IMPROVING THE QUALITY OF Al- ALLOYS HOT FORGING PARTS

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Summary: *Aluminium forgings provide the following advantages: high strength and low weight, good corrosion resistance (for most aluminium alloys), the fibre (grain) structure can be arranged to correspond to the main loading direction leading to high strength and fatigue properties. High precision forgings are designed keeping the following aspects in mind: increasing the accuracy of the component, increasing the fatigue strength, reducing the mass of the component, reducing the amount of machining and increasing the economy. This paper systematically discusses the parameters influencing the accuracy of forgings and forging tool life. Detailed characteristics of alloys AlZnMgCu1.5 (EN-AW 7075) for forging are described. By using the software Simufact. Forming for real part and production conditions, appropriate numerical modelling and recommendations for improved manufacturing have been made.*
Keywords: *Hot forging, Al-alloys, precision manufacturing*

1. INTRODUCTION

In research and development of forging processes the use of process simulation programs and physical modeling techniques is complementary. By using these tools the forging tool designer could decrease costs by improving achievable tolerances, increasing tool life, predicting and preventing flow defects, and predicting part properties. In most cases numerical models provide more flexibility in the analysis of the metal flow than physical models since they allow for quick changes in the tooling design and its motion. On the other hand, physical modeling helps the designer to visualize problems with the process and the tooling that may arise during the tryout of the actual tooling [1].

In general forging entails the sequential deformation of the workpiece material through a number of different processes. Furthermore, each forging operation comprises all the input variables such as billet material, dies, the conditions at the die-

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workpiece interface, the mechanics of shape change in the workzone, and the characteristics of the processing equipment.

The main objectives of the physical and numerical modeling for the design in forging processes are [1]:

a) To develop adequate die design and establish process parameters:

- to assure die fill,
- to prevent flow induced defects such as laps and cold shuts,
- to predict processing limits that should not be exceeded so that internal and surface defects are avoided,
- to predict temperatures so that part properties, friction conditions and die life can be controlled (only numerical modeling).

b) To improve part quality and complexity while reducing manufacturing costs by:

- predicting and improving microstructure and grain flow (only numerical modeling),
- reducing die try-out and lead times,
- reducing rejects and improving material yield.

The life of tool and piece quality is very complicated function of numerous parameters that can be divided into three main groups: constructional, productional and exploitation. Tribological effects are extremely dominant. Fig. 2 show the interaction occurring between these influences [2].

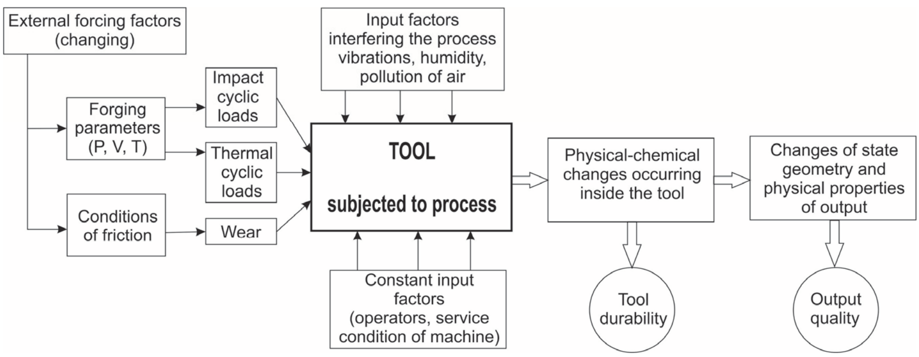

Fig. 2 *Factors influencing the tool life and the quality of a piece [2].*

2. FORGING OF Al-ALLOYS

Alloys of aluminium, designed for processing of hot forging, deliver parts with very accurate dimensions, surface quality, with minimal request for additional processing. The achieved degree of deformations in different stages of forging can be well above those achieved in forging steel or copper alloys. Using Al-alloy of high strength (duralum) allows the production of responsible parts with increased carrying capacity, for example in the car and aircraft industries. Precision forging ensures the development of complicated forging of the so-fiber structure that follows the contour of the forging, high quality microstructure and good mechanical properties and dimension tolerances. The general effects of the successful completion of cavity designs and the quality of realized term structure pieces are shown in Figure 3 [3].

The fibre structure affects the statical and dynamical strength properties in particular, as well as the stress corrosion properties of certain alloys (AlZnMgCu).

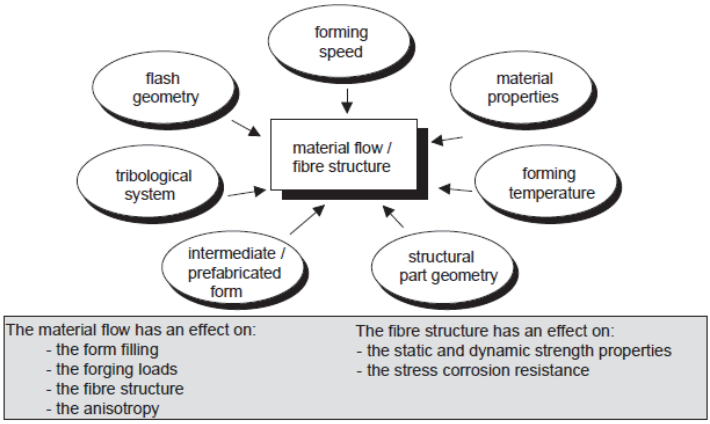

Fig. 3 *Parameters influencing the material flow and fibre structure*

A large number of Al-alloys can be forged, from the pure Al alloys to high strength ones. The most commonly forged heat treated alloy are medium and high strength ones. These materials are very sensitive to temperature changes forging. Low temperatures lead to incomplete recrystallization of deformed and undesirable microstructure. Large grains of inhomogeneous structure lead to poor mechanical properties of forged parts. The increased degree of deformation in different stages of forging increases the strength of forging. In contrast, the increase in temperature forging and prolonging treatment time leads to reduction of strength of the forging [3], [4].

Temperature of forging Al-alloy depends on the type of alloy and is in the range of 320 to 480°C. Tools must be preheated in order to avoid thermal stress. The main problem with forging Al-alloy is the need for precise temperature keeping items, which significantly affects the strain rate. Forging temperature intervals are narrow and must be respected.

Precision Forging is a die forging process which saves at least one finishing or supplementary operation compared to conventional die forging. Its merits are:

- 0° – 1° side tapers (draft)
- Thinner work-piece sections
- More narrow tolerances
- Smaller radii
- High quality surface finish
- Shorter production times for finished product

3. EXAMPLE OF FORGING Al-ALLOY

The following analysis provides an example of the axial symmetry of forging parts from the production company "Peter Drapšin - Blacksmith" from Mladenovac. The initial piece has dimensions Ø90 x 216 mm. Forging material is AlZnMgCu1.5 alloy (EN AW-7075), made in two ways: a classical preparation for hot forming (modification, casting, homogenization, extrusion, heat treatment) and special casting process under the influence of electromagnetic fields [4], [5].

This paper outlines the results of the alloy obtained by the second method of fabrication. These alloys have high strength and are suitable for hot working. The chemical composition of the alloy is given in the table below. Mechanical properties vary in the intersection of cast bars. Averaged characteristics are: Rm = 470 MPa, Rp = 310 MPa, Ag = 7%, hardness of 115 HB. Flow curves are shown in Figure 4 [3].

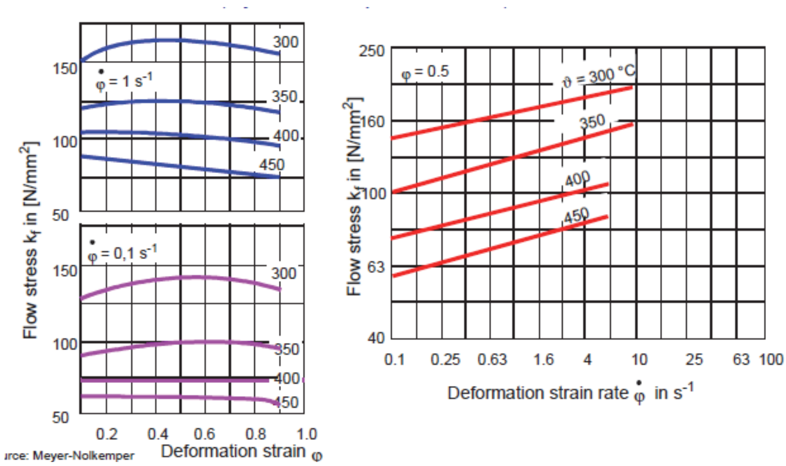

Fig. 4 *Flow Curves for AlZnMgCu1,5* [3]

Table 1 *Chemical composition of alloy EN AW 7075*

Element	Zn	Mg	Cu	Mn	Cr	Fe
Content %	5.51	2.29	1.45	0.13	0.19	0.14

Before forging tool is heated at temperatures of 250°C, a piece is kept at a processing temperature of 405-415°C. Forging is done in two operations: a preliminary upsetting and final forging, on the electro-hydraulic press LASCO 1600.

Numerical simulation of the forging process is done with known specialized software Simufact. Forging 11. Geometry pieces are axis-symmetric, and the problem is solved in 2D, which significantly simplifies the analysis. The results are an introduction to the analysis of parts of much more complex configurations.

In the following images, a distribution of effective strain and stress in the main section of pieces and the forming force are shown.

Equivalent stress reaches a maximum value at the end of the processing phase of forging and wreath is 86.59 MPa in the zone radius of die. The greatest deformations are achieved in the central zone of pieces, with forming deep profile. Flow within the pieces leads to a rise in temperature in the center of the piece. By choosing the optimal values of internal and external radii, flash geometry, as well as providing reliable operating conditions (temperature, speed, lubricant), the requirements for a reliable forging are met.

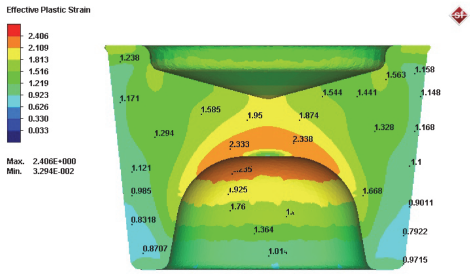

Fig. 5 *Distribution of effective strain*

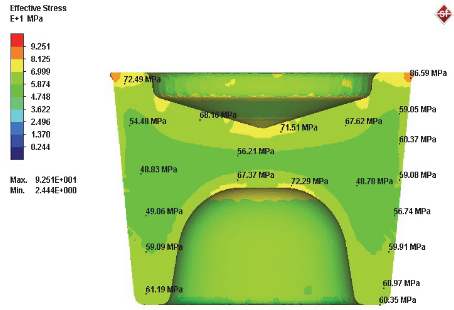

Fig. 6 *Distribution of effective stress*

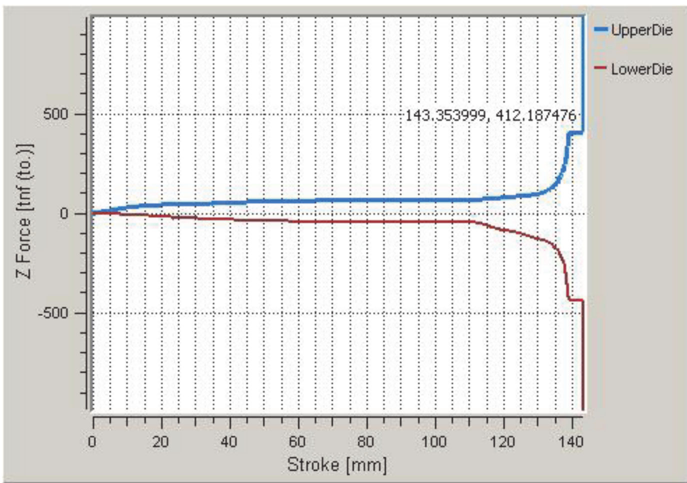

Fig. 9 *Dependence of forging force on stroke*

2. CONCLUSION

By hot forging of high strength Al-alloys, parts with high-quality structure can be obtained, with required accuracy parameters, surface quality and mechanical properties. Unlike steel forging, for metal flow process and provision of high-quality microstructure of Al-alloy ingots, it is necessary to control the influence of temperature and deformation speed precisely.

By choosing the optimal values of internal and external radii, flash geometry as well as providing reliable operating conditions (temperature, speed, lubricant) the requirements for a reliable forging are met. Numerical analysis and application of finite elements method are efficient tools for optimisation of forming process, tools construction and improvement of products quality. When developing parts of complex geometry with high requirements regarding quality, numerical tools and element of so called virtual production, reliable and economically justified designing of optimal technologies of Al-alloys hot forging is made possible.

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