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SEMI-PLANETARY ROLLING AND CHANGES OF FINE STRUCTURE AND MICROSTRUCTURE

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ABSTRACT

The strain intensity in the proximity of planetary cylinder, in the case of semi-planetary rolling is greater than in the proximity of the massive cylinder. This fact leads at the variation of the microstructure and fine structure characteristics: the mosaic block dimension, second order stresses, dislocations density, micro-hardness into the thickness of rolled body. In the paper it presents the research results for identify and evaluate the structure modifications at the semi-planetary rolling.

KEYWORDS: semi-planetary rolling, fine structure, X ray diffraction.

1.Introduction

Plastic deformation strongly affects the microstructure and mechanical properties of the material. Thus plastic deformation leads to the variation of the dimension of mosaic blocks, dislocation density, value of second order stress, at the fine structure level and, consequently, change of the mechanical properties (for example micro-hardness).

The microstructure evolution and the changes of the mechanical properties induced by plastic deformation depend not only on the deformation process but also on the properties of the material, in particular on its crystalline structure, stacking fault energy and the value of the self-diffusion coefficient [1].

The semi-planetary rolling model is presented in figure 1 and it leads to an asymmetrical stress and strain state on the thickness of the semi-product [2].

The strain developed in the proximity of the superior planetary cylinder has greater intensity then the strains developed in the proximity of massive cylinder.

As effect, after semi-planetary rolling the body, with initial rectilinear form, becomes curve body. Also, as a reversible process, the curved body may take a final rectilinear form.

An important application of semi-planetary rolling, which may become a solution for quality assurance of the metallurgical products, may be the unbending of the continuous cast slabs of different metallic materials that have in certain temperature range a fragility domain.

Thus is the case of the construction steels with great mechanical resistance, micro and low alloyed steels with fine microstructure.

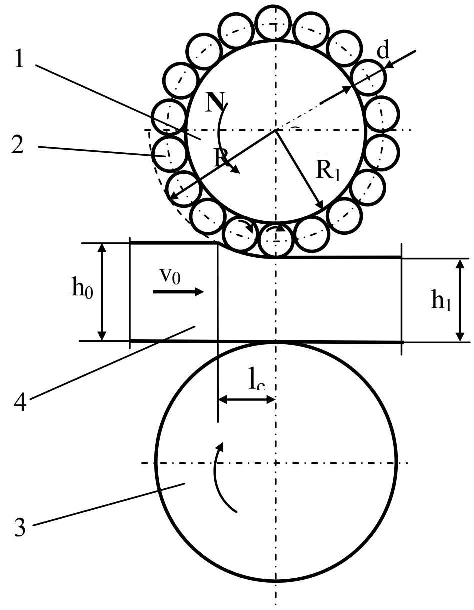


Fig.1. *Scheme of semi-planetary rolling process: 1-planetary cylinder, 2-sattelite cylinder, 3-massive inferior cylinder, 4-rolled body*

At the same time in the unbending zone, into the proximity of interior surface of slab section, a plane tensile stress state is developed. Coupled, these two causes, respectively, the reduced plasticity of steel and the bi-axial tensile stress state may lead at the appearance of the superficial fissures and the discontinuity defect.

The semi-planetary rolling applied at unbending zone, to the exit of slab from curve thread of the continuous casting machine, for example placing a semiplanetary rolling mill into the drawing mill, induces an unbending moment in the condition of the compression stress state [3, 4].

The semiplanetary rolling is characterized by the variation of strain intensity in the thickness of the body, grater in the proximity of the planetary cylinder, smaller in the proximity of the massive cylinder and minimum values at the half of thickness.

This fact will lead at the changes of the crystalline lattice and variation of microstructure and of the properties of deformed material.

2.Research conditions

In the aim of the observing of the influence of the deformation on the structure and properties of deformed material we made a metallographic study, analyze by diffraction of the X-radiation and the measurement of the micro–hardness [5 - 7].

The samples were prepared form aluminum and their shape was rectangular prism having dimension of 10×12×100 mm.

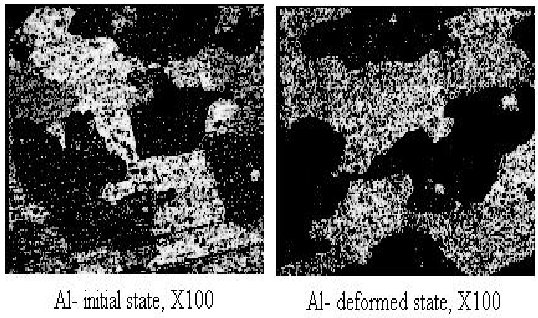
The deformation has been performed on a original semiplanetary rolling mill which is composed of a planetary cylinder with appearance surface of 80mm, composed by a support cylinder and 18 satellite cylinders with active surface dimensions of Ø12×50mm, and the massive cylinder surface of Ø80×50mm. The revolution of the planetary cylinder is 200 rpm and of massive cylinder is 2 rpm.

Analysis of fine structure modifications induced of the semiplanetary rolling has been performed on a diffractometer type DRON 3. This apparatus has following work parameter: copper anti-cathode (λ=1.541 Å), U= 34 kV, I=30 mA, and monocromathor in the diffracted beam.

The micro-hardness was measured with an adequate apparatus type PMT-3 and for micro-structural analysis an optical microscope equipped with a digital system for quantitative analysis.

3.Experimental results

In the figure 2 the microstructures of the initial (non-deformed) and deformed aluminum samples are presented, respectively. Because the deformation degree is relatively small, the semiplanetary rolling does not produce a visible modification of the crystalline grains. The dimension of crystalline grains increases in the proximity of the planetary cylinder and near the massive cylinder this structural parameter is not modified.



(a) (b)

Fig. 2. *Microstructure of aluminum samples before (a) and after (b) deformation*

According to the X-ray diffraction analysis the aluminum sample was cross scanned with the advance step of 2 mm, resulting 6 measuring points. In figure 3 is shown the irradiation scheme of the samples.

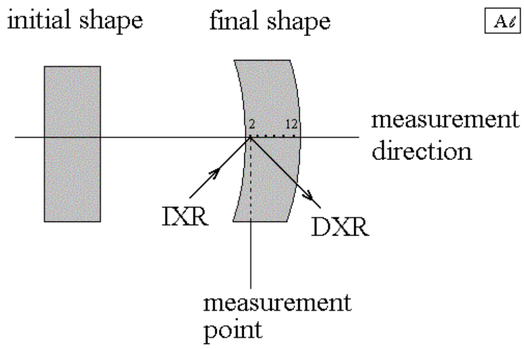


Fig. 3. *Irradiation and X-ray scanning scheme of deformed sample*

In order to analysis of fine structure of aluminum samples the diffraction lines (111) and (311) are considered. First diffraction line is used at the evaluation of the dimension of mosaic blocks in the $\langle 111 \rangle$ crystallographic direction. The evaluation of the second order internal stress and the dislocation density levels is done from the analysis of the second diffraction line.

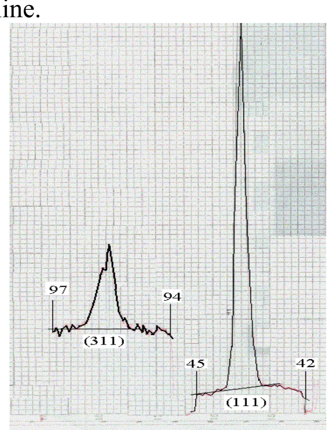


Fig. 4. *Aspects of the diffraction lines (111) and (311) for deformed aluminum sample*

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The (111) diffraction line appears into angular range, $2\theta \in (42^0, 45^0)$ and the (311) diffraction line is in angular domain, $2\theta \in (94^0, 97^0)$. In figure 4 the shape of above mentioned diffraction lines is displayed.

In figure 5 the variation of the (111) diffraction line width, $B_{(111)}$, that is inverse proportional with the mosaic blocks dimensions, $D_{(111)}$, is carried out. Between the two sizes there is the relation:

$$D_{(111)} \approx \frac{1}{B_{(111)}} \qquad (1)$$

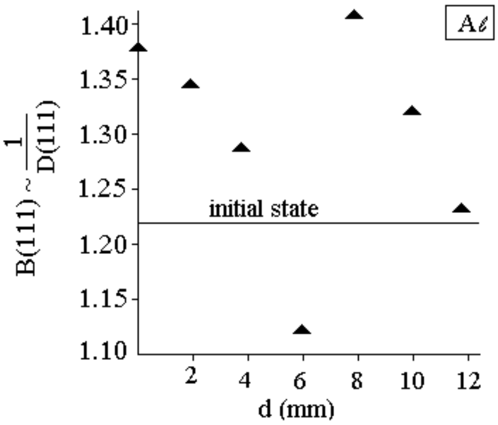

Fig. 5. *Cross distribution of the width of diffraction line on cross section*

The analysis shows that the deformation determines the increasing of the mosaic block dimensions.

The mosaic block dimensions have an important variation. In the marginal layer, at the proximity of the contact surface with the planetary cylinder the dimension of the mosaic block decreases. The value of the mosaic block dimension follows the variation of deformation intensity. At the middle of the thickness an abrupt jump of the mosaic block dimensions is observed. This fact may be determined by the extension of the mosaic blocks at the very small plastic deformation. In the part of the massive cylinder the value of mosaic blocks dimension it maintains at the contact surface and decreases to the interior layers. This aspect is explained by the action of the dead zone into the marginal layer at the contact surface with the massive cylinder.

It denotes because of the small value of the b/h ratio the deformation in the width direction of sample is great enough for determine smaller deformation intensity in direction of the thickness.

In figure 6 it presents the distributions of the widths of diffraction lines (311).

The width of diffraction line is direct proportional to the level of the second order internal stress, according to the relation:

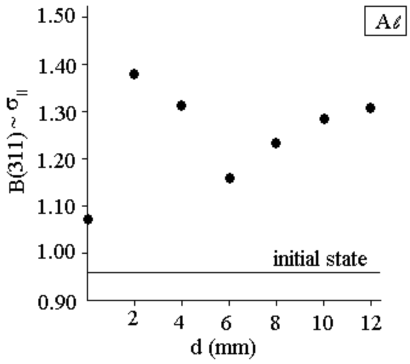

Fig. 6. *Cross distribution of the second order internal stress*

The second order stress registers a minim value at the middle of the deformed body. At the contact surface with the planetary cylinder the second order stress has a lower value.

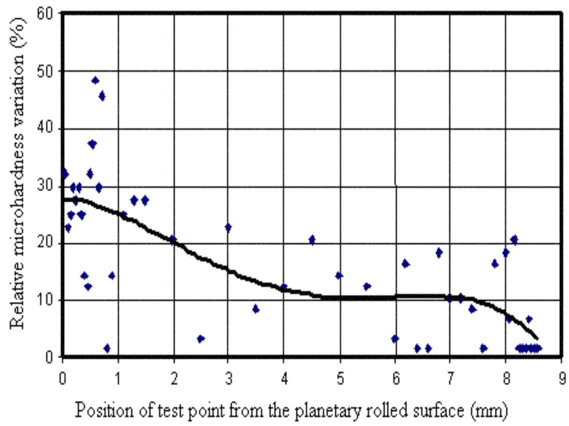

Fig. 7. *Cross distribution of micro hardness*

This fact can be explained by the effect of mechanical relaxation induced by the deformation in width direction, because the ratio b/h is small, relatively. Consequently, the second order stresses really correspond to the repartition of the strain intensity in the thickness of sample. Therefore the repartition of the second order stresses is the most factors for study of influence of asymmetrical deformation of the fine structure of metallic material.
The variation of micro-hardness is showed in figure 7 and its can be connected with distribution of second order stresses.

4. Conclusions

Semiplanetary rolling is an interesting deformation process for the obtaining of the curve pieces or for unbending of the curved parts. Because the diameter of the satellite cylinder is much smaller of the diameter of massive cylinder the strain intensity is variable in the section of the body.

This is greater at the proximity of planetary cylinder, smaller at the proximity of massive cylinder.

Between the strain intensity and the modification of micro and fine structure is a correlation. The experimental researches proved this correlation. The dimension of the crystalline grain is very small influenced.

The dimension of the mosaic blocks follows the variation of the strain intensity for the value of the ratio b/h great, relatively. Thus, in the proximity of the planetary cylinder this factor has great value, registers a minimum at the middle of the thickness

The best parameter of the fine structure what very good corresponds at the variation of the principal deformation factor of the semiplanetary rolling process, respectively, local strain intensity is the second order internal stress. Thus, in case of the deformed body with the geometrical ratio b/h small, because the deformation to the width direction is enough great, in the proximity of the planetary cylinder appears a relaxation of the second order stresses.

The second order stress has a minimum value at the middle of the thickness and increases slowly to the massive cylinder proximity. In case of the geometrical ratio greater of 2 the deformation in the width direction is negligible and the second order stress has the maximum value at the proximity of the planetary cylinder where the strain intensity has maximum value.

The micro-hardness increases with 25% almost in the proximity of the planetary cylinder and littler, 5% approximately, at the proximity of the massive cylinder.

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