Some characteristics of surface hardening of steel 65g in the electric-spark method

S N Sharifullin¹, I A Fayzrakhmanov², N R Adigamov³, R R Akhmetzyanov³, R R Shaykhutdinov³, R M Lyadov², V A Shustov³, A T Bayniyazova³

¹Kazan (Volga region) Federal University, Russia
²kfti KSC RAS them. E. K. Zavoysky, Russia
³Kazan state agrarian University, Russia

E-mail: saidchist@mail.ru

Abstract. The paper presents the results of studies of some physical and mechanical properties of metal samples made of 65G steel, hardened by electrospark method. Researches are connected with the solution of problems of increase of a resource of work of details and working bodies of agricultural machines. The elemental composition, phase composition and microstructure of the surface of 65G steel samples processed by the electrospark method were investigated.

1. Introduction.
Now there is a problem of increase of a resource of work of working bodies and high-precision details of domestic and foreign agricultural machines (ACM) and the equipment working in the conditions of the abrasive environment. Significant wear of these parts and working bodies leads not only to a change in their geometric dimensions, but also to a violation of agricultural requirements in the work of ACM, which in turn adversely affects the final result: yield. Seasonal work in agricultural production leads to the fact that many of the details and the working bodies of the ACM and equipment, such as the ploughshare, coulter discs, the cutting elements of the mower, the elements of the kinematic chain of fuel pumps, the elements of precision pairs etc. not withstand a season of work. According to the Ministry of agriculture and food of the Republic of Tatarstan, the cost of spare parts and repair of domestic and foreign schemes and equipment in 2017 alone amounted to about 3 billion rubles. The existing traditional technologies of production, repair and restoration of schemes and the equipment do not meet the modern requirements imposed to their resource. The only way out here is the use of high-performance technologies. One of such technologies is plasma technologies of surface hardening. In this direction there are results of researches of authors and this material [1-4]. However, the most complete solution is possible using an integrated technology for surface hardening of details and working organs of domestic and foreign agricultural machinery based on the methods of plasma deposition, plasma hardening, plastic deformation, vibration of arc and electric-spark hardening with the use of metal-ceramic powders. At the same time, the optimization of the technological process of hardening for specific parts and working bodies of ACM and equipment will be due to the control of modes of concentrated energy flows with different compositions of metal-ceramic powders. Optimal modes of concentrated energy flows will be determined on the basis of theoretical and experimental studies of their gas-dynamic, thermal and energy characteristics. The use of metal-ceramic powders
(MCP), such as carbides, nitrides, borides and oxides, in combination with hardening technologies based on concentrated energy flows will allow to vary in a wide range of physical and mechanical properties of hardened surfaces of parts and working bodies of ACM and equipment.

This paper presents the results of studies of some physical and mechanical properties of metal samples made of 65G steel, hardened by electrospark method. The elemental composition, phase composition and microstructure of the surface of 65G steel samples treated by electrospark method were investigated.

2. Materials and research methods.
Studies were carried out on samples of 65G steel with a size of 30x30 mm with a thickness of 2 mm. Processing was carried out at technological installations of electric spark hardening developed by GOSNITI (Moscow). A tungsten-cobalt bar with a diameter of 4 mm served as an electrode. Studies of the surface morphology and elemental composition of the samples were carried out using a Zeiss EVO 50 XVP scanning electron microscope (SEM) with INCA Energy-350 and INCA Wave-500 elemental analyzers. The crystal structure and phase composition were studied on a Dron-7 X-ray diffractometer with a CuKα X-ray source (0.154178 nm). The surface layer of the following samples was investigated: sample No. 1 — original, sample No. 2 with an electric-spark treatment.

3. Results and discussions.
Carbon (21.59 at.%) and iron (77.33 at.%) are present in the fully cleaned area of the initial sample (Fig. 1). Silicon and manganese are also observed in low concentrations. The square indicates the area from which the elemental composition was analyzed.

![Elemental composition of the original sample after cleaning the surface with an abrasive wheel](image)

| Element | Weight % | Atomic % |
|---------|----------|----------|
| C K     | 5.60     | 21.59    |
| Si K    | 0.22     | 0.36     |
| Mn K    | 0.86     | 0.72     |
| Fe K    | 93.32    | 77.33    |

Figure 1. Elemental composition of the original sample after cleaning the surface with an abrasive wheel

The interplanar spacings were calculated based on the X-ray diffraction pattern of the initial sample (Fig. 2). From a comparison of the obtained interplanar distances and the ratio of the intensities of the lines with the literary data (Mirkin) it can be concluded that the most intense reflections belong to α-Fe. According to our estimate, using the well-known Debye-Scherrer formula:
\[ D = \frac{0.94 \lambda}{\beta \cos \theta}, \]  

(1)

where \( \lambda \) is the X-ray wavelength (\( \lambda_{Cuka} = 0.154178 \text{ nm} \)), \( \beta \) is the reflection width at half-height, \( \theta \) is half the diffraction angle, the average crystallite size is about 21 nm.

Sample No. 2 was investigated in the same modes as the original sample. Figure 3 shows micrographs of the surface of a sample surface, taken by SEM at various magnifications and modes (SE) or QBSD. Observed a developed surface due to the treatment.

The following figures show the elemental analysis data. Squares indicate the areas from which the elemental composition was analyzed.

Figure 4 shows the spectrum from a relatively large sample area. Unlike the original sample, cobalt and tungsten are present in appreciable amounts.

![Graph](image)

**Figure 2.** Radiograph of the original sample
Figure 3. The surface of sample number 2
Figure 4. Elemental composition of sample No. 2 after processing. Border area of the area subjected to local processing.
Figure 5. Elemental composition of sample number 2 after processing. Border area of the area subjected to local processing.

| Element | Weight % | Atomic % |
|---------|----------|----------|
| C K     | 8.16     | 27.56    |
| O K     | 4.03     | 10.22    |
| Mn K    | 1.13     | 0.83     |
| Fe K    | 82.29    | 59.74    |
| Zn K    | 1.27     | 0.79     |
| Sn L    | 1.41     | 0.48     |
| WM      | 1.70     | 0.38     |

Figure 6. Elemental composition of sample number 2 after processing. Localized Area.

| Element | Weight % | Atomic % |
|---------|----------|----------|
| C K     | 6.96     | 37.30    |
| O K     | 2.91     | 11.71    |
| V K     | 0.37     | 0.47     |
| Fe K    | 16.47    | 18.98    |
| Ce K    | 7.55     | 8.24     |
| Sn L    | 1.54     | 0.84     |
| WM      | 64.20    | 22.47    |
In fig. 6 shows the measurements of the elemental composition of the zone of the sample area No. 2, subjected to local processing. The main components of this area are tungsten and cobalt. The tungsten content even exceeds the atomic concentration of iron.

In fig. 7 shows the radiograph after surface treatment. If we compare with the radiograph of the original sample, it has undergone significant changes and is very complex. In addition to the intense reflex from alfa-Fe (44.7°), there is a rather intense peak at 40°, as well as less intense peaks that were absent from the original sample. Decoding such a complex spectrum is not possible at this stage of research. Based on the elemental composition, it can be assumed that these can be compounds (oxides, carbides) and alloys of iron, cobalt tungsten. In addition, there is a significant increase in x-ray scattering compared to the original sample. This result indicates the presence of significant distortions in the structure of the treated surface, the presence of various micro and macro stresses.

4. Conclusions.
1. Electro-spark treatment leads to surface hardening metal products. When this occurs, both surface doping with elements of the electrode material and the formation of various oxides and carbides.
2. The energy of the electric spark discharge allows not only to create the surface of the part is a hardened layer with the base melted and mixed with the electrode material, but also the base material is hardened by the depth of the part by 0.5 - 1.0 mm.
3. In terms of production to cover the entire surface of the product area electro-sparking step electrode movement should be about 1.5 of its diameter. In the manual method, it is recommended to perform the processing several times or the technological process should be mechanized.
References

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