

Method of Electrolyte-Plasma Surface Hardening of 65G and 20GL Low-Alloy Steels Samples

Bauyrzhan Rakhadilov^{1,a}, Laila Zhurerova^{1,b}, Alexander Pavlov^{2,c}

¹D. Serikbaev East Kazakhstan state technical university, Serikbaev str. 19, 070010, Ust Kamenogorsk city, Kazakhstan

²S. Amanzholov East Kazakhstan state university, 30 Gvardeiskoi divisii str. 34, 070002, Ust Kamenogorsk city, Kazakhstan

E-mail: ^abor1988@mail.ru, ^bleila_uka@mail.ru, ^cAlexandr_Pavlov_1988@mail.ru

Abstract. This work is devoted to formation of modified surface layers in 65G and 20GL steels which using for the manufacture of railway transport parts, as well as the study of influence of the parameters of electrolyte-plasma surface hardening method on the changes in structural-phase states, improving of wear-resistance.

The process of electrolyte-plasma surface hardening of 65G and 20GL steels samples conducted in the electrolyte from water solution of 20% sodium carbonate, in the mode ~850°C – 2 seconds, ~1200°C - 3 seconds. It is established that in the initial state 20GL steel has ferrite-pearlite structure, and the 60G steel consists of pearlite and cement structure. After application of electrolyte-plasma surface hardening is observed the formation of carbides particles and martensite phase components in the structure of 20GL and 60G steels. It is determined that after electrolyte-plasma surface hardening with heating time - 2 seconds, the abrasive wear-resistance of 65G and 20GL steels increased to 1.3 times and 1.2 times, respectively, and the microhardness is increased to 1.6 times and 1.3 times, respectively.

Introduction.

In connection with the increasing requirements for durability and reliability of railway transport parts such as spring beams, carts, pivots and coupler of a freight car, and become a significant priority problem of surface hardening and improving the operating properties of these parts. For the manufacture of railway transport parts which is operating in conditions of dry friction, high contact and impact loads leading to wear, low-alloy steels are often using. Analysis of studies showed that after prolonged use of these parts, the wear of their working surfaces is accompanied by a reduction in operating properties, which in particular causes deterioration in the quality of manufactured parts or is connected with their frequent replacement [1, 2].

The traditional methods of hardening of railway transport parts are used for a long time and largely exhausted its possibilities. However, the improvement of operational performance of the working surface in conditions of increased wear, evaluates mainly to the structural phase changes, as well as improving mechanical and tribological properties of surface layer.



Recently in the industry resource-saving technologies of surface hardening in the low-temperature plasma is one of the most promising methods. This method gives the ability to change the structure and properties of working surfaces and, as a consequence, to improve their operating properties.

Therefore, the aim of this work is to provide a method of electrolyte-plasma surface hardening (EPSH) for railway transport parts, which allows obtaining a modified hardened surface layer with high wear-resistance.

Results and Discussion

The 65G and 20GL steel samples were used as a research material. The samples subjected to standard thermal process under the following modes for steels: 65G (quenching 830°C, oil, the release at 470 °C, air) and 20GL (quenching 880 - 900°C, the release at 600 - 650°C) and electrolyte-plasma quenching (~850°C - 2s, ~1200°C - 3 s). The chemical composition of 65G and 20GL steels presented in table 1.

Table 1 – Chemical composition of 65G and 20GL steels

Steel grade	C	Mn	Si	Cr	Ni	Cu	S	P
65G	-	0.9 0-1.20	0.17- 0.37	~ 0.25	0.25	~ 0.20	~ 0.035	~ 0.035
20GL	0.15 - 0.25	1.2 - 1.6	0.2 - 0.4	-	-	-	~ 0.04	~ 0.04

Structural studies of 65G and 20GL steel samples conducted at the D. Serikbayev East Kazakhstan State Technical university, "Nanotechnology and new materials" Research Institute, by X-Ray diffraction method by XPertPRO X-Ray diffractometer in monochromatization CrK α radiation ($\lambda=2.2897$ Å), elemental surface analysis after electrolyte-plasma modification at the FEI XL 30 FEG scanning electron microscope, metallographic analysis on the NEOPHOT 21 and AXIOPHOT-2 optical microscopes, mechanical testing of microhardness was performed at the PMT-3M according to State standard 9450-76 and measurement of wear-resistance when rubbing against loosely fixed abrasive particles according to State standard 23.208-79. 65G and 20GL steel samples after mechanical grinding and polishing using diamond pastes, subjected to selective chemical etching to reveal the microstructure of steel surfaces [3].

Electrolyte-plasma surface hardening (EPSH) of the steel samples were carried out at the installation that are designed and manufactured at the "Nanotechnology and new materials" Research Institute [4]. The installation consists of a power source, electrolyte-plasma processing chamber and the personal computer [4, 5]. EPSH process of 65G and 20GL steel samples conducted in the electrolyte from water solution of 20% sodium carbonate in the following modes: supply voltage between anode and sample during heating to the quenching temperature – 320 V, the heating time - 2 and 3 seconds, and the samples were heated up to a temperature of ~850, ~1200°C, respectively.

Metallographic analysis showed that the 20GL steel surface in the initial state has a ferritic-perlitic structure, 60G steel consists of pearlite and cementite (Fig.1-a, d). After EPSH for 2 s we observe the formation of the martensitic phase constituting in the structure of 65G and 20GL steels (Fig.1-b, e), with increasing heating time up to 3 s there is a coarsening of martensite grains.

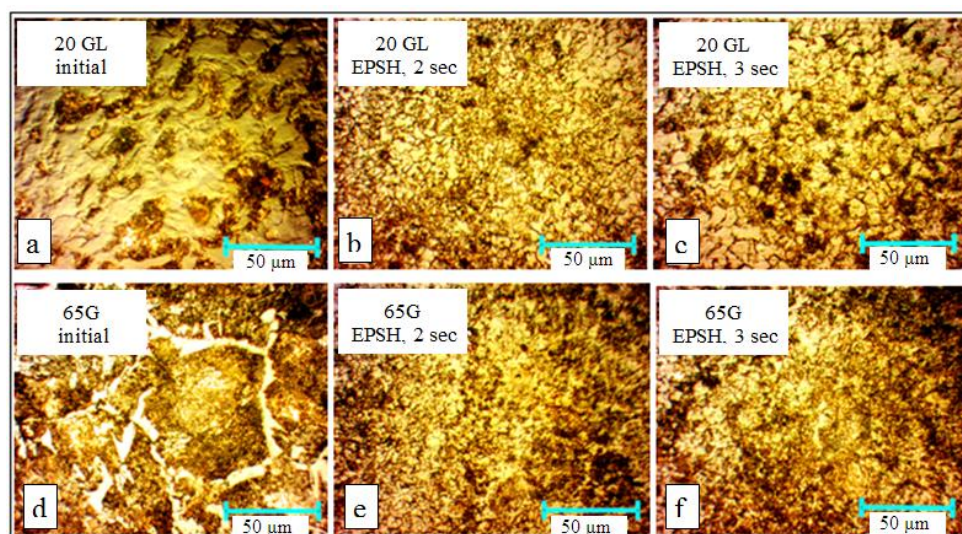


Figure 1 - Microstructure of 65G and 20GL steels before and after EPSH
a, b, c - 20GL steel; d, e, f - 65G steel

Figure 2 shows images of 20GL and 65G steels microstructure in the cross section after electrolyte-plasma surface hardening with heating duration - 2 s. From figure 2 it is seen that the cross section structure of 20GL and 65G steels after electrolyte-plasma surface hardening is divided into 3 zones: on the surface there is a 1-zone of a hardened layer with martensitic structure; 2-zone - layer of thermal influence; 3-zone - matrix. The thickness of the modified layer of 65G and 20GL steels after electrolyte-plasma surface hardening is $\sim 500\text{--}550\text{ }\mu\text{m}$.

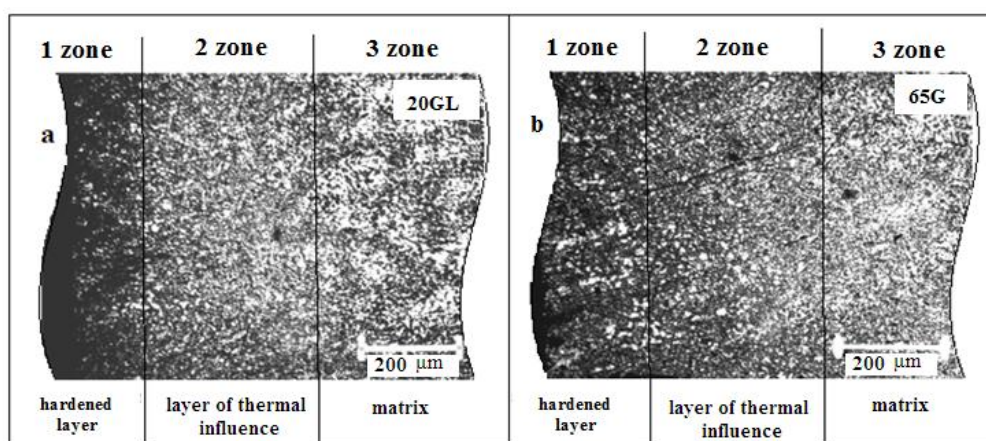


Figure 2 - Microstructure of the cross section of 65G and 20GL steels after EPSH

In order to study in detail changes in the morphology and structure of 65G and 20GL steel samples, electron-microscopic analysis of the surface was conducted. Figure 3 shows SEM-images of 20GL (Fig.3, d-f) and 65G (Fig.3, a-e) steel surfaces before and after EPSH. The structure of 65G and 20GL steels in the initial state consists of ferrite and lamellar pearlite, and cementite. After EPSH the formation of martensite at the boundaries is observed, which is introducing as a small particles. It is assumed that the detected fine particles are the carbides of alloying elements. The wear-resistance of 20GL steel is improved, possibly due to the formation of these small particles. Since, it is known [6] that the dispersed separation prevents the volume of grains relatively mild matrix from abrasion.

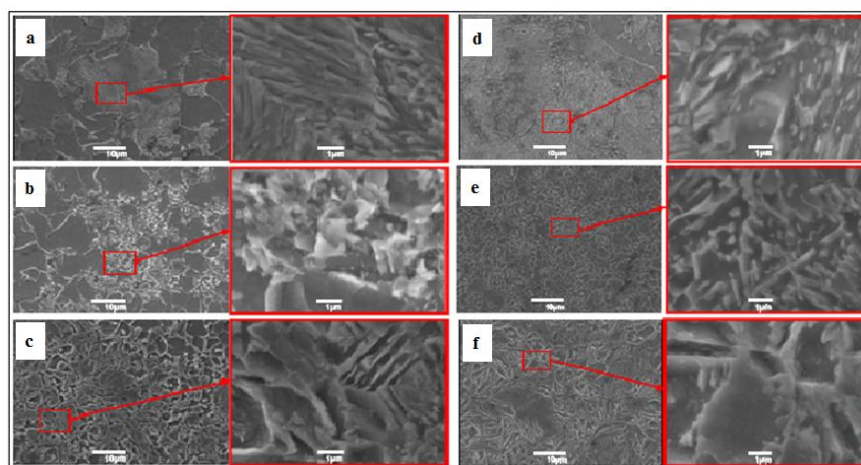


Figure 3 – SEM images of the surface of 65G and 20GL steels
 a, d - before processing; b, e – after EPSH with heating time 2 sec;
 c, f – after EPSH with heating time 3 sec

For the purpose of identification of change of element structure of a surface, the power dispersive analysis of a surface of samples of steel 65G and 20GL before and after EPSH has been carried out. In figures 4-5 results of the power dispersive analysis are shown. Analyses have shown that after EPSH with heating during 2 sec. on a surface of steel 20GL oxides are observed. Nevertheless, after EPSH considerable changes of element structure of a surface of 65G and 20GL steels isn't observed.

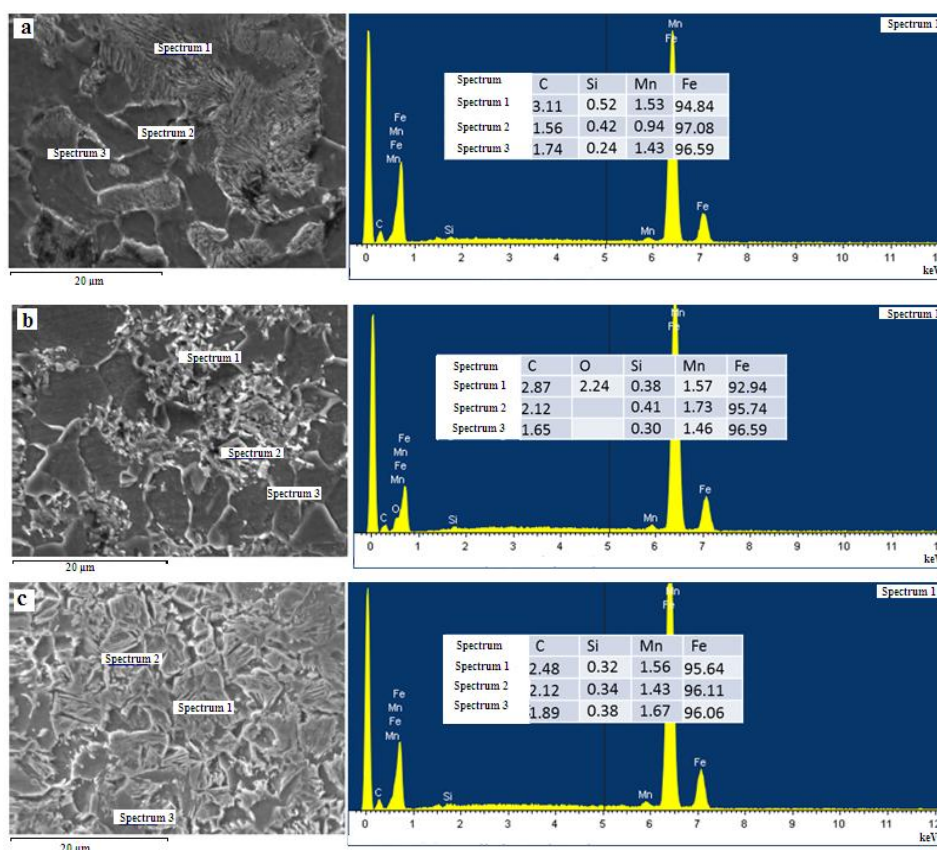


Figure 4 – Results of the SEM analysis of a surface of steel 20GL
 a, b – after EPSH heating duration of 2 sec.; c– after EPSH heating duration of 3 sec

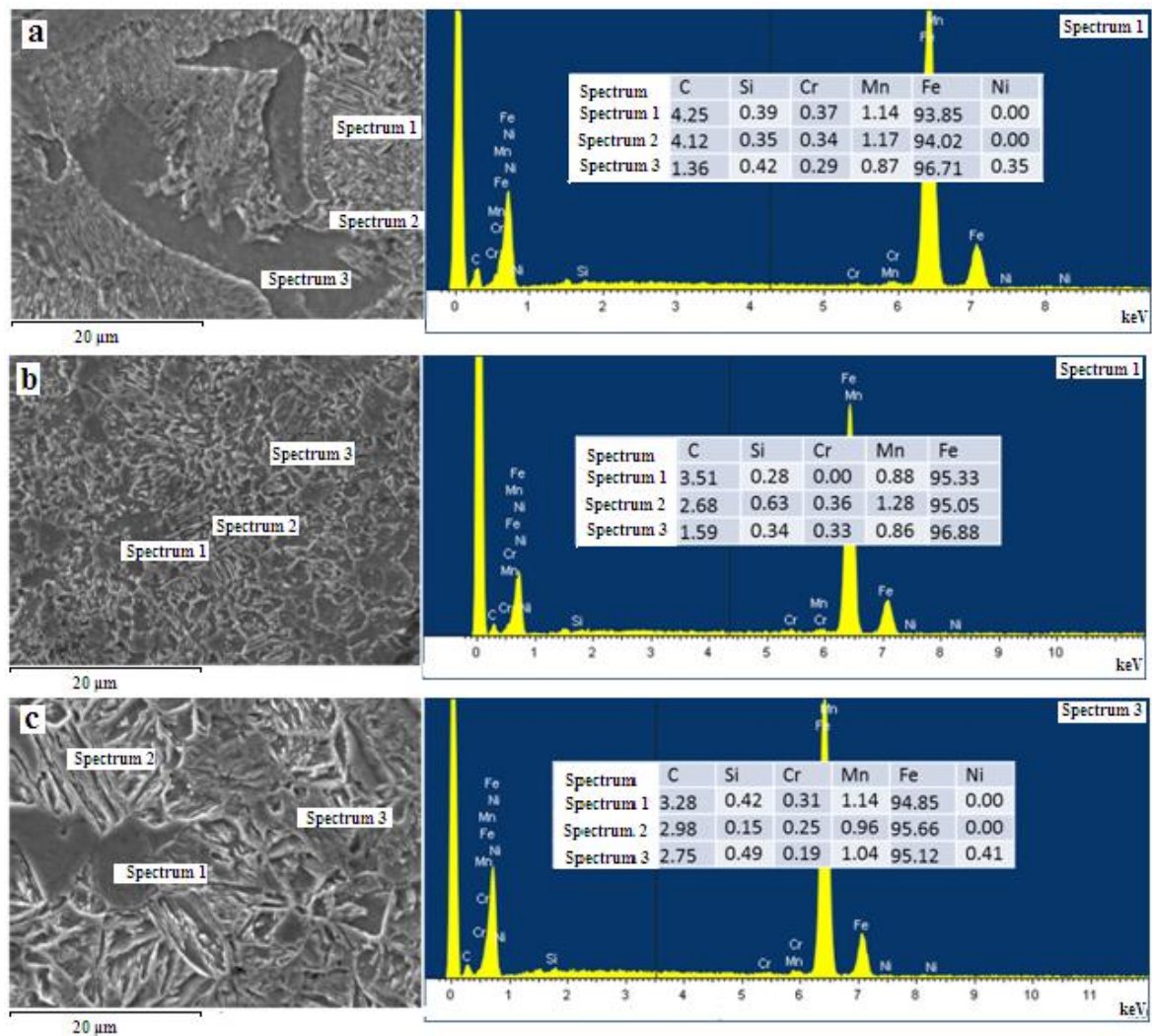


Figure 5 - Results of the SEM analysis of a surface of 65G steel
 a, b – after EPSH heating duration of 2 sec.; c – after EPSH heating duration of 3 sec

Figure 6 shows the wear rate (mm^3/Nm) of the samples of 65G and 20GL steels before and after EPSH. Tests were conducted by the “ball-disk” scheme. It is seen that all the processed samples show a significant decrease in wear-rate in comparison to the original material. The wear-rate of the 65G and 20GL steels and after EPSH during 2 s is reduced to 30%, indicating a significant increase of steels wear-resistance.

Abrasive wear-resistance was evaluated by comparing the mass loss of 65G and 20GL steels samples before and after EPSH. The relative wear-resistance of the steel samples was determined by the formulas according to State standard [7]. As we can see from figure 6, mass loss of samples steels 65G and 20GL and after hardening EPSH less than the samples in the initial state, indicating increased resistance to abrasive wear of 65G and 20GL steels after surface hardening. After EPSH the abrasive wear-resistance of 65G and 20GL steels increased to 1.3 times and 1.2 times, respectively.

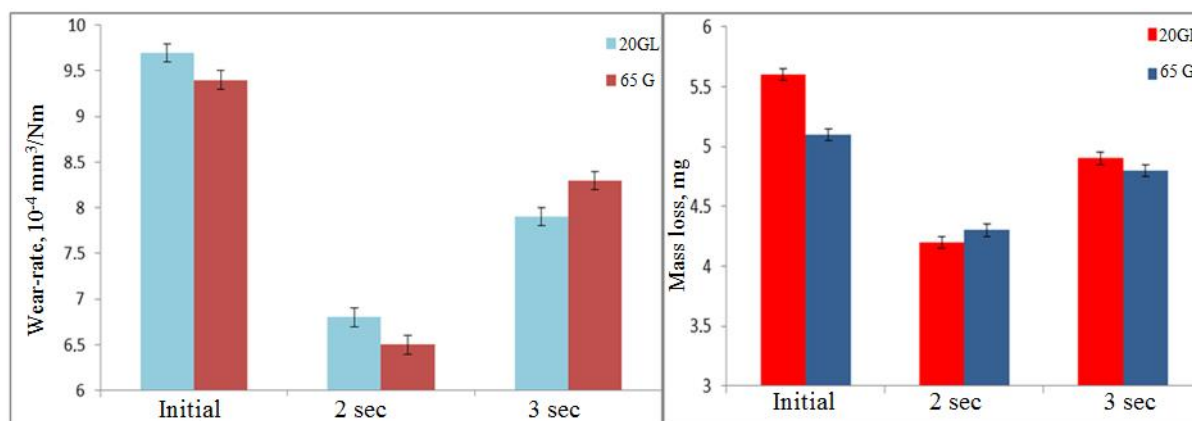


Figure 6 – Evaluation of wear-resistance of 65G and 20GL steels samples before and after EPSH

Figure 7 shows the dependence of the microhardness of 65G and 20GL steels from duration of electrolyte plasma processing. The microhardness of 65G and 20GL steels in the initial state is 2430 and 1690 MPa, respectively. It is established that microhardness of 20GL steel after EPSH (heating time of 2 s) was increased to 1.6 times, and the hardness of 65G steel after EPSH (heating time of 2 s) was increased to 1.3 times, comparing to the initial state.

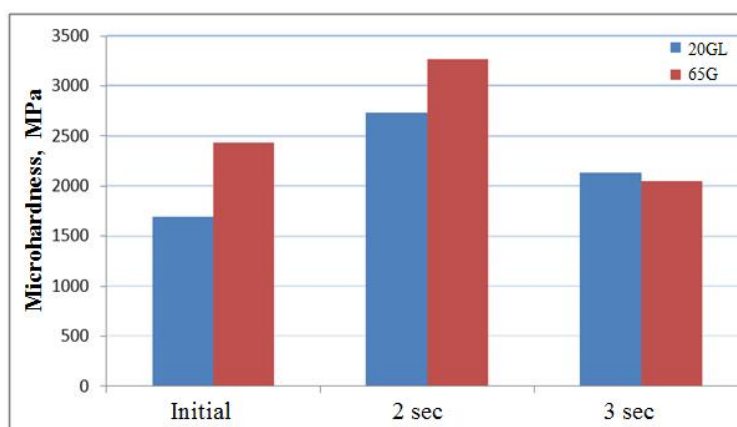


Figure 7 - Microhardness of 65G and 20GL steels

Conclusion

Thus, based on the analysis of the obtained experimental results of investigation of modified surface layers of 65G and 20GL steels after EPSH, we can draw the following conclusions:

- the EPSH method is developed and optimal modes of surface hardening of low-alloy steels 65G and 20GL in plasma electrolyte is determined, which allows to obtain a modified surface layer with ~500-550 μm thickness and with improved performance characteristics;
- it is determined that the abrasive wear-resistance of 65G and 20GL steels increased to 1.3 times and 1.2 times, respectively;
- it is established that the microhardness of 65G and 20GL steels after EPSH (heating time - 2 s) was increased to 1.6 times and 1.3 times, respectively, depending to the initial state.
- it is revealed that after electrolyte-plasma surface hardening morphological structure of 20GL and 60G steels consists of martensite grains, with the small carbide particles in the boundaries;
- it is discovered that the structure of the cross section of 65G and 20GL steels after EPSH has a zonal characteristic: on the surface there is a 1-zone teletravel hardened layer with martensitic structure; 2-zone – layer thermal influence; 3-zone - matrix.

Thus, studies have shown perceptivity and expediency of application of the developed method for improvement of operational properties of railway transport details, operating in conditions of friction and wear.

This work was financially supported by Committee of Science of MES RK by the "Development of resource-saving technologies of surface hardening of steel parts for railway transport" project under the contract № 63 of 12 February 2015.

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