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Some Recommendations for the Application of Powder Alloys in the Restoration of Agricultural Machinery Parts by Plasma Surface and Spraying Methods

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Annotation: The practice of using plasma surfacing and spraying in agricultural and engineering production for the purpose of restoring and hardening parts of agricultural machinery has shown a relatively high efficiency of these processes. To further improve the efficiency of these methods of restoring and hardening parts, far from all the possibilities and reserves have been used, which include a reduction in consumption and the use of cheaper working gases; expansion of the range of remanufactured parts, due to the combined use of various powder filler materials.

Keywords: plasma surfacing, spraying, self-fluxing, iron-based powder, optimal composition, wear resistance, fluidity of powder, chemical composition, self-fluxing efficiency.

The powder alloy for surfacing must first of all meet its intended purpose - obtaining a deposited layer (coating) with the necessary service properties. However, obtaining a high-quality deposited layer is associated with a number of additional requirements for the powder alloy, the possibility of using the chosen method of coating deposition, as well as those related to their particle size distribution, fluidity, and gas saturation.

The studied iron-based powder hard alloys Sormite 1, US-25, FBKh-6-2, and T-590 are prepared by spraying liquid metal with water or compressed gases, or by mechanical crushing. Powdered alloys are usually supplied in plastic or metal cans, hermetically sealed. The granule metric composition of the powder is quite variety, so it was of interest to identify the most desirable, from the point of view of manufacturability, size of the powder fraction for surfacing. All alloys selected for the study were thoroughly dried at a temperature of 200 ^{0}C. The powders that passed the sieve analysis were subjected to the test.

Fluidity is one of the important characteristics of a powder. Fluidity was determined by the ratio of powder weighing (in grams) to the powder flow time (per second).

The results of experiments on the flow ability of powdered hard alloys based on iron, shown in Table 1, show that an increase in the size of the fraction significantly worsens the flow ability of the material.

Figure 1. Fluidity of powdered carbide alloys based on iron

Granulemetric composition, (mm)	Fluidity, (g/s)				
	sormite	US-25	FBH-6-21	T-59OP	PG-L101
0,25…0,315	4,2	4,0	5,0	2,4	3,4
0,4…0,5	3,41	3,20	2,42	1,78	2,20
0,56…0,7	1,70	1,50	1,67	0,60	1,10

Other important factors affecting the fluidity of the powder is the chemical composition, the content of dissolved gases.

In this regard, the qualitative and quantitative compositions of materials, as well as gases, were determined (Table 2)

Figure 2. Quality and quantity composition of materials

Material	Chemical composition, (%)					
	C	Si	Cr	Mп	Ni	B
Sormite	3,42	3,09	27,57	0,84	2,78	-
US-25	4,85	2,08	41,06	0,78	1,36	-
T-59OP	5,10	2,54	46,00	0,65	-	2,0
FBH-6-2	4,00	2,28	33,97	1,98	-	1,35
PG-L101	5,70	6,07	55,83	3,26	3,26	-

The determination of chemical elements was carried out in accordance with GOST 16412.0-70. Gases were determined by the vacuum melting method.

Figure 3. Chemical elements

Material	Gas content, (%)		
	$[O] \times 10^{-2}$	$[N] \times 10^{-3}$	$[H] \times 10^{-3}$
Sormite	8,2	3,8	1,7
US-25	13,9	5,9	0,4
T-59OP	5,4	3,2	1,2
FBH-6-2	13,1	8,3	3,4
PG-L101	13,0	6,7	0,9

The presence of gases in the material significantly complicates the surfacing process. As various studies have shown, the oxygen content in iron-chromium-carbon alloys intended for gas and plasma surfacing should not exceed 0.06-0.08%.

The oxygen content in powders of small fractions, as a rule, is higher, since a decrease in grain size leads to an increase in the specific surface area, and, consequently, an increase in the content of the oxide film.

Powders with a coarse granule metric composition contain significantly less gas. However, an increase in the fraction reduces the fluidity; as a result, the pulsating consumption of powders sharply worsens the quality of the deposited layer.

As it was established by experimental verification, when surfacing powders are fed into the plasma torch, powders having a spherical shape with a granule metric composition of 0.4 ... 0.5 mm have the best flow properties. Powders obtained by spraying liquid metal with water or an inert gas satisfy all the requirements of plasma surfacing. These powders have the best fluidity.

However, of the iron-chromium-carbon alloys, only sormite alloy is currently produced by spraying. All other cast powders were obtained by crushing, which affected their technological properties. At the same time, a certain size of the fraction - 0.5 mm satisfies all the requirements chosen for the analysis of alloys.

It has been established from literary sources that in order to ensure self-fluxing of iron-based powders, it is necessary to add aluminum powder to them. In this case, the working gases for plasma surfacing and spraying can be argon or nitrogen.

Analytical calculation of the required amount of introduced aluminum is very complicated and hardly necessary. Therefore, in this work, the question of the fundamental possibility of reducing the cost of protective argon by introducing active additives was solved. As was established from the literature, even with a minimal aluminum addition of about 1%, good bead formation was observed.

Nevertheless, the quality of the deposit did not always satisfy a number of requirements. Therefore, it was decided to experimentally determine the composition, considering that the optimal amount of aluminum corresponds to the minimum additive that provides a continuous, non-porous seam. As samples, surfacing of compositions with different aluminum content from 1 to 12% was made.

The required amount of aluminum according to the results of the research was established from the diagrams (Fig. 1).

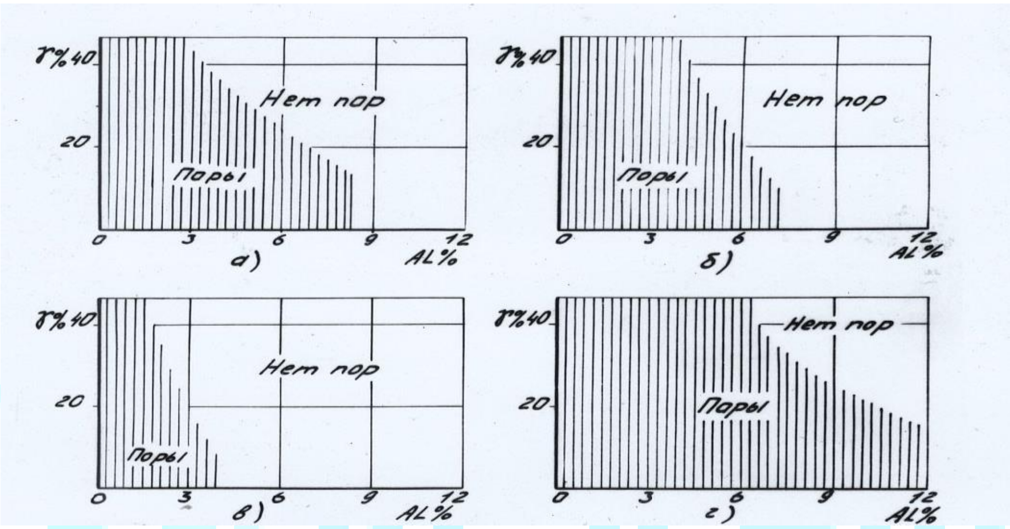

Fig. 1. Diagrams of the influence of the aluminum content and the mixing of the weld pool on the porosity of the overlays.

a- sormite; b-US-25; v-FBH-6-2; g-T-59OP

The best compositions studied were: Sormite + 6...8% Al; US-25+6…7% Al; FBKh-6-2 + 3% Al; T-59OP+10…12% Al.

The hardness of the overlays changed with an increase in the percentage of aluminum (Fig. 2). Moreover, at small values it decreased and after a certain minimum it increased monotonically.

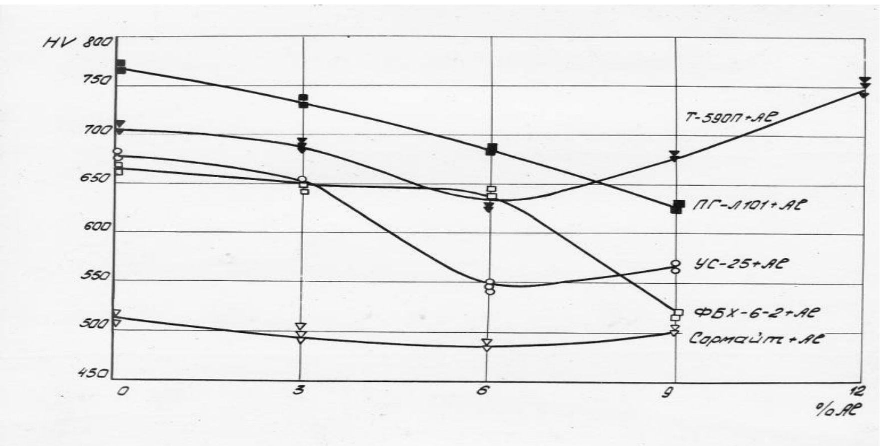

Fig. 2. Graph of the change in the hardness of the overlays on the aluminum content

The study of the use of iron-based hard powder alloys for plasma surfacing and spraying is devoted to a number of works in which, in particular, in Wagner's work, the role of gas shielding is shown, and the best protective media are determined. It is noted that one or another gas affects the formation of the bead in different ways, and in some cases, the properties of the surfacing and spraying itself change to a significant extent.

Therefore, it was of some interest to compare the results of the obtained powder compositions with surfacing produced in gas shielding and without it. The quality of self-fluxing was evaluated by the waste of the main alloying elements, the presence of pores, cracks, and non-fusion. The waste of the main elements is characterized by the data given in table 4.

Figure 4. Waste of the main elements

Type of protection	Chemical composition in (%)					
	C	Si	Cr	Mn	Ni	Al
Argon	2,50	2,48	21,47	0,55	1,04	1,37
Nitrogen	1,9	1,69	14,82	0,45	2,17	1,16
Carbon dioxide	2,05	1,69	14,67	0,40	2,15	0,95
Without gas protection	1,62	1,47	13,96	0,48	1,77	1,78
Raw material	3,42	3,09	27,57	0,84	2,78	6…8

As can be seen from Table 4, the lowest loss of elements was obtained during surfacing in argon. As for surfacing in carbon dioxide and nitrogen, in these cases the burn-out of the elements was approximately within the limits obtained even without gas shielding, in addition, pores were found during surfacing in nitrogen.

Cracks and non-fusion were absent in all variants of surfacing. The optimal amount of aluminum additive for the entire group of investigated alloys is sormite + 6 ... 8%; US-25+6…7%; Al; FBKh-6-2+ 2…3% Al; T-59OP +10…12% Al; PG-L101 +2…3% Al.

Checking the effectiveness of self-fluxing in comparison with protection in gaseous media (Ar; N_2; CO_2) showed that the quality of the deposited layer in the developed compositions is not inferior to surfacing in argon. The most important criterion for the quality of the deposited metal is its wear resistance. Therefore, when choosing an alloy and the method of its surfacing, one should pay attention to the result of the entire process - obtaining the desired properties of working surfaces.

At the same time, the surfacing process itself, which is associated with a number of chemical reactions and structural transformations, can lead to a change in the properties of the coating.

In the process of surfacing, the depth of penetration can change, dilution of the surfacing metal with the base material and, as a result, some decrease in the hardness of the coatings, which to a certain extent affects wear resistance.

From a review of literary sources, it has been established that at present there are not enough experimental data evaluating the effect of plasma surfacing on the main characteristic, its abrasion resistance. In addition, it is of particular interest to reveal such a relationship in the developed self-fluxing compositions.

Friction and wear tests can be attributed to one of the most complex and time-consuming processes. In this regard, M.M. Khrushchev believes that the creation of a universal laboratory method for testing wear is impossible, and in research it is necessary to strive to use the method that most closely imitates the operating conditions of the material during operation.

Our tests were based on a comparative method, in which the wear resistance of overlays was compared with the wear resistance of a standard of hardened steel 45 (HRC 45), which corresponds to the properties of the steel most used in agricultural engineering.

The results of wear testing of overlays are shown in Figure 3.

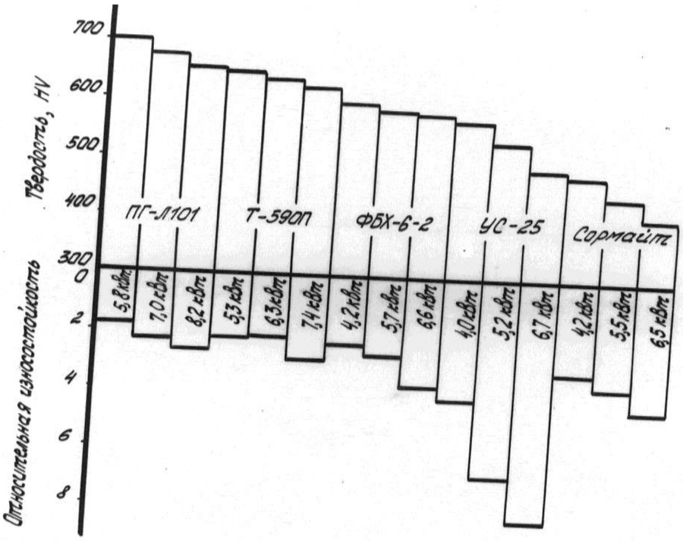

Fig. 3. Diagram of relative wear resistance and hardness of overlays

The best wear resistance was obtained for US-25 + Al and Sormite + Al materials deposited in modes with significant penetration.

Studies aimed at reducing the cost of materials for surfacing and spraying were carried out by mixing nickel and iron-based powders in certain ratios (Table 5). Experiments have shown that when spraying and surfacing mixtures, the quality of coatings, their physical and mechanical properties are even higher than when using only chromium-nickel powder.

It should be noted that the cost of iron-based powders such as sormite are significantly lower than chromium-nickel powders. The hardness of powder mixtures is HRC 49-53. Wear resistance is up to 5 times that of steel 45 hardened to HRC 54-56.

Fatigue strength increases by 30-45%, at the same time, when using one powdered chromium-nickel alloy (PG-KhN80SR2), the fatigue strength decreases by 5-10% made it possible to reduce the content of the latter in the mixture to 20% and thereby significantly reduce the cost of the coating material.

Figure 5. Composition of powder mixtures

Conventional designation of the powder mixture	The composition of the powder mixture
PS-1	50% PG-KhN80SR2
	50% Sormite-1
PS-2	50% CISN 60
	50% Sormite-1 (PG-S1)
PS-3	50% PG-KhN80SR2
	50% FBH-6-2
PS-4	30% PG-KhN80SR3
	70% Сормайт-1
PS-5	20% ПГ-ХН80СР4
	80% Сормайт-1

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