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High temperature thermos-cyclical treatment as a method of influencing the structure and properties of carbonized 20Mn steel

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Abstract. The paper discusses the issues of improving the mechanical properties and wear resistance of structural steel working under wear conditions. A method for the surface treatment of the complex, which consists in carrying out carburizing and subsequent high temperature thermal cycling (HTTC) was suggested. The proposed method allows to increase processing density carbides, crushed and make its structure more uniform. After HTTC, followed by hardening from different temperatures in the structure of martensite formed, globular carbides and residual austenite. The residual austenite is capable of deformation martensite γ→ α' transformation at wear (DMTW), increasing the relative wear resistance of the investigated steel by 2-2.5 times depending on the conditions of wear.

The practical value of the work lies in the fact that by changing of surface treatment quantitative relationship between martensite and austenite can be adjusted , to vary the degree of metastable austenite, getting into the surface layers of differentiated chemical composition and structure gradient without the use of special equipment and without creating special sections at thermal workshops.

Keywords: *complex surface treatment, carburizing, metastable austenite, thermal cycling, wear resistance*

One of the main tasks undertaken at enterprises, is a resource-saving due to constantly rising prices for iron ore and other materials, and as a result, the metal. Increased durability of spare parts from various steels for tools and equipment engineering and metallurgical plants can significantly reduce the consumption of materials.

In the operation of the most intensely subjected to temperature and power effects of the surface layers of parts and tools, so that the structure and properties of the surface layers has an important impact on their performance. Solving this problem requires the improvement of existing and creation of new methods of processing metals. Its solution is currently is associated with intensive spread along with other types of thermal and chemical-thermal treatment, thermal cycling treatment (TCT), which allows to improve the mechanical properties not only in the leading edge, but also over the entire volume tool [1-4].

With TCT alloy matrix which undergoes a phase transformation (for example, iron-based alloys) there are significant interfacial diffusion strain at repeated transformations, as well as the temperature gradients between the individual elements of the matrix, which leads to an increase in transformation centers and, ultimately, to the grain refinement [5]. It was established [6-8] that TCT has a significant impact on the structural state of carbides. Method of TCT provides unique structure and properties of metals [6].

Unlike other kinds of heat treatment structural phase transitions occur when TCT is repeatedly applied at varying temperature heating-cooling. Necessity of repetitive processing at given temperatures, is usually due to the tendency to accumulate changes dramatically improves products quality and give them properties unattainable by ordinary heat treatment [7, 8].

Much attention is paid to studying the effect of the alternating repetition of processes of mutual dissolution – ferro-carbide allocation between mixture and austenite on the mechanical properties of carbon tool steel, which improves the toughness while maintaining high hardness and strength. The impact on the wear resistance of steels by TCT has not been thoroughly studied yet.

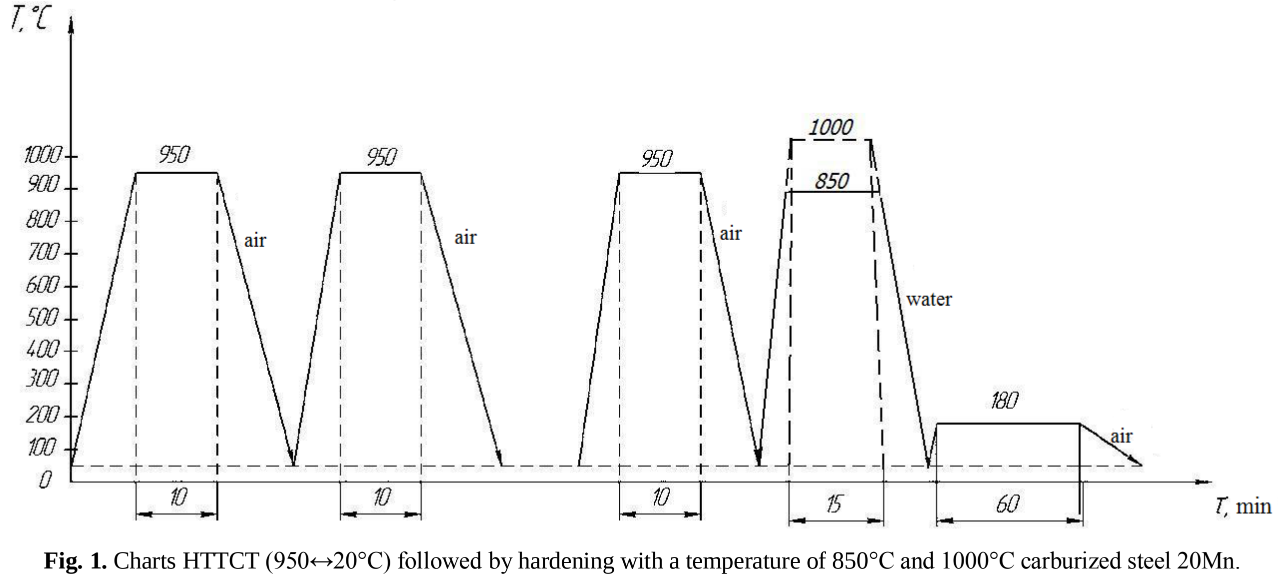


Fig. 1. Charts HTTCT (950↔20°C) followed by hardening with a temperature of 850°C and 1000°C carburized steel 20Mn.

The purpose to this work is creation of new ways to TCT for optimum microstructure and improving the wear resistance of carburized steel 20Mn.

This study examines the effect of the parameters of high-temperature thermal cycling treatment (HTTCT) on the structure and properties of the carburized steel 20Mn. The steel major alloying element is manganese, relatively inexpensive and available in Ukraine.

Samples of steel 20Mn sizes 10x10x25 mm exposed to grouting solid carburizer for 12 hours with cooling in a box. Thereafter HTTCT conducted with heating to 950 °C↔20 °C (cooling to room temperature in air), then quenching the last cycle the water temperature to 850 °C and 1000 °C and tempering at a low 180 °C. The number of cycles was 5, 11 and 17 (quenching from a temperature of 850 °C) and 2, 8 and 14 cycles (quenching from 1000 °C). Driving modes HTTCT are shown in Fig. 1.

After the standard mode of heat treatment applied in the production of (normalization at 880-900 °C, air cooling), 20Mn steel structure consists of 25 % pearlite and 75 % ferrite (Fig. 2a). After the grouting, and then develop a regime for HTTCT, the steel structure is milled. After 2 cycles of HTTCT regime 950↔20 °C at the surface of the sample is observed austenitic-martensite structure, there are some fairly large selection cementite (Fig. 2, b).

Micro-hardness $H_{\Diamond}$ = 4400 MPa confirms the presence in the structure of high residual austenite (A_{res}).

At a depth of 0.8 mm is observed structure of a mixture of martensite, cementite, and residual austenite (A_{res}). Cementite allocation large enough, and martensite needle. At a depth of about 1.1 mm is also observed structure predominantly martensite and cementite. Austenite is practically not observed, cement, fine. Micro-hardness in this area reaches 6200 MPa (Fig. 3). At a depth of 1.3-1.6 mm structure is gradually transformed into a granular pearlite, cementite particles increase in size. Micro-hardness changes are few and within 3800-4500 MPa.

TCT, grinding particles of carbides and their density, finely martensite structure and makes it more homogeneous [9].

After 8 cycles HTTCT nature of the change in thickness of the microstructure has the same character as described after 2 cycles HTTCT. In the depths of carburized layer hardness varies ambiguous. Martensite needle observed in some places the structure at a depth of 0.6-0.7 mm, and the micro hardness is 5700 MPa. At a depth of 1.8-2.3 mm there is a typical structure of the granular pearlite, the corresponding source. Micro hardness in these regions decreases to 4250 MPa.

With increasing number of cycles to 14 cycles HTTCT predominantly cementite dissolve in austenite. Grain boundary carbides are allocated string, but in part they are dissolved, it turns carbon rich austenite (Fig. 2c). On dove 0.1-0.4 mm micro hardness is 5500-6000 MPa, and then it decreases to 4500 MPa, and at a depth of 1-1.5 mm is increased again to 6500 MPa. The structure becomes more uniform fine grain. At greater depths in the thickness of samples produced structure troosto - martensite. Martensite needle are only visible in individual grains. The micro hardness at a depth of 1.6-2 mm is reduced to 4500 MPa. Isolation cementite is very dispersed, the particles have a globular shape.

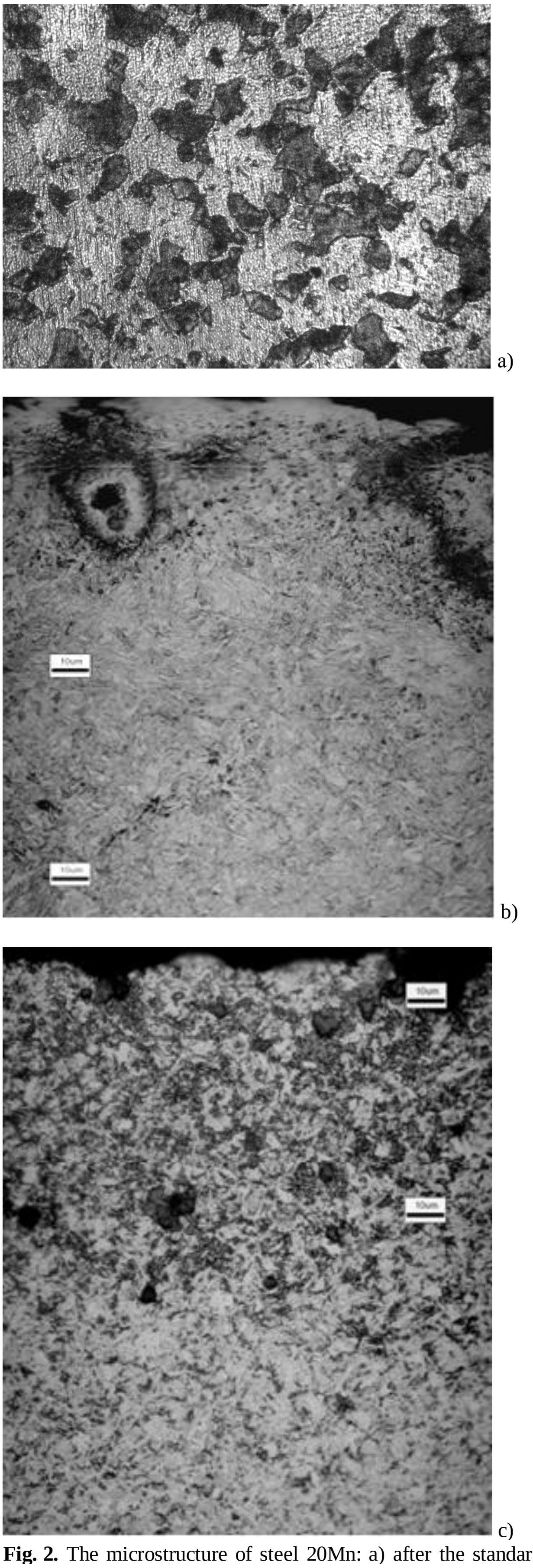


Fig. 2. The microstructure of steel 20Mn: a) after the standard mode of heat treatment (normalization) (x1200); b) after 2 cycles of HTTCT regime 950↔20 °C; c) after 14 cycles of HTTCT regime 950 ↔ 20 °C.

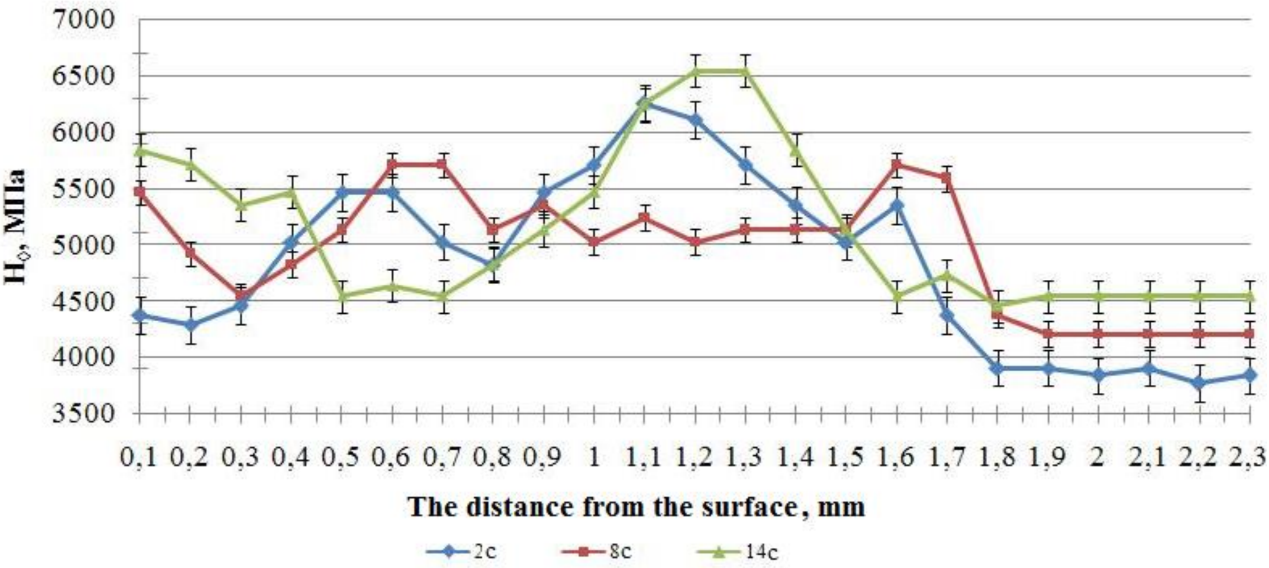


Fig. 3. Micro hardness carburized steel 20Mn after HTTCT (950 °C ↔ 20 °C), hardening from 1000 °C and tempering at 180 °C.

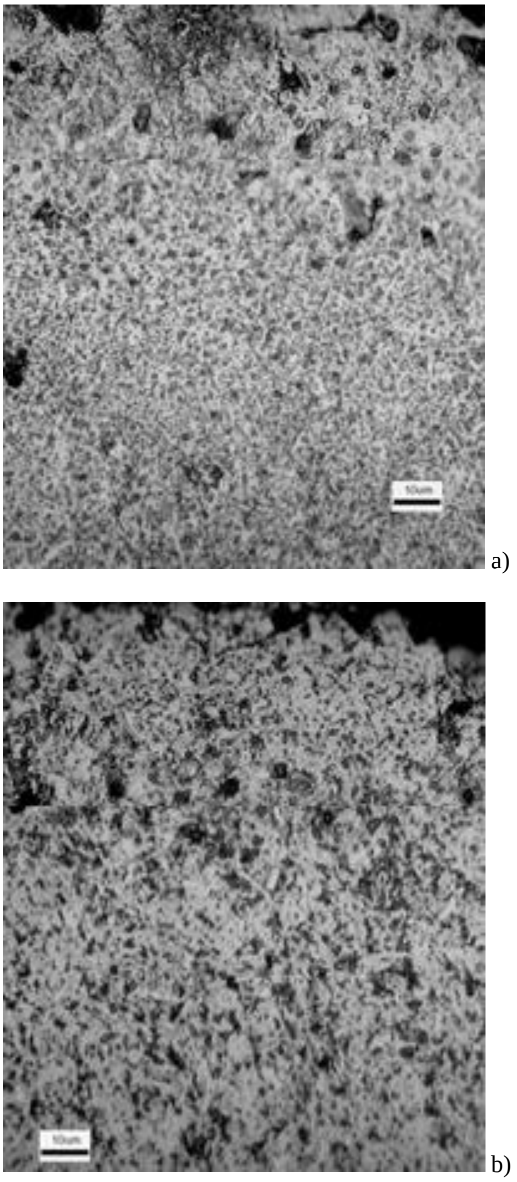


Fig. 4. The microstructure of carburized steel 20 Mn, after HTTCT (950 °C ↔ 20 °C), 850 °C by hardening and tempering at 180 °C: a) 5 cycles; b) 11 cycles.

It is noteworthy that with the increase in the number of cycles HTTCT from 2 to 14, the microhardness of the surface of samples increases from 4300 MPa to 5500 MPa, which can be attributed to structure refinement and enrichment of austenite.

Analysis of changes in the structure over the thickness of the samples after different modes HTTCT showed that it is very suitable for structure refinement and obtaining cementite precipitates dispersed phase. During the TCT changes the structure, size and morphology of carbides; at the same time decreasing the level of stress [2, 10, 11].

After thermal cycling regime by 950 °C ↔ 20 °C, followed by quenching with a temperature of 850 °C and low tempering at 180 °C (number of thermal cycles 5, 11 and 17) in the structure is observed martensite, residual austenite and cementite. With increasing number of cycles of the structure, as in the previous case, is milled. After 5 cycles HTTCT at a depth of 0.9-1.7 mm observed martensite structure, globular cement and A_{res} (Fig. 4).

The micro hardness to a depth of 0.7 mm is in the range of 4500 MPa, then increased to 6500 MPa, and at a depth of 1.7 mm is reduced again, because of a decrease in the content A_{res} content increases martensite. Then, the depth of the microstructure is gradually transformed into the structure of the core - globular sorbite.

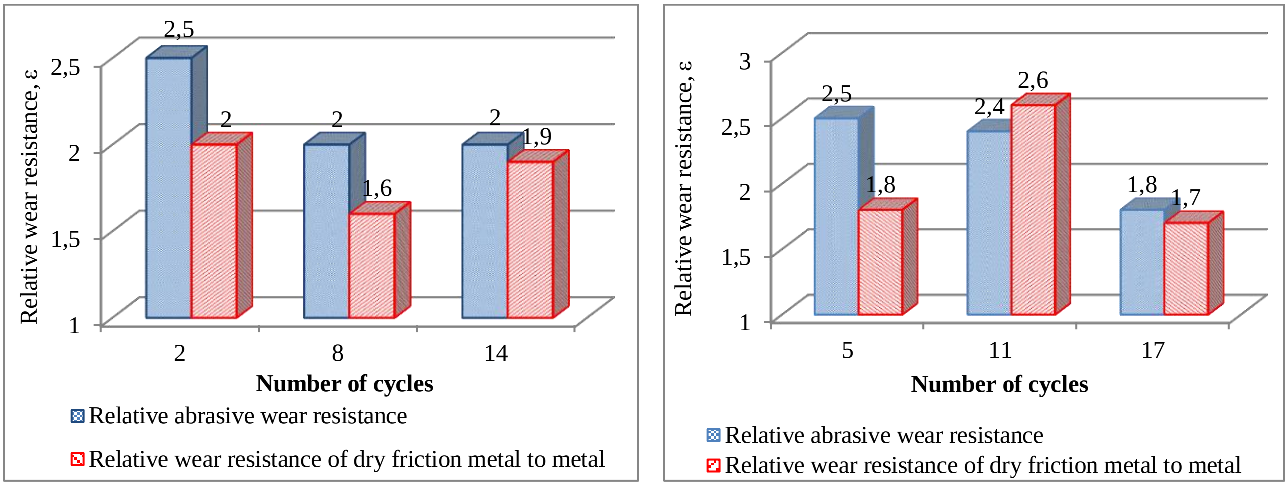
The highest rates of relative wear resistance under the dry sliding friction of metal on metal are observed after 2 cycles HTTCT (quenching from 1000 °C) ($\varepsilon = 2$) and after the 11 cycles HTTCT (quenching from 850 °C) ($\varepsilon \approx 2{,}6$) (Fig. 5, a, b). In these circumstances it is advisable to obtain the structure along with martensite and carbides metastable A_{res}. Precipitation of cementite, in turn, destabilize the residual austenite and to further facilitate its deformation martensite transformation in wear (DMTW).

With abrasive wear among fused samples after 2 cycles HTTCT (hardening from 1000 °C), 5-minute and 11-minute cycles HTTCT (hardening with a temperature of 850 °C) have high and similar values of relative wear resistance ($\varepsilon_{abr} \approx 2.5$) (Fig. 5 a, b).

This can be explained by the fact that the abrasive wear is more intense effect on the abrasive surface of the sample. The structure, with a high content of metastable A_{res} is for this kind of optimal wear.

Overall, the rise in the relative wear resistance can be attributed to obtain the optimal structure - martensite and carbides A_{res} capable of DMTW. Just formation under hard carburized and hardened surface layer softer than usual layer (with low carbon content) inhibits propagation of cracks occurring in the surface hardened layer.

The practical value of the work lies in the fact that changes in the parameters can be adjusted TCT quantitative relationship between austenite and martensite, to vary the degree of metastable austenite, getting into the surface layers of different chemical composition and structure. The developed technology will enable TCT after thermo - chemical treatment implement them with conventional equipment (salt baths, chamber and shaft furnaces), thermal management without the use of additional equipment and the creation of specialized areas.



a) b)

Fig. 5. Relative abrasive wear resistance and wear resistance under dry sliding friction metal to metal carburized steel 20Mn after HTTCT with different number of cycles and the hardening of: a) 1000 °C; b) 850 °C (leave at 180 °C).

Conclusions:

1. Conducting thermo- cycling treatment carburized steel 20Mn allows grind microstructure effectively adjust the balance of phases: martensite quenching cementite and retained austenite, as well as its degree of metastability.
2. Description of the mechanical and performance properties of the steel 20Mn can be widely changed by using chemical-thermal treatment and subsequent thermal cycling, to regulate the phase composition and the degree of metastable austenite.
3. After the optimal regimes HTTCT and subsequent hardening carburized steel 20Mn can significantly increase its durability.
4. A significant increase in wear resistance is due to the optimum conditions HTTCT and creating a favorable microstructure dispersed carbides. An additional contribution to the improvement of wear resistance of carburized steel 20Mn making optimal development $\gamma \rightarrow \alpha'$ DMTW transformation in the surface layer of the work, causing extra self-strengthening.
5. Optimal modes of HTTCT can be recommended for the restoration of a number of worn parts of metallurgical equipment operating under wear and thermal cycling simultaneously.

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