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Efficiency of Using Multisection Units for Reinforcing Bar Thermal Hardening

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It is shown that application of multisection units for thermal hardening provides reinforcing bar essential improvement of quality and achievement of additional consumer properties.

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Introduction

Thermal hardening of reinforcing bar during rolling on continuous mills was in due time one of the most advanced processes providing essential raise of mechanical and operational properties of finished low-carbon and low-alloy steel products [1]. This process carried out with the use of rolling heat content with application of interrupted hardening method provides considerable saving of material and power resources.

Technological and economic advantages featured for the present thermal hardening method promoted its wide field of application. When using interrupted hardening, intensive cooling at supercritical rate is carried out until the martensite layer reaches the certain thickness, then hardening is interrupted. The temperature of reinforcing bar is leveled on its cross-section after hardening interruption.

As intensive cooling becomes longer, the thickness of martensite layer near the surface increases but from another hand less heat remains in the medullary layers of reinforcing bar, and martensite is warmed to lower temperatures. As a result, the extent of martensite self-tempering and plastic properties get worse.

But deterioration of plastic properties is also the first sign of lower resistance to stress-corrosion cracking in the corrosion environments.

Results and Discussion

The units of reinforcing bar thermal hardening are one extended cooling section (**Figure 1a**). Enhancement of stress-corrosion cracking is achieved using steel alloys in which martensite has low temper resistance or by application of additional heat treatment of finished steel.

The problem of corrosion cracking resistance enhancement was solved by using multisection units for reinforcing bar thermal hardening. In these units each cooling section consists of spray head, cooling chamber and cut-off device (**Figure 1b**). This enabled not only to cool reinforcing bar by each section with its own intensity but also to make thermal hardening regimes in which intensive cooling periods alternate with pauses between them. This engineering solution provided application of interrupted quenching at which more favorable structural condition on cross-section of reinforcing bar is formed.

Application of interrupted hardening enabled during the first period of intensive cooling near the surface to form thin martensite layer (not thicker 0.4-0.5 mm) which is further subjected to high temper due to heat from inside layers of reinforcing bar during a pause before the second period of intensive cooling. As a result, the structure consisting of ferrite matrix with discrete spheroidized cementite inclusions is formed. Internal stresses characteristic for martensite relax almost completely at formation of similar structures. This increased stress-corrosion cracking in two-three orders as compared to one observed for the same steel reinforcing bar and the same level of strength properties but produced at application of thermal hardening regimes corresponding to interrupted hardening method [2]. Working out and application of proper regimes of faltering hardening enabled to produce high-strength reinforcing bar completely meeting the requirements of standard DSTU 3760 and GOST 10884.

Adoption of multisection units of reinforcing bar thermal hardening instead of the one-section enabled to eliminate hydrogen embrittlement problem. Numerous cases of reinforcement bars fracture in the process of manufacture, transportation or maintenance showed that this problem was serious [3].

When using one-section thermal hardening units, hydrogen embrittlement could be partially eliminated by reduction of hydrogen content in steel at the stage of its smelting. In addition, half-finished materials are stored for a long time in stock heaps before rolling. If even after this enhanced strength and lowered plastic characteristics are observed, finished steel is subjected to long storing. As a result, mechanical properties reach the required level according to the standard. But eliminating external signs of hydrogen brittle behavior such treatment can not affect the centers of possible fracture in the body of reinforcing bar.

Internal long cracks appearing in the contact area of continuous martensite layer with the structures of phase transformations of overcooled austenite can be the centers of possible fracture of high-strength reinforcing bar under the effect of raised hydrogen content. Obviously, guaranteed elimination of rod fracture can be provided only if to prevent the formation of cracks in the reinforcing bar.

As practice shows, hydrogen trapping centers can be removed using thermal hardening regimes with the same parameters which are developed for stress-corrosion fracture resistance of reinforcing bar. Internal longitudinal cracks can be also eliminated by thermal hardening regimes applied to raise corrosion cracking resistance. But the interval between the first and second periods of intensive cooling should be not shorter than 0.7 seconds. This time provides overcooled austenite decomposition by diffusion mechanism [4]. Experience of reinforcing bar thermal hardening in rolling stream also showed that besides mentioned above efficiency of using multisection units it is possible to work out regimes of thermal hardening with parameters providing reinforcing bar with ferrite-martensite, perlite-martensite, bainite and other structures formed near rolled surface. Obviously, reinforcing bar production with new structural conditions provides additional consumer properties.

One more important instance that confirms the advantage of using multisection units of thermal hardening is related to automated control of reinforcing bar hardening [5].

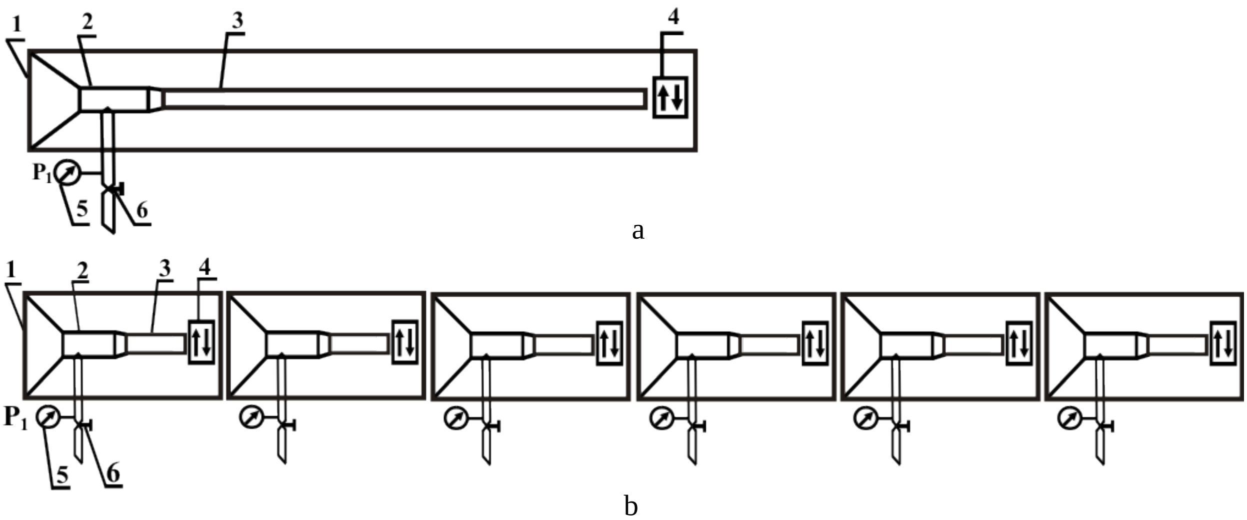

Figure 1. Flow diagrams of one-section (a) and multisection (b) units of reinforcing bar thermal hardening: 1 – counterflow drop; 2 - spray head; 3 - cooling chamber; 4 - cut-off; 5 - pressure-measuring instrument; 6 - control valve

It is determined that the optimum way to correct the set hardening regime for achievement of required mechanical properties is change of water pressure submitted to one of injectors of cooling sections of multisection unit. Pressure of water submitted to other sections is constant. Due to this processing method the optimum values of strength properties of reinforcing bar per unit of changeable pressure are achieved which makes it possible to control the hardening process.

Mentioned above examples of substantial quality improvement and additional higher consumer properties of reinforcing bar show the advantage of multisection units of thermal hardening as compared to one-section. Such unit was built at Integrated Iron & Steel Works "Krivorozhstal" (nowadays "ArselorMittal KryvyyRih") in 2000.

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Эффективность применения многосекционных установок термического упрочнения арматурного проката

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Показано, что применение многосекционных установок термического упрочнения обеспечивает арматурному прокату существенное повышение качества и достижение дополнительных потребительских свойств.