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Single crystal characteristics of the Mg - 5% Li alloy, found from the polycrystalline experimental data and the Kearns texture parameters

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This work aimed to experimentally determine of the Kearns texture parameters, elastic moduli, mechanical properties (ultimate tensile strength and yield strength) of sheets of an alloy of Mg 5 wt. % Li after various types of processing: 1) extrusion at 350 ° C through a rectangular die; 2) rolling with a change in its direction by 90° and intermediate annealing at 350°C after each pass; 3) after the subsequent alternating bending (AB) by 0.5; one; 3 and 5 cycles and evaluation of the elastic and mechanical properties of the corresponding single crystal of the alloy under study using the indicated data. The moduli of elasticity and strength characteristics of the studied polycrystalline samples were determined in the rolling direction (RD) and transverse direction (TD). Using the found parameters of the Kearns texture and the elastic and mechanical properties of the sheets, the values of the elastic modules and the ultimate strength and yield strength of the single crystal of the above alloy were estimated. The found modules of elasticity of a single crystal of an alloy Mg-5 wt. % Li deviate from their values found in previous studies by no more than 7.5%. Elastic modules and strength characteristics of the studied samples of magnesium alloy Mg 5 wt. % Li calculated from the single crystal data deviate from the experimental data by no more than 10%.

Keywords: alloy Mg 5 wt. % Li, extrusion, rolling, alternating bending, Kerns texture parameters, elastic modulus, ultimate strength, conventional yield strength, single crystal.

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Introduction

Magnesium-lithium alloys are interesting as biodegradable materials. Due to their low Young's modulus and increased corrosion resistance, these alloys have proved to be promising for endoprostheses (stents) of blood vessels, biodegradable or bio-absorbable stents. An important advantage of such stents is that due to good biological compatibility in a living organism, the structural material of the stent dissolves slowly. Subsequently, the device gradually disappears after it performs its medical function of supporting the vessel wall. Thus, the disappearance of the stent prevents the occurrence of thrombosis [1]. For example, biodegradable alloys Mg-3.5Li, Mg-8.5Li, Mg-14Li (wt.%) are known [2]. An increase in lithium in binary magnesium alloys promotes an increase in their plasticity, but at the same time, strength can still be sufficient for many biomedical applications [2].

Alloys based on Mg-Li are promising for use in aerospace, aviation, and transport structures, as well as in super heavy communication systems due to their low density and significant strength per unit mass [3]. But the practical use of these alloys is limited, in particular, by the deficiency of information about the anisotropy of their physical and mechanical characteristics. The anisotropy of properties is largely due to the crystallographic texture that occurs during various types of heat treatment and deformation of magnesium alloys [4]. The effect of texture on the anisotropy of the elastic and mechanical properties of magnesium-lithium alloys has not yet been sufficiently studied.

It is known that most modern sheet metal processing technologies imply mechanical or thermal effects that cause internal stresses in the material. The degree of their manifestation depends on the chemical composition, the initial stress state of the alloy, etc. As a result, several difficulties arise in the further processing of parts, obtaining a given geometry, which can lead to spoilage of products. Before use, rolls or sheets of metal are often subjected to straightening, this consists of an alternating bending (AB) on roller straightening machines to ensure good flatness [5].

From a practical point of view, such processing makes it possible to reduce the internal stresses of the metal. But even a small plastic deformation during alternating bending leads to noticeable structural transformations of rolled metal and its mechanical characteristics, the study of which is practically important.

From a scientific point of view, with alternating bending, it becomes possible to study the processes of changing the microstructure and texture during tension and compression of the same sample, on which, during bending, one side of the metal is stretched, and the other side is compressed. Data on metal properties, including elastic modulus, allows the design of products with expected and optimal properties for fatigue or failure.

Experimental determination of certain characteristics of a polycrystalline sample (elasticity or strength) is sometimes quite difficult, or impossible. For example, after helical extrusion in a direction perpendicular to the axis of extrusion, due to the limited thickness of the sample, there are known difficulties in measuring mechanical and elastic properties.

The description of the texture of a polycrystalline sample with a hexagonal structure using the Kearns parameters [6–8] in principle makes it possible to determine the physical and mechanical properties of the metal if the corresponding characteristics of a single crystal are known [9, 10].

In the proposed work, the authors tried to solve, to a certain extent, the inverse problem, namely, to evaluate certain characteristics of the Mg-5% Li (wt.) single crystal from the Kearns texture parameters and experimental of corresponding properties values of polycrystalline samples of the indicated magnesium alloy.

This work aimed to determine of the Kearns texture parameters as well as, mechanical properties (tensile strength and yield strength) of a polycrystalline binary Mg-5% Li alloy (wt.) after extrusion processing, rolling with a change of direction by 90° as well, as after further alternating bending by 0.5; 1.0; 3.0 and 5.0 cycles and evaluation of the elastic and mechanical properties of the corresponding single crystal of the investigated alloy according to the above data.

I. Material and methods of investigation

The original cylindrical work piece alloy Mg-5% Li (wt.) 120 mm long was first deformed by extrusion through a rectangular matrix at a temperature of 350°C. The resulting plates 6 mm thick, 60 mm wide and 120 mm long were rolled further in one direction. Rolling was carried out in 2 passes with intermediate heating up to 350°C and sheets with a thickness of 4 mm were obtained (treatment No. 1)

The sheets obtained in this way were rolled further in a direction perpendicular to the previous one, with a reduction of 10% per pass. For 10 passes with intermediate heating up to 350°C after each, sheets with a thickness of 2 mm were obtained. Next, the rolling direction changed again by 90° and carried 1 pass with a degree of deformation on a thickness of 10%. Further the rolling direction was changed by 90° after each pass and so was obtained the sheet a thickness of 1 mm (treatment No. 2).

Alternating bending (AB) (treatment No. 3) of such sheets with a thickness of 1 mm was carried out using a special device consisting of three rollers and driven manually. The bending roller had a diameter of 50 mm. During bending, the metal moved at a speed of ~150 mm/s. The bending in one direction corresponds to 0.25 cycles. The return to the original flat state corresponds to 0.5 cycles. Then, bending in the opposite direction (0.75 cycles) and return to the flat state (1.0 cycle) were carried out. Samples for the study were cut in the rolling direction of (RD) and the transverse direction (TD), after 0.5; 1.0; 3.0 and 5.0 of the AB cycles.

The dynamic resonance method was used to determine the modulus of elasticity on rectangular samples with a size of (100 × 10) mm, cut in the direction of rolling (RD) and the transverse direction (TD) from the sheet before bending (initial sheet) and sheets after 0.5; 1.0; 3.0 and 5.0 of the AB cycles. The error did not exceed 1% [11].

Mechanical tests were carried out on a tensile testing machine 250N5A WN: 143331 with a force sensor ID: 0 WN: 805506 20 kN at room temperature for samples cut from the sheets in RD and TD. The length and width of the working part of the samples were 15 mm and 12.5 mm, respectively. As the value of mechanical properties, the averaged value was taken over three batches of samples in each direction.

The Θ - 2Θ scanning of the samples was carried out on the Bragg-Brentano geometry on a DRON-3M X-ray diffractometer in filtered Kα-Mo radiation for the texture study. The profiles of diffraction lines were recorded from the plane of rolling (from two opposite sides of the sheets) as well as from the plane that is the perpendicular direction of rolling of the studied samples. A sample without texture (standard) was scanned also. The standard was produced from annealed sawdust of the investigated magnesium alloy. Before the shoot of the texture, the samples were etched to remove the 0.1 mm surface layer distorted by deformation. Based on the scanning results, inverse pole figures (IPF) of the normal direction (ND) to the rolling plane (IPF ND) were built for two opposite sides of the sheets after according number of AB cycles as well as for the rolling direction of (IPF RD). To shoot the IPF RD, typesetting samples were produced.

II. Experimental results and discussion

The inverse pole figures of the studied alloy are shown in Fig. 1. The texture of the investigated alloy sheets after processing No. 1 is characterized by a relatively weak basal component of the central type (pole density 1.14 in Fig. 1, a) and by a strong component (1010) (pole density 6.64 in Fig. 1, a). On the IPF RD are observed two strong maxima of the pole density near the $\langle 10\bar{1}0\rangle$ pole, with a value of 5.45 and $\langle 11\bar{2}0\rangle$, with a value of 6.34, (Fig. 1b). The texture can be described by a combination of a weak of the central type basal component and a deflected on 90^0 to ND basal type. Both crystallographic directions (with scattering) $\langle 10\bar{1}0\rangle$ and $\langle 11\bar{2}0\rangle$ mainly coincide with the RD of such a sheet.

Fig. 1 (c, d) shows the IPF ND and IPF RD of the alloy under study after treatment No. 2. The hexagonal axes of the crystallites are deviated from ND to the rolling plane by about 0-15° and 70^0 towards TD (Fig. 1, c, e, f, h, i). The texture consists of a combination of the basal component with scattering up to 15° towards ND and a relatively strong component $(21\bar{3}2)$. In pure magnesium, under the same conditions, a texture of the basal central type is formed.

Alloying of magnesium with lithium promotes a change in the ratio of deformation mechanisms that affect the texture. Alloying of magnesium with lithium promotes a decrease in the ratio of the c/a axes and, thereby, activates mechanisms of the not basal slip. In particular, the role of prismatic slip of dislocations in Mg-Li alloys can be significant at elevated temperatures [12]. The activation of prismatic slip and twinning is facilitating probably the formation of the deviated to the TD basal type texture components (Fig. 1).

The crystallographic directions $\langle 21\bar{3}1\rangle$ preferably coincide with the RD on the IPF RD but the region of increased pole density on the IPF RD occupies a fairly wide region between the $\langle 30\bar{3}2\rangle$, $\langle 11\bar{2}0\rangle$, and $\langle 10\bar{1}0\rangle$ poles (Fig. 1, d, g, j, m, p). The type and character of texture scattering after alternating bending depends on the number of AB cycles, as mentioned above. A more detailed description of the texture and microstructure after AB can be found in [12].

It is convenient to use the Kearns texture coefficients for a more objective quantitative assessment of the texture of hexagonal materials [6–8]. These coefficients, f_j (the index *j* means a certain direction in the sample - ND, RD, or TD), characterize how much the *c*-axes of hexagonal grains coincide with a certain geometric direction in the polycrystalline. The coefficients f_j can be found from the IPF according to the following relation

$$f_j = \langle \cos^2\alpha_i \rangle_j = \sum_i A_i P_{ji} \cos^2\alpha_i, \quad (1)$$

Where $P_{ji} = \frac{I_i/I_R}{\sum_\Delta (A_i \cdot I_i/I_R)}$, I_i/I_R is the ratio of the integral intensity of the *i*-th reflection on the *j*-th IPF to the corresponding value of the intensity of the reflection of the sample without texture I_R; I_R is the statistical weights of the *i*-th reflex ($\sum A_i P_{ji} = 1$) [6].

The multipliers A_i show what part of the surface area of the stereographic triangle around the *j*-th normal belongs to *i*-th reflection of the corresponding IPF [14]; α_i means the angle by which *i*-th crystallographic direction deviates from the hexagonal axis *c* for the *j*-th direction in the sample.

The quantitative value of some property $P(\varphi)$ relating two vector quantities or a tensor with a scalar quantity in a hexagonal single crystal can be expressed [6-8] as:

$$P(\varphi)_{ref} = P_c \cos^2\varphi + P_a(1-\cos^2\varphi), \quad (2)$$

Where $P(\varphi)_{ref}$ is the property in the selected direction, P_a and P_c is the property of the single crystal in the direction perpendicular and parallel to the [0002] direction, respectively, φ is the angle between the selected direction and [0002].

The volume contribution to the property of crystals whose axes are inclined over an angle φ to a certain direction, given that the contribution of polycrystalline grains to the volume property in accordance with their volume particle, V_i, can be found as follows:

$$P(\varphi_i)_{ref} = P_c V_i cos^2\varphi_i + P_a V_i (1-\cos\varphi_i). \quad (3)$$

If summed over the entire volume, then we can write that:

$$P(\varphi_i)_{ref} = P_c \sum_i V_i \, cos^2\varphi_i + P_a \sum_i V_i \, (1-\cos\varphi_i). \quad (4)$$

Since $\sum_i V_i = 1$, while $\sum_i V_i \, cos^2\varphi_i = f_j$ is the Kearns texture parameter, we get:

$$P(\varphi_i)_{ref} = f_j P_c + (1-f_j) P_a. \quad (5)$$

To find the Kearns texture parameters, we used the IPF in Fig. 1, and the values of A_i, which were taken from [16]. To calculate the values of the angles according to the known formulas [17], we used the ratio of the parameters of the crystal lattice of the studied Mg-5% (wt.) Li alloy $c/a = 1{,}61$ that was determined by us experimentally.

Tensor properties (for example, mechanical stresses or elastic moduli) can be found from relation (5), as shown by Kearns [8]. In this case, the sum of the parameters f_j in the three main directions of the sheet material with a hexagonal lattice must be equal to one. If the value of the parameters f_j is equal to 1/3 in each of the main directions of the sheet, then we have the isotropy of the corresponding property. Based on this, knowing two of the three Kearns parameters (for example, if we determined f_{ND} and f_{RD}), then the third parameter f_{TD} can be found from the equation:

$$f_{\text{НН}} + f_{\text{НВ}} + f_{\text{НП}} = 1. \quad (6)$$

On the other hand, if the parameters of the Kearns texture f_j and certain properties $P(\varphi_i)_{ref}$ in two directions of the polycrystalline sample are known, then the corresponding characteristics of the single crystal P_c and P_a can be estimated from a relationship like (5).

The Kearns texture parameters were calculated from the ND IPF (f_{ND}) and RD IPF (f_{RD}) from the data in Figs. 1, as well as f_{TD}, calculated by relation (6), are given in Table 1.

There are inconsistencies in the distribution of pole density on the ND IPF of opposite sides of the sheets of the studied alloy after the corresponding number of cycles

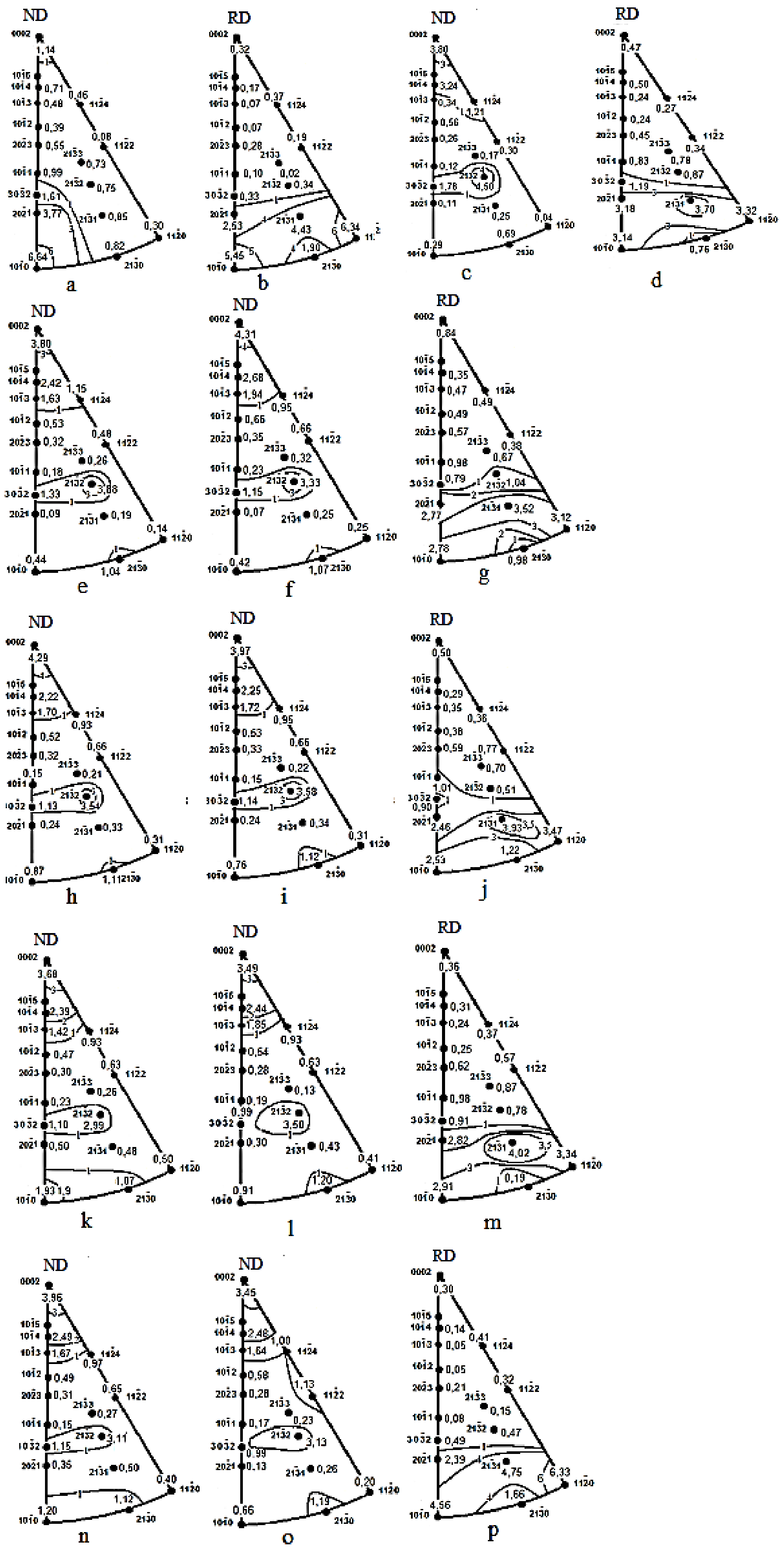

Fig. 1. Experimental IPF of the Mg-5% (wt.) Li alloy: (a, b) - after treatment No. 1; (c, d) after treatment No. 2; after the alternating bending by: 0.5 - (e - g); 1 - (h - j); 3 - (k - m); 5 - (n - p) cycles; (e, i, l, o) – stretched side of sheets; (f, h, k, n) – compressed side of sheets.

of alternate bending, as seen in Fig. 2 (e–m). This is because on the convex side the surface layers of the sample are subjected to tensile deformation (Fig. 2, f, h, k, m), while the layers on the opposite side of the sheet are subjected to compressive deformation (Fig. 2, d, g, i, l). During straightening, on the contrary, the metal layers on the convex side of the sheet are subjected to compressive deformation, while the metal layers on the concave side of the sheet are subjected to tensile deformation.

Similar inconsistencies were also observed by the authors of [18], who studied the texture of the bands of the Zr-2.5% Nb alloy. To obtain a strip from a Zr-2.5% Nb alloy pipe, a certain part was cut off, and then it was cut along its length and straightened to a flat state. We also observed similar inconsistencies when studying the significant bending of titanium [19].

The aforementioned inconsistencies in the distribution of pole density on the OPF NN of the opposite sides of the sheets of the studied Mg-5% (wt.) Li alloy after a different number of AB cycles is observed in the values of the corresponding Kearns texture coefficients (Table 1).

To account for these inconsistencies, we determined the Kearns texture parameters ($f_{\text{HH}}^{(av)}$) averaged on both sides of letters for subsequent analysis of the properties of letters after the corresponding number of AB cycles.

The values of the modulus of elasticity of the sheets of the studied magnesium alloy, measured and calculated in ND, RD, and TD according to relations of the type (5), are given in Table. 2. In the calculations, we used the value of the elasticity constants of the Mg 5 % (wt.) Li alloy single crystal $S_{33} = 1.77 * 10^{-11} Pa^{-11}$ and $S_{11} = 2.41 * 10^{-11} Pa^{-11}$ determined by us earlier [20]. Since $\frac{1}{S_{33}} = E_{0001} = E_c$, and $\frac{1}{S_{11}} = E_{10\bar{1}0} = E_a$, we have the value of the modulus of elasticity of the single crystal of the alloy under study along with the hexagonal c-axis and along the a-axis, respectively

$$E_c = 56.5 \text{ ГПа}, \tag{7}$$

$$E_a = 41.5 \text{ ГПа}. \tag{8}$$

The calculated values of the elastic modulus of the sheets of the studied magnesium alloy obtained using the corresponding above-mentioned single-crystal data differ from the experimental values by no more than 10% (Table 2).

Now we will try to solve the inverse problem and calculate the modulus of elasticity of a single crystal of the Mg – 5% (mas) Li alloy according to the modulus of elasticity of the alloy sheets, determined experimentally in the direction of rolling and transverse direction (Table 2). To do this, we compose a system of two linear equations using relations of the type (5) for the experimental values of the elastic moduli in NV and ST, with two unknowns E_c^{calc} and E_a^{calc} for each type of processing of sheets of the studied magnesium alloy. The calculations showed that the averaged values of the elastic moduli of a single crystal (E_c^{calc}, E_a^{calc}) have the following values:

$$E_c^{calc} = 53.8 \text{ GPa}, \tag{9}$$

$$E_a^{calc} = 44.6 \text{ GPa}. \tag{10}$$

Table 1

Kerns texture options of MgLi5.

	Number of cycles, n	Kerns texture options				
		$f_{ND}^{(1)}$	$f_{ND}^{(2)}$	$f_{ND}^{(av)}$	f_{RD}	f_{TD}
After extrusion	-	0.239	0.239	0.239	0.114	0,647
After an alternating bending	0	0.390	0390	0.390	0.393	0.217
	0.5	0.435	0.407	0.421	0.224	0.355
	1.0	0.409	0.388	0.399	0.188	0.391
	3.0	0.399	0.411	0.404	0.289	0.407
	5.0	0.417	0.411	0.414	0.144	0.442

Table 2

Calculated and experimental values of the modulus of elasticity Mg – 5 % (mas) Li alloy sheet.

	Number of cycles, n	$E_{ND}^{calc.}$, GPa	$E_{ND}^{exp.}$, GPa	$E_{RD}^{calc.}$, GPa	$E_{RD}^{exp.}$, GPa	$\frac{\Delta E}{E}$, %	$E_{TD}^{calc.}$, GPa	$E_{TD}^{exp.}$, GPa	$\frac{\Delta E}{E}$, %
After Extrusion	-	45.1	-	43.2	40.6	6.4	51.2	47.4	8.0
After an Alternation Bendig	0	47.4	-	47.4	50.3	5.8	47.9	52.9	9.6
	0.5	47.8	-	44.9	48.2	6.9	46.8	49.6	5.6
	1.0	47.5	-	44.2	46.8	6.3	47.4	51.9	8.7
	3.0	47,6	-	44.3	44.2	0.3	47.6	46.2	3.0
	5.0	47,7	-	43.7	46.2	5.5	48.1	47.6	1.1

Table 3

Experimental and calculated values of UTS obtained during uniaxial tensile tests of Mg-5% Li alloy specimens.

	Number of cycles, n	$\sigma^{RD}_{\mathrm{B}\,exp}$, GPa	$\sigma^{RD}_{\mathrm{B}\,calc}$, GPa	$\frac{\Delta\sigma_{RD}}{\sigma^{RD}_{\mathrm{B}\,exp}}$, %	$\sigma^{TD}_{\mathrm{B}\,exp}$, GPa	$\sigma^{TD}_{\mathrm{B}\,calc}$, GPa	$\frac{\Delta\sigma_{RD}}{\sigma^{RD}_{\mathrm{B}\,exp}}$, %
After Extrusion	-	176	178	-1.1	165	178	7.9
After an Alternation Bendig	0	180	179	0.6	184	195	6.0
	0.5	179	179	0	183	168	-8.2
	1.0	178	179	-0.6	182	171	-6.0
	3.0	179	179	0	180	176	-2.2
	5.0	178	178	0	179	178	-0.6

Table 4

Experimental and calculated values of YS obtained during uniaxial tensile tests of Mg-5% Li alloy specimens.

	Number of cycles, n	$\sigma^{RD}_{0.2\,exp}$, GPa	$\sigma^{RD}_{0.2\,calc}$, GPa	$\frac{\Delta\sigma_{RD}}{\sigma^{RD}_{0.2\,exp}}$, %	$\sigma^{TD}_{0.2\,exp}$, GPa	$\sigma^{TD}_{0.2\,calc}$, GPa	$\frac{\Delta\sigma_{TD}}{\sigma^{TD}_{0.2\,exp}}$, %
After Extrusion	-	117	119	1.7	114	121	6.1
After an Alternation Bendig	0	120	120	0	123	119	-3.3
	0.5	119	119	0	122	120	-1.6
	1.0	118	119	0.8	121	120	-0.8
	3.0	119	119	0	120	120	0
	5.0	118	119	0.8	117	120	2.6

The calculated values (9) and (10) differ from the corresponding values (7) and (8) by 4.8% and 7.5%, respectively.

Calculations using relations of the type (5) for the ultimate strength of specimens cut in RD and TD, similar to those performed above for the elastic modulus, showed that the averaged values of the ultimate strength of a single crystal of the studied magnesium alloy along its axes c ($\sigma^{\mathrm{c}}_{\mathrm{B}\,calc}$) and a ($\sigma^{a}_{\mathrm{B}\,calc}$) have the following meanings:

$$\sigma^{\mathrm{c}}_{\mathrm{B}\,calc} = 181 \text{ MPa}, \quad (11)$$

$$\sigma^{a}_{\mathrm{B}\,calc} = 178 \text{ MPa}. \quad (12)$$

Similar calculations using relations of the type (5) for the yield stress of samples cut in RD and TD showed that values of the yield stress of a single crystal of the studied magnesium alloy the averaged along its axes c ($\sigma^{\mathrm{c}}_{0.2\,calc}$) and a ($\sigma^{a}_{0.2\,calc}$) have the following meanings:

$$\sigma^{\mathrm{c}}_{0.2\,calc} = 122 \text{ MPa}, \quad (13)$$

$$\sigma^{a}_{0.2\,calc} = 118 \text{ MPa}. \quad (14)$$

Tables 3 and 4 show the experimental $\sigma^{RD}_{\mathrm{B}\,exp}$, $\sigma^{TD}_{\mathrm{B}\,exp}$, $\sigma^{RD}_{0.2\,exp}$, $\sigma^{TD}_{0.2\,exp}$ and the calculated $\sigma^{RD}_{\mathrm{B}\,calc}$, $\sigma^{TD}_{\mathrm{B}\,calc}$, $\sigma^{RD}_{0.2\,calc}$, $\sigma^{TD}_{0.2\,calc}$ values of the ultimate strength and yield strength of the studied magnesium alloy sheets. The calculated values were obtained after finding of values for the single crystal of the studied alloy were calculated using relations of the type (5) for the experimental values of strength and yield strength in RD and TD (Tables 3, 4).

The values of the ultimate strength and yield strength of the studied alloy samples, obtained by calculations using the corresponding values for the single crystal of the alloy (11) - (14), differ from the experimental values by no more than 8.2% and the corresponding values of the yield strength - by no more than 6.1% (Tables 3, 4).

Conclusions

The Kearns texture parameters, which are a measure of the deviation of the grains hexagonal axis of from a given direction in a polycrystalline sample, were found from the inverse pole figures of the direction of the normal to the sheets plane and the sheets rolling direction for an alloy of magnesium with lithium Mg-5% Li (wt.) after various types of processing: 1) extrusion at 350°C through a rectangular matrix; 2) rolling with a change in its direction by 90° and intermediate annealing at 350°C after each pass; 3) after further alternating bending by 0.5; 1.0; 3.0 and 5.0 cycles.

Estimates of the elasticity modulus after the above-mentioned types of processing using the found Kearns texture parameters and the elasticity constants of a single crystal of the Mg-5% Li (wt.) alloy, taken from [20], showed that the calculated and experimental values of the elasticity modulus of the alloy sheets differ by no more than 10%.

The inverse problem of determining the elasticity constants of a single crystal of the Mg 5 % Li (wt.) alloy was solved by the Kearns texture parameters and experimental values of the elasticity modulus of polycrystalline alloy measured in the rolling direction as well as in the transverse direction of the sheets after the above-mentioned types of processing. It has been found that the averaged values of the elastic moduli of a single crystal of the Mg-5% Li (wt.) alloy have the value E_c= 56.5 GPa; E_a= 41.5 GPa and differ from those given in [20] by no more than 4.8% and 7.5%, respectively.

The ultimate tensile strength and yield strength of a single crystal of the alloy Mg-5 % Li (wt.) were determined by the Kearns texture parameters and the experimental values of the corresponding mechanical properties measured in the rolling direction and the transverse direction of studied alloy sheets. It has been established that the averaged values of the ultimate strength of a single crystal of the studied magnesium alloy along its axes *c* ($\sigma^c_{B\,calc}$) and a ($\sigma^a_{B\,calc}$) have the following values: $\sigma^c_{B\,calc}$ = 184 MPa, $\sigma^a_{B\,calc}$ = 178 MPa, and the averaged values of the yield strength of the studied magnesium alloy single crystal along its axes c ($\sigma^c_{0.2\,calc}$) and a ($\sigma^a_{0.2\,calc}$) are: $\sigma^c_{0.2\,calc}$ = 122 MPa, $\sigma^a_{0.2\,calc}$a = 118 MPa.

It is shown that the results of calculations of the ultimate tensile strength and yield strength of sheets of the Mg-5 % Li alloy (wt.) in the rolling direction and the transverse direction after various above-mentioned types of processing using the found average values of the ultimate tensile strength and yield strength of the alloy single crystal differ from the obtained experimental values by no more than by 8.1% and 6.1% for ultimate tensile strength and yield strength, respectively.

The above results can be used to the finding the characteristics of hexagonal single crystals from the results of relevant polycrystalline experimental data, since obtaining single crystals sufficient to measure the respective properties is often a difficult problem.

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[1] Magnesium alloys, FindPatent.ru, http://www.findpatent.ru/patent/245/2456362.html [in Russian].
[2] M.A. Leeflang, J. Zhou, J. Duszczyk, Deformability and extrusion behavior of magnesium-lithium binary alloys for bio-medical applications, In K.U. Kainer (Ed.), Magnesium, Proceedings of the 8th International Conference on Magnesium Alloys and their Applications, 1182 (2009). Weinheim, Germany: Wiley-VCH, – Web source: http://www.3me.tudelft.nl/fileadmin/Faculteit/3mE/Over_de_faculteit/Afdelingen/Materials_Science___Engineering/MSE_News/scienceday2009/doc/M.A._Leeflang,_J._Zhou_and_J._Duszczyk.pdf
[3] C.O. Muga and Z.W. Zhang Strengthening, Mechanisms of Magnesium-Lithium Based Alloys and Composites, Advances in Materials Science and Engineering (2016) Article ID 1078187; https://doi.org/10.1155/2016/1078187.
[4] C.Q. Li, Xu D.K., S Yu., L.Y. Sheng, E.H. Han, Effect of Icosahedral Phase on Crystallographic Texture and Mechanical Anisotropy of Mg-4%Li Based Alloys, Acta Metallurgica Sinica (English Letters), 33(5), 475 (2017); https://www.amse.org.cn/article/2017/1006-7191/1006-7191-33-5-475.shtml.
[5] Sung-Yu Tsai and Jen-Yuan (James) Chang Design of deep learning on intelligent levelling system for industry 4.0 technology, MATEC Web of Conferences 185, 00026 (2018); https://doi.org/10.1051/matecconf/201818500026 ICPMMT 2018.
[6] J. Kearns, Thermal Expansion and Preferred Orientation in Zircaloy (1965); https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/WAPDTM472.xhtml.
[7] D. Dzunovich,, S. Betsofen, and P. Panin, Methodological aspects of the quantitative texture analysis of HCP Alloy (Ti, Zr) sheet semiproducts., Russian Metallurgy (Metally) 10, 813 (2017); https://doi.org/10.1134/S0036029517100056 https://link.springer.com/article/10.1134%2FS003602951710005.
[8] J. Kearns, On the relationship among "f" texture factors for the principal planes of zirconium, hafnium and titanium alloys, Journal of Nuclear Materials, 299(2), 171 (2001); https://doi.org/10.1016/S0022-3115(01)00686-9).
[9] V. Grytsyna, D. Malykhin, T. Yurkova et al., On Structural Aspects of Texture Changes During Rolling of Zr-2.5%Nb Alloy. East European Journal of Physics 3, 38 (2019; https://periodicals.karazin.ua/eejp/article/view/14359/13506.
[10] V. Usov, N. Shkatulyak, E., N. Rybak, Elastic properties of alloy ZE10 sheets evaluation by Kerns texture parameters. East Eur. J. Phys. 1, 43 (2021), https://periodicals.karazin.ua/eejp/article/view/16552
[11] Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impuls Excitation of Vibration; http://forlab.pt/wp-content/uploads/2015/08/E1876_mvuj8965.pdf.
[12] N. Shkatulyak, S. Smirnova, and V. Usov, Effect of Alternating Bending on Texture, Structure, and Elastic Properties of Sheets of Magnesium Lithium Alloy, Hindawi Publishing Corporation, International Journal of Metals, Article ID 349810, 8 pages, (2015); http://dx.doi.org/10.1155/2015/349810.

[13] [H. Hafekamp, M. Niemeyer, R. Bohem, U. Holzkamp, C. Jaschik and V. Kaese, Development, Processing and Applications Range of Magnesium Lithium Alloys, Material Science Forum 350-351, 31-42 (2000); https://doi.org/10.4028/www.scientific.net/MSF.350-351.31.
[14] P. R. Morris, Journal of Applied Physics 30(4) (1959); https://doi.org/10.1063/1.1702413.
[15] J. F. Nye Physical properties of crystals their representation. Their representation by tensors and matrices, (Oxford: University Press, 2006).
[16] Ya. D. Vishnyakov, A. A. Babareko , S. A. Vladimirov, I. V. Egiz, The theory of texture formation in metals and alloys, Nauka, Moscow, 1979, https://ua1lib.org/book/2990475/783dc1?id=2990475&secret=783dc1.
[17] D. W. Hogan and D. J. Dyson, Angles between planes in the hexagonal and tetragonal crystal systems, Micron, 2, 59 (1970); https://doi.org/10.1016/0047-7206(70)90045-2.
[18] V. Grytsyna, D. Malykhin, T. Yurkova et al. On Structural Aspects of Texture Changes During Rolling of Zr-2.5%Nb Alloy, East Eur. J. Phys. 3, 38 (2019); https://doi.org/10.26565/2312-4334-2019-3-05.
[19] N. Shkatulyak, E. Savchuk, V. Usov. Anisotropic damage of titanium plates under uniaxial tension after reverse bending. J. Mater Res Technol. 7, 11, 82 (2017); https://doi.org/10.1016/j.jmrt.2017.06.007
[20] N. Shkatulyak, V. Usov, S. Smirnova, Single Crystal Magnesium Lithium Alloy Elastic (4)1-11 (2015); https://www.wireilla.com/engg/ijamse/papers/4415ijamse01.pdf.

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Характеристики монокристала сплава Mg - 5% Li, знайдені за експериментальними даними полікристала і параметрам текстури Кернса

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Метою даної роботи є експериментальне визначення параметрів текстури Кернса, модулів пружності, механічних властивостей (межі міцності та плинності) листів сплаву Mg 5 мас. % Li після різних видів обробки: 1) екструзії при 350°С через прямокутну матрицю, 2) вальцювання зі зміною його напрямку на 90° та проміжного відпалу при 350°С після кожного проходу, 3) після подальшого знакозмінного вигину (ЗВ) на 0,5; 1; 3 і 5 циклів, та оцінка за зазначеними даними пружних та механічних властивостей відповідного монокристалу досліджуваного сплаву. Модулі пружності та характеристики міцності досліджуваних полікристалічних зразків визначали у напрямку вальцювання (НВ) та поперечному напрямку (ПН). За допомогою визначених параметрів текстури Кернса та пружних і механічних властивостей листів оцінили значення модулів пружності й межі міцності та плинності монокристала вищезазначеного сплаву. Модулі пружності та характеристики міцності досліджуваних зразків сплаву магнію Mg 5 мас. % Li, розрахованих за знайденими відповідними характеристиками монокристала, відхиляються від експериментальних не більше ніж на 10 %.

Ключові слова: сплав Mg 5 мас. % Li, екструзія, вальцювання, знакозмінний вигин, параметри текстури Кернса, модуль пружності, межа міцності, умовна межа плинності, монокристал.