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08ПС STEEL STRUCTURE AND PROPERTIES AS A RESULT OF ROLLING IN THE SUBCRITICAL TEMPERATURE RANGE

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Abstract. The 08пс steel structure and properties formation after rolling at subcritical temperatures with air cooling are studied. The development differs in the temperatures of the beginning and end of rolling, as well as the cooling rate in the post-deformation period. It allows to expand theoretical ideas about the patterns of 08пс deformed steel structure formation. The results of the investigation can be applied in determining rational processing modes, which involve rolling at subcritical temperatures, to increase the complex metal properties and obtain high-quality parts by cold stamping.

Key words: 8пс steel, hot rolling, microstructure, mechanical properties

The automotive industry is one of the largest consumers of the products of metallurgical enterprises producing thin low-carbon steel cold-rolled sheets. The decisive role in increasing the integral quality of cars is using of rational materials for the body parts production that would meet requirements of standards for operational reliability and safety while simultaneously minimizing the total costs of their production.

Low-carbon steel 08ps is used in the automotive industry for the production of parts from thin-rolled sheets by the method of cold stamping. Its main disadvantage is reduced strength, which may not meet safety standards, therefore the task of improving the mechanical properties of sheet steel while minimizing costs is relevant.

The properties of the steel are determined by many factors, one of the main ones is the structural factor. It is possible to control the structure of hot-rolled steel by changing the temperature conditions at the end of rolling and the metal cooling modes.

Structural and substructural changes in steel are a complex set of processes that accord with each other. During deformation, there are sliding within the grain and twinning develop in austenite, which is manifested in the wave-like grain boundaries nature. The determination the quantitative ratio of ordinary and special boundaries in the ferrite component of structural steels is of scientific interest. This allows to purposefully influence the grain boundary structure and improve the operational characteristics of metals and alloys with BCC lattice [1].

In the hot deformation range, structural changes are associated with the subgranular structure formation. In the interval after compression, the steel partially restores the structure. Therefore, the structure of hot-deformed steel is the result of several pressings at different temperatures and pauses between them, that is, static and dynamic processes of structural changes are superimposed [2].

During rolling and cooling, a number of processes occur one after another or simultaneously: phase recrystallization of the matrix, changes in the size and shape of ferrite grains, orientation and degree of perfection of crystallites. The nature of development and the degree of completion of these processes depend on the temperatures at which rolling occurs and ends, on the degree of compression, the rate of deformation and cooling of the metal.

Adverse temperature conditions characteristic of traditional hot rolling technology can be prevented by metal processing in the region of the single-phase ferrite structure below the critical point A_{r1}. Rolling of a thin sheet in the subcritical temperature range will ensure obtaining a uniform metal structure, which determines its mechanical properties level, as well as the quality of stamped parts [2, 3].

The conditions at the end of the deformation determine the final steel structure.

The structural components of hot-rolled low-carbon steel 08пс are soft plastic ferrite and hard brittle cementite. The mechanical properties level and the ability of hot-rolled metal to drawing depends mainly on the ferrite grains size and shape, as well as on the cementite amount, shape and distribution. ДСТУ 2834–94 regulates the ferrite grain size, which for hot-rolled products should be no more than 62 microns, and the ferrite grain irregularity is allowed within the limits of three adjacent grain numbers. High grain heterogeneity leads to irregular metal deformation during drawing, which can be the reason of the cracks formation.

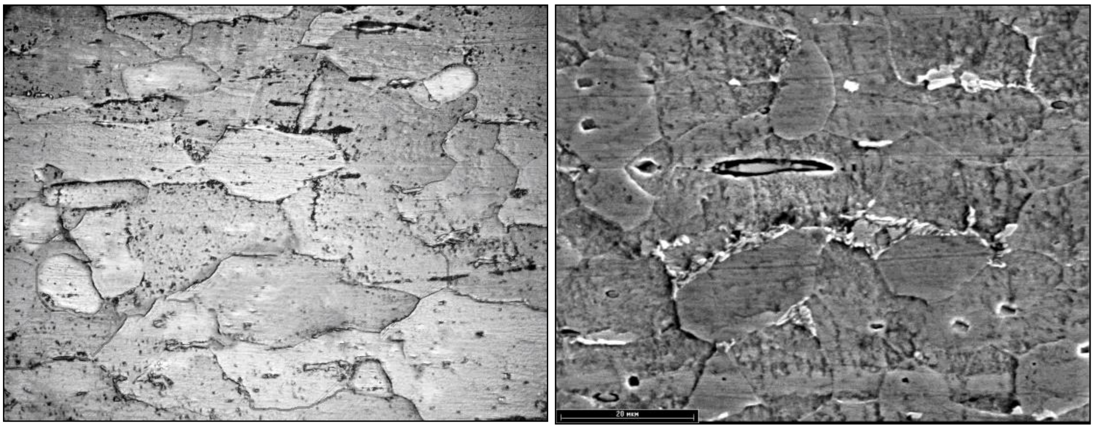
A uniform structure is also necessary in hot-rolled metal, which used as a rolling stock for cold rolling mills. The favorable structure of rolled metal is the main reason for achieving high capacity to deep drawing after residual heat treatment, since the hot-rolled metal's structure significantly affects on the structure after cold rolling and subsequent recrystallization. The metal's deformation degree in these conditions can reach 70-80%, therefore, the large grain heterogeneity, which worsens the technological deformability at cold rolling temperatures, can cause the formation of cracks in the sheet, and, as a result, production accidents. At the same time, grain heterogeneity is not eliminated either by cold rolling or by recrystallization annealing [3, 4].

The analysis of scientific information showed that the problem of the grain heterogeneous structure formation is solved by the temperature and deformation parameters adjusting of the thin-rolled products manufacture, which allows to ensure the final structure optimal characteristics and the required metal's mechanical properties level in accordance with ДСТУ 2834-94. Thus, the study of the influence of rolling modes at subcritical temperatures on the low-carbon steel structure and properties formation is an actual task.

Research methodology and results. The metal was heated before deformation in an electric furnace CH 1,62,51/11-I2 with a heating rate of 3°C/s, exposure time 2-4 s. Rolling was carried out on a laboratory single-cell mill дуо280 for two passes in the austenitic and ferrite-pearlite temperature ranges (the rolling speed was 1.4 m/s, the duration of the pause between passes was 13-15 s). The post-deformation processing mode is cooling of the samples in air (V ~5-8ºC/s).

The 08пс steel samples microstructure was studied using a metallographic and electron microscope JSM-840 with a "Link-860/|500" microanalysis system, the substructure on the cross-section of 08пс steel samples was studied using an electron microscope JEM - 200Cx. The mechanical properties of the metal was determined using standard tensile test methods.

The results of the research on the structure formation and quantitative structure parameters features showed that the 08пс steel initial billet microstructure (Fig. 1, a) is characterized by a 20-90 microns ferrite grain size in the surface and 10-60 microns one in the central zone of the sheet.



a **b**

Fig. 1. Microstructure of 08пс steel: a – initial billet, ×200; b – ε=16.4%, ×1500

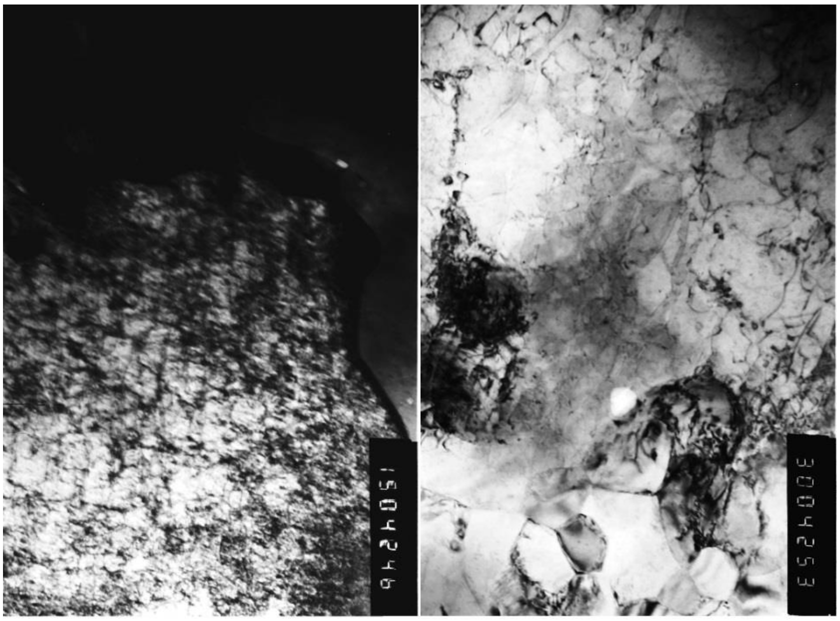
After rolling for two passes in the austenitic and ferrite-pearlite temperature regions, a surface layer is formed in the structure of the sheet, with the grain size 15-160 μm. In the structure of the deformed sheet central zone, the grain size is 10-60 μm. When studying at a high magnification in the 08пс steel deformed sample structure layers of pearlite and segregation of cementite along the grain boundaries are observed (Fig. 1, b).

A mixed structure with large ferrite grains on the surface or in the central zones of the sheet, which are unevenly deformed during subsequent cold rolling, leads to the formation of transverse cracks along the sheet edges. Grain boundaries affect almost all processes that occur during deformation (in particular, in recrystallization), the reliability, durability and quality of the material depend on them.

At certain misorientation parameters, some of the nodes of neighboring grains coincide. Such a boundary, exists in a plane containing coinciding nodes, is special because it has an ordered structure with its own period and special properties. Using light microscopy methods, the presence of special low-energy boundaries in the ferrite component in low-pearlite steels has been established from studies of their grain-boundary structure [5].

Thus, the study of the ferrite substructure in order to control the structure formation processes to obtain rolled metal with a high complex of mechanical properties is important.

Electron-microscopic studies of thin foils from 08пс steel samples allows to observe structural changes during the tested deformation mode (Fig. 2).



a b

Fig. 2. Central zone substructure of the of the 08пс deformed steel sample:

a - × 15000; b - × 20000

The substructure was studied in the surface and central zones of the billet and the sample rolled according to the regime: T_h= 1000°C; T_1 = 750°C (austenitic-ferritic region), T_2 = 600°C (ferrite-pearlite region), degree of deformation 16.4%, cooling in air. Deformation of the billet in the austenitic-ferritic and ferritic-pearlitic regions with air cooling leads to structural changes in the surface layer of the sheet: in the surface zone structure there are no lamellar pearlite colonies and large cementite crystals in the middle of the ferrite grains. Along with spheroidized pearlite colonies and individual cementite crystals, separate areas of products of pearlite transformation of austenite with a smaller interlaminar distance than in pearlite are observed at the boundaries of ferrite grains.

It is known that the main mechanism of recrystallization (grain boundaries migration) can be slows down or stops with cementite plates or round-shaped fine carbides. In Fig. 2 fragments of the substructure of the deformed piece of 08пс steel central zone are shown. Fig. 2 data analysis showing that there are dispersed particles (probably carbides, nitrides and carbonitrides) at the ferite grains boundaries and in the grain volume. On this particles dislocations attach and block the processes of selective and secondary recrystallization.

Structural changes in the 08пс steel deformed sample led to the formation of a heterogeneous structure in the surface layer with a larger spread of ferrite grain size values than in the billet. These changes indicate the implementation of recrystallization and polygonization processes, but the processes of secondary recrystallization on the sheet surface developed more intensively, which led to the formation of a heterogeneous structure and a level of properties that does not meet the requirements of ДСТУ 2834-94: $\sigma_в$ = 450 MPa; σ_{02} = 375 MPa; δ = 23%; HRB 85.

Conclusions. The structure and properties of 08пс steel after rolling at subcritical temperatures were studied. A comparative analysis of the substructure of the low-carbon steel initial billet and deformed samples was carried out. It was established that there are changes in the structure of the deformed samples and the initial blank, which indicate the implementation of polygonization and recrystallization processes. This leads to the formation of a level of mechanical properties that does not correspond to ДСТУ 2834-94 requirements. The results of the research allow to establish rational modes of thin-rolled steel 08пс processing to form a homogeneous metal structure the and improve the complex of its mechanical properties.

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