Advanced Materials Research Vol. 814 (2013) pp 68-75
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doi:10.4028/www.scientific.net/AMR.814.68

RESEARCH OF COMBINED PROCESS "ROLLING-PRESSING" INFLUENCE ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF ALUMINIUM

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Keywords: combined process "rolling-pressing", equal-channel step die, mechanical properties, microstructure of deformed aluminum.

Abstract

In the development of new technology forming the ultimate goal is increasing of productivity, expansion of range, creating a compact production, capable of rapid reconfiguration for mobile release of the new product. But the main purpose, of course, is improvement the quality of the source material. When used as a raw material of various grades of steel, non-ferrous metals and their alloys, the main aspect of quality improvement is increasing the strength characteristics. Often to increase the strength of deformable metal should be given reduced grain structure, up to subultra and even nano-level. There are several ways to obtain sub-ultra-fine-grain structure of metals and alloys, and one of those ways is a method of severe plastic deformation of the metal, implemented in the whole volume of the deformable metal.

On the department "Plastic Metal Working" of Karaganda State Industrial University was previously developed and proposed a new method of combined rolling and pressing in equal-channel step die, which compared to conventional compression in the traditional equal-channel step die ensures the continuity of the process and removes the restrictions on the size of the original pieces. The essence of the method is that workpiece which is pre-heated to a temperature of the beginning of deformation is applied to the forming rolls, which due to contact friction forces captured it in roll gap and pushed through the channels of equal- channel step die. At the exit from the die installed a second pair of rolls, which pulls the workpiece from the die.

In the research of the process were made theoretical studies, after which were received the empirical formulas to determine the rolling force in the rolls and pressing force in the matrix. Also were obtained formulas for the kinematic state of the process.

Also conducted a simulation of the process in the software package Deform-3D, in which produced the picture of stress - strain state and analyzed the resulting force.

In this work, laboratory studies were performed of the combined process. In particular, a laboratory experiment was conducted to implement the combined process of "rolling-compaction", whose main purpose was to research the effect of the scheme on the deformation changes in the microstructure and mechanical properties of the original pieces, made of aluminum alloy AK6.

Research of the mechanical properties and microstructure of deformed aluminum billet by this way was found that the implementation of the combined process of "rolling-compression" increases strength properties of aluminum, and reduced plastic properties, and the original grain during deformation is reduced.

Introduction

Despite the big prospects, until recently the issue of nano-structural (NS) metals and alloys use as constructional and functional materials of new generation still remained disputable. Only during last years there was breakthrough outlined in this area, connected with the development of new ways of volumetric NS materials reception as well as with research of fundamental mechanisms leading to achievement of their new properties. Currently existing technologies of intensive plastic deformation realization though allow the production of volumetric nano-structural materials, but until now the industrial technology of such materials reception did not exist yet – cost price of such production is too high. Therefore the development of new principles of intensive plastic deformation (IPD) use for production of volumetric NS metals with perspective properties is the actual problem currently.

Scheme of combined process

In works [1-11] authors have offered the new technology of intensive plastic deformation realization in the process of deformation – it is the combined process of "rolling-pressing" with the use of equal channel echelon matrix (Fig. 1), and advantages of this process are given.

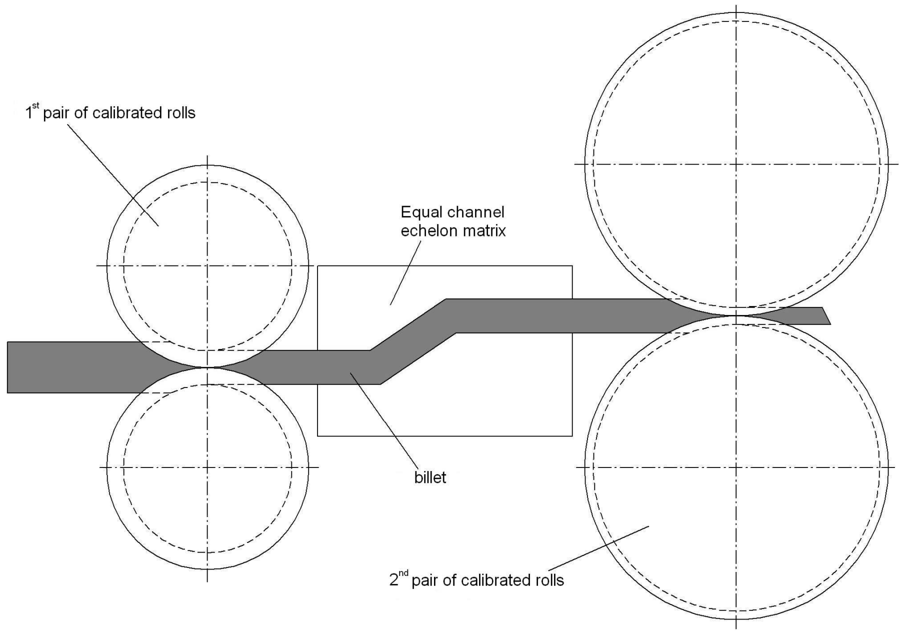


Fig. 1 – Combined process "rolling-pressing"

The essence of this process is that the deformed billet preliminarily heated to the temperature of deformation beginning is moved to rolls which grasp it by means of contact friction forces into rolls throat, and at their output it is pushed through channels of equal channel echelon matrix. After the billet completely leaving the rolls throat, next billet is supplied to them, which passes through rolls and comes into the matrix and pushes out the earlier deformed billet from the matrix. It means that in this case the process of billets pressing in equal channel echelon matrix is realized at the expense of use of friction contact forces arising on the surface of metal contact with rotating rolls. During the realization of this combined process of deformation both flat and calibrated rolls can be applied. It has been thus proved that it is the most expedient to use calibrated rolls as the working tool carrying out the role of punch and pushing the billet through channels in the matrix [1].

Earlier at the Metals forming chair of Karaganda State Industrial University there were theoretical researches of this combined process [1, 5-8] held, as a result of them there were empirical formulas detected for definition of rolling and pressing force, optimum value of matrix channels joining angle, as well as diameters of rolls at the entry and exit from the matrix. Besides it, there was computer modeling carried out of this process in program complex DEFORM-3D [2, 3, 9-11] where there was stressed and deformed state of the metal studied, temperature distribution along the section of the sample, optimum geometrical and technology factors for successful course of the process.

Laboratory experiment

This work is devoted to research of new deformation scheme influence on micro-structural changes and mechanical properties changes, proceeding in aluminum.

Aluminum and its alloys, because of their unique technical and operational characteristics, occupy an important place in modern industry. The presence of these properties, such as high electrical conductivity and corrosion resistance combined with low weight, have led to the fact that aluminum and its alloys are widely used in machine building, electric power, transportation, aviation and other industries. A special place in the structure of production of semi-finished aluminum and its alloys occupy lengthy blanks, which are used to make ropes, cables, electrodes, welding rod, welding wire. These products are also widely used in military, aerospace and aviation industries. And for several decades in the production of a lot of attention is paid to improving the quality of aluminum, by achieving a high level of its mechanical properties, in particular, and by obtaining ultrafine-grained structure.

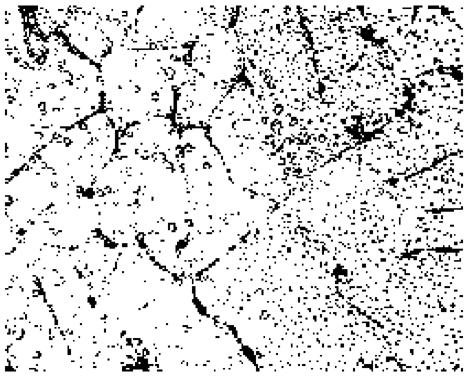
Laboratory experiment was carried out at billets with dimensions h x b x l = 16 x 30 x 200mm, made of aluminum alloy AK6, at the simplified installation developed by us for realization of combined process “rolling-pressing” with the use of flat rolls and equal channel echelon matrix (Fig. 2) on the basis of rolling mill DUO-100. Simplification is connected with currently absence second pair of flat rolls. In this case the process of billets deformation at the installation, realizing the combined process “rolling-pressing", is realized as follows: billet, preliminarily heated to temperature of deformation beginning is supplied to rolls of laboratory mill DUO-100 which at the expense of contact friction forces grasps it into the throat of rolls and pushes through channels of equal channel echelon matrix. After the billet completely leaving the rolls throat, next billet is supplied to them, which passes through rolls and comes into the matrix and pushes out the earlier deformed billet from the matrix, and so on. Due to design simplification, in the end of deformation of all batch of billets, it was necessary to disassemble matrix and to take out the last preparation. As in the process of rolling, unlike the pressing in equal channels echelon matrix, there is still the change of initial billet dimensions then for realization of following deformation cycles after each cycle of deformation the rolls throat was reduced and replaced by corresponding size of equal channel echelon matrix.

Fig. 2 – Machine for realization of combined process “rolling-pressing”

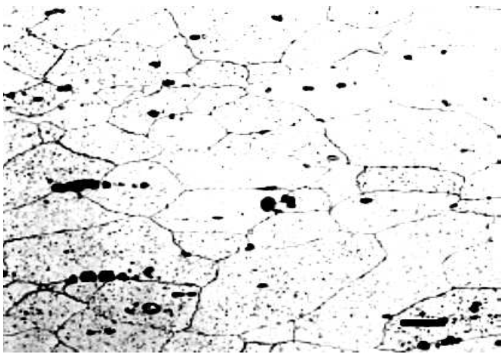
Results and discussion

Microstructural researches of the aluminum billets deformed at the new scheme have shown that in the initial condition aluminum has coarse-grained structure with the average size of grain of 118 microns (Fig. 3a). Already after the first cycle of deformation the aluminum structure is strongly crushed (42 microns) in comparison with initial one and gets strip character, especially in longitudinal section of billet (Fig. 3b). In longitudinal section the share of extended elements is more than in the cross-section. According to scanning electronic microscopy (SEM), after the first cycle there is fragmented structure formed with small angular misalignment. There are fragments seen surrounded by partially big angular and partially small angular borders that is characteristic for materials after the first equal channels passing (Fig. 4).

After the second pass fragments become smaller (Fig. 3d, e). There are both small and large elements of structure observed. In longitudinal section the oblongness of structure (Fig. 3d) is less expressed and equal axis elements of quite small sizes with small angular borders formed (fig. 4b). Most part of borders is wavy and indistinct.

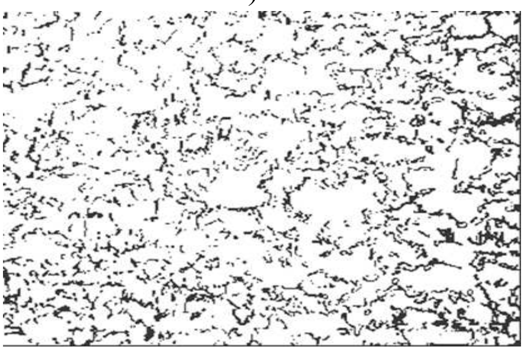


a)

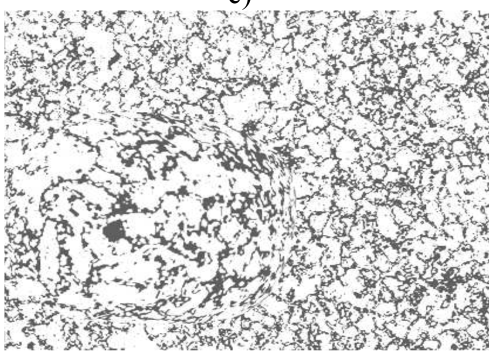


b)

c)



d)



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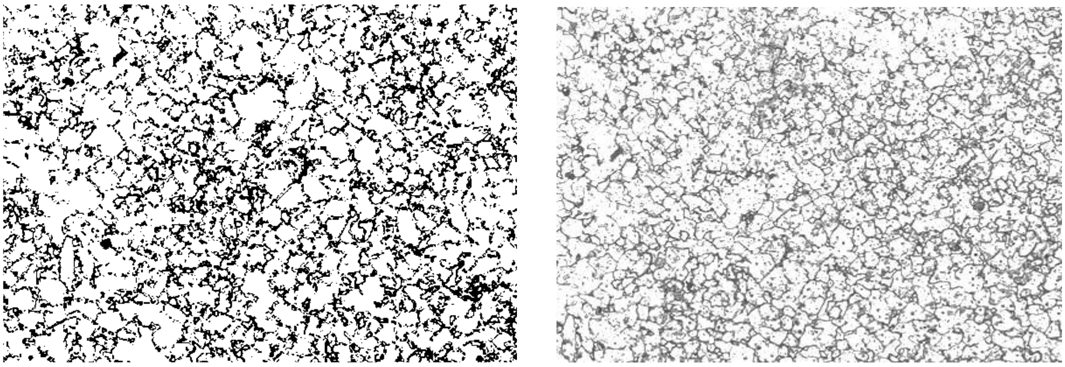
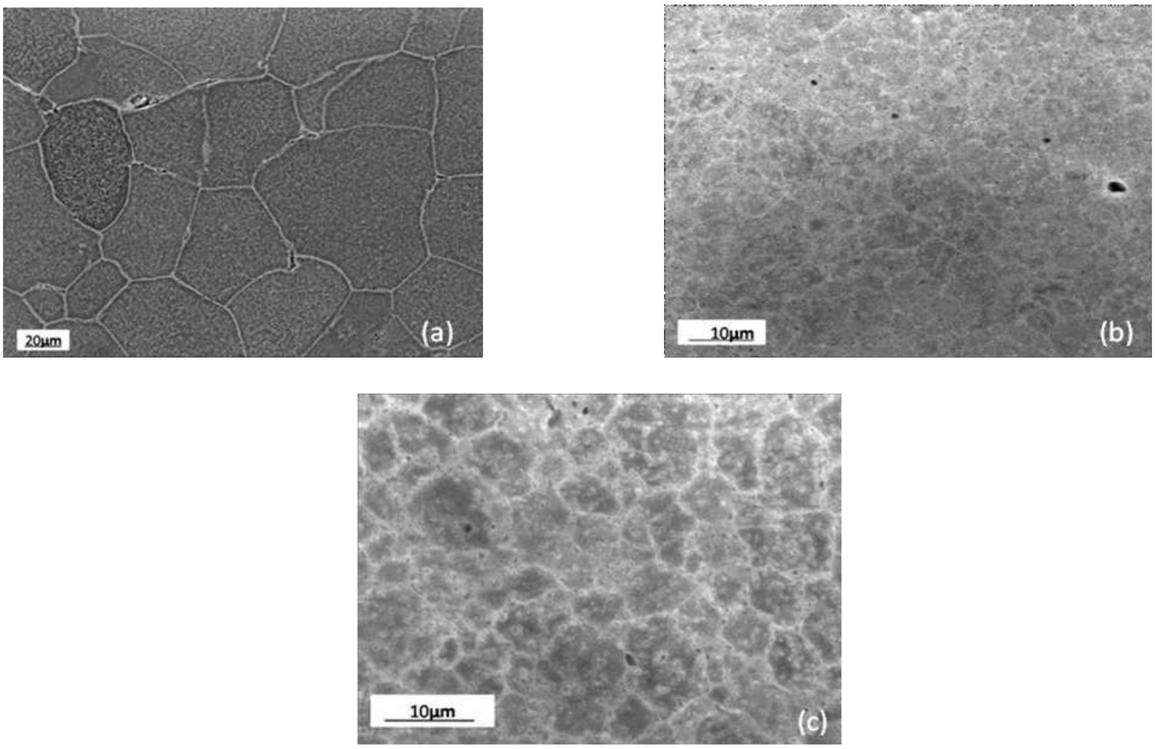


f) g)

a – initial structure; b, c – after the first cycle of deformation (longitudinal direction b), (cross sectional direction c); d, e – after second cycle of deformation (longitudinal direction d), (cross sectional direction e); f, g – after third cycle of deformation (longitudinal direction f), (cross sectional direction g)

Figure 3 – Optical photography of aluminum billets micro-structure, ×200

After the third cycle of deformation the microstructure type in longitudinal and cross-section considerably does not change. Structural elements in both sections are more approached to equal axe form, there are no areas with obvious strip structure. The size of grains/fragments is about 3.5 microns. Borders of grains become more accurately expressed (Fig. 4c) that is, probably, the sign of dynamic re-crystallization course.



a – after the first cycle of deformation (longitudinal direction); b – after second cycle of deformation (longitudinal direction); c – after third cycle of deformation (longitudinal direction)

Figure 4 – SEM micro-photography of aluminum billets

As per results of mechanical properties study there were trends of dependence built for strength and plasticity properties from deformation level (Figures 5, 6).

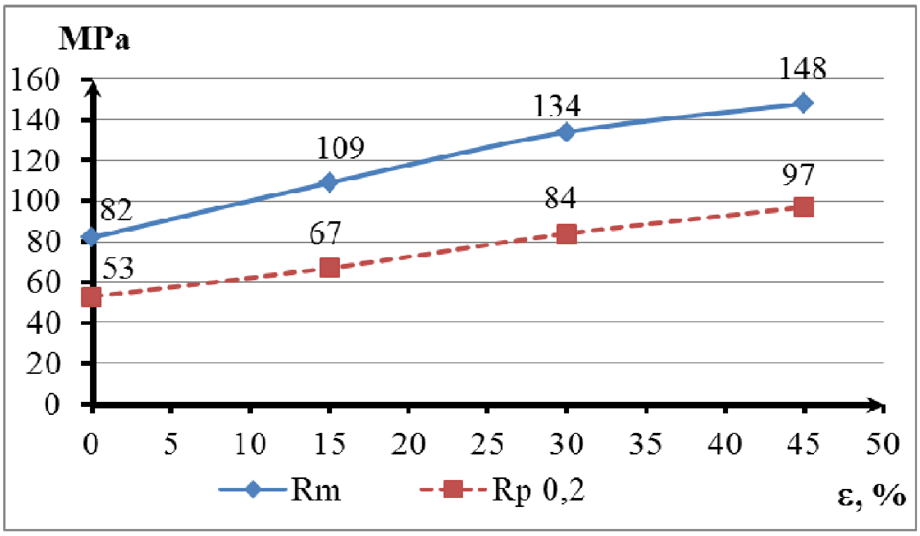


Figure 5 – Trends of strength characteristics dependence on the level of deformation

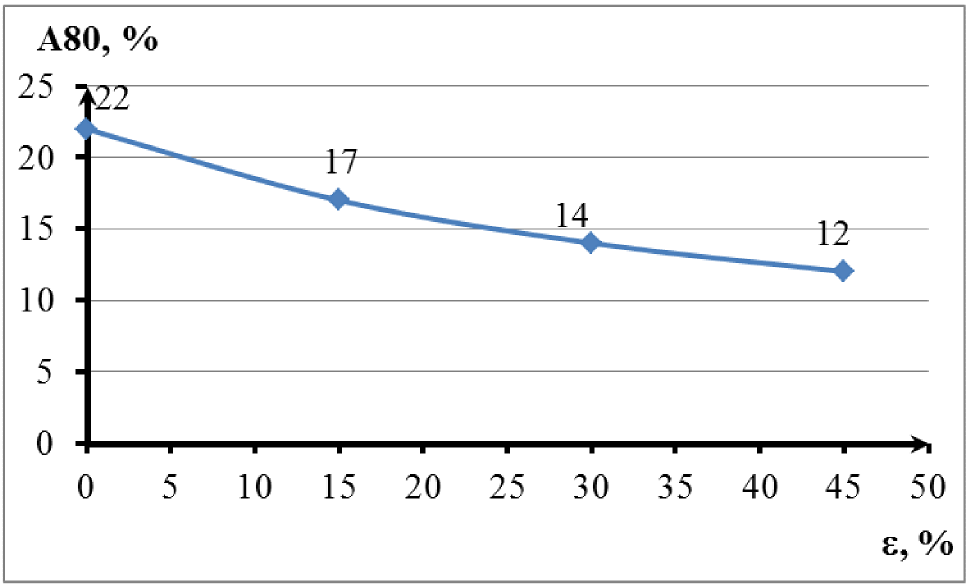


Figure 6 – Trends of plasticity characteristics dependence on the level of deformation

At these trends dependences are presented in the form of four points. The first point is located at the axis of ordinates, corresponds to parameter of not deformed aluminum; other three points correspond to parameters after each cycle of deformation. As a result it was revealed that during the deformation of aluminum billets by means of the combined process «rolling-pressing» strength properties of metal are increasing, and plastic properties are decreasing. At the same time the resource of plasticity of the received sample is above the resource of plasticity of aluminum subjected to classical rolling.

Conclusions

During the carried out laboratory experiment there was studied the influences of the new combined process of deformation "rolling-pressing" on the microstructure and mechanical properties of aluminum and the following was revealed:

1. At the first cycle of deformation the structure is strongly crushed from 118 microns to 42 microns.
2. In the deformation beginning the non-uniform strip structure is formed.

3. After the third cycle of deformation structure in cross-section and longitudinal section is becoming almost homogeneous and big angular borders are found. Borders become more accurate that shows processes of dynamic recrystallization.

4. Strength after 3 cycles of deformation increases from 82 to 148 units, relative lengthening decreases with 22 to 12%, despite this resource of plasticity of the received sample is above the resource of plasticity of aluminum subjected to classical rolling.

These results tells that offered technology can be recommended for introduction in to manufacturing for reception of billets from non-ferrous and ferrous metals and alloys with sub-ultra-fine grain structure and raised level of mechanical properties.

Currently, small-sized billets is prepared predominantly by pressing that does not find significant using in the industry. The introduction of this technology in production will produce high-quality long-axis workpiece sub-ultra-fine grain structure. Since this technology is applicable to not only deformation of aluminum, but also steel and various alloys, that its implementation in the production enable replace expensive alloys and steels cheaper deformed by this technology, and having high mechanical properties. This eventually would give a significant economic effect.

So the arrangement with the company ArcelorMittal Temirtau JSC about approbation of this technology in conditions of Mechanical shop of this company and further introduction of this technology in manufacturing for reception of high-quality preparations which will be used further for manufacturing of small details of responsible appointment now is already reached.

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