A. GRYC, T. BAJOR, H. DYJA

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THE ANALYSIS OF INFLUENCE THE PARAMETERS OF ROLLING PROCESS IN THREE HIGH SKEW ROLLING MILL OF AZ31 MAGNESIUM ALLOY BARS ON TEMPERATURE DISTRIBUTION

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The work presents the results of numerical investigations of AZ31 magnesium alloy bars obtaining by the rolling process in a three high skew rolling mill. An analysis of impact the magnitude of inflicted deformation on temperature distribution in the material was made. The calculations were made using Finite Element Method (FEM) for 3D deformation state taking into account thermal phenomena that occur during applied deformation scheme. Theoretical investigations were made for two variants of deformation, one temperature of the process that equals 400 °C and four rolling rates of 25, 75 and 100 rev/min.

Key words: AZ31 magnesium alloy, three high skew rolling mill, temperature distribiution, deformation, FEM

INTRODUCTION

Demand for magnesium alloys products causes the interest in new technologies of its plastic working. Due to its properties such as high strength and good fluidity, these alloys are used to make structural components in the automotive, aerospace and electronics [1-5]. There is also an increased interest in this type of alloys in medicine [6]. Magnesium alloys subjected to large plastic deformation can be used for hydrogen storage [7].

Appropriate designing of plastic working process allows to obtain products with high strength properties and low weight, what is significant advantage of modern and more frequently used lightweight constructional materials. Process of selection the process parameters of plastic working is widely and theoretically analyzed for each strain variant, as it allows to reduce the costs of technology implementation. Numerical investigations are successfully applied during deformation of steel, light alloys in a variety of plastic working processes [8-10].

Change in the pattern of deformation significantly improves the mechanical properties of the finished product. To the methods that combine different patterns of deformation process also includes the process of rolling bars or tubes in a three high skew rolling mill. However propose a new technology for obtaining bars from a particular material requires a detailed analysis of the plastic working conditions.

TESTING MATERIAL AND METHODOLOGY

Test were carried out for AZ31 magnesium alloy with chemical composition as given in Table 1.

Table 1 **Chemical composition of the investigated alloy**

	Component contents / wt %							
	Mg	Al	Mn	Nd	Sb	Zn	Fe	Si
AZ31	96,284	2,58	0,12	0,005	0,017	0,99	0,002	0,02

Numerical investigations of the rolling process in a three high skew rolling mill were made using following input parameters: ingot temperature of 400 °C, rotational speed of rolls – 25 rev/min, 75 rev/min and 100 rev/min, friction coefficient: 0,4; friction factor 0,8; thermal conductivity coefficient for heat transfer between strip and rolls 20 000 W/m^{2}K. Applied tools, rolls reflect the real conditions of the deformation process.

Analyzed diameter of starting material was 30 mm. The rolling process of a magnesium alloy bar was carried out in two variants. The first involved the realization of the deformation in two passes, there was reduction of ingot diameter from 30 mm to 26 mm and then to 24 mm. The second variant related to the rolling process in a single pass, as shown in Table 2.

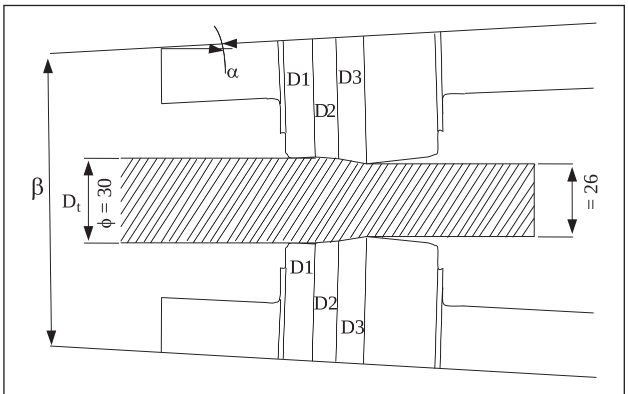

Figure 1 Scheme of the process of rolling in three high skew rolling mill

T. Gryc, T. Bajor, H. Dyja, Czestochowa University of Technology, Czestochowa, Poland

Table 2 **Parameters of the rolling process in a three high skew rolling mill**

Variant	Real strain	Elongation factor
I	$\varepsilon_1 = 0{,}14$ $\varepsilon_2 = 0{,}08$	$\lambda_1 = 1{,}33$ $\lambda_2 = 1{,}17$
II	$\varepsilon_2 = 0{,}08$	$\lambda_1 = 1{,}56$

Theoretical analysis was made on the base of the results obtained from computer simulations carried out in Forge3D program.

Due to the axisymmetric character of the process the calculations were carried out in a plane state of strain. In the work the analysis of rotational speed impact on temperature distribution in cross-section of rolled bar was presented. The analysis was carried out for the three planes as shown in Figure 2. The first of the planes is located in 1/3 of the length of the rolling gap, the second in 2/3 of the length of the rolling gap and the last one in the plane of the bar exit from the rolling gap.

TESTING RESULTS

The paper presents an analysis carried out for two variants of assumed deformation. It concerns the influence of rotational speed of the rolls on the temperature distribution over the cross section of the rolled bar. Figure 3 shows the results of numerical investigations of the temperature distribution in the cross-section of the bar for rotational speed of 25, 75 and 100 rev/min when

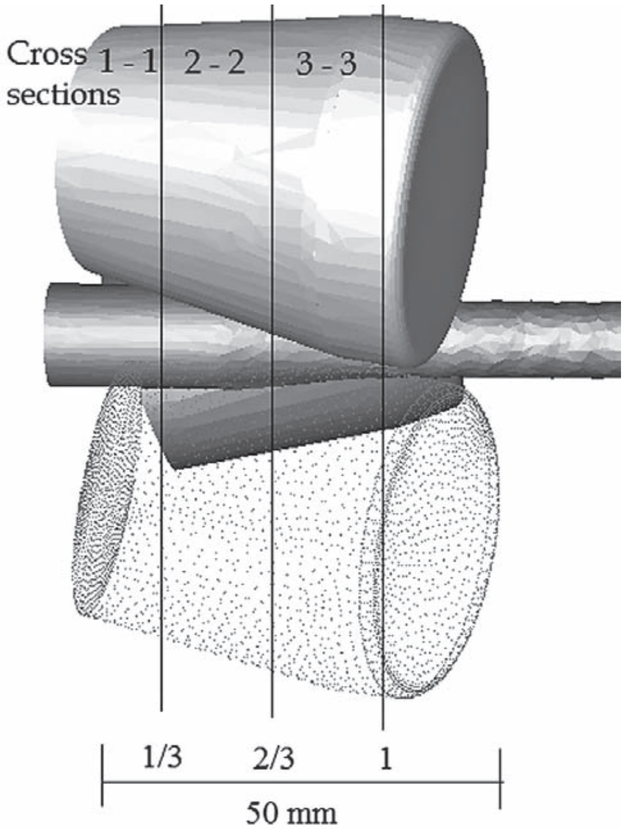

Figure 2 The cross-sections in which the temperature distributions in deformed bars were analyzed

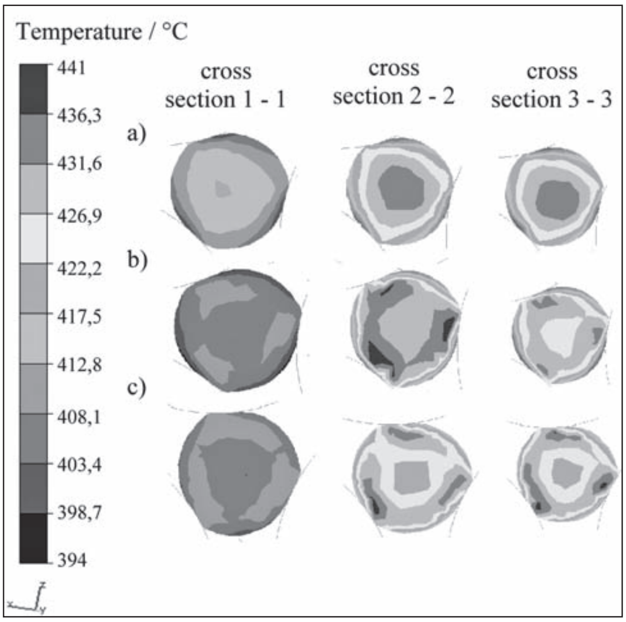

Figure 3 Temperature distributions in cross-sections of the rolled bar during the rolling of ingot with diameter of ϕ 30 mm to the bar with diameter of ϕ 26 mm with temperature of 400 °C and rotational speed of the rolls of: a) n_w = 25 rev/min, b) n_w = 75 rev/min, c) n_w = 100 rev/min

the material was heating to temperature of 400 °C for the bar rolled with reduction of the diameter from 30 mm to 26 mm. Figure 4 shows the temperature distribution in the same conditions of the process and for the next stage of the diameter reduction. Whereas, Figure 5 presents the temperature distribution during the rolling process realized in a single pass.

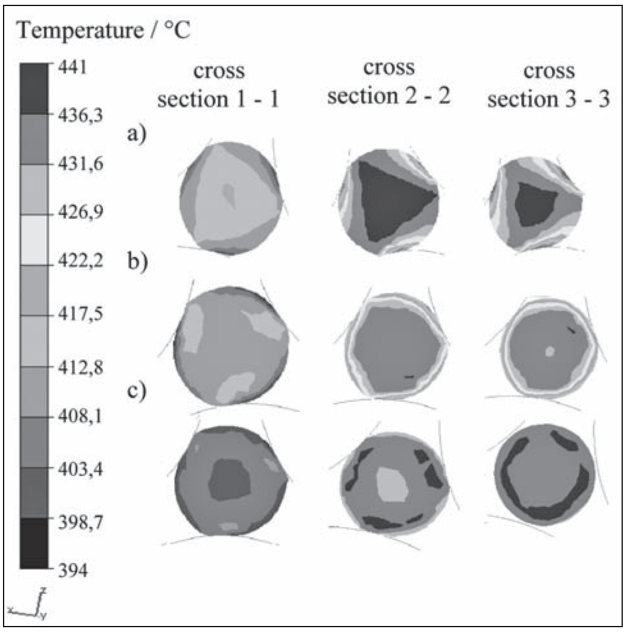

Figure 4 Temperature distributions in cross-sections of the rolled bar during the rolling of ingot with diameter of ϕ 26 mm to the bar with diameter of ϕ 24 mm with temperature of 400 °C and rotational speed of the rolls of: a) n_w = 25 rev/min, b) n_w = 75 rev/min, c) n_w = 100 rev/min

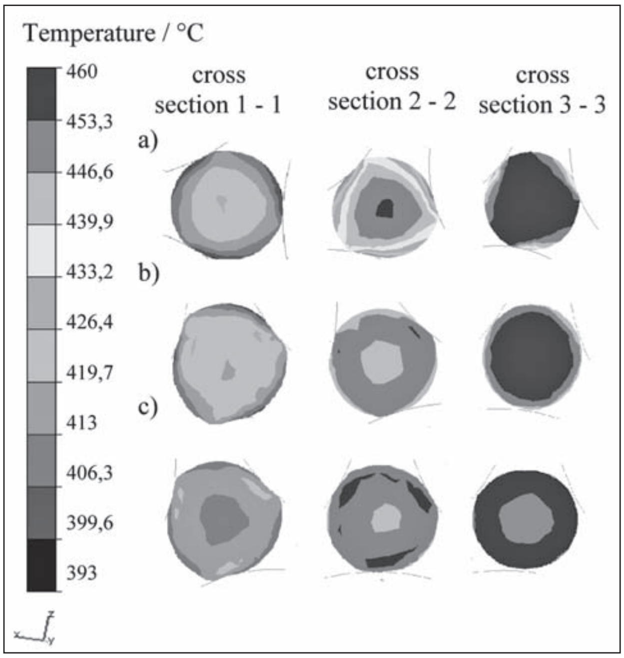

Figure 5 Temperature distributions in cross-sections of the rolled bar during the rolling of ingot with diameter of ϕ 30 mm to the bar with diameter of ϕ 24 mm with temperature of 400 °C and rotational speed of the rolls of: a) n_w = 25 rev/min, b) n_w = 75 rev/min, c) n_w = 100 rev/min

From the data presented in Figure 3 results that the highest value of temperature during the reduction in diameter from ϕ 30 mm to ϕ 26 mm in the rolling process has been observed on the surface of the bar and equals approx. 441 °C for the bar rolled at a rotational speed of rolls of n_w 75 and 100 rev/min.

Further performing of the rolling process caused an increase of temperature in all analyzed cases. The highest value of temperature in the roller axis was observed for the bar rolled at a speed of 25 rev/min. Whereas, at higher rolling rates the temperature increase on the surface of the bar was observed (Figure 4).

Using the same strain in a single pass resulted in a significant increase in the temperature accumulated in material. When the rolling rate was the lowest the accumulation was observed in the axis of the bar, whereas at rotation speed of 100 rev/min it appeared in the subsurface layer (Figure 5).

SUMMARY

Theoretical analysis carried out showed that the largest increase of temperature occurs in the superficial zone of the bar while the material exits from the rolling gap, for all analyzed rolling cases. The temperature growth and increase of the rolling rate result in rising the area of higher temperature, that among others comes from the cumulation of strain energy.

Application of temperature of 400 °C and rotational speed 100 rev/min during the rolling of bars causes uniform heating of the subsurface layer to 460 °C.

REFERENCES

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

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

[3] Kuc D., Hadasik E., Bednarczyk I.: Plasticity and microstructure of hot deformed magnesium alloy AZ61, Diffusion and Defect Data Pt.B: Solid State Phenomena 191 (2012), 101-108.

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

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

[6] Staiger M. P., Pietak A.M., Hudmai J., Dias G.: Magnesium and its alloys as orthopedic biomaterials: A review, Biomaterials 27 (2006) 9, 1728-1734.

[7] Stier W., Camargo L. G., Oskarsson F., Jonnson H: Hydrogen Storage in magnesium based alloys, Prepr. Pap. – Am. Chem. Soc. Div. Fuel. Chem., 50 (2005) 1, 15.

[8] Kawałek A., Dyja H., Mróz S., Knapiński M. Effect of plate asymetric rolling parameters on the change of the total unit pressure of roll, Metalurgija 52 (2011) 3, 163-166.

[9] Laber K., Dyja H., Kałamorz M.: Analysis of the technology of rolling 5,5 mm-diameter wire rod of cold upsetting steel in the Morgan Block mill, Metalurgija 54 (2015) 2, 415-418.

[10] Kawalla R., Oswald M., Schmidt C., Ullmann M., Vogt H. P., Cuong N. D.: New technology for production of magnesium strips and sheets, Metalurgija 47 (2008) 3, 195-198.

Note: The professional translator for English language is Czeslaw Grochowina, Studio-Tekst, Poland