12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

FORGED PIECES FROM MAGNESIUM ALLOYS AND THEIR UTILIZATION IN AUTOMOTIVE INDUSTRY

Miroslav Greger
VSB-Technical University Ostrava
17. listopadu 15, 708 33 Ostrava-Poruba
Czech Republic

Radim Kocich
VSB-Technical University Ostrava
17. listopadu 15, 708 33 Ostrava-Poruba
Czech Republic

Vlastimil Karas
KOVOLIT, a.s.
Nádražní 344, 664 42 Modřice
Czech Republic

ABSTRACT
The paper presents an investigation on the effect of process variables and material condition on forgeability of magnesium wrought alloys of Mg-Al-Zn group, AZ31, AZ61 and AZ91. The experimental work includes studies of forging capabilities of the alloys in closed-die forging at hot and warm-working temperatures. Forging tests are performed for material both in as-cast and as-worked condition, for two variants of workpiece geometry. The different variants of the workpiece indicated fracture-related problems in forging magnesium alloys in the warm-working temperature regime, which involved interaction between material condition and process variables, and state of stress. By means of numerical calculations it was concluded, that in addition to material condition, a favourable stale of stress, provided by a closed-die, can greatly improving the forgeability of magnesium alloys in the warm-working range.
Keywords: die-forging, magnesium alloys, properties

1. INTRODUCTION

Automotive manufacturers are facing enormous challenges to reduce vehicle weight to increase fuel economy, due to tightened government regulations and increased gas prices. Currently, magnesium alloys pay attention to alternative material to reduce vehicle weight because they are 33% lighter than the weight of aluminum alloys [1]. Most magnesium alloys are produced by casting techniques such as sand cast, low and high-pressure cast. Cast magnesium alloys are widely employed in powertrain applications, airbag supports, and seat frame in automobiles. Cast magnesium alloys have low ductility compared to other structural materials. Forging procese is generally employed to obtain a more homogenous microstructure and better mechanical properties compared to cast alloys.

In automotive applications, cast AZ91 magnesium alloy is widely employed in powertrain applications, brake/clutch pedals, airbag supports, and steering column mounting brackets. However, forging AZ61, AZ31 and AM50 magnesium alloys are rapidly growing in automotive applications such as door inners and instrument panel beams [2]. Especially, forging AM50 and AZ31 are popular for the components and structures required better ductility.

Lower forging temperature provides higher precision, with significant decrease in workability. As stale of stress, in addition to material factors (limited number of slip systems in magnesium alloys at low temperatures, grain size, resistance of a metal to failure is regarded one of the main factors responsible for plasticity, closed-die forging seems particularly advisable technology to apply to account for worse workability of magnesium alloys in the temperature regime. Flashless forging in closed dies provides a few advantages over conventional forging processes, among others, providing favourable stale of stress. Taking advantage of this fact, it is expected to achieve better mechanical properties of magnesium wrought alloys by means of warm-precision forging. The aim of the paper is estimation of workability limit of a relatively ductile magnesium alloy AZ31 in as-cast, and more brittle, AZ61 grade in as-forged condition at warm-forging temperatures and in a complex stale of stress [3].

2. EXPERIMENTAL PROCEDURE

The forging tests were performed at various temperatures in hot and warm working range. The studies of closed-die forging consisted of two parts. The first was closed-die forging of as-cast material. In addition to variable-working temperature, the effect of stress was investigated by using two cases of forging stock geometry. Resulted from two possible technological solutions preventing from eccentric placement of workpiece. The second part of the study involved forging of pre-worked material. As before, effect of variable temperature was investigated. On the basis of tests of forging as-cast material, more favourable variant of geometry was selected and the effect on the condition of the material was investigated.

The equipment employed was hydraulic press of capacity 18 MN and average forming speed of a ram 1 mm/s. Tool temperature was 200 °C [4]. Lubricant used in the experiment was Wessely HP 517. The materials used in the study were magnesium alloys, AZ31, AZ61, AZ91 and AM50 for the second part of the research. Forging of die-forged pieces were also tested in the forging shop KOVOLIT - Modrice. Results of forging are presented below.

a) Forged piece of shaft, material AZ31, AZ61, AZ91

Tool temperature varied from approx. 90 to 100 ^{o}C. Material temperature was between 380 and 400^{o}C. Mass of one blank is 45g. Fig. 1 shows a photo of the forged piece.

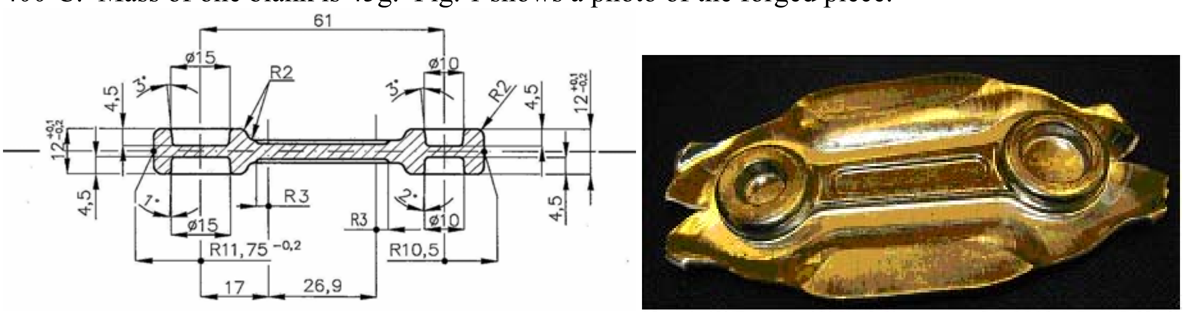


Figure 1. Forged piece of shaft

b) Forged piece of male screw, material AZ31, AZ61, AZ91

Tool temperature varied from approx. 90 to 100^{o}C. Material temperature was between 320 and 350^{o}C. Mass of one blank is 30g. Fig. 2 shows a photo of the forged piece.

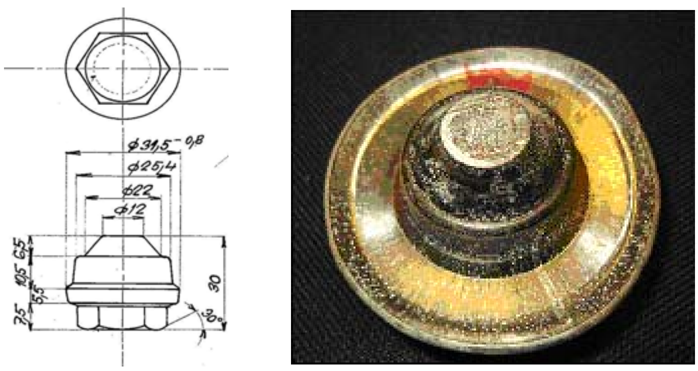


Figure 2. Forged piece of male- screw

c) Forged rotation piece, material AM60, AZ31, AZ61
Tool temperature varied from approx. 105 to 130 °C. Material temperature was between 330 and 370°C. Fig. 3 shows a photo of the forged piece.

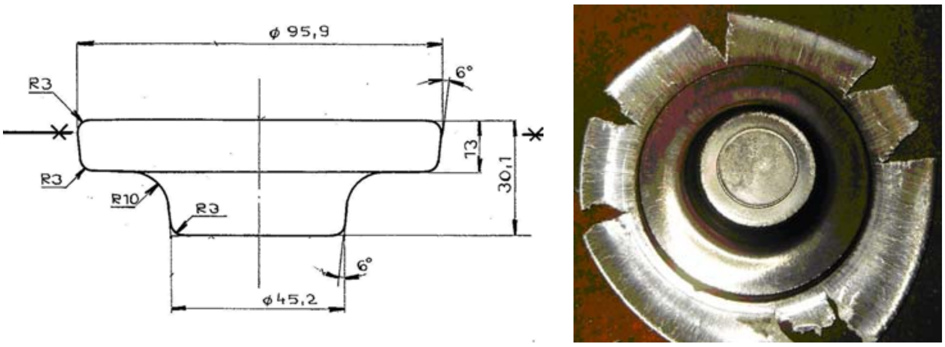


Figure 3.Rotating symmetrical forged piece

d) Forged piece of half axis vehicle, material AM60, AZ31, ZK60,
Tool temperature varied from approx. 120 to 140°C. Material temperature was between 350 and 385°C. Fig. 4 shows a photo of the forged piece.

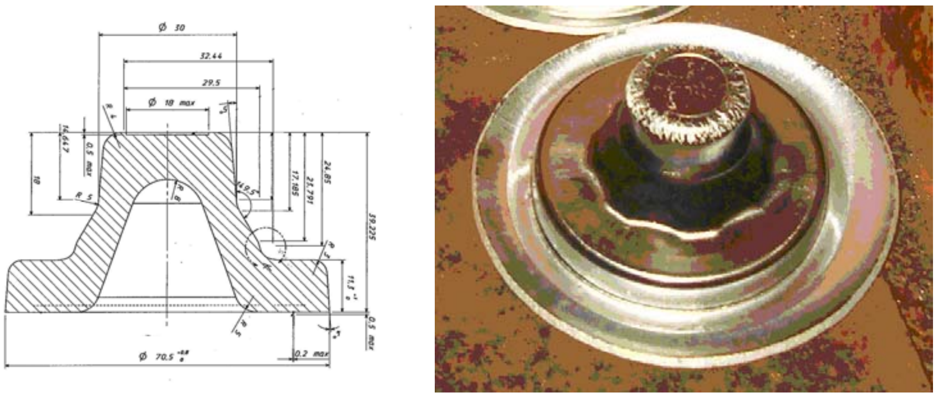


Figure 4. Forged piece of half-axis wehicle

e) Forged piece of shaft, material AZ31, ZK60
Tool temperature varied from approx. 120 to 140°C. Material temperature was between 350 and 385°C. Fig. 5 shows a photo of the forged piece.

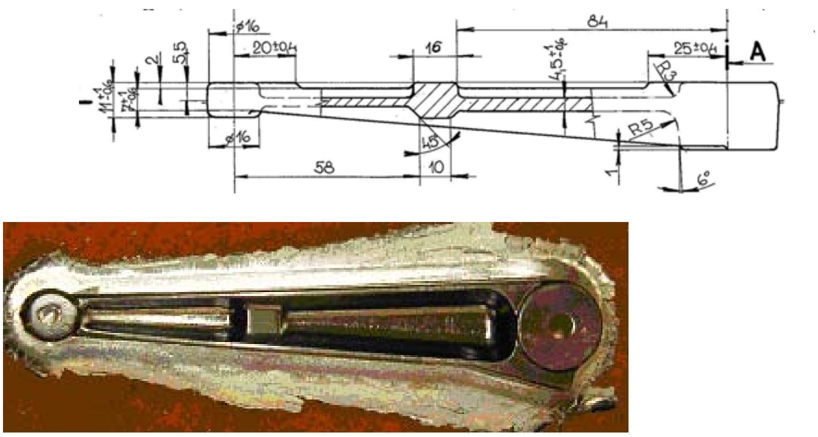
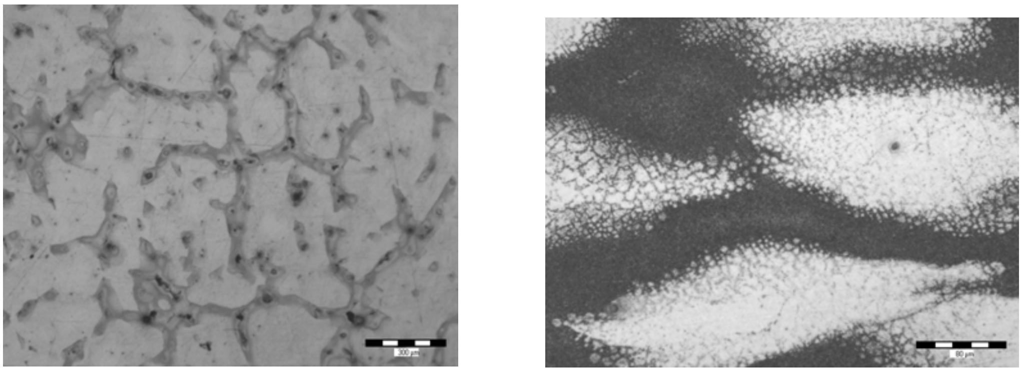


Figure 5. Forged piece of shaft

3. SUMMARY AND CONCLUSIONS

Basic physical-metallurgical characteristics of magnesium alloys in initial state, after heat treatment and after selected classical (rolling, forging) forming processes were investigated, as well as development of magnesium alloys properties in dependence on non-conventional technologies of forming. In as-cast state great extent of inter-dendritic segregation was established, which makes it impossible to achieve steady state, Fig. 6.



a) b)

Figure 6. Structure of alloy AZ31 in cast state and after forging shaft no. 1

This was confirmed by differential thermal analysis. Heterogeneity of chemical composition is related to occurrence of the phase $Mg_{17}(A1,Zn)_{12}$, which is part of eutectic surrounded by dispersion. Effected heat treatment did not lead to complete homogenisation of structure. Partial fragments of the phase $Mg_{17}(A1,Zn)_{12}$ remained preserved in inter- dendritic areas [4].

This phase limits considerably plastic properties of the given alloys at conventional technologies of forming. Realised microanalysis and transmission electron microscopy contributed to more detailed identification of phases and to explanation of their influence on deformation behaviour of selected alloys. Homogenisation annealing increases alloy's strength and toughness in comparison with the initial state, as well as its resistance to impacts to a maximum value.

Selected formed magnesium alloys were subjected to application of technologies die-forging. With growing extent of plastic deformation nucleation spots for forming of new grains also increased and at the same time there occurred repeated deformation induced precipitation of dispersive minority phases. These processes resulted in gradual refining of micro-structure, grain size decreased down to $d \approx 3{,}6\ \mu m$ and in its further homogenisation in volume of matrix, which was manifested by enhancement of strength characteristics of the alloy, without distinct deterioration of plastic properties. One of the reasons of achievement of high strength consisted in obtaining very fine grains, which act in conformity with the Hall-Petch relation positively on increase of strength. Magnesium alloys achieve after application of die-forging technologies at the values of deformation $K > 3$ higher strength properties.

4. ACKNOWLEDGEMENTS

The work was realised within the frame of solution of research plan VZ MSM 6198910013 and project MagForge.

5. REFERENCES

[1] Behrens B.A.., Schmidt I.: Improving the properties of forged magnesium parts by optimized process parameters. Materials Processing Technology. 2007, 187-188, 761-765.

[2] Greger M., Jonšta Z., Widomská M., Kocich R.: The experience at extrusion of magnesium alloy MgA19Znl by equal channel angular pressing. *Elektronika* 2004, nr.8-9, p. 172-174.

[3] Greger M., Muskalski Z., Widomská M.: Grain refinement and superplasticity of magnesium alloys. *In NANO '06.* VUT Brno 2006 p. 135-141.

[4] Greger M., Čížek L., Pražmovski M.: Mechanical properties of magnesium alloy AZ61 prepared ECAP technology. *Mechanika,* 89, nr. 321, 2007, pp.123-124.