Structural Phase Transitions of Low-Carbon Alloy Steels during Electrolytic-Plasma Processing

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***Abstract*—We investigated 18XH3MA-SH steel, hardened by electrolytic-plasma treatment. Scanned surface transient analysis showed that during the electrolytic-plasma chemical modification of the surface heating occurs together with details of the release.**

Keywords-electrolytic-plasma processing; martensite; microstructure

I. INTRODUCTION

Development of mechanical engineering through the establishment of important processes and to strengthen the new surface of layers are important to solve the problem of the reliability of parts of machine. Mechanical properties of particles on the surface of layer and increasing the point of view of the microstructure of the surface details because of the consolidated impact of the energy flows are one of the most common methods, they have stimulated the development of new methods of modification.

One of the promising methods is electrolytic-plasma processing (EPP). It includes heat treating of the surface of the plasma stream with the electrochemical retail, it means electrochemical machining processing. Plasma flow completes part of the ionized gas, up to 1000V with a high potential of water electrolyte solution.

The main method of EPP is: the possibility of increasing the strength of the surface, it requires special training to analyze surface before and after required processing; the importance of environmental safety.

Low-carbon alloy steels were analyzed to increase strength training for samples of technologies thermal. Technology can increase the strength of parts of the plasma electrolyte.

II. RESEARCH AND MATERIALS

Research selected parts of the drill bit with the existing plant «Vostokmashzavod» JSC (JSC «SHKMZ»). Contact durability, abrasion and impact-abrasive wear resistance drilling details bits in the production of «SHKMZ» satisfied Gas Hardening. The disadvantages of this technology machining are education warping and cracking parts of mild steel and high labor intensity and energy intensity of production. EPP ` for the following parts of the drill bit is used: 18XH3MA-SH (0,16-0,18% C; 3,3% Ni; 0,9% Cr; 0,51% Mo; 0,44% Mn; 0,34% Si; 0,05% Al; 0,008% S; 0,012% P; 0,015% N; 0,01% O; 0,01% H) GOST 4543-71 [1]. Electro-alloy remelting low carbon, alloy, heat-resistant steel used at temperatures from -70 to +450^{0}C. Alloying elements - carbon, chromium, molybdenum, manganese, silicon increases the strength. Nickel provides good strength for toughness and strength and provides a molybdenum heat resistant steel. Samples of 10 × 10 × 20 mm cut from a diamond drill bit cutters disk 1 mm thick which is immersed in the coolant. At low cutting speeds n = 350 r / min, and low load m = 250 g sample does not undergo thermal deformation and impact. Microanalysis for metallographic polished sections after polishing with toothpaste chromia etched with a 5% ethanolic solution of nitric acid.

Experimental studies and tests were conducted in a regional university laboratory of engineering profile «IRGETAS» WKGTU. D.Serikbaev and the Regional Science and Technology Park «Altai» .Metallic-graficity analysis was performed on metallographic microscope « Axioscop-2MAT» with digital camera Sony. Samples of the steel structure of qualitative and quantitative phase analysis of X-ray diffractometer «X'Pert PRO» company «Pananalytical», using Cu-K radiation. Microhardness measurement was performed on diamond pyramid PMT-3. Abrasion resistance was evaluated by the sample weight loss in unit time as a result of abrasion of the test sample on disc with an abrasive, sliding friction without lubrication material. For weight measurement samples are used electronic scales HV-120 up to 0.1 mg.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Electrolytic-plasma processing is the most effective multifactor experience to choose the terms of the plan which is carried out.

For multivariate experience that allows you to isolate a specific area and the physical meaning of all possible variables that are independent of view. Depending on the temperature or on inhomogeneous temperature distribution in particle size. In the most cases this uneven work during manufacture of various industrial processes, in the processing of hot pressure welding, heat processing in a simple and thermochemical, and "HDTV", electric, laser, electric light are followed by using of a rapid heating of the plasma electrolyte[3].

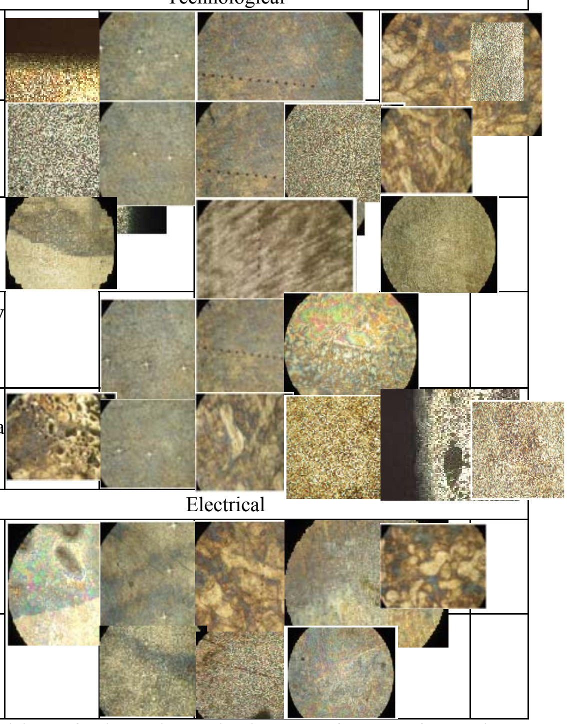
The average significance of data. The last stage of the experiment about the average values of tests and advanced matrix is given in Table I.

TABLE I. VARIABLE FACTORS IN THE ELECTROLYTIC-PLASMA PROCESSING

Designation of levels of factor parameter	Physical factors	Levels of factors	
		Minimum	Maximum
X1	Heating time	1	10
X2	Hardening time	1	10
X3	Number of cycles	20	40
X4	Voltage, V	180	220

TABLE II. MATRIX OF THE IMPACT OF EPP ON QUALITY OF HARDENABLE STEEL SURFACE

	EPP's mode	Quality hardening indicators					
		Physical and mechanical					
		Thickness ,x100	Microhardness,X100	The wear resistance ,x100	The phase composition,X100	The Elemental composition ,X100	Roughness ,x100
Electrolyte-10 Na_2CO_3	Technological						
	Heating time,s						
	Hardening titim time,C						
	The number of cycles,n						
	Size,V (mm³)						
	Temperaure,⁰C						
	Electrical						
	Voltage, V						
	Current,A						



This table of the electrolyzing surfaces after plasma processing and after chemical and thermal processing, we can see that the fastest and most efficient way[2,3]. Table II presents a matrix of influence of technological parameters using electrolyte-10% soda Na_2CO_3 diluted in water, on the performance as a reinforcing surface. Analysis of this matrix shows that practically all the considered state parameters of **EPP** influence on quality of hardenable steel surface. But it should be noted that the major process parameters such as the thickness of the hardening, microhardness and steel wear resistance, depends on the heating time, hardening time, number of cycles, and a voltage, which determine the heating temperature.

The heating temperature is the main parameter of the phase transformations to become 18XH3MA-SH, which is equal to 860^{0C}. Main factors are determined, they are the quality of hardening steel at EPP: heating time, time hardening and strain of current. The dependence of the temperature is required by the heating time, heating time and cooling, as well as the values of voltage:

$$T = 4{,}5*2th+ 4{,}8hU- 18htohl \qquad (1)$$

where T- is the temperature of heating steel, ht - heating time (sec.) t cool - Time of cooling in a stream of electrolyte (sec.), U - voltage (V), In real-time mode only EPP influences on the quality of the fatigue strength and is not only resistant to increasing the strength of the pages, as well as, but to improve the strength of steel EPP Increased efficiency and production of a wide spectrum is controlled. The processing time from the start of phase change, which allows to determine the temperature (for steel Ac_1 + 50-60⁰C S to eutectoid) and the completion of the phase transformation temperature (for steel Ac_3 + 50-60⁰C to eutectoid) is defined (Table III MEMST4543-71) [3,6].

TABLE III. FOR STEEL 18XH3MA-SH -POINT TEMPERATURE, 0C

Ac_1	Ac_3	Ar_3	Ar_1	Mn (105)
800	840	400	350	336

EPP heating cycle with a change in the steel enough for 4 seconds and 4 seconds hardening in accordance 20 cycles [4].

Regularities of phase transformations on the critical points Ac_1 steel 18XH3MA-SH are presented in Figure I.

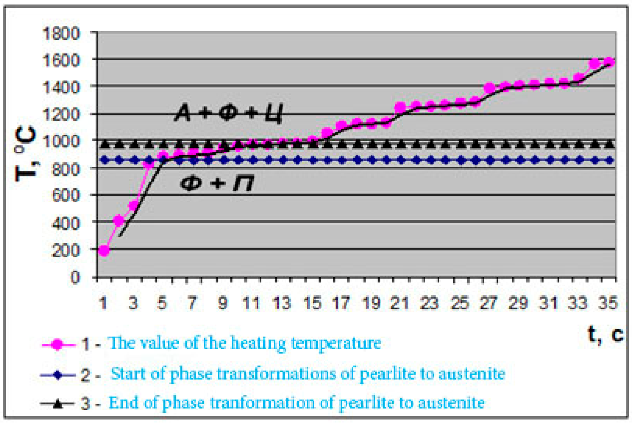


FIGURE I. THE NATURE OF THE TEMPERATURE OF THE BEGINNING AND END OF PEARLITE TO AUSTENITE TRANSFORMATION DURING CYCLIC ELECTROLITIC - PLASMA HEATING STEEL 18XH3MA-SH

Thus, the above mentioned types of heating more than the rest of the energy are needed to change a tendency to appear in the ion thermal cycle of austenite steel heat relatively quickly. 18XH3MA-SH -ferrite, austenite recrystallization line above which the austenite and ferrite and cementite structure. At the same time, it was not the same as the carbon in austenite particles than heating. Adding into the austenitic structure tsementita- austenite particles has been a significant slowdown the growth. This should be taken into account when analyzing the structure of formation in the following ways.

Electrolyte-plasma surface processing model is determined by qualitative and quantitative analy sis of three points (Figure II).

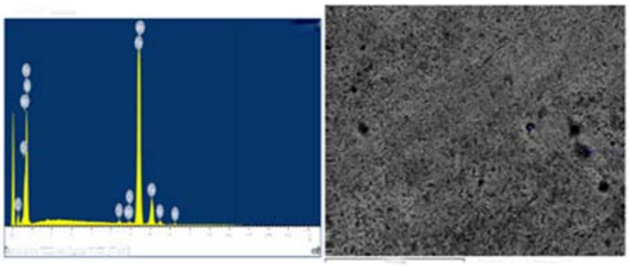


FIGURE II. SCANNING ELEMENT ANALYSIS OF STEEL 18XH3MA-SH AFTER EPP.

Increasing of the carbon content (Table IV), relative to the starting state due to the fact that the gas plasma electric layer discharge an electric current flows from the aqueous solution of soda ash Na_2CO_3, carbon ions are formed [2,4] carburized surface of that sample.

TABLE IV. QUALITATIVE AND QUANTITATIVE ANALYSIS OF THE TREATED SAMPLE

Spectrum	C	Na	Si	Cr	Mn	Fe	Ni	Total
Spectrum 1	0,56	-	-	0,66	0,48	95,73	2,57	100,00
Spectrum 2	0,69	0,38	-	0,66	-	95,75	2,52	100,00
Spectrum 3	0,71	-	0,31	0,54	0,54	95,48	2,42	100,00

TABLE V. THE PHASE COMPOSITION OF THE SAMPLES BECAME 18XH3MA-SH

Type of treatment		Phase composition	2Theta [deg]	d [A]	h	k	L	I [%]
After of EPP	The initial state	α – Phase	44,6770	2,02670	1	1	0	100
			65,0280	1,43310	2	0	0	11,5
			82,3440	1,17010	2	1	1	17,4
		$Cr_{0,6}Fe_{1,4}$	63,8452	1,45673	3	0	2	17,0
			67,0481	1,39471	2	0	5	13,0
			61,7392	1,50127	2	1	3	21,0
		$Fe_{2,7}Mo_{0,8}Ni_{0,1}$	96,9814	1,02862	4	0	0	6,00
			98,1489	1,01948	4	0	1	1,00
			99,4724	1,00944	2	2	4	20,0
		Fe_3C;	44,7500	2,02350	1	1	0	10,8
			65,1078	1,43150	2	0	0	10,0
			82,4440	1,16890	2	1	1	37,0
			99,0643	1,01250	2	2	0	14,0

All results are in% by weightRaster elemental analysis of the treated surface showed that the electrolytic-plasma heating of the sample, along with hardening, a chemical modification of the surface-layer metal.

X-ray diffraction analysis of samples of steel 18XH3MA-SH -ablesupply (Figure III) and then revealed the presence of EPP lines Fe phase based on Fe, line $Fe_{2.7}Mo_{0.8}Ni_{0.1}$- phase $Cr_{0.6}Fe_{1.4}$ – phase. After the **EPP**- observed increasing in the intensity and broadening of diffraction lines (see Figure III b) relatively to the initial state (see Figure III a), indicating a tight co-distance due to thermal effects. The phase composition of the samples became 18XH3MA-SH is shown in Table V.

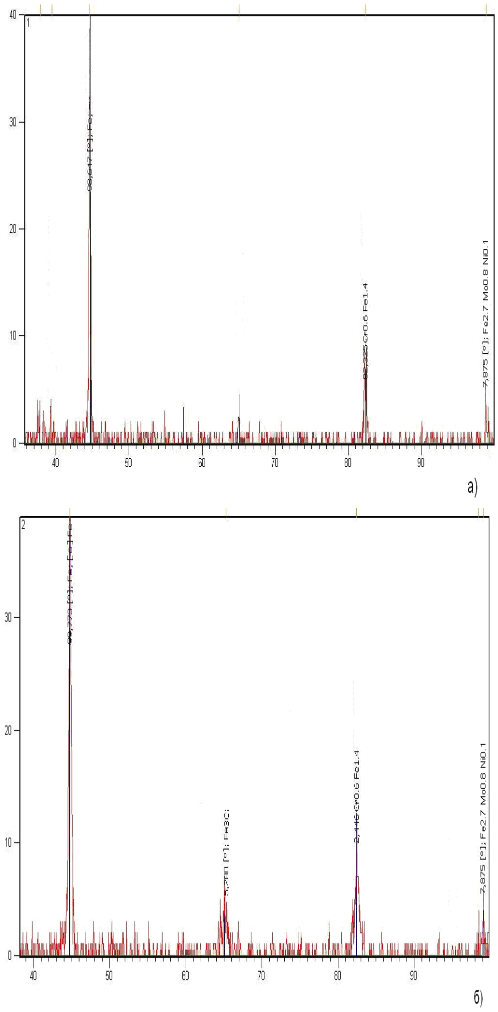


FIGURE III. THE X-RAY DIFFRACTION STEEL 18XH3MA-SH. A) - IN THE INITIAL STATE, B) - AFTER OF EPP.

It is known [1,6], the martensitic quenching (A→ M) transformation does not proceed to the end, and remain in the steel products of decomposition. The presence of lines after **EPP-** residual cementite Fe3C phase and α-phase based on Fe, line Cr0.6 Fe1.4 - phase line Fe2,7 Mo0,8 Ni0,1 - phase indicate the appearance of martensite tempering. According to the theory Kurdjumov-Sachs [5], martensite crystals formed on the shear plane at the time of its formation. Play a major role stress. The sources of stress are: temperature gradients over the cross section; heterogeneity of chemical composition; structural imperfections; Different crystal orientation in space; various specific volume of martensite and austenite, various coefficients of linear expansion phases.

The cross section of Electrolytic-plasma treated sample there are three zones (Figure IV). The microstructure of a machined surface (zone I) is characterized by a dark layer thickness of about 100um, structural phase transitions which are formed under the influence of cyclic high-temperature plasma. Particular attention should be paid to the activation of the plasma flow direction of mass transport of alloying elements from both the anode and the electrolyte of which is detected by SEM. Under the dark layer (zone II) there is a fine-grained lamellar structure of the martensitic class, which goes into the initial pearlite-ferrite structure (zone III).

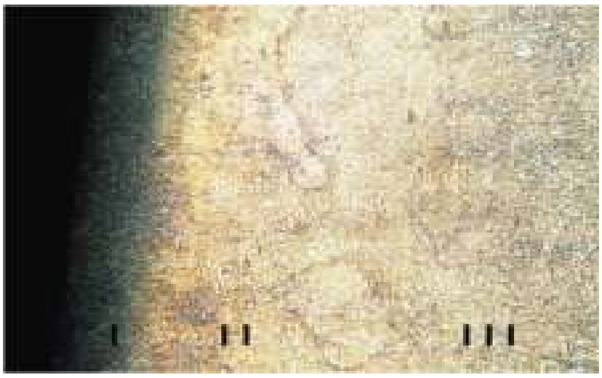


FIGURE IV. THE MICROSTRUCTURE OF THE CROSS SECTION OF STEEL 18XH3MA-SH AFTER EPP

It was found that the electrolytic-plasma treatment provides a hardened layer thickness of 1000 ... 1700 mkm (Figure V). Microhardness measurements on the sample surface after the plasma electrolytic processing averaged 7000 MPa (Figure V). With increasing distance from the treated surface microhardness uniformly reduced to the initial state, and an average of 3000 MPa.

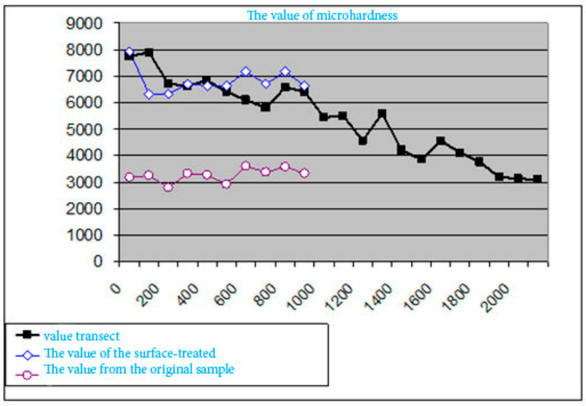


FIGURE V. THE VALUE OF MICROHARDNESS STEEL 18XH3MA-SH AFTER EPP

Initial sample than of "SHKMZ" heat treatment of steel patterns with less wear and tear, but lower than the EPO and durability. Abrasive objections bit **EPP** sample of the best wear resistance. Thus, on the basis of the results found that the most effective way of surface hardening of the drill bit is electrolytic-plasma treatment. The advantages of this method are: low power consumption at high autoheating, the possibility of local surface processing of complex configuration, operating under intense stress, ease of implementation process.

IV. CONCLUSION

1. Electrolytic- plasma treatment of alloying elements in the surface layers of modified soda ash Na_2CO_3 aerated water appears in the plasma layer, also affects the appearance of the surface structure of martensite;

2. After electrolytic-plasma processing became 18XH3MA-SH and increased the hardness of more than 2 times the initial state;

3. The abrasive wear resistance of steel samples 18XH3MA-SH after plasma electrolytic processing, the wear resistance exceeds the same sample treated in the «Vostokmashzavod» JSC, at least twice.

4. The abrasive wear resistance of the samples exceeds the durability of the samples treated according to the technology of «Vostokmashzavod» not less than twice.

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