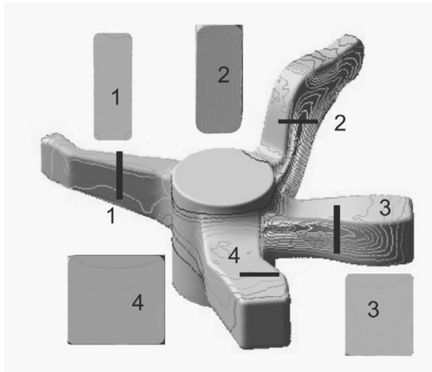
The strong inhomogeneity of strain in cross-section of all arms is observed. It can be explained by deficiency of circumferential symmetry in arrangement of arms.

The flow lines are showed in Figure 5c. Flow lines were determined with assumption of structural homogeneity.

a)



b)



c)

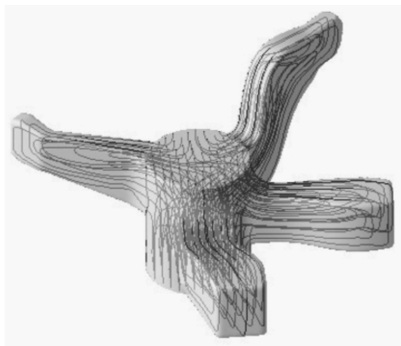


Fig. 5. Calculated last stage of extrusion: a) temperature [°C], b) strain intensity, c) flow lines

4. Conclusions

Analyzed side-extrusion process is the method of deformation in which occurs large unit pressure (over 1000 MPa). It causes lower lifetime of tools and difficulties with proper tolerance obtaining. Last problem is less significant in the case of described process because final product is obtained in opened forging die (where volume fluctuations are compensated by flash). Large pressures on surface of tools are concentrated in central area of forging body. However, total force in last stage of extrusion is significantly lower (up to 10 MN) than for opened-die final forging of steering knuckle, where value of force is about 20 MN (Fig. 6).

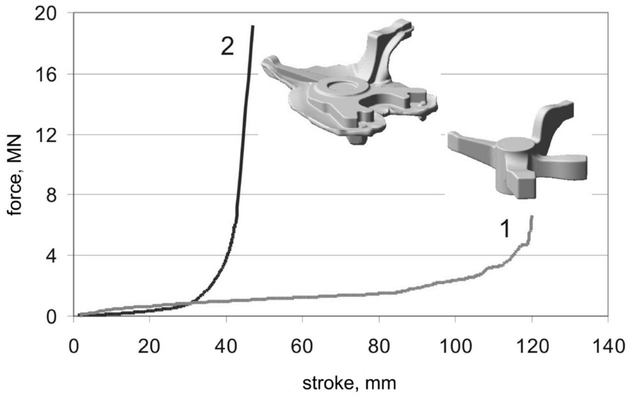


Fig. 6. Force in process: 1- side-extrusion of preform, 2- open die forging

The main advantage of described process is high charge yield (about 85%), whereas traditional technology gives yield about 30%.

Side-extrusion process leads to formation of advantageous structure. It allows to obtain the higher quality and decrease of mass of final product. It's very important in automotive parts production.

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