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Structure characteristics after rolling of magnesium alloys

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Abstract: The presented article shows selected physical-metallurgical characteristics of magnesium alloys after hot rolling. The attention has been focussed on the analysis of mutual relations existing between the deformation conditions, micro structural parameters, and the achieved mechanical properties. The possibility of the method of equal channel angular pressing is also discussed for obtaining of new properties of magnesium alloys.

Keywords: Structure, Rolling, Equal channel angular pressing

1. INTRODUCTION

Magnesium and magnesium alloys are primarily used in aeronautical and automotive marked in wide variety of structural characteristics because of their favorable combination of tensile strength 160 to 365 MPa, elastic modulus (45 GPa), and low density (1 740 kg/m^3).

Scope of utilisation of foundry magnesium alloys is continuously being extended, so if we want to operate as competitive producers, it is necessary to investigate very actively properties of individual alloys, optimise their chemical composition, study issues of their metallurgical preparation, including heat treatment. Recently, however, increases also utilisation of formed magnesium alloys [1,3].

2. EXPERIMENTAL PROCEDURES AND RESULTS

2.1. Materials tested

For the experimental study of selected mechanical properties the model magnesium alloy in the shape of plates AZ91 was used. Plate dimensions were 200x100x15 mm.

There were used two states of these alloys for next investigation:

- Initial casting into sand form- state O

- Casting alloy after application of heat treatment in electrical vacuum furnace classic type 0816 Vak with argon atmosphere. The solid solution heat treatment (T4 after ASTM) was applied: pre-heating 375 °C/3 hours + 415 °C/18 hours and cooling on air- state HT.

,2.2. Rolling conditions

Forming techniques are therefore based mostly on hot forming. There was used hot forming method on two-high rolling mill with diameter of rolls 70 mm. Average value of the strain rate during rolling was $1{,}23.s^{-1}$.

Hot forming was performed on wedge shaped samples showed in Figure1. The rolling temperatures were following: $T_1=420^oC$, $T_2=390^oC$, $T_3=380^oC$, $T_4=360^oC$, $T_5=340^oC$ and $T_6=320^oC$. Features of samples after rolling show Figure 2.

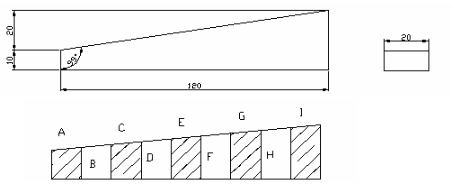


Figure 1. Shape and size of sample before rolling

Figure 2. Features of samples after rolling

Calculated deformations on the outset of signed parts all wedges were following:
A - ε = 0, C - ε = 0,083, E - ε = 0,20, G - ε = 0,294, I - ε = 0,368 .

From all wedges in signed parts were cut samples for metallographic analysis. From the eye evaluation cracks respectively fracture of wedges forming at $T_2=390^oC$ respectively $T_1=420^oC$ were observed namely at state O as showed in samples N^o. 1 in Figure 2.

2.3. Structure and properties after forming

The samples describes above were etched in highly diluted Nital and structure was observed on light microscopy NEOPHOT 2.

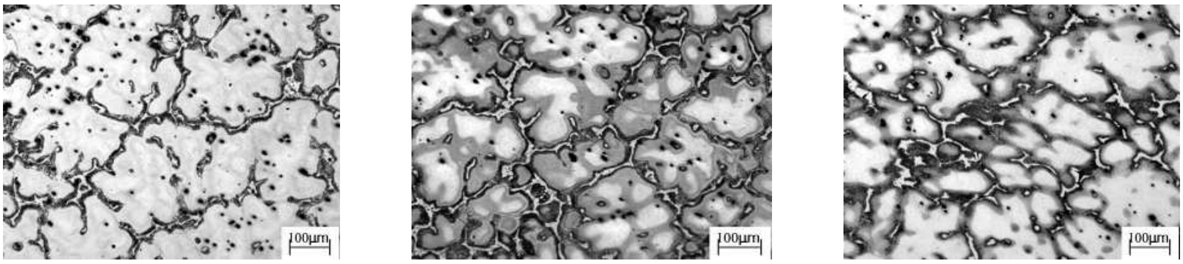
From analyze of metallographic pictures we can postulate following results:

The selected structure of this alloy in initial state O is shown in Figure 3a and selected structure after heat treatment- state HT is shown in Figure 4a.

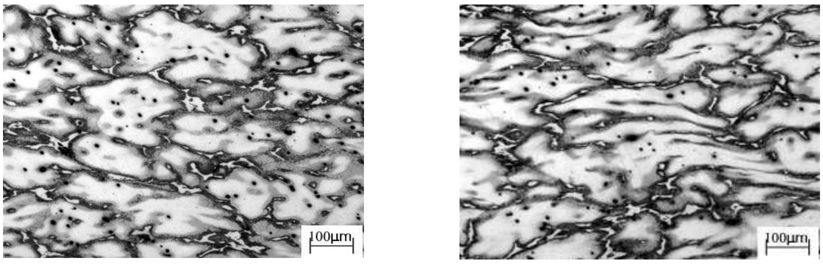
The basic structure of magnesium alloy AZ91- state O consists of solid solution matrix on the Mg base and massive γ- phase $Mg_{17}Al_{12}$, $Mg_{17}(Al,Zn)_{12}$ respectively with fine precipitates this phases near the grain boundary (dendritic segregation, Figure 3a). After heat treatment- state HT (Figure 4a) massive γ-phase partially dissolve and solid solution matrix on the Mg base is more homogenous. Detailed description is in paper [2].

On the base of analysis structures after rolling samples in initial state within the range temperatures 320-420^oC we can presume that the best results were obtained at temperature $T_3=380^oC$. Selected structures after rolling samples in initial state at this temperature show Figure 3b-e. This pictures show structure development at steps of deformation. From this analysis is seen arising shape deformation of the grains and arising solving of massive γ- phase $Mg_{17}Al_{12}$ at arising steps of deformation. The step of recrystallization is in initial stage of deformations very low a little development of recrystallization is occurred at step G in Figure 3d.

Selected structures after rolling of heat treatment samples show Figure 4b-e. The similar conditions for deformation development were occurred at rolling samples after heat treatment where the best results at the same of temperature T_3=380^{o}C were reached. The step of recrystallization in this stage- HT showed a more extension of recrystallization in each stage of deformation against the state O (see Figure 4d). At lower deformation temperatures the step of recrystallization was much lower and at temperatures T_5=340^{o}C and T_6=320^{o}C nearly no ones recrystallization was occurred and deformations traces at higher deformations were indicated.

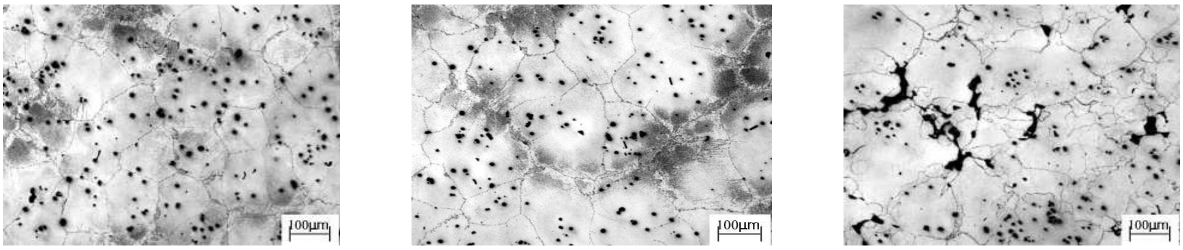


a) A - ε = 0, b) C - ε = 0,083 c) E - ε = 0,20

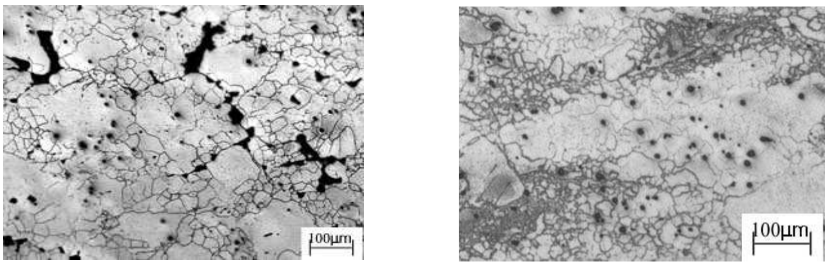


d) G - ε = 0,294 e) I - ε = 0,368

Figure 3. Sample of state O after rolling at T_3=380^{o}C



a) C - ε = 0,083 b) C - ε = 0,083 c) E - ε = 0,20



d) G - ε = 0,294 e) I - ε = 0,368

Figure 4. Sample of state HT after rolling at T_3=380^{o}C

2.3. Realization of the ECAP technology

The basic arrangement of tools for realisation of the ECAP technology is demonstrated in Figure 5. Plastic deformation realised with use of the ECAP technology represents a complex process, which depends on great number of factors.

The experiments were aimed at verification of functionality of the proposed equipment, determination of deformation resistance, deformability and change of structure at extrusion of the alloy MgAl9Zn1- state HT (AZ91). Original input examples were made of hot-formed semi-products. Square section of the input samples was 8 x 8 mm. In order to increase deformation in the volume of the sample, the samples were turned after each internal extrusion around the longitudinal axis by 90 ^{o} and extruded again.

During extrusion there occurs generation of distinct slip bands. Intensity of these changes depends on number of extrusions, i.e. on the total magnitude of accumulated plastic deformation (Figure 6) in the volume of the original sample.

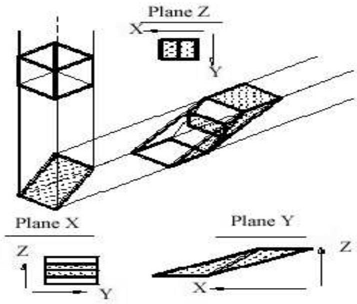


Figure 5. Principle of shearing rate passage on through the ECAP die

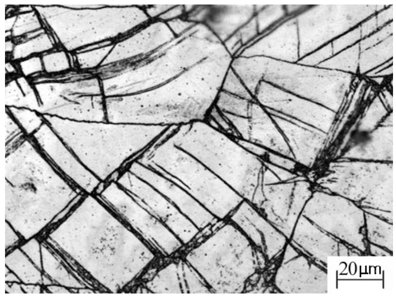


Figure 6. Generation of distinct slip bands after the fourth extrusion (temperature annealing 380^{o}C)

3. CONCLUSIONS

From the result discussed above we can postulate following conclusions:

- The possibility of hot rolling for magnesium alloy AZ91 in initial state O and after heat treatment- state HT was found.
- After heat treatment- state HT partial homogenization of structure were achieved.
- More extension of recrystallization in each stage of deformation in state HT against the state O was occurred.
- The possibility of using ECAP method was verified.

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