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Combined Deformation and Thermal Processing of Rolled Corrosion-Resistant and Bearing Steels

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The review shows the technology of combined deformation and heat treatment as a promising direction in the development of competitive production of rolled special steel. Substantial energy savings by allowing the use of heat rolling instead separate heating heat treatment or reduction of its duration is presented. The state of cross-cutting technology at factories special metallurgy of the CIS is analyzed, the concept of a modular line for the implementation of the combined deformation and heat treatment of special steels is determined.

Keywords: COMBINED DEFORMATION AND THERMAL PROCESSING, MODULAR LINES, RECONSTRUCTION, SPECIAL STEELS, GAUGE, COMPETITIVENESS, PHYSICAL AND MECHANICAL PROPERTIES, MICROSTRUCTURE, ENERGY SAVING

Introduction

Peculiarity of production of rolled special steels (bearing and alloy structural steel, corrosion resistant, instrumentation, heat-resistant, etc.) is the long duration and a variety of heat treatment - annealing (including long-spheroidizing), hardening, thermal improvement, normalization, homogenization. Its purpose - to ensure high standards of the microstructure responsible for the complex of properties, reliability and durability of machine parts and structures in strategic industries - aviation, energy (including nuclear), transportation, petrochemical, defense, etc. A promising direction in development of the production of special steels is to combine in a stream of high-quality hot-deformation and heat treatment. In this case, first, the necessary conditions for the formation of the regulated structure of the metal are created. As a result, the mechanical properties of steels - flexibility, strength, fracture toughness, etc. are improved, what provides simultaneous execution of the increasing demands of current domestic and foreign standards to them. Second, the energy saving effect is achieved through the use of heat rolling heat exchange heating under a separate heat treatment or reduction of its duration in thermal stations and shops [1].

Results and Discussion

Institute "USSI" in 1970-1980's. in the experimental-industrial conditions of high-grade mill plants "DSS", "Krivorozhstal", "Serp i Molot", "Krasnyi Oktiabr", Donetsk, Zlatoust, Makeyevka smelters and experimental conditions of laboratory mills Institute CSINM, National University of Science and Technology "MISIS" and other businesses and organizations made numerous (more than 50 works) studies [1, 3-7, etc.] through modeling technology combined deformation-heat treatment of rolled diameter from 10 to 60 mm. The microstructure and properties of various special steels after deformation and heat treatment were studied.

Modern grades of rolled special steels and types of conventional heat treatment in a state of supply (normalizing, hardening, annealing, etc.) are presented in the table. The two main schemes of combined deformation and heat treatment in a mill stream are considered. First, the so-called "preliminary" treatment for high-carbon bearing and tool steels. It uses a homogenizing heat, and low-temperature controlled rolling, the subsequent annealing of the reduced spheroidizing and further manufacturing of products (bearings, tools) and their standard heat treatment of the consumer. Second, for the construction and corrosion-

resistant steel it is considered to use "direct" deformation-heat treatment of steel in the mill stream - without heat treatment of parts for the consumer. It is shown that the strain-heat treatment significantly reduces the rolled products and accelerates further processing are due to the implementation of structural effects in comparison with conventional heat treatment with separate heating [2-4].

Structural effects are associated with a particular condition of hot-austenite grain size, dislocation structure and distribution of carbide phase and its influence on the kinetics of phase and structural transformations during rolling and subsequent cooling [3, 4]. Optimization of the microstructure is provided at a controlled (temperature, degree and speed) of hot deformation and subsequent accelerated or delayed cooling in conjunction with optimum heat treatment regimes.

In the corrosion-resistant and structural steels the assumptions made by M.L. Bernstein [4] were confirmed that at high temperatures (1050-1150 ° C) thermal destabilization of the austenite is fine and thin-film phase, the redistribution of harmful impurities (phosphorus, sulfur), provided clarification of the grain boundaries during high-temperature austenitizing when heated by hot rolling, as well as the boundaries of recrystallized grains. This allowed, for example, significantly increase the fracture toughness of martensite and fracture of structural steels, transverse toughness of austenitic stainless steels.

Heat treatment of special steels and alloys in the stream section rolling mill has its own characteristics and problems in comparison with steels for general purposes. This is due to the large difference in the composition, the kinetics of structural phase transitions and special steels, a wide range of requirements for heat treatment, microstructure and properties of the finished products. Therefore on existing mills only very simple scheme was implemented - hardening of the available cooling devices in the rolling lines, such as reinforcing steel. Different assortment of special steel (bars, strip, coils, wire rods, rolled calibrated supplied with different heat treatment) determines the need to implement a rolling mill for each type of metal from one group or another of their grades through technology: heating, rolling, accelerated cooling, hardening, annealing, as well as further processing of appropriate technology - editing, sizing, heat treating, finishing, and other special steels for the concept of combined deformation and heat treatment can be carried out by using the principle of modular technologies that have been successfully applied in recent years [5].

The basis for selection strain and thermal modes through energy-saving technologies are the corresponding kinetic diagrams of structure formation and phase transformation during hot deformation and cooling.

Institute "USSI" has undertaken extensive studies [6, 7, etc.] to research the kinetics and structure of recrystallization of hot-deformed austenite and their impact on transformations and controlled cooling properties after heat treatment of steel and special steels and alloys. The diagrams of the kinetics of recrystallization of hot-deformed austenite for the main 12 grades of the four groups of special steels and alloys - structural, corrosion, bearing, heat-resistant. Effective use of diagrams of recrystallization kinetics is shown in the choice of parameters of rolling, providing reception fine-grained (8-15 mm) and homogeneous ultrafine (0.8-1.5 microns) of the structure of austenite [6].

The use of combined diagrams of recrystallization , allocation of excess carbides and diagrams $\gamma \rightarrow \alpha$-transformation during cooling of hot-deformed austenite for high-carbon bearing and tool steels can obtain in them (with accelerated cooling after rolling) austenite grain refinement, carbide, reduction of carbide mesh [2, 6, 7]. The latter is achieved by a sufficiently high density of dislocations in the fine-grained dynamically recrystallized and hardened at the end of the low-temperature rolling of austenite.

It should be noted that the advanced technology of combined deformation and heat treatment of bearing steels involves homogenizing heating of the billet, controlled rolling with intermediate accelerated cooling, low-temperature rolling (including interrupted finishing cooling), cut spheroidizing annealed steel or rolled for calibration. Normalization with rolling heating alloy structural steels is carried out using controlled rolling and subsequent cooling rolled sheet in the air. For alloy structural steels with thermal improvement combined with deformation-heat treatment is controlled rolling with cooling between passes and after the end of deformation, etc. - hardening in baths of rolling mill, the transfer of hardened rods to the area of heat treatment and tempering in gas furnaces, under standard (according to GOST , EN) temperatures.

For corrosion-resistant steels hardened with rolling heating optimal solution is heating after deformation of the metal to a temperature of quenching followed by cooling in the mill line. This delivers compliance with the requirements of modern standards of heating temperature for

Table 1. Perspective kinds of the combined deformation and heat treatment of rolling special steels

Group of steels	Basic steel grades	Combined deformation and heat treatment	Traditional heat treatment
Structural high-quality alloyed	15Х, 30Х, 30Х2Н2М, 12ХН3А, 30ХГСА, 50ХМ, 17Г1С	Thermal improvement with rolling heating with controlled rolling, cooling, quenching and tempering in the line of the mill	Separate operation of hardening and tempering (thermal improvement) in the thermal shop
		Normalization from the rolling heating	Normalization in the thermal shop
corrosion resistant	12Х18Н10Т, 10Х17Н13М2Т, 08Х13, 40Х13	Deformation and heat treatment in the mill stream with controlled rolling controlled accelerated cooling for steels with higher demand for the yield strength. Tempering with, immediately after rolling, heating up the temperature of quenching and subsequent cooling in the mill line	Separate hardening in furnaces and baths of thermal and forging shops
Bearing (including corrosion and heat resistant of high quality)	ШХ15, ШХ4, ШХ15СГ, ШХ15-ШД, 95Х18 8Х4М4В2Ф1-Ш (ДИ 43-Ш), 8Х4В9Ф2-Ш (ЭИ 347-Ш)	Combined deformation-heat treatment using the homogenizing heat, controlled rolling, intermediate accelerated cooling , low-temperature rolling (including interrupted finishing cooling) and subsequent reduced spheroidizing annealing of rolled products or rolling in furnaces for calibration in the area of the rolling mill	Heating and rolling of billets, intermediate accelerated cooling, final cooling of the rolled sheet in the air; spheroidizing annealing from the separate heating and thermal calibration shops
Instrumental	Х, 7ХФ, ХВ4Ф, 9Х1, ХВГ, Х12, Х12МФ, Х6ВФ, 9Х5ВФ, 8Х4В2МФС2, 5ХНМ,4Х5МФ1С, 3Х2В8Ф, 6ХВГ, Р9, Р6М5, Р9К5		

hardening, creating the necessary condition of high temperature austenite and, consequently, the final microstructure [7].

At the same time, analysis of the current state of cross-cutting energy technologies [7] showed that section rolling mills of special metallurgy of Ukraine have insufficient equipment to perform the rapid cooling and the almost complete absence of heat treatment in the line of mills. Combined deformation-heat treatment in the CIS is partially implemented in accordance with the developed by SE "USSI" together with the design institutes for a number of factories technological tasks for the rental of structural steels with normalization and thermal improvement, corrosion-resistant steels with quenching in the medium and fine grade rolling mills in Russia (Zlatoust MC), Belarus (BMP, Zhlobin), Moldova (MMP, Rybnitsa).

With many years experience of work in accordance with the Mining Sector Development Programs on behalf of the Ukrainian Ministry of Industrial Policy of Ukraine, SE "USSI" in 2009 developed an advanced resource-saving technology of controlled plastic deformation, combined with heat treatment of rolled products for increased physical and mechanical properties of special steels [7]. As a result of pilot testing of technologies increased physical and mechanical properties of rolled steel were obtained, decrease in the duration of heat treatment processes 17-100% was reached, what can provide significant energy savings in the production of special steels.

Conclusions

In order to implement cross-cutting technologies and to obtain competitive products of alloy structural steel, bearings (including heat-resistant for the aviation), corrosion-resistant steel with improved physical and mechanical properties

of the technological scheme, determine the composition and layout equipment, on which in conjunction with SE "GIPROPROM" and PJSC "DSS" has developed recommendations for the design of retrofit and renovation of rolling-thermal production of special steels, including - for the creation of new modular lines.

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Совмещенная деформационно-термическая обработка проката коррозионностойких и подшипниковых сталей

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В обзоре рассматривается технология совмещенной деформационно-термической обработки как перспективное направление в развитии производства конкурентоспособного проката специальных сталей. Показано существенное энергосбережение за счет возможности использования тепла прокатного нагрева взамен отдельной термообработки или сокращения ее длительности. Проанализировано состояние сквозной технологии на заводах спецметаллургии СНГ, рассмотрена концепция создания модульных линий для реализации совмещенной деформационно-термической обработки спецсталей.