

Investigation of Structure Formation Features in Cr-Mo Steel Bar Section in The Process of Energy-Saving Heat Treatment

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Structure formation in electric steel 42Cr4Mo2 under continuous cooling is investigated. The results are given in the form of continuous cooling transformation diagram. It is recommended to cool electric steel 42Cr4Mo2 bar section at the mass-averaged rate 1.0-2.3°C/s during thermal-mechanical treatment for bainite formation, which will allow reducing time of subsequent softening heat treatment.

Keywords: ALLOYED STEEL, BAR SECTION, THERMAL-MECHANICAL TREATMENT, COOLING RATE, MICROSTRUCTURE, BAINITE, HEAT TREATMENT

Introduction

Under conditions of economic crisis, it is necessary to develop technologies that will reduce energy consumption with maintenance of proper quality of metal products manufactured, especially in motor-vehicle construction when producing essential components. Bar section of round or square section made of hot-rolled and/or heat treated carbonaceous alloyed steels is a raw material for them.

At Republican Unitary Enterprise "Byelorussian Steel Works" (RUE "BSW"), round alloyed superduty steel bar section with 140 mm in diameter is manufactured from continuous cast blooms 300x400 mm. 42Cr4Mo2 steel bar section manufacturing technique [1] includes postheating up to ~1250°C and hot deformation on a reversing mill 850. After rolling, metal with 140 mm in diameter with final temperature approximately 1000°C is air cooled down to 350-200°C.

As steels alloyed with carbide-stabilizing elements have high flaking susceptibility, anti-flaking treatment (AFT) is used: high-temperature tempering with bar section heating up to 680°C, soaking 6.5 hours and furnace cooling. The overall heat treatment can last up to 35 hours, so the process is energy consuming. Heat treatment

conditions should ensure not only lack of flakes, but also provide necessary values of metal hardness [1, 2]. After complex technological measures at steelmaking stage, the hydrogen content in steel (without heat AFT) is less than 1.0 ppm (safety content is not more than 2.0 ppm), which eliminated the necessity to carry out additional AFT for majority of alloyed steels.

The tasks of investigation were structure formation features and hardness of hot-rolled bar section with no additional heat treatment. The subject of investigation was electric steel 42Cr4Mo2 samples manufactured by RUE "BSW" (Table 1). Microstructure and hardness of hot-rolled bar section are presented in Figure 1.

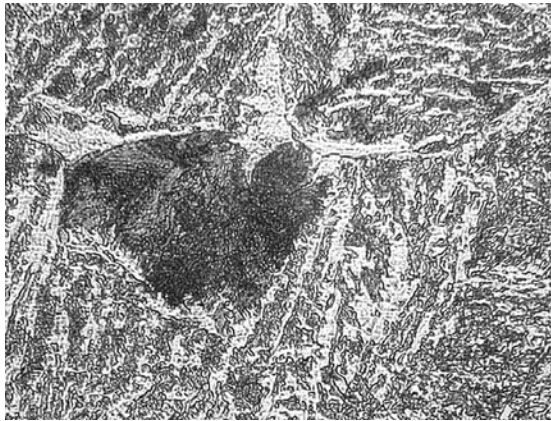
Results and Discussion

The initial microstructure of hot-rolled bar section after air cooling (Figure 1) consists of structurally free ferrite (10-15%), bainite (approximately 70-75%) and thin-platy perlite (15-20%). The hardness of bar section rises towards the centre, and its values (≤ 270 HB) do not meet specified requirements (≤ 250 HB). Moreover, a wide spread in hardness values is considered to be unacceptable according to standards [1].

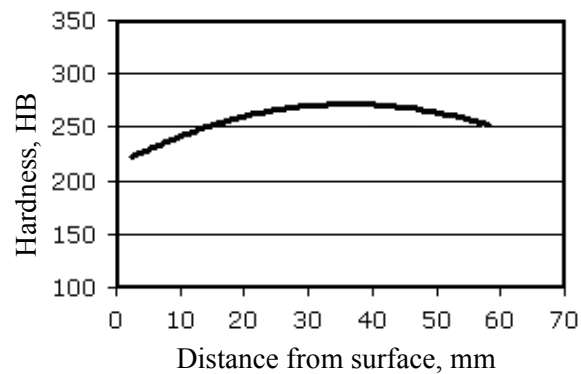
Heat treatment modes with shortened time 18

Table 1. Chemical composition of steel 42Cr4Mo2

Weight percentage of elements, %								
C	Mn	Si	P	S	Cr	Mo	Cu	Al
0.391	0.748	0.257	0.013	0.023	1.083	0.248	0.114	0.024
Requirements [1]								
0.36-0.42	0.5-0.8	0.10-0.35	max 0.035	0.02-0.035	0.9-1.10	0.15-0.30	≤0.35	0.02-0.06



a



b

Figure 1. Microstructure (*a*) x 500 and average hardness values (*b*) of electric steel 42Cr4Mo2 hot-rolled bar section with diameter of 140 mm

hours (at lower temperatures of soaking) were tested. There were no flakes in the bar section, however we did not reach the target values of hardness.

Steel alloying with carbide-stabilizing elements (Cr, Mo) promotes decrease of carbon and iron diffusion constants and lowers the rate of carbon content leveling in austenite, which results in the rise of temperature of cementite-type carbide dissociation. Therefore, the structural changes during tempering (coagulation and spheroidization of carbides), which soften steel, take place at the elevated temperatures. Thus, lowering of soaking temperature of Cr-Mo steel hot-rolled bar section with a view of power resources saving will not ensure the target values of hardness under existing structure condition.

In bainite as more nonequilibrium structure, the structural changes are known to progress faster and can begin at temperatures reduced from 400°C during tempering [3]. Therefore, steel should have bainite structure in the initial state in order to shorten softening heat treatment. The process of thermal-mechanical treatment (TMT), namely, high-temperature thermal-mechanical treatment with isothermal austenite decomposition in bainite area (HTMISO) can be applied as an effective

method to obtain guaranteed standard values of hardness. The use of HTMISO process will enable to carry out the subsequent softening treatment (tempering) at lower temperatures as carbides formed in the upper interregion are less dispersed, and their coagulation starts at lower temperatures.

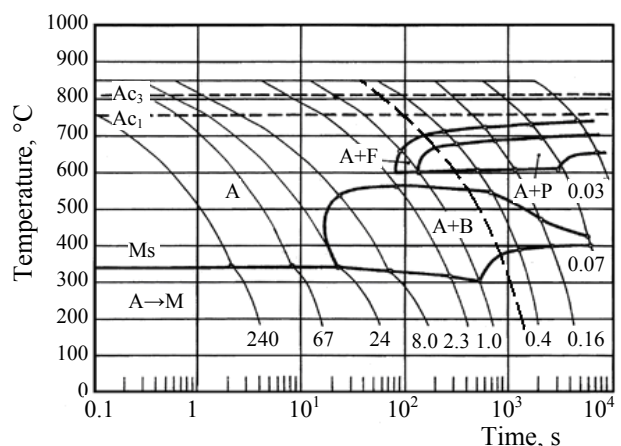


Figure 2. CCT diagram of austenite transformation in continuous cast electric steel 42Cr4Mo2

Kinetics of austenite transformation was investigated for implementation of HTMISO processes for electric steel 42Cr4Mo2. Steel 38CrMn (GOST 4543) is an analogue for

investigated electric steel 42Cr4Mo2 in relation to chemical composition, but CCT diagram is available only for steel 35CrMn [4] and was not reconsidered further. Impact of cooling rate on electric steel 42Cr4Mo2 structure formation was investigated with the use of dilatometric and microstructural methods. The results of investigation of phase transformations in electric steel 42Cr4Mo2 after cooling at various rates are presented in the form of CCT diagram (Figure 2). There are figures under cooling curves that characterize the average cooling rate ($^{\circ}\text{C/s}$).

Perlite transformation area is a little displaced in relation to bainite in the diagram since alloying elements diffuse at the very small rate, increasing duration of austenite decomposition process via diffusion, and lower polymorphic transformation rate due to formation of strongly enriched cementite,

which changes the values of both lattice parameters and surface energy [5]. There is an area of increased stability of austenite in the temperature range of 430-600 $^{\circ}\text{C}$ in the diagram.

The structure consists of ferrite and perlite at the minimum cooling rate 0.03 $^{\circ}\text{C/s}$. As the cooling rate increases, amount of austenite decomposed by diffusive mechanism (Figure 3a) reduces and by intermediate mechanism – increases (Figure 3b). At cooling rate above 1 $^{\circ}\text{C/s}$ (Figure 3c), diffusive decomposition is suppressed, and α -ferrum is formed by shift mechanism (Figure 3d). Cr and Mo steel alloying has a major effect on austenite decomposition by intermediate kinetics. As a result, bainite is formed as a part of combined structure in the wide range of cooling rates from 0.07 up to 24 $^{\circ}\text{C/s}$.

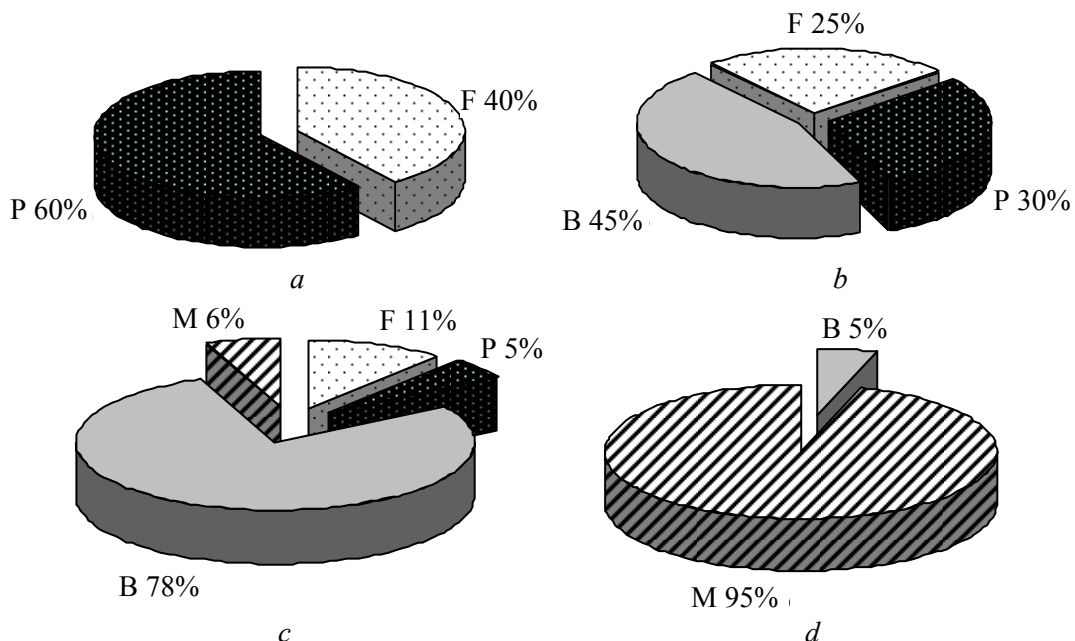


Figure 3. Weighting of structures (F – ferrite, P – perlite, B – bainite, M – martensite) in electric steel 42Cr4Mo2 formed after austenitization at 850 $^{\circ}\text{C}$ and subsequent continuous cooling at the rates, $^{\circ}\text{C/s}$: a – 0.03; b – 0.4; c – 1.0; d – 24.0

At cooling rate 1 $^{\circ}\text{C/s}$, austenite starts being decomposed on ferrite at 655 $^{\circ}\text{C}$. Bainite is formed in the temperature interval 560-310 $^{\circ}\text{C}$ (Figure 2). The structure consists of: 78% bainite, 11% ferrite, 5% perlite and 6% martensite (Figure 3c). When cooling at the rate 2.3 $^{\circ}\text{C/s}$, austenite is decomposed on bainite in amount of 75-80% in the interval 560-315 $^{\circ}\text{C}$, martensite is formed at the temperatures lower 315 $^{\circ}\text{C}$. At cooling rate above 8 $^{\circ}\text{C/s}$, the martensite transformation is dominant, and decomposition occurs by diffusionless mechanism at 24 $^{\circ}\text{C/s}$.

According to existing technique of electric steel 42Cr4Mo2 section bar manufacturing, the

structure consists of bainite, ferrite and perlite at rolling and cooling (Figure 1). According to CCT diagram constructed, this microstructure corresponds to cooling at the rate approximately 0.6 $^{\circ}\text{C/s}$ (Figure 2, dotted line). In accordance with CCT diagram constructed, it is possible to obtain bainite in steel 42Cr4Mo2 by using thermal-mechanical treatment with cooling after hot rolling at the mass-averaged rate 1.0-2.3 $^{\circ}\text{C/s}$, which will allow the subsequent softening tempering at soaking temperatures lower by 150 $^{\circ}\text{C}$ than existing.

Using the obtained scientific results, heat treatment modes for alloyed bar section are being currently corrected at RUE “Byelorussian Steel Works”.

Conclusions

Austenite decomposition in Cr-Mo electric steel under continuous cooling at various rates was investigated.

When Cr-Mo steel continuous cooling, ferrite-perlite structure is dominant at cooling rates 0.03-0.16 °C/s, bainite at 0.4-2.3 °C/s and martensite at cooling rates above 8 °C/s.

When manufacturing electric steel 42Cr4Mo2 section bar, mass-averaged cooling rate 1.0-2.3 °C/s is recommended during thermal-mechanical treatment.

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Исследование особенностей структурообразования в прокате из хромомолибденовой стали при энергосберегающей термической обработке

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Исследовано структурообразование в электростали 42Cr4Mo2 при непрерывном охлаждении, результаты обобщены в виде термокинетической диаграммы. При термомеханической обработке для образования бейнита охлаждение проката из электростали 42Cr4Mo2 рекомендовано проводить со среднемассовой скоростью 1-2,3 °C/с. Получение бейнита позволит сократить продолжительность последующей смягчающей термической обработки.