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INFLUENCE OF ELECTROLYTIC PLASMA CEMENTATION ON THE MICROHARDNESS AND WEAR RESISTANCE OF STEEL 12Cr18Ni10Ti

WPŁYW OBRÓBKI ELEKTROLITYCZNO-PLAZMOWEJ NA WŁASNOŚCI MECHANICZNE STALI 12Cr18Ni10Ti

Key words:

component: microstructure; microhardness; wear resistance

Słowa kluczowe:

mikrostruktura; mikrotwardość; odporność na zużywanie

Summary

The present work presents the results of electrolytic-plasma treatment influence on the mechanical properties and structural-phase condition of the surface layers of 12Cr18Ni10Ti steel.

In the work, the mechanical characteristics of the surface layers that have been pack cemented by electrolytic plasma with the composition of 10%

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Na_2CO_3 and 10% $C_3H_8O_3$ are investigated. The operational parameters for the processing are determined. The optimal content of components in saturating mixtures of plasma by cementation is defined. Structural research of the samples was carried out by x-ray diffraction analysis, and optical and electron microscopy. The comparative study of the structure, phase and chemical composition of the modified surface layers of steel 12Cr18Ni10Ti is executed after electrolytic plasma processing. According to the study, after electrolyte plasma processing, high wear resistance and hardness increased by a factor of 2 to 2.5 more than in the original condition. A hardened layer with a thickness 200–250 μm is formed. It is shown that, after the electrolyte-plasma processing of steel 12Cr18Ni10Ti, the microstructure contains particles of carbides and has a fine-grained martensitic structure.

INTRODUCTION

Cathode diffusion saturation is one of the variants of the electrochemical-thermal treatments of metals and alloys carried out in aqueous electrolytes **[L. 1–2].** The perspective direction of increasing the resource of the equipment and the energy-dispersing creation of new technological processes for obtaining hardening and a protective coating is electrochemical-thermal hardening. In particular, high-speed cathode cementation with the subsequent hardening in the electrolyte is effective for strengthening of small-size equipment in light industry. Surface enrichment of low-carbon 12Cr18Ni10Ti steel by electrolyte heating allows the increase of microhardness, wear-resistance and durability with the formation of resistant coatings by alloying and inoculation. Thus, the application of the optimal mode of high-speed cementation, which improves mechanical properties, can improve the quality, reliability, and durability of surfaces. As carbon-containing compounds are used, carbonate sodium, glycerine, and acetone **[L. 3].** The drawback of many well-known compositions is the poor performance of electrolytes due to their rapid depletion of satiating components. Acetone and ammonia solutions are included in this category. In addition, one should take into account the inevitable oxidation of the treated surface, which has a significant impact on the corrosive properties of the subject material. In the works **[L. 4–5]**, the authors observed the formation of particles of a ferromagnetic iron (α-phase) in the modified ions of carbon austenitic stainless steel. However, the questions of the optimisation of modes of electrolytic-plasma cementation of the austenitic steel surface to ensure its high mechanical properties and possibilities of their control have not studied sufficiently.

The aim of this work is the definition of optimal modes of electrolytic-plasma cementation to provide maximum microhardness and wear resistance to the case-hardened cemented diffusion layer of steel 12Cr18Ni10Ti in the

electrolyte at different modes of processing. Analysis of the relationship between the temperature of processing and the microhardness of the surface and the development of recommendations on the use of these properties to non-destructive control of the parameters of case-hardened cemented layer are also presented.

MATERIAL AND METHODS OF RESEARCH

For the study, plate samples of size 20x20x5 mm^3 of flat-rolled steel 12Cr18Ni10Ti were produced, containing, % (mass.): 0.12. 17.2 Cr, 10.7 Ni, 0.5 Ti, from 1.07 Mn, 0.032 P, 0.013 S. of Electrolytic-plasma grouting was carried out as follows: first, the heated sample at a voltage of 320 V In and the power of the current 30-40 A within a temperature 850–950^{0}C and maintained for 12–14 seconds. The heating of the samples carried out the plasma, with the sample partially immersed in the electrolyte to a depth of 4–6 mm, then lowered the voltage of up to 180 V and current up to 15–25 A and kept at the correct temperature during 5–7 minutes, after which carried out training in the flow of cooled electrolyte. The electrolyte used was an aqueous solution containing 10% of glycerine ($C_3H_8O_3$) and 15% of sodium carbonate (Na_2CO_3). The temperature of the electrolyte was 25±5^{0}C at the entrance to the chamber. Heating temperature measured using a multimeter UT70B with built-in chromel-alumel thermocouple and varied from 800^{0}C up to 950^{0}C with steps of 50^{0}C.

Study of phase composition and crystalline structures of the samples were carried out by x-ray diffraction analysis on the diffractometer X Pert Pro using CuK_α - radiation. The morphology of the surface structure studied in the raster electron microscope JSM-6390LV, equipped with prefix energodispersion analysis and optical microscope MIM-7. Measuring microhardness (H_μ) was carried out by the method of the Vickers on microhadometer PMT-3 under a load on the indenter – 100 g.

Tests of the abrasive wear used loose abrasive particles in the zone of friction and press to the sample using a rotating rubber roller. The sample was placed in the sample-holder of the test installation. The sample was pressed to the roller with a force of 44.1±0.25 N at 60±2 rpm for 600 revolutions. A continuous supply of the abrasive material in the zone of friction was assured. The count of the revolutions was carried out from the start of the feeding of the abrasive material.

RESEARCH RESULTS AND THEIR DISCUSSION

Figure 1 presents fragments of the macrostructure of the surface of steel 12Cr18Ni10Ti after etching the surface with a solution of 10% oxalic acid for

30-90 sec. The results of metallographic research testify to the fact that, on a) the visible grain of austenite the initial condition of the steel, to b) and c) are visible near the borders of the granules enriched iron carbides. It is known that the formation of carbides on the limits of the grain of austenite has a direct effect on the mechanical properties of steel. Thus, the microstructure of the hardened surface of the sample is a fine-grained martensite structure with dispersed inclusions insoluble carbides. A comparison of the microstructure d) of the source and e) of the processed showed that the modification of the surface of the carbon contributes to the crushing of granules matrix.

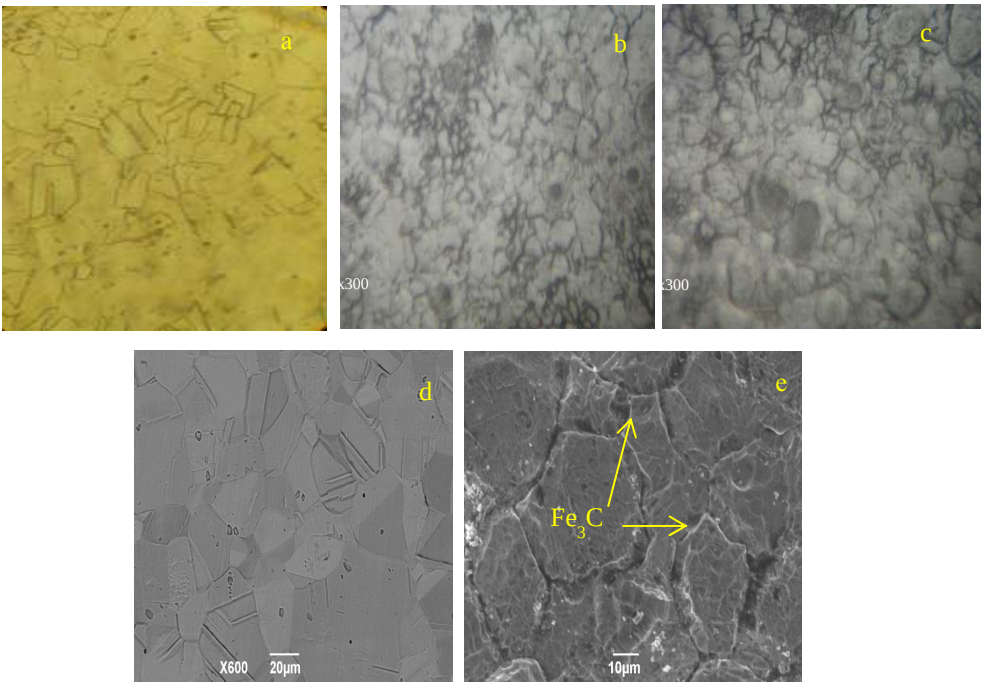

Fig.1 . The microstructure of the surface of steel 12Cr18Ni10Ti (x300): a) the initial, b) after treatment at the temperature of 850 ^{0}C within 3 minutes, c) after processing at the temperature of 900^{0}C for 5 min, d) original (x600), e) after processing at the temperature of 950^{0}C for 7 minutes (x1000)

Rys. 1. Mikrostruktura stali 12Cr18Ni10Ti (x300): a) stan wyjściowy, b) po obróbce w temperaturze 850^{0}C w czasie 3 minut, c) po obróbce w temperaturze 900^{0}C w czasie 5 min, d) stan wyjściowy (x600), e) po obróbce w temperaturze 950^{0}C w czasie 7 minut (x1000)

According to the data of x-ray phase analysis, it was found that austenite is formed in the grains of dendrites and forms the basis of eutectics. The presence of austenite in the structure is explained by the high cooling rate and a high content of alloying elements. At cooling rates of 200–800^{0}C/sec, the diffusion

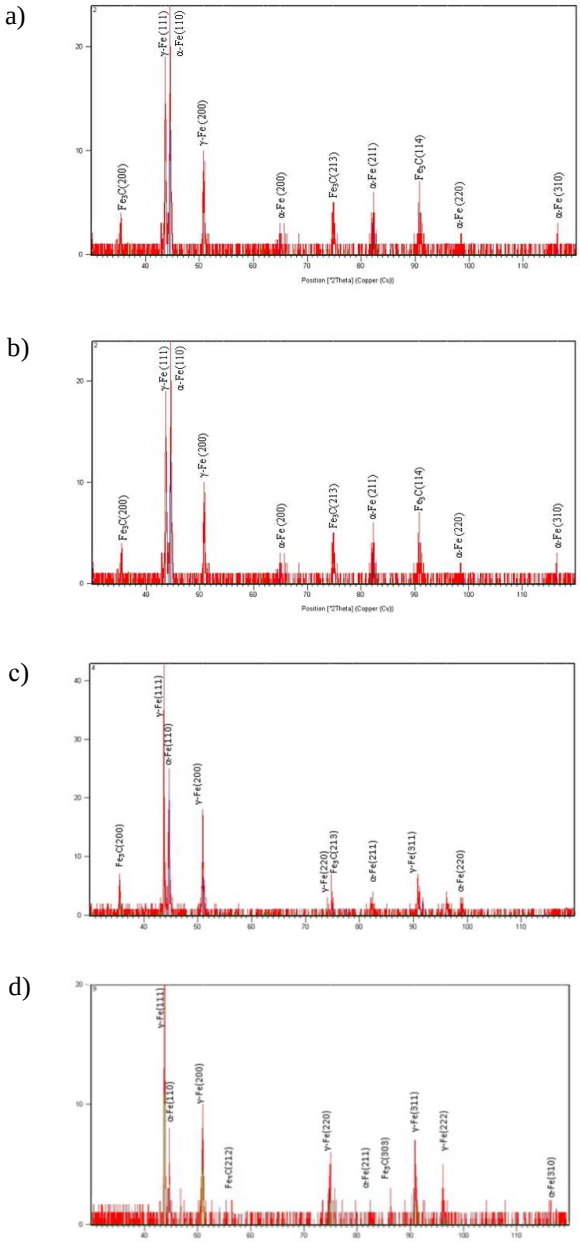

Fig. 2. x-Ray diffractogram steel 12Cr18Ni10Ti: a) in the initial state, and b) after processing at temperature 850^{0}C within 3 min, c) at a temperature of 850^{0}C during the 5 min, d) at a temperature of 850^{0}C within 7 min

Rys. 2. Dyfraktogram rentgenowski stali 12Cr18Ni10Ti: a) stan wyjściowy, b) po obróbce w temperaturze 850^{0}C w czasie 3 min, c) po obróbce w temperaturze 850^{0}C w czasie 5 min, d) po obróbce w temperaturze 850^{0}C w czasie 7 min

decomposition of austenite and the emergence of martensite do not take place until the end. The present and the line of phase Fe_3C (carbides), FeO and α- phase on the basis of Fe testifies to the emergence of martensite quenching.

According to the data of x-ray analysis, we found that the intensity of the lines α-phase sample were processed at a temperature of 850^0C in a period of 3, 5 and 7 minutes compared with the original, have increased significantly, as the lines and phase Fe_3C. There is just a widening of diffraction lines relative to the initial state, which is explained by the fact that the processing was taking place in a difficult position due to the thermal impact.

Analysis of the images obtained by the method of scanning electron microscopy allows to conclude that, as a result of electrolyte-plasma processing, namely in the cathode of cementation, there is a change in the surface morphology of steel. It is obvious that, at temperatures of 800-900^0C (**Figure 3a**) for 3min, a modified surface layer is formed from 30 to 40 mμ, and at the temperature of 850-950^0C (**Figure 3b**) within 5min a modified surface layer is formed from 42 to 55 mμ, and within 7 minutes of processing (**Figure 3c**) a modified surface layer is formed from 49 to 65 mμ.

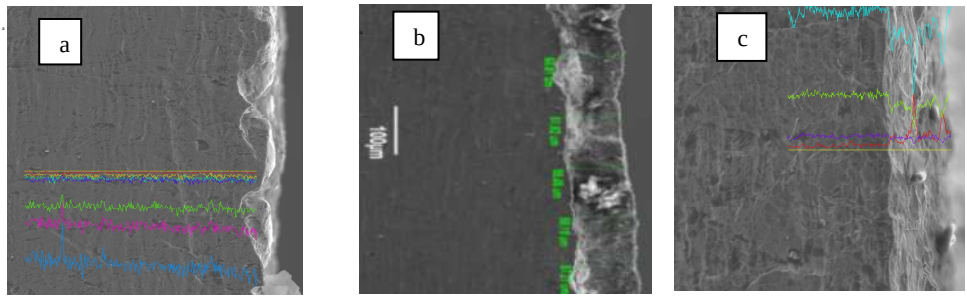

Fig. 3. Modified layer on the surface of samples of steel after processing: a) at a temperature of 800^0C during 3 min, b) at a temperature of 900^0C within 5 min, c) at a temperature of 950^0C during 7 min

Rys. 3. Modyfikowana warstwa wierzchnia próbki stali po obróbce: a) w temperaturze 800^0C w czasie 3 min, b) w temperaturze 900^0C w czasie 5 min, c) w temperaturze 950^0C w czasie 7 min

The distribution of hardness along the thickness of the samples was investigated with the help of microhadometer PMT-3 when the load on the indenter of 1 N (100 g). The treated samples were tested 60 times, 20 of the test were made at a distance from the surface of 5 mμ, 20 on the centre of the sample and 20 below. It is known that the original microhardness of the sample was 170–200 HV. After cementation, within the temperature of 800–900^0C for 3 min (**Figure 4a**), the microhardness of the sample was increased to 445 HV

(4450 MPa). Within the temperature of 850-950^{0}C during the 5 min **(Figure 4b)** the microhardness increased to 470HV (4700 MPa), and within 5 minutes (**Figure 4c**) saturation increased 2.5 times producing a microhardness of 485HV (4850 MPa).

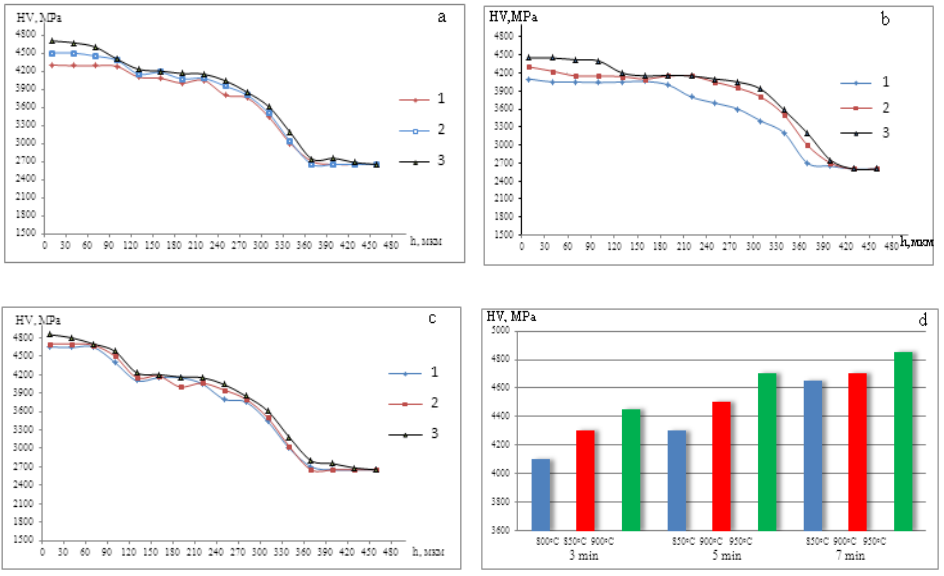

Fig. 4. The distribution of microhardness of the surface layer to the bone samples of steel 12Cr18Ni10Ti: a) after processing for 3 min at 800^{0}C (1), 850^{0}C (2) and 900^{0}C (3), b) 5 min at 850^{0}C (1), 900^{0}C (2) and 950^{0}C (3), c) 7 min at 850^{0}C (1), 900^{0}C (2) and 950^{0}C (3) with the subsequent hardening, d) histogram depending microhardness of time and temperature of the electrolyte-plasma processing

Rys. 4. Rozkład mikrotwardości warstwy wierzchniej próbki ze stali 12Cr18Ni10Ti: a) po obróbce w czasie 3 min w temperaturze 800^{0}C (1), 850^{0}C (2) oraz 900^{0}C (3), b) 5 min w 850^{0}C (1), 900^{0}C (2) oraz 950^{0}C (3), c) 7 min w 850^{0}C (1), 900^{0}C (2) oraz 950^{0}C (3) z późniejszym hartowaniem, d) zależność mikrotwardości w zależności od czasu i temperatury obróbki

It is established that, during cementation, as the duration of saturation and temperature of the treatment increases, the microhardness increases 2–2.5 times in comparison to the initial state.

The table below shows normal values of the loss of the mass of the samples before and after the treatment:

Table 1. Normal values of the loss of mass of steel 12Cr18Ni10Ti after electrolytic-plasma cementation at different temperatures

Tabela 1. Wartości ubytku masy stali 12Cr18Ni10Ti po obróbce elektrolityczno-plazmowej w różnych temperaturach

The sample steel 12Cr18Ni10Ti	Loss of mas g, gram
The source	0.0465
After processing 850 ^{0}C, 3 min	0.0429
After processing 900 ^{0}C, 3 min	0.0415
After processing 950 ^{0}C, 3 min	0.0397

CONCLUSIONS

It is established that in the electrolyte-plasma processing of steel 12Cr18Ni10Ti within the temperature of 800-900^{0}C for 3min formed a modified surface layer with a thickness from 30 to 40 mμ, at 850–950^{0}C within 5min from 42 to 55 mμ, and within 7 minutes of processing, a layer was formed of a thickness of up to 49 65 mμ. A carbonised modified layer has a variable concentration of carbon in depth, decreasing from the surface to the core of the sample, which contributes to increased hardness and the strength of the surface.

It was found that, when processing within the temperature of 800–950^{0}C within 3.5 and 7 minutes, particles Fe_3C phase carbide iron usually formed around grains, which restricted the growth of grain size, and are also the main phase of austenite γ-Fe and martensite α-Fe.

It is established that the increase in the time and temperature of the electrolyte-plasma processing of steel contributes to the increase of the microhardness from 2–2.5 times and wear resistance as compared with the original steel 12Cr18Ni10Ti.

Acknowledgment

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Streszczenie

W pracy przedstawiono wyniki wpływu obróbki elektrolityczno-plazmowej na własności mechaniczne i stan strukturalno-fazowy warstwy wierzchniej stali 12Cr18Ni10Ti. W pracy badano charakterystyki mechaniczne warstwy wierzchniej stali cementowanej w elektrolitycznej plazmie o składzie 10% Na2CO3 i 10% C3H8O3. Określono warunki prowadzenia procesu oraz optymalny skład mieszaniny plazmy. Badania strukturalne próbek prowadzono z wykorzystaniem analizy rentgenowskiej dyfrakcyjnej, mikroskopii optycznej i elektronowej. Badania porównawcze struktury, faz i składu chemicznego modyfikowanej warstwy wierzchniej stali 12Cr18Ni10Ti wykonano po obróbce elektrolityczno-plazmowej. Na podstawie badań stwierdzono, że w wyniku obróbki wzrosła odporność na zużywanie i twardość (2–2,5-krotnie w odniesieniu do stanu przed obróbką). Utwardzona warstwa ma grubość 200–250 μm. Świadczy to o tym, że w wyniku obróbki elektrolityczno-plazmowej stali *12Cr18Ni10Ti* jej mikrostruktura zawiera cząstki węglików i ma drobnoziarnistą strukturę martenzytyczną.