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DEVELOPMENT OF HOT ROLLING TECHNOLOGY USING THE METHOD OF PHYSICAL MODELING

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These days, ensuring the high quality of thin products (0,6 – 2,0 mm) is the most promising direction for the development of hot-rolled strip production. Hot-rolled strips can be used in place of a more expensive cold-rolled strip. The effect of cooling modes on quality of hot-rolled metal was observed heating at different temperature, the degree of deformation was observed after cooling by water-air mixture. It was observed that the micro hardness of the samples decreases and the amount of structurally free ferrite increases by decreasing the cooling time and increasing the temperature.

Key words: Gleeble-3800, rolling, sheet, structure, temperature

INTRODUCTION

Numerous schemes of Thermo mechanical processing (TMP) rolled products have been developed and are being actively used [1]. In the production of carbon sheets, it is great interest to provide a scheme for formation of perlite, based on the plastic deformation of steel in austenite state and subsequent isothermal transformation of austenite in the pearlite region [2]. Other things being equal, an increase in cooling rate leads to an increase in strength properties of the rolled metal. This reduces the plastic properties. At a very high cooling rate, a padded layer of metal forms on the surface strip. To the discrepancy between mechanical properties of hot-rolled steel and the requirements of standards, i.e. to get a marriage can lead to heterogeneity of the microstructure along the thickness of strip, increased hardness and “brittleness” of the incandescent surface. Thus, the microstructure of hot-rolled thin strips produced on known mills is often characterized by considerable grain size (large grain on the surface), which leads to the formation of various defects when using such metal for cold stamping. Thus, the microstructure of hot-rolled thin strips produced on known mills is often characterized by considerable grain size (large grain on the surface), which leads to the formation of various defects when using such metal for cold stamping.

The main reason for the heterogeneity of thin strips is incorrect assignment of temperature deformation modes of rolling and cooling. Technological solutions are effective for one mill is often unacceptable for another [3]. Therefore, the study of the influence of temperature regimes rolling and quenching, as well as the cooling of strips on quality of hot-rolled steel, rolled and chilled in a new mill and a retractable roller table is great importance [4]. The plastic deformation of samples from steel A1 was carried out on the “tension-compression” module. The samples were heated at a rate of 100 °C / s to a temperature of 1 100 °C and held at these temperatures 1 h. Further, each heated sample was cooled to temperatures of 800, 900 and 1 000 °C, deformed by cyclic compression at the rolling speeds of the longitudinal wedge mill (LWM).

MATERIALS AND METHODS

For the purpose of rolling high-quality sheets of metals and alloys, it offers a LWM and a new design of the diverting roller. The work investigated the effect of cooling with a water-air mixture on the structure and properties of rolled sheets of steel A1 having the following chemical composition / wt. %: C 0,15, Mn 0,95, Si 0,29, P 0,011, S 0,012, V 0,11, Ti 0,012, Cu 0,20, As 0,020. The analogue of the experimental steel A1 is the steel St3Gsp of the CIS countries (C 0,14 - 0,2, Mn 0,8 - 1,1, Si 0,15 - 0,3, P 0,04, S 0,05, Ni 0,3, Cr 0,3, N 0,008, Cu 0,3, As 0,08). To determine the effect degree of deformation and subsequent water-air cooling on the structure of steel A1, Samples with a size of Ø 10,0 × 15,0 mm were tested by compression on the Gleeble-3800 test complex. The Gleeble-3500 is a fully digital closed-loop thermo mechanical testing system. It is based on software based on easy-to-use Windows operating systems and a block of powerful processors that provide an interface for creat-

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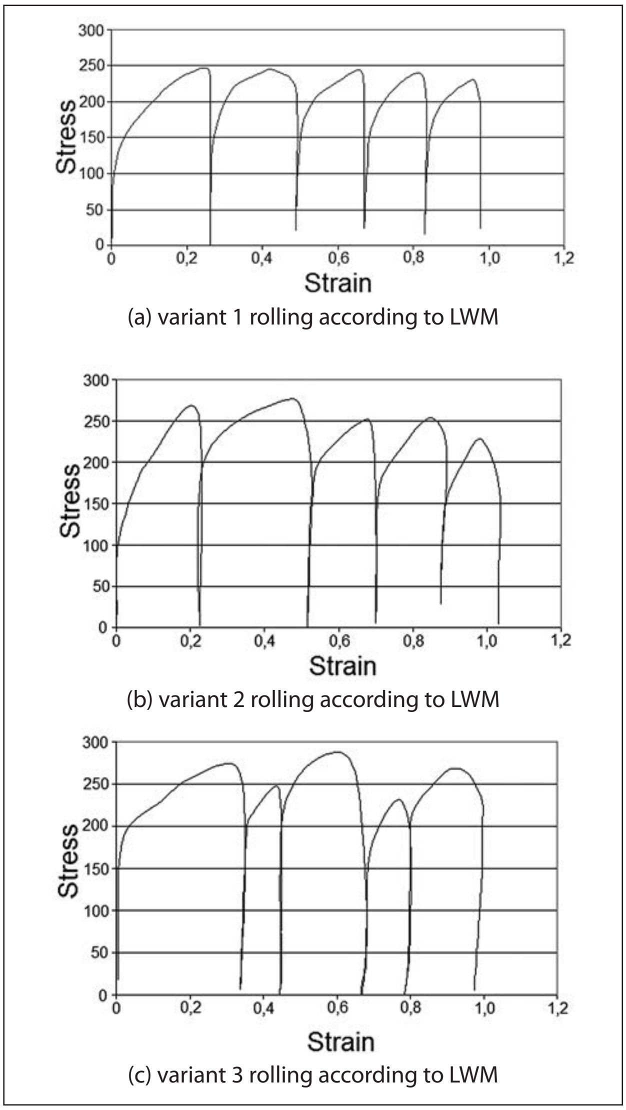
ing, conducting and processing programs for physical modeling and thermo mechanical tests. The heating system of the Gleeble-3500 unit allows direct current transmission to heat samples at a speed of up to 10 000 °C / s and maintain a constant equilibrium temperature. Thanks to high thermal conductivity of grippers that hold the samples Gleeble-3500 complex can cool the samples at high speed. The additional cooling system allows you to achieve a cooling rate of more than 10 000 °C / s on the sample surface. Thermocouples and an optional infrared pyrometer transmit signals for precise temperature control of the samples. The Gleeble-3500 mechanical system is a closed, fully integrated servo hydraulic system capable of developing a force of up to 100 kN, the maximum speed of mobile traverse: 1 000 mm / s. LVDT sensors / force sensors (strain gauges) or non-contact laser extensometers provide feedback for the precise implementation of the mechanical test program. All tests can be carried out under reduced pressure or in a protective atmosphere. Plastic deformation of samples made of A1 steel was performed on the «tension-compression» module. The samples were heated at a rate of 100 °C / s to temperatures of 1 100 °C and maintained at these temperatures of 1 h. Further, each heated sample was cooled to temperatures of 800, 900 and 1 000 °C, deformed by cyclic compression at rolling speeds of a LWM. When drawing up the experiment plan, time of the inter-formation pause was determined basis law of the constancy of the second volumes during rolling in a five-cell LWM [5]. In intervals of cyclic deformation after switching off electric drive of installation, the sample remained clamped by strikers and active loading was replaced by a relaxation stage. Subsequently, the samples were cooled with air, water-air mixture and naturally to room temperature. The sections for metallographic research were prepared according to the traditional method on grinding and polishing wheels. A solution of nitric acid in ethyl alcohol was used to etch the samples.

Metallographic analysis was performed using a universal microscope Neophot 32 (Carl Zeiss, Jena) (Germany). The Neophot 32 microscope is designed for metallographic microscopy and creation of photographs. The observation can be made by the light and dark field method, in polarized light, with a change in magnification multiplicities. Magnification of microscope, multiple: from 10 to 2 000. The microscope is equipped with an Olympus digital SLR camera with output of the resulting image and saving images to a computer. Using above method, the influence of temperature, compression, deformation rate and inter formational pause on the deformation resistance of A1 steel was studied. It is known that speed effect at high temperature is determined by the speed of such processes as hardening and softening. An increase in rate of deformation corresponds to a more hardened state, since probability of partial softening of metal during plastic deformation decreases. The data available in various monographs on rate dependence of the deformation resistance of steels are in many cases contradictory and do not always allow us to definitely judge the influence of this factor on the deformation resistance. In most studies, there is an increase in the values of deformation resistance with an increase in the deformation rate.

RESULTS AND DISCUSSION

It should be noted that in our experiments, with an increase in the rate of deformation in cyclic compression, value of the deformation resistance decreases in magnitude. Figures 1-3 show laws of variation of the strain resistance σ as a function of cyclic deformation with different compressions ε and deformation rates. From analysis and comparison of the hardening curves of A1 steel, it follows that the deformation resistance of this steel at temperatures of 800, 900 and 1 000 °C increases in the initial deformation cycle and decreases in the last cycles. In our opinion, dynamic and static softening and the thermal effect of deformation have a significant impact on the deformation resistance curves. Thus, with increasing compression and thus the rate of deformation, character of the hardening curves changes. At low deformation rates, there is a monotonous hardening of the metal, i.e., the deformation resistance increases at the end of the sample compression process [6]. During transition from one precipitation cycle to another precipitation cycle, the maximum values of the strain resistance decrease. The presence of such a feature of the rheological behavior of steel under study can be explained by the course of dynamic and static recrystallization during precipitation and in the inter-formation pauses. If we compare the maximum values of the deformation resistance of samples deposited at different temperatures, we can see that the value of the deformation resistance is significantly affected by temperature. When the temperature increases, the value of the deformation resistance decreases. At the same time, difference in strain resistances increases in the first and fifth cycles of deformation, i.e., the value increases $\Delta\sigma = \sigma_1 - \sigma_2$, residual hardening decreases, as the return and recrystallization processes have time to pass more completely. All this indicates the passage of dynamic and static recrystallization at elevated temperatures. Figures 4 show the microstructure of A1 steel samples obtained under the temperature-strain conditions of rolling thin sheets on a LWM.

An increase in precipitation temperature to 1 000 °C leads to an overall coarsening of grain (see Figure 4a). Thus, the samples, upset and cooled according to variant 1, 2 and 3, have the structure of coarse ferrite with dimensions of 84 - 97 µm, thick-plate pearlite, consisting of alternating plates of ferrite and cementite, with an average inter-plate distance n=0,82 – 0,91 µm. The size of the coarse-lamellar pearlite colonies reaches 66 - 83 µm, while the size of excess cementite corresponds to 3 - 4 points (see Figure 4b and 4c). The formation of such a coarse-grained structure during upsetting and cooling

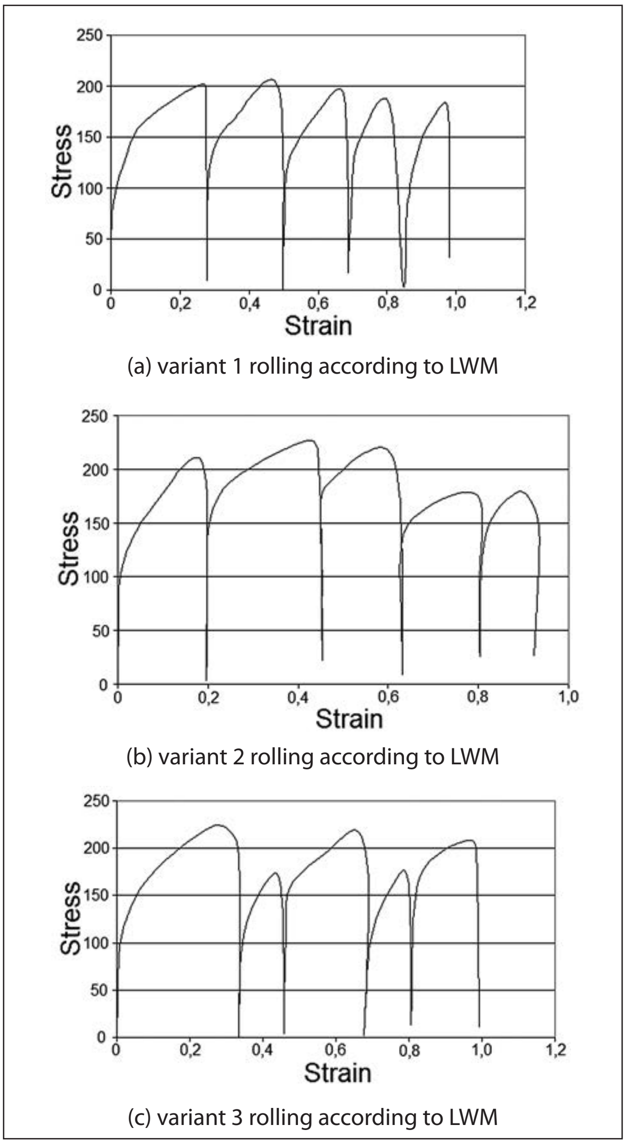


(a) variant 1 rolling according to LWM

(b) variant 2 rolling according to LWM

(c) variant 3 rolling according to LWM

Figure 1 Change in resistance to deformation at temperature 800 °C



(a) variant 1 rolling according to LWM

(b) variant 2 rolling according to LWM

(c) variant 3 rolling according to LWM

Figure 2 Change in resistance to deformation at temperature 900 °C

according to variant 1, 2 and 3 can be explained by the creation of conditions for the passage of complete primary recrystallization in the deformed austenite matrix during high-temperature upsetting, as well as by an increase in the size of austenite grains at high temperatures. It is known that larger initial austenite grain size, larger inherited ferrite + pearlite structure.

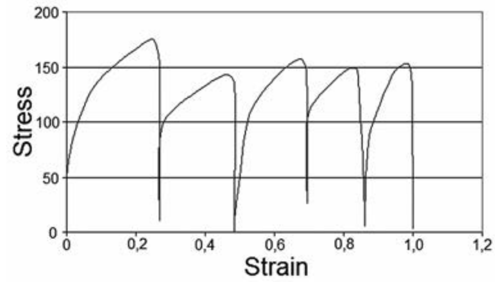
The presence of such large grains during upsetting and cooling according to variant 1 can be explained by the gradient of work hardening of austenite and ferrite grains over entire section of the strip at a low deformation temperature. Upon slow cooling, recrystallization under conditions of such a gradation of work hardening causes enhanced grain growth over the sample cross section. It should be noted that the reason for formation of an uneven-grained structure over cross-section of the sample at a temperature of 800 ° C may also be non-uniformity of deformation.

Since at low rolling temperatures, austenitic and ferrite grains may undergo deformation to a lesser or greater extent. Thus, from analysis of the microstructure of A1 steel, it can be concluded that a uniform structure, fine-grained over the thickness of the samples, is obtained upon deformation and cooling with a water-air mixture according to option 1 (Figure 4a). According to the results of the study of structure, it was found that with late cooling modes, internal structure of A1 steel is formed according to the same regularities.

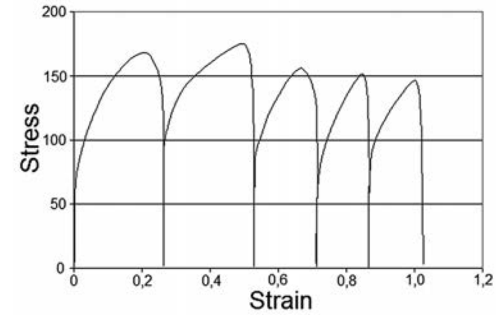
CONCLUSIONS

1 Heating to temperatures of 800 °C and deformation with a degree of 65 – 70 % when cooling with a water-air mixture of 3 and 6 s does not always ensure the formation of a fine-grained ferritic-sorbitol structure in high-carbon samples;

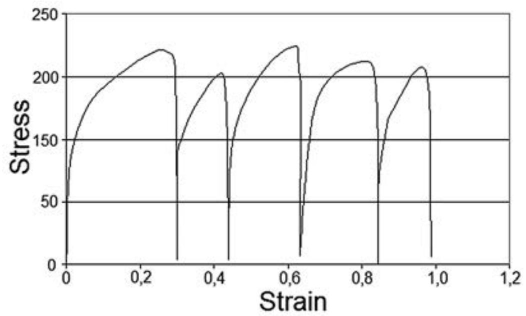
2 Heating of the samples to temperatures of 900 and 1 000 °C, deformation with a degree of 65 – 70 %, and cooling by a water-air mixture 3 and 6 s leads to the formation of a sorbitol structure in samples of high-carbon steel with an inter plastic distance of 0,23 – 0,62 μm.



(a) variant 1 rolling according to LWM



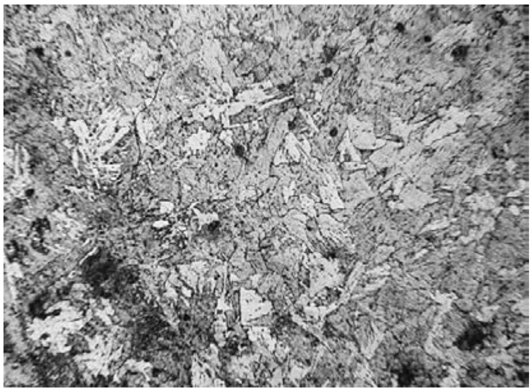
(b) variant 2 rolling according to LWM



(c) variant 3 rolling according to LWM

Figure 3 Change in resistance to deformation at temperature 1 000 °C

(a) variant 1 rolling according to LWM



(b) variant 2 rolling according to LWM

(c) variant 3 rolling according to LWM

Figure 4 Microstructure of A1 steel deposited at a temperature of 1 000 °C × 500

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Note: The responsible for England language is L. D. Sergeeva, Almaty, Kazakhstan