

ТЕХНОЛОГИЧЕСКИЕ ОСОБЕННОСТИ ПРОИЗВОДСТВА ВЫСОКОПРОЧНОГО СТАЛЬНОГО ЛИСТА

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Abstract: Innovative technological processes for conceptually new integrated deformation-thermal production of flat rolled stock with enhanced physical-mechanical properties and minimized alloying system have been devised on the basis of recently discovered metallophysical laws of influence, through hot plastic rolling deformation, upon microstructure-phase conversions and states of steel in metallurgical products.

KEYWORDS: STEEL PLATES, ROLLING, MECHANICAL PROPERTIES, INTEGRATED DEFORMATION AND THERMAL CYCLING.

1. Introduction

Steels in the form of flat hot-rolled products represent the largest product segment of the metallurgical industry in its present state of development. The operations required in order to attain intermediate fabrication/final performance characteristics of various steel classes and grades are traditionally attained through individual heat-treatment processes applied to hot-rolled products at steel manufacturing/processing plants.

Russian scientists are primarily responsible for the discovery of metal-physical effects and technological possibilities of the radical influence on structural phase as well as the mechanical properties of steel through various combinations of hot plastic deformation and high temperature phase transition, in the middle of the 20th century. Since that time, this particular area was widely developed in both theoretical-scientific and practical-technological sense for modern steel making and steel-consuming industries.

2. Preconditions and means for resolving the problem

Due to the fact that one of the original English definitions for a certain methodology of complex processing was thermo-mechanical treatment (TMT), Russia adopted the direct translation of the term – «термомеханическая обработка». Early results of laboratory research combined with industrial testing and structural applications of TMT steel products had clearly shown that such definitive term as thermo-mechanical treatment did not fully reflect metal-physical principles and, furthermore, distorted the adaptive metallurgy essence of newly developed methods of production and various practical applications of steel with new highly complex levels of physical, mechanical, technological, functional, service and marketing values [1].

An early opinion was that the TMT effect for structural steel could only be achieved by the application of pressure according to specifically regulated technology of hot rolling or forging coupled with an immediate rapid quenching of newly formed austenite into martensite. An effort to prevent the processes of recrystallization and deformed austenite relaxation prior to its martensite transformation was considered a break-through in the areas of steel hardening theory and practice. It also became a corner stone in the metal-physical principal of TMT, specifically, high-temperature HTMT. The possibility to obtain record high hardening values for structural steel (ultimate strength up to 2200-2500 MPa), not achievable by traditional hardening techniques would be a result of practical implementation of this principal.

Despite the extreme scientific and practical importance of having structural steel imparted simultaneously with high strength, impact and plasticity values, the practical task of quenching non-crystallized austenite remains technologically unrealized. There are

several considerable difficulties with the practical technological implementations of hardening into martensite for parts produced from structural steel after controlled deformation. Furthermore, certain practical integrated deformation and thermal cycling approaches in use are simply incorrect. The practical results of HTMT industrial testing and specific research have shown the opposite, the recrystallization processes should be controlled and performed by regulated stages of hot plastic deformation in order to achieve desired microstructural phases, especially small fragment and small grain structure in the steel products [2].

The significance of technological development and theoretical research into new multifaceted and complex processes such as hot rolling should not be underestimated. This multiple-pass deformation process is simplified into – recrystallization – deformation – temperature – speed cycling in order to create a small modular grain structure with new conditional state of boundaries preventing deleterious impurity sedimentation as well as highly dispersed formations of interstitial phases on both grain boundaries and inside of the grain body.

Such processes to classify more correctly not as TMT, but as integrated deformation and thermal cycling (IDTC).

The most important technological parameters of IDTC (fig.1) with hot rolling during deformation-temperature-speed cycling are: temperature range control, reduction rate, duration of deformation pauses, temperature and time intervals between the previous passage and beginning of transfer bar forced cooling,

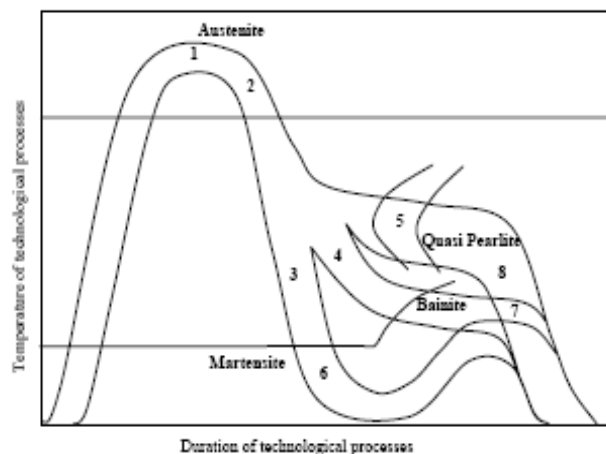


Fig.1. Physical metallurgy scenarios for generation of required microstructural phase conditions of steel plates by IDTC production: 1- deformation recrystallization cycling; 2 - controlled cooling; 3 - martensite transformation; 4 - bainite transformation; 5 - pearlite transformation; 6 - low temperature kinetic martensite tempering; 7 - low temperature kinetic bainite tempering; 8 - dynamic quasi pearlite tempering.

conducted according to the program of integral plastic deformation process and structural phase transformation of steel in single heat cycle. Combination of special consideration for selection of rolling scenarios starting from cast raw bars up to a final rolled steel product and technological implementation of metal-physical principals of deformation-temperature cycling provides an improved homogeneity of microstructure and phase distribution, as well as increased physical and mechanical properties of structural steel.

The reversing thick plate Mill 2000 was built according to the progressive Russian concept of HTMT and designed to produce flat steel products with record levels of structural strength. For the first time in practical steel making this mill demonstrates a complex of technological equipment integrated in single heat cycle developed specifically for HTMT and consists of heating and reheating furnaces for slabs and transfer bars, continuous in-line straightening equipment, intensive controlled quenching cooling and low temperature tempering.

The Industrial implementation of HTMT permitted the introduction of a groundbreaking production and engineering process of highly hardened flat steel with unique properties based not only by their absolute value, but also in combination with mechanical properties and functionality and workmanship [3]:

Yield Strength of 1,700-1,900 MPa;
Tensile Strength of 2,000-2,400 MPa;
Relative elongation of 10-14%;
Hardness up to 700 HB;

Highly competitive results of resistance to high-energy impulse impact loads.

The Complexity of the modern steel market from both the production and marketing standpoints for JSC «Steel Works Red October» has forced a broadening of the original projected product line of Mill 2000 outside of HTMT concept.

That is why metal-physical theory and suitable technological solutions were found in order to facilitate the requirements of steel consumers, primarily in the machine-engineering field. Newly created processes of controlled rolling and transfer bar cooling are significantly different not only from conventional hot rolling but also from HTMT. These new scenarios have implemented combinations of deformation strategies and post-rolling cooling regimes further reaching than HTMT. The dominating principal of these few integrated technologies is the creation of defined microstructural phase condition in transfer bar during multi-pass plastic deformation, finishing by controlled cooling temperature and time to established phase transformation in order to achieve desired morphology and complexity of properties in the final product.

The principal innovation and most prospective methods are achieved by the creation of new technological solutions for Mill 2000 allowing a production of plates with divorced pearlite and quasi-pearlite structure. Such structures appear during the dynamic decay of austenite. HTMT rolled products are produced for special very high final hardness applications that limit actual workmanship of material. Simultaneously quasipearlite microstructure material is a product, which has universal applications due to a combination of its final mechanical properties, which are comparable to the properties of annealed material. Additionally the structural strength significantly increases in parts produced from dynamically annealed quasi-pearlite rolled stock because of quench hardening. As a result of implementation of integrated technologies on JSC Red October' Mill 2000 allows the development and world debut of a new type of production – integrated deformation-thermal production, or IDT production of rolled stock. There are two categories of IDT flat products: high quench hardened to dislocated martensite (fig.2), table 1 and softened to quasipearlite microstructure (fig.3), table 2. Premiering these principals and newly developed processes of deformation recrystallization cycling (DRC) are released identically during rolling. In combination with controlled cooling DRC provides a small modular grain structure with new conditional state of boundaries preventing deleterious impurity sedimentation as well

as highly dispersed formations of interstitial phases on both grain boundaries and inside of the grain body. Also DRC improves flatness isotropy of plates during IDT production in hardened condition

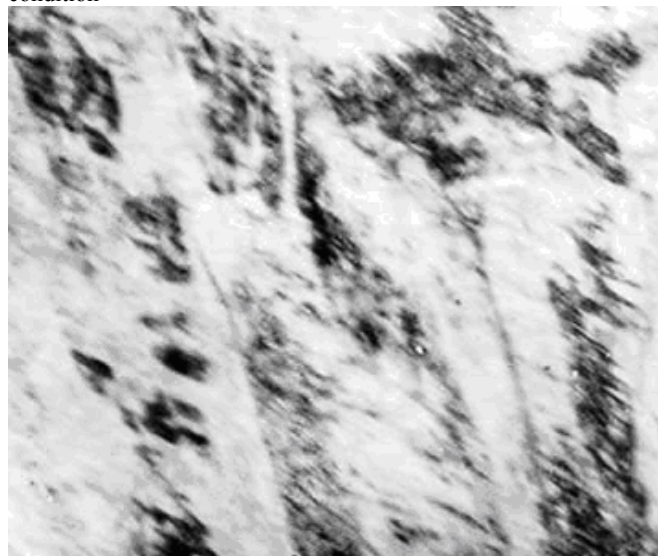


Fig.2.Dislocated martensite microstructure photo (x 20 000)

Table 1.

Type of Technology	Major Mechanical Properties		
	YP, MPa	E, %	KCU, J/cm2
IDT - Technology Type № 1	1700-1900	8-12	50-70
Conventional Technology	1400-1700	5-7	30-50



Fig.3. Quasipearlite micro structure photo (x15 000)

Table 2.

Type of Technology	Microstructure	Major Mechanical Properties		
		YP, MPa	E, %	KCU, J/cm2
IDT- Technology Type № 2	Quasipearlite after rolling	500-800	18-22	120-150
	Martensite after quenching	1700-1800	8-12	50-70
Conventional Technology	Martensite	1400-1700	5-7	30-50

Few modifications are required to be implemented in order to facilitate Mill's 2000 product range increase by IDT production of thin plates down to 4.0 mm, or below. Besides roll's form to improve shape and rolls adjustment of four-high finishing stand, it is also important to conduct transfer bar rolling at adiabatic stabilization temperature avoiding intermediate reheating by slab rolling with reduction per pass increased to 45-50%. The number of passes required should be reduced 1.5-2.0 times, as well as deformation duration shortened to 30-50 seconds. Intensive four-high stand finishing deformation development was created with considerations to possible implementation of cross rolling technology.

3. Conclusion

IDT production concept drastically reduces production costs as a result of newly developed through technology, achieving resources saving production minimization together with structural application of new products, optimal alloying degree, methods of liquid steel production, annealing-free slab preparation, effective

development of microstructure and complex properties of final steel product. This innovation introduces a new marketing ideology to end users of these revolutionary plate products.

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