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STRUCTURE AND MECHANICAL PROPERTIES SELECTED MAGNESIUM – ZIRCONIUM ALLOYS

Stanislav Rusz, Lubomír Čížek, Stanislav Tylšar, Jan Kedroň, Michal Salajka
VŠB-Technical University of Ostrava
17.listopadu 15, 708 33 Ostrava
Czech Republic

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

Tibor Donič
Technical University of Žilina
Velký Diel, 010 26 Žilina
Slovakia

ABSTRACT
One of the boisterously developing areas is the development of nano-structural materials, which at present belongs to the priority areas of scientific research aimed at materials and also at forming technologies all over the world. Significance of use of these materials grows especially in automotive industry, in military and space industries.
This paper informs namely on ECAP technology investigations that have been oriented by overall objectives of acquiring new knowledge concerning deformation resistances, stress condition impacts and structure and properties of nonferrous metals and its alloys. Magnesium - zirconium alloy and WE43 magnesium alloy for investigation was used.
Keywords: processing technology, structure and mechanical properties, non-ferrous metals

1. INTRODUCTION
Increasing the share of light structural materials in structures of airplanes or vehicles leads to reduction of environmental load.
The interest in application of magnesium alloys in wide spectrum of industries rises from traditional used alloys as the main alloying component which is continuously improving and still new types are being developed [1,2,3,4]. Non-ferrous metals and their alloys can be recycled very well and they replace more and more the steels.The increasing use of magnesium alloys is caused by the progress in the manufacturing of new reliable alloys with the addition of Zr, Ce, Cd, RE and very light alloys are made from Li [1,2,5].
One of the intensive advancing areas is the development of nano-structural materials, which at present belongs to the priority areas of scientific research aimed at materials and also at forming technologies all over the world. This concerns specifically forming of non-ferrous metals and their alloys. At the same time costs of production of products made of these materials are substantially falling down. Significance of use of these materials grows especially in automotive industry, in military and space industries. News technologies, which use high deformation for obtaining of fine-grained structure, comprise namely the following ones: High Pressure Torsion, Equal Channel Angular Extrusion, Cyclic Channel Die Compression, Cyclic Extrusion Compression, Continuous Extrusion Forming and Accumulative Roll Bonding.
Presented experimental work was focused on the study of microstructure and mechanical properties selected non-ferrous metals after application of ECAP [6,7,8] method. Measurement of hardness for

mechanical properties determination and methods of light microscopy for the study of microstructures was used.

2. MATERIALS AND EXPERIMENTAL PROCEDURES

The as-cast magnesium Mg-Zr alloy and magnesium alloy WE43 were used for investigation of structure and properties in experimental part of the work. Chemical composition of alloys is given in the Table 1. These alloys at 400°C were extruded to diameter 50 mm 600 mm lenght and next at 400°C/1 hour annealed. Samples of dimensions 15x15x55 mm for ECAP processing were used.

Table 1. Chemical composition of used magnesium alloys (in wt %)

Used materials	Al	Cu	Mn	Zn	La	Y	Nd	Zr
Mg-Zr	-	-	0,016	0,004	0,003	-	-	0,453
WE43	0,007	0,03	0,002	0,008	0,009	4,01	2,04	0,494

The principle of ECAP technology in works [6,7,8] is presented. 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° [8]. The testing laboratory is situated at the facilities of VSB-Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Mechanical Technology. The working site of development of new technologies has at its disposal a hydraulic press of the type DP 1600 kN. The ECAP forming was realised at condition describe above under temperature above 250 °C. At this temperature the total number of 3 passes was applied in dependence of the development of extrusion (for Mg-Zr alloy the 1st - 3rd pass and for WE43 the 1st pass). After next passes the samples were destroyed. The extruded material was then divided into individual series for manufacture testing specimens for mechanical test and metallographic evaluation. The hardness test for mechanical properties determination on HPO250 equipment was made.

The extruded material after all passes was then cute at centre of sample in dimensions 15x15x15mm into individual series for manufacture of individual testing specimens for metallographic evaluation and mechanical tests in upright direction of deformation.

The samples for metallographic evaluation were prepared in usual manner. Polishing of samples was made in two stages. In the first stage the samples were polished on cloth with use of the Al_2O_3 based polishing suspension. In the second stage the polishing was made on very fine velvet cloth with short fibres. Diamond powder with grain size of 1 µm was used as polishing material. Diamond was applied by spraying and cloth was regularly wetted by alcohol-based liquid.

The samples were then etched by Nital. Duration of etching varied from 5 to 10 seconds. Light microscope NEOPHOT 2 was used for evaluation of microstructure of alloys.

3. RESULTS AND DISCUSSION

3.1. Hardness test

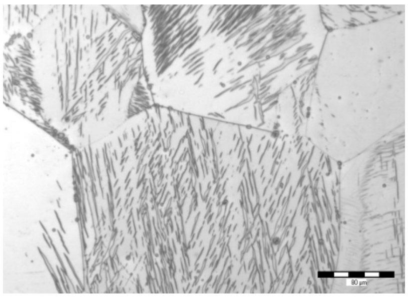
Mechanical properties by Vickers hardness method were tested. Results of Vickers hardness HV5 are shown in Tab. 2. Average values of hardness in this picture from five measurements were calculated. In the case of Mg-Zr alloy these values increase from the 1st to 3rd passes. This increasing is more significant between initial state and the 1st pass while between the 2nd and 3rd passes increased slightly. In the case of WE43 alloy the increasing of hardness was more significant than in the case Mg-Zr alloy.

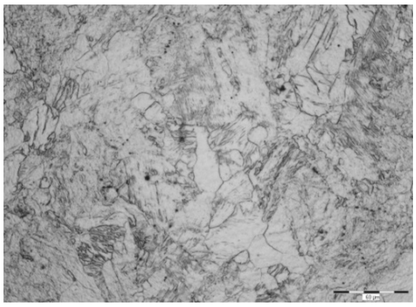
Table 2. Hardness of used alloys

Alloy/No of passes	*Initial state*	*1st pass*	*2nd pass*	*3rd pass*
Mg-Zr	*27*	*36*	*35*	*35*
WE43	*70*	*102*	-	-

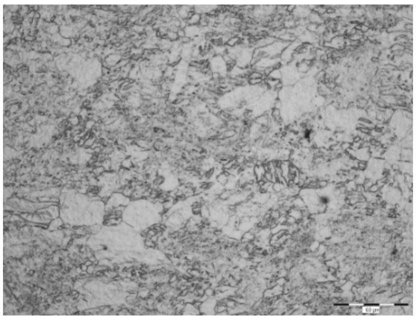
3.2. Metallographic analysis

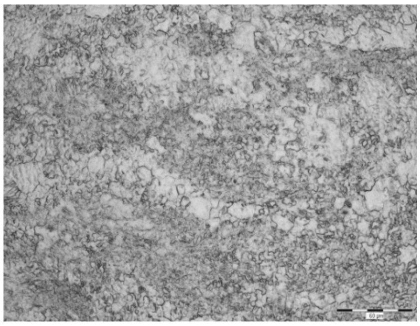
Figures 1 and 2 show the obtained results of analysis of selected samples.





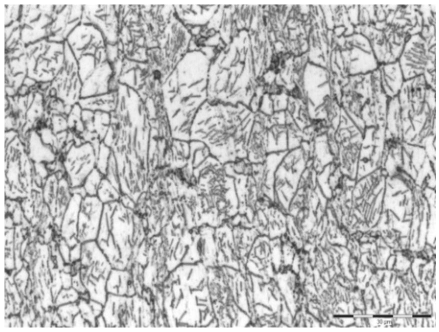
a) initial state *b) the 1st pass (upright cut)*





c) the 2nd pass (upright cut) *d) the 3rd pass (upright cut)*

Fig.1 Microstructure of the alloy Mg-Zr



a) initial state *b) the 1st pass (upright cut)*

Figure 2. Microstructure of the WE43 magnesium alloy

Microstructure of the alloy Mg-Zr in initial state is shown in Fig. 1a. This microstructure is formed mostly by equi-axed grains of various sizes, which contain oblong particles. Due to the fact that the alloy with this composition has been developed recently and its structure is not described in available literature it can be assumed that these can be grains of magnesium based solid solution, in which a precipitation of fine minority phases could have occurred during solidification due to influence of positive solubility coefficient [9]. However, due to orientation of these etch patterns it is impossible to completely exclude the possibility that these are so called artefacts caused by imperfect removal of the deformed surface layer on the cut. It is also possible to take into consideration forming of a relief at surface deformation during preparation of the sample, or decoration of possible twins or glide bands enriched by dissolved zirconium. It was verified by thorough repeated preparation of the sample surface realised with maximum care, whether this effect disappears, but this phenomenon repeatedly re-appeared even in these cases of extra-careful preparation. Detailed explanation of this will require application of chemical or electrolytic methods of polishing or possibly even etching of the sample surface (provided that etching effect is achieved), or by methods of electron microscopy.

Microstructure of the alloy Mg-Zr after applied deformation (the 1^{st} - 3^{rd} pass) is shown in Fig. 1b-d. As it is seen from this figure fine grain microstructure vas occurred after deformation. The most change of microstructure after the 1^{st} pass is detected while after the 2^{nd} and the 3^{rd} pass refinement shows lower value.
Microstructure of the alloy WE43 in initial state is shown in Fig. 2a. Microstructure of the alloy WE43 after applied deformation (the 1^{st} pass) is shown in Fig. 1b. Microstructure of the alloy WE43 in initial state is formed mostly by equi-axed grains with less size of grain than in the case of Mg-Zr alloy. In the region of grain boundary the occurrence of intermetalic phases may be expected.

4. CONCLUSIONS

The ECAP process of magnesium alloys was the first time applied on new developed die for magnesium alloys. Microstructure of initial state of the Mg-Zr alloy is formed by large polyedric grains of Mg based solid solution with dimensions in the range of 100 – 500 μm.
Maximum value of strengthening is reached at the 1^{st} pass. At the 2^{nd} pass this value decrease and continue to the 3^{rd} pass approximately on the same level.
Metallographic evaluations microstructures of the Mg-Zr alloy have also confirmed more intensive refining of grains already after the 1^{st} pass.
The similar results in the case WE43 alloy were occurred. The strengthening in the case this alloy is more intensive than in the alloy Mg-Zr.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] ASM Handbook No.2, Properties and Selection: Nonferrous Alloys and special – Purpose Materials, ASM International, Metals park Ohio, 1990, p. 29
[2] Baker, H.: ASM Specialty Handbook. Magnesium and Magnesium Alloys, ed. Avedesian, ASM International, The Materials Information Society, USA, 1999
[3] Dobrzański, L.A.,Tański T., Čížek L.: Influence of modification with chemical elements on structure of magnesium casting alloys. Proceedings of 13th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice – Wisla, 2005, p.99-202
[4] Čížek L., Greger M., Pawlica L.,.Dobrzański L.A., Tański T.: Study of selected properties of magnesium alloy AZ91 after heat treatment and forming, Journal of Materials Processing Technology, 157-158, 2004, p. 466-471
[5] Hadasik E., Kuc D., Mikuszewski T.: Plasticity and microstructure of Mg-Li alloy, Metallurgy-News, 78, 8, 2011, p.617-621
[6] Srinivasan R., Chaudhur, P. K., Cherukuri, B., Han, Q., Swenson, D., Gros, P. Continuous Severe Plastic Deformation Processing of Aluminium Alloys, Final Technical Report, DOE Award Number: DE-FC36-01ID14022, 2006, p. 1- 68
[7] Inwahashi, Y.,Wang, J., Horita, M., Nemoto, Z. and Langdon, T. G Principle of equal–channel angular pressing for processing of ultra–fine grained materials, Scripta Materialia, vol.35, 1995, p.143-147
[8] Rusz S.,: Final Technical Report of the Project GAČR No. 101/08/1110, 2011.
[9] Drápala J., Kuchař L., Tomášek K., Trojanová Z.: Magnesium, its alloys and binary systems magnesium–admixture, VŠB-TU, Ostrava 2004