Hydraulic control valve spool restoration by composite galvanic coating

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Abstract. Methods of restoration of hydraulic control valve spools by galvanic coatings are considered. Methods for preparing parts for applying electroplated composite coatings in order to increase the adhesion strength of electrolytic iron to alloy steel are proposed. The optimal modes of electrolysis for obtaining high-quality galvanic coatings are selected, the composition of the electrolyte is substantiated and the optimal content of the dispersed phase in it is selected. The design features of the coating bath for active mixing of the dispersed phase in the electrolyte are substantiated. The parameters of the technological process for spools restoration by applying composite galvanic iron-based coatings are proposed.

1. Introduction
In the technical equipment of the agro-industrial complex of the Russian Federation, tractors and agricultural machines that are obsolete are currently involved. Large agro-industrial enterprises with sufficient financial resources acquire imported equipment, while small farms are forced to use existing equipment. In this regard, the problem of restoring and increasing the durability of parts, components and assemblies of the agricultural machinery in use is very urgent. The maintenance and servicing base still has a wide network of repair enterprises, the rhythmic work of which is hampered by the routine maintenance of spare service parts and components, machine tool aging and technological equipment. At repair bases, it is necessary to organize the restoration and manufacture of repair units of a wider range of products.

The range of remanufactured parts also includes parts for precision pairs of hydraulic units. As structural materials of plungers and spools, the chromium, chromium-nickel, chromonickel-tungstic steels with beryllium content are used.

Among the various methods for restoring these parts, the technological processes that leave unchanged the microstructure of the parts and increase their strength characteristics, should be chosen. The main task of these processes is to protect the remanufactured parts from corrosion. These methods include the restoration of parts by electroplating. Most often, parts of precision pairs are restored by aging and chromium plating. When comparing these processes, it should be noted that the chromium plating process is inefficient, even when using high-speed electrolytes and intensive processes in chromium plating practice [1–4]. When applying coatings of standard chromium plating electrolytes, it is difficult to achieve a constant concentration of components during the coating process, which often leads to heterogeneity of the formed layers.

A universal approach to the selection of a method for restoring parts was given by A.N. Batishchev [5]. He proposed to use the energy criterion $\varphi_\alpha$ for this purpose. It should be noted that the assessment
of the methods of restoring parts according to this criterion showed that the most rational of them is ironing (φs = 0.36). This testifies to the high efficiency of this galvanic method of restoring parts with low wear. To increase the wear resistance of parts, it is recommended to use composite galvanic coatings (hereinafter – CGC) or iron-based alloys [6, 7].

2. Materials and methods

Since CGC are designed to increase the resource of agricultural machinery parts, they can be used not only to restore parts that work during abrasive wear, but also to be applied to new or restored parts in various ways. The hardenable parts must be preliminarily brought to the nominal dimensions and washed with cold running water, –

after anode treatment in warm (313 ... 323K) running water for 20 ... 30 sec. Practical experience shows the time of the rinsing operation in warm water is closely related to the “current interruption” technique. If the flushing time is increased, the interruption time should be reduced and conversely.

The special hanging tools are used, designed to process 60 spools simultaneously. After degreasing, the hanging tools are fed for rinsing with hot running water, which should ensure complete removal of the solution remains from the parts. Then the parts are washed with cold running water, dismantled from the hangers for degrading, and installed in working devices. If a batch of degreased parts is gathered before the rest of the process, they should be stored after degreasing without rinsing. In this case, the washing is carried out before assembling the parts into the working device.

The hanging tool for coating can handle 12 spools simultaneously. Since it is necessary to apply coatings on finished parts, the surfaces that are not subject to restoration must be isolated from corrosive effects of electrolytes, for example, protective covers made of vinyl plastic or acid-resistant rubber. Since the spools are made of chromium steel, it is advisable to carry out their anode treatment in a 30% sulfuric acid solution at a current density of 60 ... 80 A/dm² for 30 ... 50 sec (a higher current density – Dc = 70 ... 80 A/dm² is used for etching spools) [7–9]. Along with 30% sulfuric acid for chromium steel, it is possible to recommend anode treatment in a saturated solution of aluminum sulfate (Al₂(SO₄) ∙ 18H₂O – 350 kg/m³), containing 20 kg/m³ of sulfuric acid [10]. The etching in this solution is carried out at Dc = 60 ... 70 A/dm², T = 291 ... 295 K for 45 ... 60 sec.

In an electrolyte tank for anode treatment with a volume of 1 m³, 5 hangers with spools are hung (when the tank is powered from a VAKR-6300/12 rectifier or other similar power). The parts are washed after anode treatment in warm (313 ... 323K) running water for 20 ... 30 sec. Practical experience shows the time of the rinsing operation in warm water is closely related to the “current interruption” technique. If the flushing time is increased, the interruption time should be reduced and conversely.

Composite coatings are applied with a chloride electrolyte of composition (kg/m³) of: FeCl₂ ∙ 4H₂O – 550 ... 600; white alumina of M14 type – 90 ... 100; pH = 0,7 ... 1,0 at a temperature of 313 K. Coating begins with holding the part in the electrolyte without current for 30 ... 45 sec, which is quite enough to equalize the temperature difference between the solution and the part, and activate the anodically processed surface. The deposition of CGC is carried out at an initial current density Dc = 1 ... 1.5 A/dm² for 5 ... 7 minutes, then the current density is increased to 5 ... 7 A/dm² and the process is carried out for 5 ... 7 minutes, followed by a gradual increase in the current density, the working density (20 ... 25 A/dm²). The electrolysis time at the working current density in applying coatings
with a thickness of 0.40 ... 0.75 mm is 2.0 ... 3.5 h. The electrolyte acidity during the deposition of CGC is adjusted within pH = 0.7 ... 1.0 using diluted hydrochloric acid on a 1:5 ratio. To reduce the electrolyte oxidation rate during electrolysis breaks, it is acidified to pH = 0.3 ... 0.5, and the low-carbon steel plates are left in it.

If it is necessary to restore Fe (III), the electrolyte is processed under current with an increased of 3 ... 5 times of the cathode surface in comparison with the anode and current density of 4 ... 8 A/dm².

3. Results and discussion

The spools operating under conditions of hydroabrasive wear and made of chromium steel, heat-treated to a hardness of HRC = 56 ... 63, in accordance with the previously given data, should be restored with coatings containing dispersed phase (hereinafter – DP) in an amount of 15 ... 30% (vol.). Therefore, the concentration of the DP in the suspended electrolyte (hereinafter – SE) can be reduced to 60 ... 80 kg/m². The initial current density considering the material of the part should be reduced to 0.75 ... 1.0 A/dm².

The working volume of the tank for ironing (1m³) allows its loading with hangers with a total area under the covering of 75 ... 80 dm², at a volumetric current density of 1.5 ... 2.0 A/dm³. The main factor that ensures the obtaining of high-quality CGC with a uniform content of solid particles in the coating, regardless of the location of the part relative to the tank walls, is ES mixing. The studies on determining the impact of the stirring type on the uniformity of DP distribution in the suspended electrolyte and coating showed that mechanical stirring using one stirrer, regardless of its rotation speed, did not provide the required distribution of particles in the SE and CGC. At a stirrer rotation speed of the order of 3 s⁻¹, the upper electrolyte layer (10 ... 15 mm) had practically no solid particles in its composition.

Two stirrers with their synchronous rotation also did not allow achieving the desired quality of SE, while their counter-rotation at a rate of about 12.5 s⁻¹, ensured sufficient uniformity of DP distribution in the electrolyte, but solid particles were not evenly included in the coating. A further increase in the rotation speed reduced the number of inclusions in the coatings, probably due to the particles washing off from the cathode surface by the SE flow.

The installation of four mixers with their counter and synchronous rotation made it possible to achieve a more uniform distribution of particles in the SE and CGC. Thus, the counter-rotation of the mixers located diagonally of the tank, at a stirring speed of 12.5 s⁻¹, ensured the uniformity of the DP distribution in the SE at the level of 20% deviation from the average value. And at a stirrer rotation speed of 25 s⁻¹, the deviation was about 13%. At the same time, the particles were more intensively washed off by the flow, and their content in the coating was less than that required for a significant increase in the wear resistance of the CGC.

The best in terms of the uniformity of DP distribution in the electrolyte turned out to be jet mixing with the supply of a jet from the mixer along the reflector under the perforated bottom-partition of the tank. In stirring at a rate of 25 s⁻¹, the dispersed phase was diffused throughout the entire volume of the tank, and was rather evenly included in the iron electrolytic deposits. The deviation in the content of DP in the CGC along the height and length of the samples simulating the full height and width of the hanger was about 10 ... 15%. An increase in the stirring rate to 50 s⁻¹ led to a decrease in the DP content in the coating due to the particles washout.

Jet mixing turned out to be less energy-intensive, does not require special gearboxes to reduce the engine speed, and made it possible to quickly transfer particles from the day of the electrolyzer to a suspended state after electrolysis breaks. Therefore, in industrial practice, the use of jet mixing is preferable. Thus, to obtain a uniform SE, it is possible to recommend jet mixing when the SE is supplied through a special compartment under the perforated bottom of the tank at a stirrer rotation speed of 25 s⁻¹.

After the coating has been applied, the parts are washed and neutralized in accordance with the usual requirements of ironing technology. For neutralization, a NaOH solution (60 ... 80 kg/m³) is used at a temperature of 338 ... 348 K for 5 ... 10 minutes. Parts that have undergone neutralization are
washed with hot water, dried and controlled by the quality of the applied coating. If necessary, it is passivated in a solution containing 15 ... 20 kg/m$^3$ of triethanolamine and 5 ... 7 kg/m$^3$ of sodium nitrite, and for long-term storage it is preserved with oils and special papers.

The composition of the ironing line is determined by the technological operations of the process, and includes a set of tanks for electrolytic degreasing, hot washing, cold washing, anode treatment, ironing, and neutralization. In addition to the tanks, the line is equipped with a monorail lifting device (Q = 0.25 t), a reserve tank, a drying box, a mounting table, a rack for equipment, a tank control post, a table for controlling coatings, a unit for filtration and pumping solutions.

It should be noted that for the spools finishing treatment, restored with CGC, it is possible to use the existing recommendations for the “pure iron” on centerless grinding machines of 3М184А, PC12, PC12S types. However, considering the increased hardness of CGC (due to the inclusion of a filler), instead of abrasive disk of 1 500x150x305 25A 40-P CM1 K6 type, the disks on a carborundum or cubonite base with a soft or medium soft bond, should be used.

The disk rotation speed should be at least 30 ... 35 m/s, and the supply of coolant-lubricant should be increased, in comparison with conventional grinding, 1,5 times. In this case, a flat and wide tip should be used, the width of which should be at least 1,25 times the width of the circle.

4. Conclusion

On the basis of the above recommendations, a technological process for the restoration of hydraulic control valve spools with iron-based composite coatings was developed for repair production.

To restore parts subject to hydroabrasive wear, it is possible to use galvanic coatings based on iron alloys with the inclusion of white alumina as a filler, as well as composite coatings with subsequent laser treatment, which have a number of advantages over, in particular, plasma spraying [11].

References

[1] Mironov V V 2015 Restoration of plungers of in-line diesel fuel pumps by applying galvanic gas-phase chromium, abstract of candidate dissertation (Ryazan, 2001) 12 p
[2] Yilbas B S, Patel F and Karatas C 2015 Laser Surface Engineering (Waugh J.L.G. Woodhead Publishing) pp 97-105
[3] Semenova E E 2004 Technology of restoration and hardening of surfaces of spools of hydraulic boosters of steering by galvanic gas-phase chromium plating, candidate dissertation (Penza, 2004) 170 p
[4] Ionov P A 1999 The choice of optimal modes for the restoration of worn-out parts by electrospark surfacing: By the example of the valve of the hydraulic distributor R-75, candidate dissertation (Saransk) 198 p
[5] Batishchev A N 1992 Justification of a rational way to restore parts Mechanization and electrification of agriculture 9(12) 30-31
[6] Kisel Yu E 2001 Increasing the durability of high-wear parts of agricultural machinery with composite electrochemical coatings based on iron alloys, abstract of dissertation (Moscow) 18 p
[7] Kisel Yu E, Kisel P E, Guryanov G V and Yudina E M 2009 Scattering of micro-hardness of electroplated coatings Proc. of the Kuban State Agrarian University 19 219-222
[8] Melkov M P 1971 Solid rest of automotive parts (Moscow: Transport) 224 p
[9] Guryanov G V and Kisel Y E 2006 Antifriction and wear-resistant electrochemical coatings, monograph (Bryansk)
[10] Shaidullin A M 1990 Increasing the adhesion strength of electrolytic iron with alloy steel when restoring parts of agricultural machinery, abstract of dissertation (Chisinau) 19 p
[11] Yudina E M, Guryanov G V, Kisel Yu E and Lysenko A N 2015 Laser hardening of composite electrochemical coatings Rural mechanic 2 38-39