PECULIARITIES OF STRUCTURE FORMATION OF LOW-ALLOYED STEELS DURING HEAT TREATMENT OF PLATES IN – LINE OF THE ROLLING MILLS

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Abstract: *Mechanism of austenitization of steels with inital pearlitic-ferritic and austenitic-ferritic structures was studied. In steels with ferritic- pearlitic structure the oriented formation of austenite at boundaries of of ferritic grains and its growth along certain crystallographic planes was found.. It is the evidence of widmanstatten nature of this polymorphous $\alpha \rightarrow \gamma$ transformation. At heating of steel with initial austenitic-ferritic structure process of austenite formation during following heat treatment with phase transformation is not accompanied by expected grain refinement. It this case heat treatment does not provide increasing of complex of mechanical properties of rolled plates in comparison with hot rolled state.*

Plate rolled products from low-carbon and low-alloyed steels to provide the necessary complex of mechanical and technological properties is subjected to different types of heat treatment. Austenitization is the obligatory part of such treatments.

Effectiveness of austenitization in many respects depends on initial structure of steel. At heat treatment in line of rolling mill, based on hot loading of plates in continuos rolling furnaces [1], low-carbon low alloyed steels have ferritic-pearlitic structure and at hot loading in intercritical range of temperatures they may have austenitic-ferritic structure.

Process of austenitization of steels with ferritic-pearlitic structures was studied by numerous investigatirs [2-4]. But despite of this fact, many questions, connected with mechanism of $\alpha \rightarrow \gamma$ transformation in low-alloyed steels in real conditions of their heat treatment remain the subject of discussion yet. It is necessary to fulfill the special investigation of influence of austenitic-ferritic structure, formed in result of preliminary cooling of plates after hot rolling to temperature of intercritical region, on character of grain size changing in result of following heat treatment with phase transformation

In this work the austenitization of low-alloyed steel 10HSND was investigated. Thes steel are widely used for producing of plate rolled products for general applications. Samples 20x30 mm, were cut out from hot rolled plates with sickness 14 mm were heated to temperatures in the range 700-900 °C with step 20 °C. After that they were cooled on air. Duration of heating was 2 minutes for every 1 mm of plate cross-section. It corresponds to existing conditions of austenitization of plate rolled products during heat treatment in industrial conditions. Volume of austenite decomposition products, formed after cooling of steel was calculated by the method of secants. The error of evaluation was less than 3%.

Process of structure transformations of previously overheated steels at repeated heating was studied by high-temperature metallography. Samples with size 3x12x72 mm were heated in vacuum chamber of IMASH-5S unit ($p=2*10^{-5}$ mm Hg.) to the temperature 1050°C. They were soaked at this temperature 10 minutes and cooled with the cooling rate 0.5 °C/s to 600 and 750°C. It provides the correspondent formation of ferritic-pearlitic and austenitic-ferritic structure. After that they were subjected to repeated heating to temperature 930°C with exposition time 3-5 minutes.

Formation of austenite intermediate decomposition products with spherical and needle shape on boundaries of ferrite grains in this typical feature of structure of steel after cooling on air from different temperatures of intercritical range. Ratio of structure components, there appearance, shape and location depend on temperature of heating. Thus, at cooling from lower part of intercritical range in structure of steel along with ferrite and pearlite the bainite appears. It has the shape of chain of separate grains around the α-phase. With increasing of heating temperature in the range A_{c1}-A_{c3}, the amount of bainite component increases and reaches the maximum at 780-820°C (figure 1). In this case the bainite areas have the shape of plates (needles) extended from boundaries to body of ferrite grain. They decompose rather easy during the tempering at 650°C with formation of fine-dyspersated carbides. At following increasing of heating temperature with their approaching to A_{c3} point the amount of bainite component decreases and pearlite and pearlite-bainite complexes appear in steel.

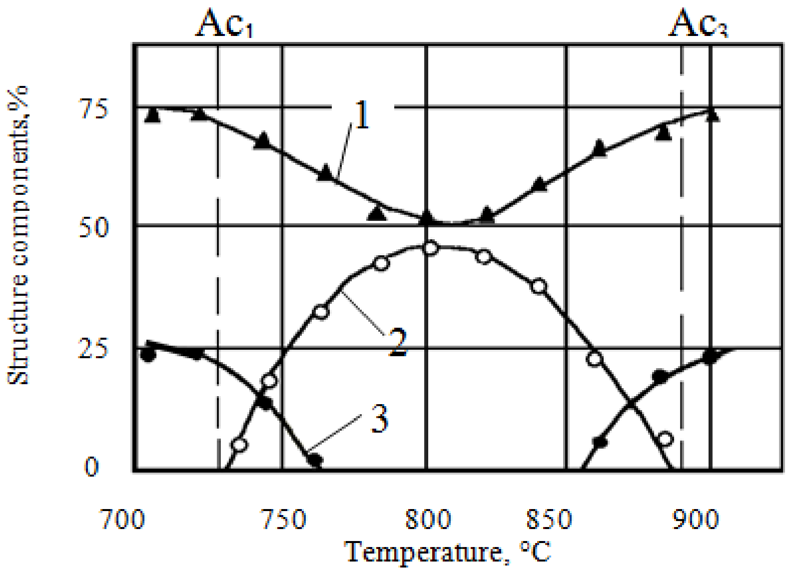


Fig. 1. Amount of structure components in 10HSND steel after cooling on air from different temperatures of intercritigal range: 1 - ferrite, 2 - bainite, 3 – pearlite

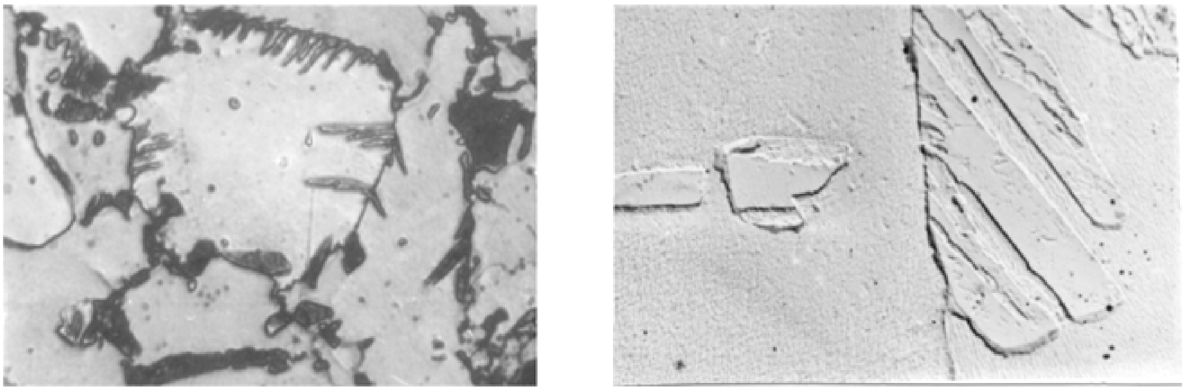
Obtained data about changes in structure of low alloyed plate steels permit to define more exactly our conception about mechanism of austenitization during heat treatment.

Formation of austenite at heating of steel take place not only in pearlite, but widely on ferrite grains boundaries. At first pearlite areas subjected to austenitization. Ends of cementite plates in place where they go out on boundaries of pearlite colonies are the preferable places for austenite nucleation. More rare case is the nucleation on the contact surface between ferrite and cementite. In this case formation of austenite easier occurs along the ferrite lamina in pearlite. Cementite plates play role of barrier for $\alpha \rightarrow \gamma$ transfor mation. In separate regions, where continuity of cementite is broken, and austenite formed in adjacent ferrite laminas. Austenite regions in this case are rather isometric. It is the evidence of approximately equal austenite growth rate along and crosswise pearlite plates. Absence of strict oriented connection between ferrite and pearlite permits to make the conclusion about normal nature of transformation mechanism of crystal lattice during austenitization of pearlite despite of more expected oriented shift character of transformation, taking into account similarity of crystal lattices of austenite and cementite.

The fact of austenite nucleation directly on boundaries of ferrite grains. This tendency becomes clear at short-term expositions. At heating of steel above the A_{c1} point on 10-20°C the austenite case forms on ferrite grain boundary at firs step. Next, with increasing of temperature austeinte is formed as set of parallel plates, located on one side of ferrite grain boundary, more rarely – on both sides of it. As a rule, austenite plates connected by common basis and have the similar orientation inside of ferrite grain. Angle between parallel sets of plates usually equal to 60 or 120° (figure 2).

At heating above certain threshold temperature that corresponds to 760-780°C for investigated steels, the activation of oriented nucleation of austenite is observed inside of ferritic grain. Shape of austenite regions is pronounced needle-like. They nucleate directly at austenite massifs or on ferrite grain boundaries and are growing along certain crystallographic planes.

Oriented formation of austenite and existence of crystalographic relationship with structure-free ferrite gives the arguments to consider the mechanism of polymorphous transformation on this stage of austenitization as widmanstatten, characterized by shift nature of lattice transformation.



a b

Fig. 2 Oriented formation of austenite in normalized steel 10HSND at 780°C
a – x1000, b – x4200

Considerable interest has the fact that many of nucleated in ferrite austenite grains have not the contacts with pearlite and massifs of austenite, formed earlier. It points out on the fact that grain boundaries and another structure imperfections of the α-phase are rather benefit places for nucleation of austenite form the energetic point of view, but in the course of further development of austenite transformation transfer of carbon is possible not only in direction "cementite-austenite-ferrite" but in direction "cementite-ferrite-austenite" too.

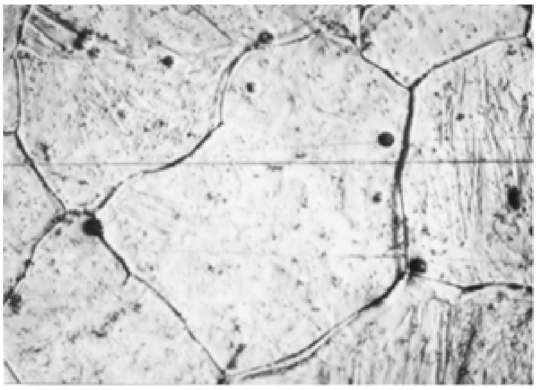
At temperature of heating higher than 820°C $\alpha \to \gamma$ transformation realizes by the growing existing regions of γ-phase and practically full absence of new regions nucleation. Austenite plates become wider and growing inside the body of ferritic grain. Ferritic spaces, separated them, disappear. Well-developed substructure forms in austenitic grains.

Heating of previously overheated steel with ferritic-pearlitic structure causes the considerable refinement of initial austenite grain at phase transformation. In result of heating of steel with initial austenite-ferritic structure, that was formed by preliminary cooling of samples from 1050°C to intercritical range (750°C), the process of austenite formation does not correspond by grain refinement. Obtained grain does not differ in shape and size from initial (figure 3).

This recovery of former austenitic grain at repeated heating explains by the influence of austenite regions that were not subjected to transformation in result of preliminary cooling in two-phase region on structure mechanism of $\alpha \to \gamma$- transformation. It is significant that disappearing of excessive ferrite formed at cooling to 750°C in the shape of net on boundaries of former austenitic grains occurs due to migration of austenite region boundaries in direction of absorbed ferrite. It provides complete recovering of initial austenite grain shape.

Parallel with recovering of austenitic grain at repeated heating of steel with austenitic-ferritic structure, the formation of new grains is observed. They have practically the same size, but not coincide with the former grains in shape. It is important that separate regions with more coarse grains comparing with initial were found. It points out on possibility of some coarsening of former austenite grain at heating of steel with austenitic-ferritic structure..

It is necessary to note that growth of separate coarse austenitic grains takes place in account of adjacent finer grains. This process is similar to secondary recrystallization except the fact that only certain austenitic grains are growing in this case.



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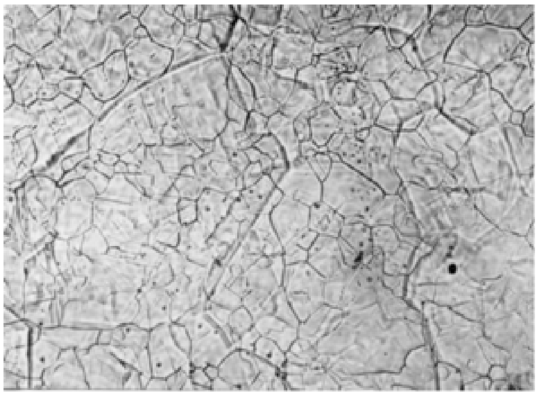

b

Fig. 3. Change of austenite grain previously overheated (1050 ^{O}C) 10HSND steel at repeated heating to 930 ^{O}C after preliminary cooling to 750 (a) u 600 ^{O}C (b), x 400

It is possible to assume that one of reasons of abnormal growing of separate grains is the state of ferritic-austenitic matrix before $\alpha \rightarrow \gamma$-transformation start. Presence of recrystallized α-phase regions causes the formation of austenite nucleus with different orientation. They stabilize the initial matrix, increase the difference in grain size and promote to selective growth of these austenitic grains that have the increased size to this moment or reach it due to migration of interphase boundary. Besides that, at formation of new austenitic grains in recrystallized matrix some of them may be separated by partially conjugated boundaries. In result they obtain the possibility of accelerated growth, but there is no any connection of them with former austenitic grain. One of possible reasons of abnormal growth of certain austenitic grains may be the nonuniformity of their chemical composition, intensified by the redistribution of carbon and alloying elements between α and γ-phases at exposure in intercritical range of temperatures.

Uncovered fact of recovering and coarsening of grain after heating of steel with initial austenitic-ferritic structure permits to conclude that heat treatment of plates with temperature of hot loading in intercritical range does not provide the increasing of complex of mechanical properties (cold-resistance in particular) comparing with hot rolled state and in somre cases may cause their decreasing.

The complex nature of structure transformations that take place during heating of low-alloyed steels with different initial structure must be taken into account for selecting of optimal parameters of heat treatment of plates in-line of rolling mills. The development and realization of new intensive energy- and resource-saving technologies is impossible without this consideration.

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