A. GRYC, T. BAJOR, H. DYJA, S. SAWICKI, K. LABER

ISSN 0543-5846
METABK 53(4) 489-492 (2014)
UDC – UDK 669.721:621-42:621-462:539.5=111

PHYSICAL MODELLING OF PLASTIC DEFORMATION CONDITIONS FOR THE ROLLING PROCES OF AZ31 BARS IN A THREE HIGH SKEW ROLLING MILL

Received – Primljeno: 2013-12-17
Accepted – Prihvaćeno: 2014-05-30
Original Scientific Paper – Izvorni znanstveni rad

The article presents results of the research concerning the physical modeling of plastic working of AZ31 magnesium alloy using two research methods. These studies were conducted using a metallurgical process simulator and torsional plastometer. The research was done for temperature range 200 ÷ 400 °C and strain rate from 0,1 to 20,0 s^{-1}, depending on the testing method. The results allow to determine the coefficients in yield equation needed for the numerical research. Moreover the most advantageous temperature - velocity conditions to realize the process of bars rolling in three high skew rolling mill can be determined.

Key words: magnesium alloys, rods, physical modeling, plastometric tests, torsion tests

INTRODUCTION

Magnesium alloys replace the previously used construction materials such as steels and aluminum alloys. Recently increase the interest in magnesium alloys application in the automotive and aerospace industry and everywhere the most important is high-strength and lightweight of the product [1 - 6].

The basis for designing of hot working processes for magnesium alloy rods obtaining are plasticity characteristics, which represent the yield stress as a function of the deformation limit determined by plastometric testing, such as torsion or compression test under different temperature - velocity conditions.

The ability of selecting the type of studies that should be made is not simple in case of reflecting the conditions during working processes, such as rolling the bars in three high skew rolling mill [7, 8].

Determination of the rolling parameters for magnesium alloy rods rolled in three high skew rolling mill allows to obtain the product characterized by good mechanical properties and having diversified properties in cross section, which provides new possibilities for this type of products application.

Rods from AZ31 magnesium alloy are used in the production of constructional elements for aircraft, working at room temperature, as well as parts that carry small loads, such as tanks, housings, covers, fittings and fuel oil. Also moderately loaded elements for aircraft constructions such as airplanes and helicopters plating e.g. compressor housings, parts of wheels, steering rods, fork tail wheels or trusses are prepared from them. AZ31 alloy rods can work in temperature range from - 190 °C to 150 °C [8 - 13].

A. Gryc, T. Bajor, H. Dyja, S. Sawicki, K. Laber, Czestochowa University of Technology, Czestochowa, Poland

USED MATERIAL AND TESTING METHODOLOGY

AZ31 magnesium alloy with the chemical composition: Mg – 96,284 %, Al – 2,58 %, Zn – 0,99 %, Mn-0,12 %, Nd – 0,005 %, Sb – 0,017 %, Fe – 0,002 %, Si – 0,002% was tested. Actual state of deformation during rolling of the bars in three high skew rolling mill is not easy to render, so two types of tests were conducted: compression test on the Gleeble 3800 metallurgical processes simulator and torsion tests in torsional plastometer BAHR STD 812. The tests were performed in the temperature range T = 200 ÷ 400 °C and strain rate range $\dot{\varepsilon}$ = 0,1 ÷ 20 s^{-1}.

During compression tests conducted on the Gleeble 3800 simulator the samples were heated using 2 °C/s rate and chromel - copel thermocouples attached to the central portion of the sample. During the torsion tests the heating rate of the samples was also 2 °C/s. All tests were performed in a vacuum in order to eliminate the phenomenon of oxidation the sample surface during tests made at elevated temperatures.

TESTING RESULTS AND DISCUSSION

On the basis of compression tests made using the Gleblee 3800 metallurgical processes simulator the following characteristics of the material were determined. The courses of yield stress changes depending on true strain for three temperatures of 200 ºC, 300 ºC and 400 ºC and three different strain rates of 0,1 s^{-1}, 1 s^{-1} and 10 s^{-1} are shown in Figures 1 ÷ 3.

Based on presented data in Figures 1÷3 can be seen that the yield stress test of AZ31 magnesium alloy is strongly dependent on the velocity and temperature of the process. With the increase of deformation temperature in range of the deformation values $0 < \varepsilon < 0,8$ for the lowest temperature the highest value of yield stress σ_p was observed for the strain in range from 0,2 to 0,5 and strain rate 10 s^{-1}.

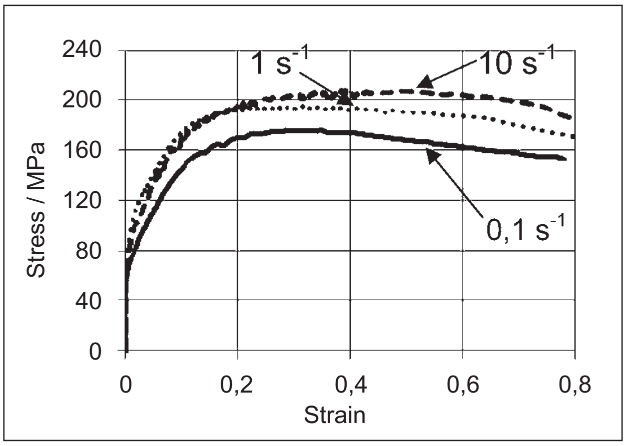

Figure 1 The strain-stress curves for AZ31 at temperature 200 °C (compression test – Gleeble 3800)

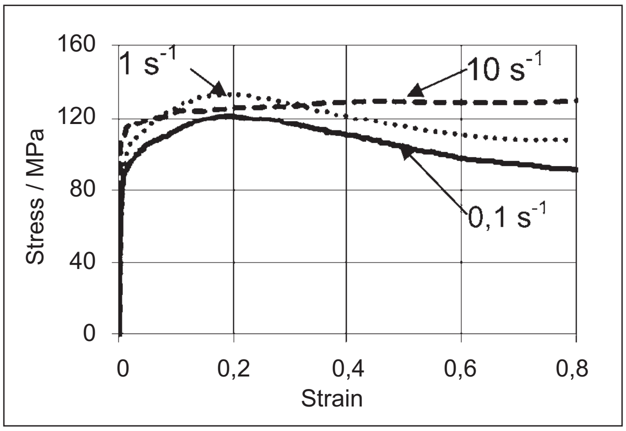

Figure 2 The strain-stress curves for AZ31 at temperature 300 °C (compression test – Gleeble 3800)

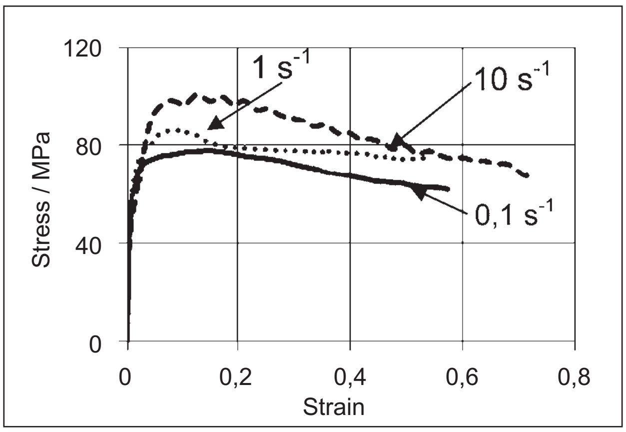

Figure 3 The strain-stress curves for AZ31 at temperature 400 °C (compression test – Gleeble 3800)

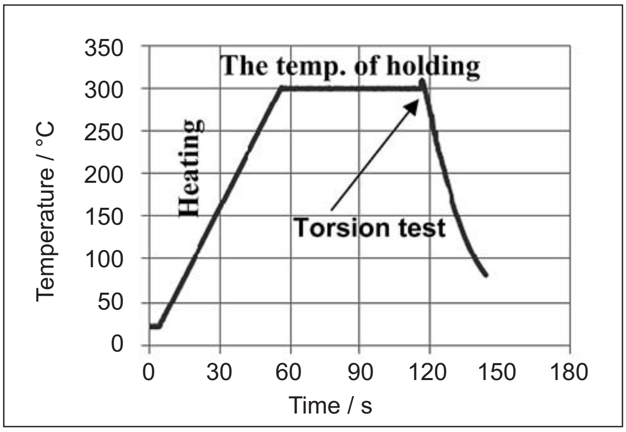

Figure 4 Diagram of torsion test course

Further increase of inflicted deformation causes stabilization or slightly subsidence of yield stress values.

For a strain rate of 10 s^{-1} at 400 °C the highest yield stress values were obtained for the strains in the range from 0,1 to 0,3, while for 1 s^{-1} strain rate the interval is narrowed from 0,1 to 0,15. Analysing the curves shown in Figures 1÷3 it can be concluded that during plastic working of AZ31 magnesium alloy at low speed of deformation the recovery and recrystallization processes occur.

According to the scheme shown in Figure 4 and based on tensile tests carried out by a torsion plastometer STD 812 BAHR the material characteristics were determined as shown in Figures 5 and 6.

On the basis of flow curves contained in Figure 5 and 6 it can be concluded that the yield stress values of investigated alloy depend on inflicted strain value and temperature of the torsion process. In addition, strain rate has a large impact on the value. At temperature of 300 °C the highest stress values were obtained for the strain in the range from 0,01 to 0,015 and a strain rate of 10 s^{-1}. For a strain rate 1 s^{-1}, the highest values of yield stress were obtained for the strain located in the range of 0,005 to 0,007. At a temperature of 400 °C the highest stress values were obtained for the strain in the range of 0,005 to 0,007 and a strain rate equal 10 s^{-1}. For a strain rate of 1 s^{-1} the maximum yield stress values were obtained for the strains in the range from 0,005 to 0,006. At a strain rate of 20 s^{-1}, the highest yield stress values were obtained for the range from 0,005 to 0,006 at low plasticity reserve.

In order to determine the effect of strain rate and temperature to changes occurring in the structure, the analysis was made using optical microscopy as shown in Figure 7 and 8. The light microscope Nikon Eclipse Ma 200 was used for the investigations.

With the temperature rise at the same strain rate (Figure 7) significant grain refinement can be observed. Carrying out the rolling process at low temperatures causes appearing of the new grain nuclei located along the shear bands. While the process temperature is 400 °C and strain rate is changing from 1 to 20 s^{-1} the strong influence of those variation on the changes taking place

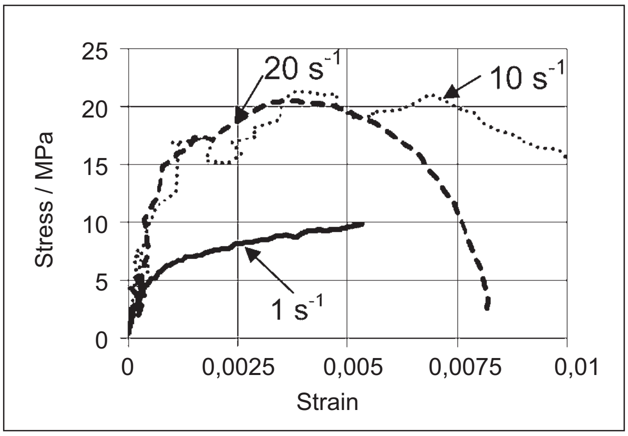

Figure 5 The strain-stress curves for AZ31 at a temperature 300 °C (torsion test – BAHR STD 812)

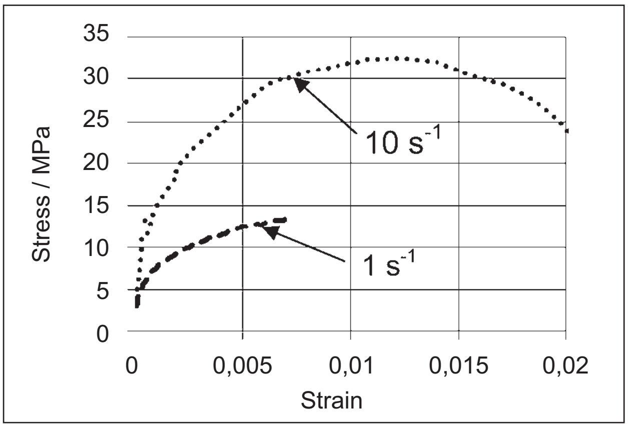

Figure 6 The strain-stress curves for AZ31 at a temperature 400 °C (torsion test – BAHR STD 812)

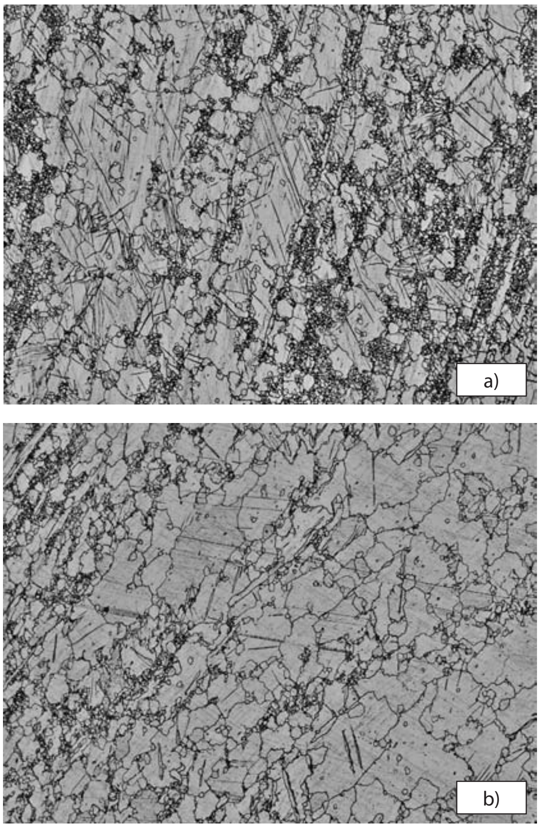

Figure 7 Structure of AZ31 alloy after torsion test (magnification 50 x) for $\dot{\varepsilon} = 10\ s^{-1}$ and temperature: a) 300 °C, b) 400 °C

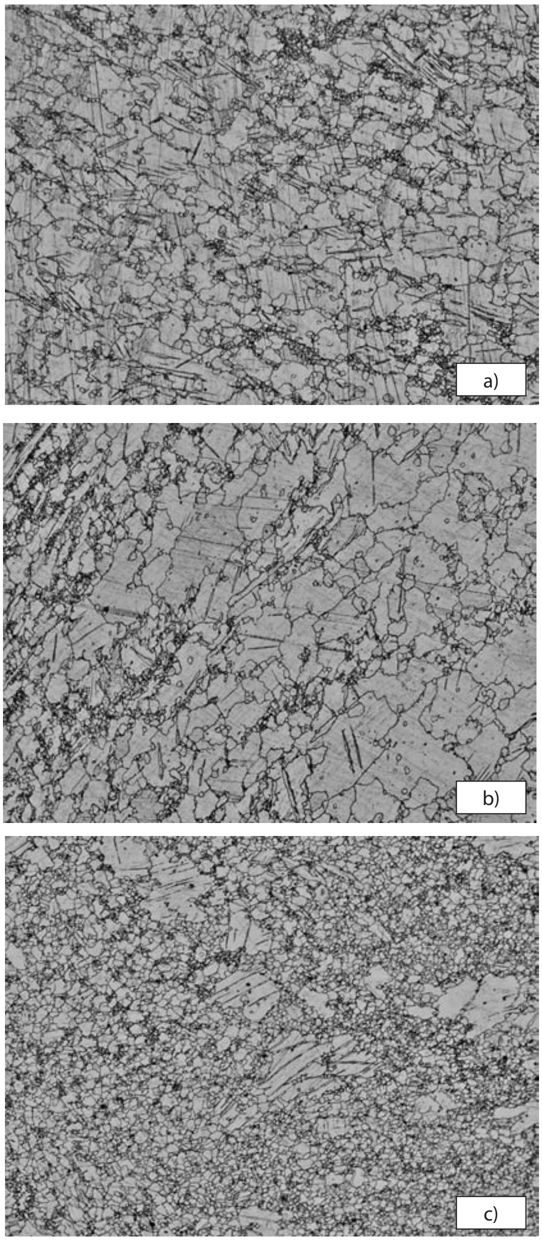

Figure 8 Structure of AZ31 alloy after torsion test (magnification 50 x) for: a) temp. 400 °C and $\dot{\varepsilon} = 1\ s^{-1}$, b) temp. 400 °C and $\dot{\varepsilon} = 10\ s^{-1}$, c) temp. 400 °C and $\dot{\varepsilon} = 20\ s^{-1}$

in the structure can be observed. The Figure 8c shows the most fragmented structure of the alloy with a few large grains aligned along the shear bands.

Appropriate research methods selection is very important when attempting to modelling the plastic working processes. Also the modelling of rods rolling in three high skew rolling mill requires running some initial tests that will map the course of the real process even in a limited level. During the process of rods rolling in three high skew rolling mill we are dealing with compression, tension and torsion processes. In addition, poor plasticity range of AZ31 magnesium alloy causes difficulties when this kind of plastic working process is conducted. The torsion tests shows different behaviour of the material on prevailing state of stress that result in a visible effect of temperature associated with high shear and rebuilding of the structure. The shear bands occurring at temperature 400 °C gave the opportunity to obtain a material with a fine grain. Strong fragmentation of the structure is the result of dynamic recrystallization and healing phenomena. It has a significant impact on the growth of plasticity, which is very important for the deformation of magnesium alloys with a compact hexagonal crystallographic structure. Due to the crystallographic network (A3) possessed the alloys are characterized by a heterogeneous texture, properties anisotropy and the limited plasticity range.

SUMMARY

The investigations carried out allow to draw the following findings and conclusions:

- The shape of the plastic flow curves of investigated alloy in a temperature range from 200 °C to 400 °C depends on the thermal effect of plastic deformation.
- Torsion tests for temperature 400 °C and a strain rate of 20 s^{-1} makes it possible to observe strong rebuilding of the material structure. The accumulated strain energy in the form of dislocation substructure results in dynamic recrystallization process occurring.

REFERENCES

[1] Z. Yang, J. P. Li, J. X. Zang, G. W. Lorimer, J. Robson, Review on Research and Development of Magnesium Alloys, Acta Metallurgica Sinica (Engl. Lett.), 21 (2008) 5, 313-328.

[2] Y. Chen, Q. Wang, J. Peng, C. Zhai, W. Ding, Effects of extrusion ratio on the microstructure and mechanical properties of AZ31 Mg alloy; Journal of Materials Processing Technology 182 (2007), 281-285.

[3] X. M. Feng, T. T. Ai, Microstructure evolution and mechanical behavior of AZ31 Mg alloy processed by equal-channel angular pressing, Transactions of Nonferrous Metals Society of China 19 (2009), 293-298.

[4] R. L. Edgar, Magnesium Alloys and their Application, K. U. Kainer Pub., France, (2000), 3-8.

[5] P. Lichy, J. Beno, M. Cagala, J. Hampl, Thermophysical and thermomechanical properties of selected alloys based on magnesium, Metalurgija 52 (2013) 4, 473-476.

[6] R. Kawalla, M. Oswald, C. Schmidt, M. Ullmann, H.P. Vogt, N. D. Cuong, New technology for production of magnesium strips and sheets, Metalurgija, 47 (2008), 195-198.

[7] J. C. Tan, M. J. Tan, Superplasticity and grain boundary sliding characteristics in two stage deformation of Mg-3Al-1Zn alloy sheet, Materials Science and Engineering A 339 (2003) 1, 81-89.

[8] A. Kawałek, A. Milenin, H. Dyja, Analysis of the effect of die shape on the state of strain in the process of extrusion of thin-walled aluminium sections, Metalurgija 44 (2005) 2, 97-101.

[9] A. Kawałek, The theoretical and experimental analysis of the effect of asymmetrical rolling on the value of unit pressure, Journal of Materials Processing Technology 157 (2004), 531-535.

[10] J. Michalik, C. Kolmasiak: Physical modeling of stress during continuous casting of ST3S steel, Metalurgija 48 (2009) 2, 71-74.

[11] T. Bajor, M. Krakowiak: Numerical analysis of pressure distribution in extrusion process of AZ31 alloy by modified ECAE method, Rudy i Metale Nieżelazne 58 (2013) 11, 760-763.

[12] D. Pellegrini, A. Ghiotti, S. Bruschi, Effect of warm forming conditions on AZ31B flow behaviour and microstructural characteristics, International Journal of Material Forming 4 (2011) 2, 155-161.

[13] G. Ambrogio, C. Bruni, L. Filice, F. Gabrielli, On the Formability of Magnesium Alloy Sheets in Warm Conditions, Key Engineering Materials 344 (2007), 55-62.

Note: Jasińska J. is responsible for English language, Czestochowa, Poland