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FORMABILITY OF MAGNESIUM ALLOYS

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ABSTRACT
The paper is focused on issues of processing of non-ferrous metals in practice, namely on Mg-Al-Zn based on magnesium alloys with graded Al contents. It is well known that forming of these alloys is difficult since this feature is caused by their crystallographic arrangement. Nevertheless, application of appropriate methods of forming, such as e.g. some of SPD processes, makes it possible to achieve even in these alloys with comparatively very low formability very good results with orientation on their final mechanical properties, not only strength but also proven plastic properties. Methods ARB a ECAP were used in the described experiment.
Keywords: equal channel angular pressing, rolling, structure and properties

1. INTRODUCTION
Ratio of exploitation of magnesium based on materials very rapidly increases at present. This is not given by their service properties, but also by its very low mass and also certain possibility of its use as replacement of Al based materials. Production of final products made of Mg alloys is, however, accompanied by many factors, which must be mastered for its successful implementation into practice. These issues comprise among others the problems related to forming of these alloys, i.e. the problems ensuing for their crystallographic substance, such as small number of slip planes or occurrence of inter-metallic phases, which deteriorate formability. Partial contribution to solution of these problems, apart from metallurgical modifications, consists also in unconventional methods of forming based on SPD processes, which can be a certain variant of elimination of some of existing drawbacks of classical forming processes.

2. EXPERIMENTAL MATERIALS AND PROCEDURE
Forming of Mg-Al-Zn alloys was realised by conventional way, e.g. by rolling. There were, nevertheless, used two different ways of rolling in order to enable determination of differences of different approach at deformations as such. These rolled products were in the next stage subjected to the technology of Equal Channel Angular Pressing [1-7]. Materials processed in this manner were subjected to a hot tensile test for determination of the obtained mechanical values.
Another SPD method that was used was the ARB technology, which was applied on alloys AZ91+T4, AZ61+T4. Table 1 gives their chemical composition.

2.1. Conventional rolling + ECAP
Materials made of the alloy AZ 91+T4 (Fig. 1, 2), which were first rolled by: single pass and 3 passes with intermediate heating to rolling temperature (Fig.3)

and then pressed, were subjected to hot tensile test in order to determinate a possibility of super-plastic behaviour [8-11].

Table 1. Chemical composition of used alloys

Alloy	Chemical composition %									
	Al	Zn	Mn	Si	Cu	Fe	Sn	Ni	Pb	Ce
AZ91-A	8.95	0.76	0.21	0.041	0.003	0.008	0.01	0.003	0.059	0.01
AZ61-B	5.92	0.49	0.15	0.037	0.003	0.007	0.01	0.003	0.034	0.01

3. EXPERIMENTAL RESULTS

Equal channel angular pressing was made in two stages. The first stage consisted of 4 passes at the temperature 250°C. It was followed by the second stage consisting of 1 pass at the temperature 180°C (Fig. 4). The samples were similarly as in the previous cases re-heated to the chosen forming temperature in a muffle furnace with connected inert atmosphere Ar_2. After obtaining of the required temperature and a 5-minute dwell at this temperature the material was charged into thermally insulated matrix with resistance heating, the temperature of which was identical to that of the chosen forming temperature [12].

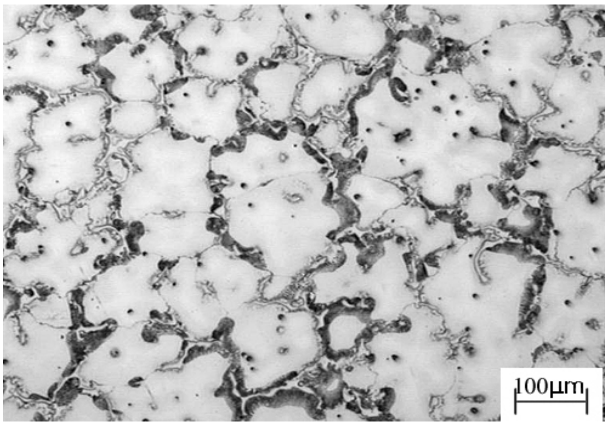

Figure 1. AZ91 alloy without T4

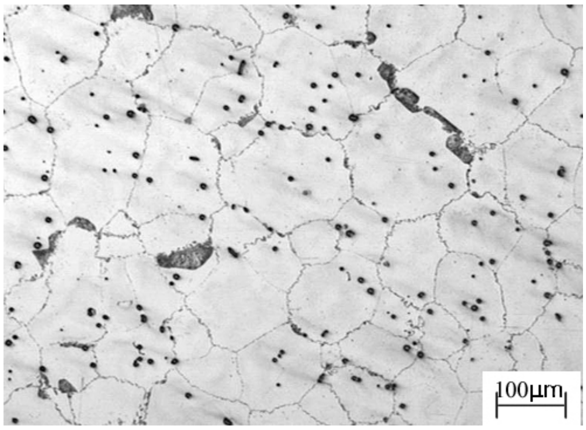

Figure 2. AZ91 alloy after T4

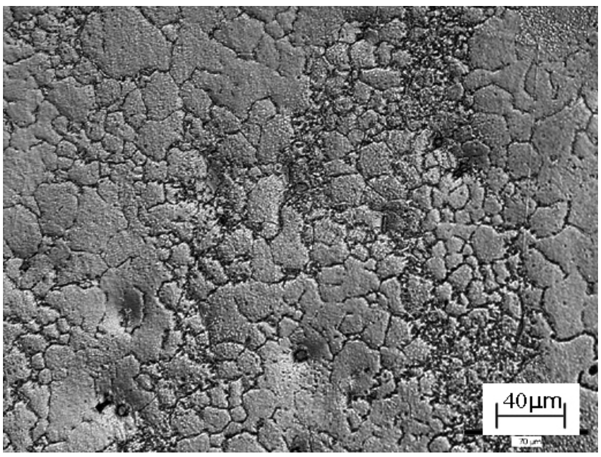

Figure 3. AZ91 + T4 after 3rd pass rolling

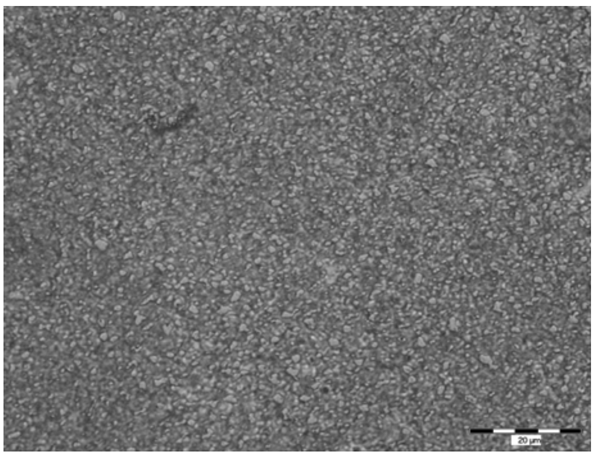

Figure 4. AZ91 + T4 after rolling and ECAP

3.1. Hot Tensile test

Temperature used at the tensile test was 250 °C and strain rate was $\dot{e} = 2x10^{-4}$. The samples obtained after processing by ECAP technology were adjusted to the required shape and then subjected to the tensile test (Fig. 5), during which the set temperature was controlled by PID regulator, which used a thermo-couple situated directly on the tested sample. Material rolled first by single pass (I, II, III) and then pressed, achieved elongation of approx. 200 %, while materials first rolled by several passes and then pressed, achieved elongation of up to 413 %. Before the tensile test microstructures of both groups did not differ significantly from each other.

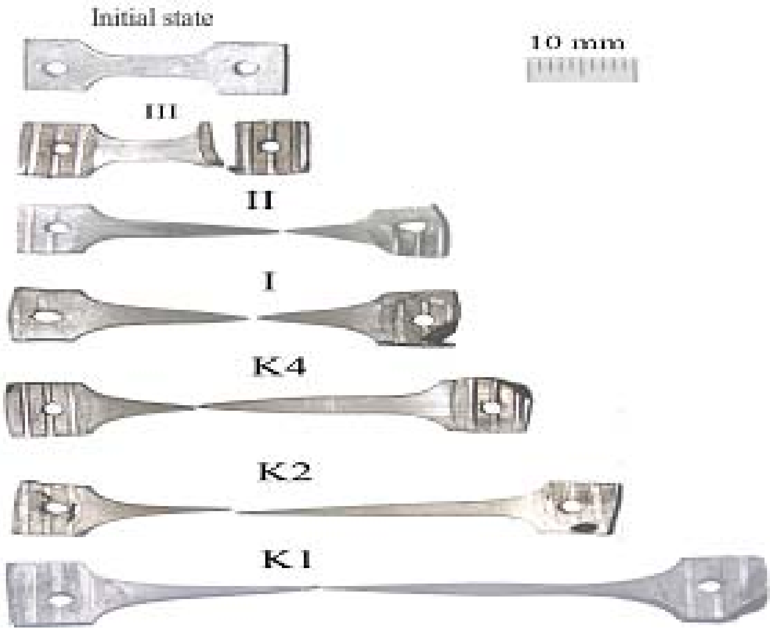

Figure 5. Samples of AZ91+ T4 alloy after ECAP and hot tensile test

Table 2. Values of strength and elongation of AZ 91 alloy + T4 after ECAP

Marking of sample	AZ 91 + T4	
	Elongation [%]	UTS [MPa]
I	294	15
II	286	19
K1	418	28
K2	384	32
K4	358	58.7

Table 2 gives obtained values of elongation in individual samples after hot tensile test, where there are apparent the differences mentioned above between various methods of rolling applied prior to application of the ECAP technology, which has important influence on final plastic properties of obtained materials. An increase of plasticity with growing applied deformation can be observed at rolling by both methods, e.g at rolling by single pass and rolling by several passes. In the latter case the obtained ductility was higher, which was probably caused by more homogenous structure obtained by re-crystallisation processes, which at this type of rolling could have developed more than at single-pass rolling.

3. SUMMARY AND CONCLUSIONS

It is evident from micro-structures and mechanical tests that at high temperatures big elongation and lower strength are achieved after ECAP in comparison with conventional methods of forming, which are caused probably by the following factors:

1) There occurred disintegration of original precipitates to small particles, which facilitated movement of dislocations (e.g. by transversal slip), resulting in recovery of micro-structure.

2) Comparatively small grain size, which enables slip deformation mechanism at the grain boundaries.

It means that during plastic deformation realised by the ECAP technology there occurred disintegration of staminate precipitates. There is also obvious occurrence of precipitates in the form of formations, the size of which exceeded 10 μm, but only in materials that were rolled by single pass. In materials rolled by several passes the distribution of precipitates is comparatively homogenous, with decreasing magnitude of deformation there is visible a growing proportion of longer staminate formations, which did not disintegrate into these smaller particles, which indicates also influence of magnitude of previous deformation at rolling .

4. ACKNOWLEDGEMENTS

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