Journal of Trends in the Development of Machinery and Associated Technology
Vol. 16, No. 1, 2012, ISSN 2303-4009 (online), p.p. 51-54

STRUCTURE OF AZ31 MAGNESIUM ALLOY AFTER ECAP PROCESSING

Stanislav Rusz, Lubomir Cizek, Stanislav Tylsar, Jan Kedron, Michal Salajka
VSB – Technical University of Ostrava, 708 33 Ostrava – Poruba, Czech Republic

Jan Dutkiewicz, Polish Academy of Science, Institute of Metallurgy and Materials Science, Reymonta St. 25 30-059 Krakow, Poland

Marcel Klos, Visteon, a.s., Luzicka 14, 741 01 Novy Jicin, Czech Republic

Eugenius Hadasik, Silesian University of Technology Katowice, Krasinskiego 8, 40-090 Katowice, Poland

ABSTRACT
The paper presents results of investigations of mechanical properties and micro-structure specimens made of AZ31 magnesium alloy after the ECAP processing. These properties and micro-structure are influenced by technological factors during application of the ECAP method, namely by selection of suitable temperature for processing. The ECAP tool is presented by new shape geometry of channel. Measurement of micro-hardness showed an increased value after application of higher number of passes in agreement with high occurrence of fine grains.
Keywords: severe plastic deformation, ECAP process, mechanical properties

1. INTRODUCTION - MAGNESIUM ALLOYS
The alloy of the type AZ31 is typical example of magnesium alloy. Alloys with addition of aluminium are at present one of the most widespread and most used magnesium alloys. At the first stage a hot casting is processed, this is then followed by mechanical processing in order to break up the cast micro-structure and the casting was prepared for the following processing – homogenisation or grain refinement. During casting other elements were added, such as Zr, Sc, Y and La, for obtaining the ultra-fined grained (UFG) structure [1,2]. Optimisation of the weight distribution by adding of one of several of the above elements influences the next forming process and thus also achievement of the required UFG and even nano-structure. The forming temperature of Mg alloys is another very important factor [3,5].
The alloy AZ31 with the chemical composition given in Table 1 (as specified by spectral analysis) were used for the experiments. The alloy was produced by casting followed by extrusion on hydraulic press in order to obtain the smallest possible heterogeneities in its structure.

Table 1. Chemical composition of the verified alloy AZ31

Prvek	Al	Zn	Mn	Cu	Si	Fe	Mg
[hm %]	3,07	0,765	0,246	0,0016	0,019	0,000996	95,1

2. FORMING TOOL WITH NEW CHANNEL GEOMETRY
New ECAP tool is a combination of the classically used channel with the in-built helix with spiral angle of 30° in its horizontal part. During initial experimental works a tool of similar type was manufactured. This helix had the spiral angle of 10°. It was found during the subsequent comparison

with other types of modifications that used of helix has substantial influence on final grain refinement and particularly on its homogeneity. On the basis of comparison of the shapes of curves of resistance to deformation for individual channel geometries it is possible to state that the best results were achieved with use of helix. In this way more homogenous course of extrusion process was also thus achieved[4,6]. On the basis of total results of analysis of influence of individual ECAP tool geometries realised in the past, the variant using the in-built helix in horizontal channel with the spiral angle of 30°, was chosen as an optimum variant. Results of experiments and mathematical simulations have confirmed the influence of the increased spiral angle of the helix on the increased intensity of deformation and thus on the required refinement of structure.

2.1. ECAP Tool geometry

As it was already mentioned above, the ECAP technology is used in cooperation also with other technologies using SPD. The new concept of the tool uses connection of classical Equal Channel Angular Pressing and twist extrusion = ECAP + TE. The new tool contains an in-built helix with spiral angle of 30°. Advantage of the in-built helix consists in creation of counter-pressure, which enables an increase of the degree of deformation and thus achievement of substantial grain refinement at smaller number of passes through the ECAP tool in comparison with the previously used tool geometries. Parameters of the forming tool: rounding radii R_1 = 2.5 mm, R_2 = 0.5 mm, φ = 90°, Ψ = 45°, γ=30°. Figure 1 shows schematic illustration of the tool.

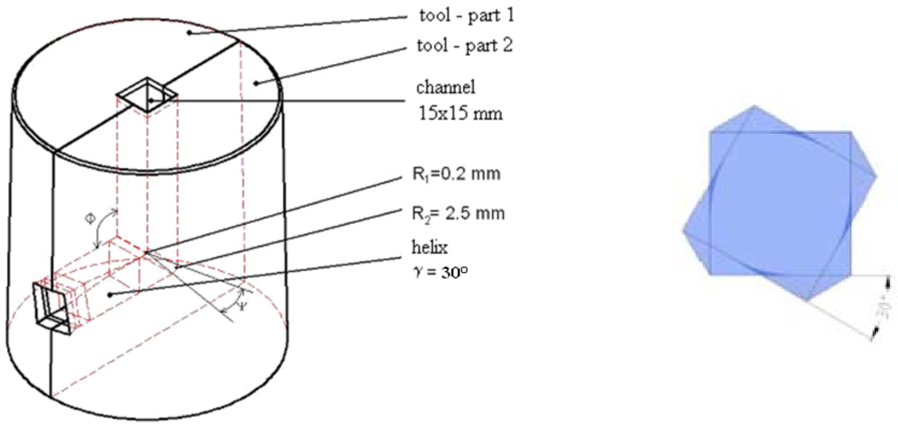


Figure 1. Tool with in-built helix with the spiral angle of 30°

2.2 Experimental equipment

The testing laboratory is situated at the facilities of VSB-Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Mechanical Technology. The extrusion itself is performed on hydraulic press DP 1600 kN with possibility of programmed control of the extrusion process (see Fig. 2).

Figure 2. Equipment for experiments

3. EXPERIMENTS

Magnesium alloy AZ31 supplied in the form of bars with dimensions Ø50 – 600 mm, prepared by hot extrusion, was prepared as an experimental material for extrusion on the above mentioned equipment. Two samples were taken from the blank for measurement of hardness, each from the opposite end. (see Fig. 3). The specimens were cut to halves; one part was used for measurement of hardness and the other one for heat treatment and for metallographic analysis. The remaining parts were cut and milled to the specimens with dimensions 15 x 15 – 60 mm for use at experiments on the ECAP equipment.

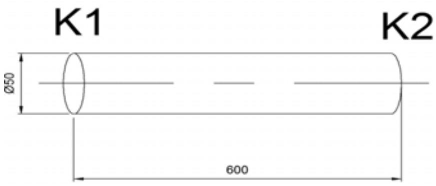


Figure 3. Geometry of specimens

3.1. Stress – strain curves

According to the assumptions the increase deformable resistance occurs in all the instruments of ECAP with the increasing number of passes. Selected readings of stress-strain curves after selected passes through the channel for magnesium alloy AZ31 is shown in Fig. 4. Experiments were performed at the temperature of 220° C. Very good results were achieved using tools geometry with embedded helix after the 1st and 5th passes through the ECAP tool.

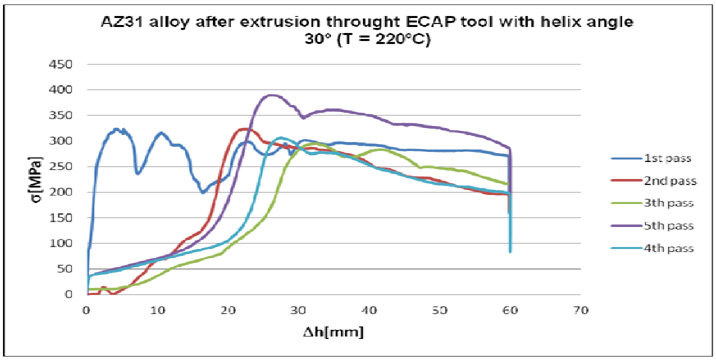


Figure 4. The stress – strain curves of magnesium alloy AZ31

3.2. Measurement of distribution of hardness

The specimens for measurement of distribution of hardness in initial state of material were taken from the supplied blanks. The taken specimen has the shape of semi-circle and a mesh was plotted on it for realisation of indents. Diagram of the mesh design and its realisation is shown in Fig. 5. Dimension of each mesh segment was 5 mm.

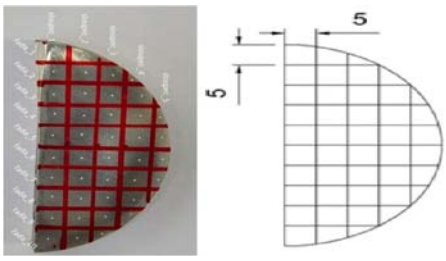
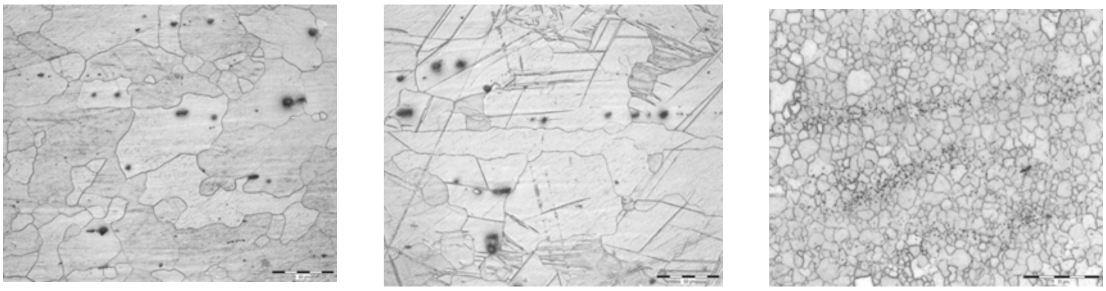


Figure 5. Example of layout of the mesh of evaluated points on the specimen for determination of hardness

Average hardness of the initial state of the alloy AZ31 was 55.984 HV5. In the initial material for the ECAP process produced by casting with subsequent extrusion a considerable heterogeneity was determined, which was manifested in the obtained values of hardness. After 4th passes through the ECAP tool the average value of hardness 69.206 HV5 was achieved. Hardness increased approx. by 30%.

3.3. Metallographic analysis



a b) c)

Figure 6. Structure of the alloy AZ31_a) initial state, b) specimen edge (magnification 200), c) after 3rd pass (magnification 1000)

It is possible to assume from the analysis of initial states of the alloy AZ31 (see Figs. 6) that structures are formed by irregular grains of solid solutions of tramp elements dissolved in magnesium matrix. In comparison with the initial state we may observe substantial grain refinement, including their more uniform size. This has unequivocally proved the efficiency of the new geometry of the ECAP tool from the viewpoint of substantial grain refinement. During the next stage of experimental works tensile tests will be performed on short specimens for verification of the obtained results – influence of structure refinement on enhancement of mechanical properties.

4. CONCLUSIONS

It may be stated on the basis of the obtained results that the new geometry of the ECAP tool has considerable influence of efficiency of the grain refinement process. It follows from metallographic analysis that substantial structure refinement takes place already after the 2nd and 3rd passes. Due to the fact that the semi-products used for specimens showed already considerable heterogeneity (according to measurement of hardness). It will be necessary to achieve in future a very good homogeneity for the subsequent ECAP process. Future works will also verify influence of lower temperature on strengthening and final structure.

5. ACKNOWLEDGMENTS

The authors would like to acknowledge gratefully the Ministry of Education, Youth and sports of Czech Republic for its support to the project “Creation of an international team of scientist and participation in scientific networks in the sphere of nanotechnology and unconventional forming metal”, CZ.1.07/2.3.00/20.0038.

european social fund in the czech republic EUROPEAN UNION MINISTRY OF EDUCATION, YOUTH AND SPORTS OP Education for Competitiveness

INVESTMENTS IN EDUCATION DEVELOPMENT

6. REFERENCES

[1] Morishige, T., Hirata, T., Uesugi, T., Takigawa, Y.,Tsujikawa, M. and Higasia, K.: Effect of Mg content on the minimum grain size of Al-Mg alloys obtained by friction stir processing, Scripta Materialia, 64 (2011), p. 355-358

[2] Yanga, Y.Q., Lia, B.C. and Zhanga, Z.M.: Flow stress of wrought magnesium alloys during hot compression deformation at high temperatures, Materials Science and Engineering: A, vol. 499, Issues 1-2,2009, p.238-241

[3] Hadasik E., Kuc D. and Mikuszewski T.: Plasticity and microstructure of Mg-Li alloy, Metallurgy-News, 78, 8. 2011, p.617-621

[4] Varyukhin, V., Beygelzimer, Y., Kulagin, R., Prokof'eva, O. and Reshetov, A. Twist Extrusion: Fundamentals and Applications, Materials Science Forum 2-vol. set, Vols. 667-669 (2011), ISSN 0255-5476, p. 31-38

[5] Duan, Z. C. and Langdon, T. G. Effect of a Special ECAP Die Configuration on Microhardness Distributions in Pure Aluminum, Materials Science Forum 2-vol. set, Vols. 667-669 (2011), ISSN 0255-5476, p. 69-74

[6] Zhilyaev, A. P., Langdon, T., G. Progress in Materials Science, 53 (2008), p. 893–979