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RESTORATION OF WORN SURFACES OF PARTS BY PLASMA SPRAYING OF COMPOSITE COATINGS

The article describes the technology for restoring and strengthening worn surfaces of parts by plasma spraying of composite coatings made from m-rolls. The composition of the powders was selected taking into account the following premises. The oil-retaining ability of the applied coatings is ensured by the Ni, Cr, Fe component. The number of ion-dipole bonds between metal ions and oil dipole groups increases, the oil-retaining ability of the metal surface and its wear resistance increase. The hardness of the applied coatings is ensured by carbide inclusions. At the same time, the degree of deformation of the friction surface of the coatings and the area of actual contact of the run-in tribological interfaces decreases. Conditions are created to improve the anti-friction properties of friction pairs. The combination of components in powders ensures the formation of sawn coatings with a friction-friendly structure of hard carbide inclusions distributed in a relatively soft matrix. Recommendations are given on optimal plasma spraying modes and areas of application of restored parts. The structure of coatings obtained using optimal technology consists of a solution (binder, matrix) and carbide inclusions. This structure is characterized by oil-retaining ability and hardness, creating the prerequisites for wear resistance and improving the anti-friction properties of the surface restored by spraying. Oil-holding capacity is ensured by the presence of nickel, iron, carbon, chromium, which determine the effective interaction of the lubricant and coating due to forces of physical and chemical nature. Increased hardness of the layers is provided by the carbide phase. The surface of such a coating is characterized by significant fluctuations in hardness with low values in certain extended areas formed mainly by the binder material.

***Key words**: plasma spraying processes, powder compositions, plasma spraying in air, metal alloys based on m-rolls, performance characteristics, morphology and structure.*

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ВОССТАНОВЛЕНИЕ ИЗНОШЕННЫХ ПОВЕРХНОСТЕЙ ДЕТАЛЕЙ ПЛАЗМЕННЫМ НАПЫЛЕНИЕМ КОМПОЗИЦИОННЫХ ПОКРЫТИЙ

В статье описана технология восстановления-упрочнения изношенных поверхностей деталей плазменным напылением композиционных покрытий из м-кроллей. Состав порошков выбран с учетом следующих предпосылок. Маслоудерживающая способность наносимых покрытий обеспечивается компонентом Ni,Cr,Fe. Возрастает количество ион-дипольных связей между ионами металла и дипольными группами масла, повышается маслоудерживающая способность поверхности металла и его износостойкость. Твердость наносимых покрытий обеспечивается карбидными включениями. При этом уменьшается степень деформации поверхности трения покрытий и площадь фактического контакта приработанных трибосопряжений. Создаются условия для улучшения антифрикционных свойств пар трения. Сочетание в порошках компонентов обеспечивает формирование напиленных покрытий с благоприятной для трения структурой из твердых карбидных включений, распределенных в относительно мягкой матрице. Даны рекомендации по оптимальным режимам плазменного напыления и области применения восстановленных деталей.

Структура полученных по оптимальной технологии покрытий состоит из раствора (связующего вещества, матрицы) и карбидных включений. Эта структура характеризуется маслоудерживающей способностью и твердостью, создающими предпосылки износостойкости и улучшения антифрикционных свойств восстановленной напылением поверхности. Маслоудерживающая способность обеспечивается наличием никеля, железа, углерода, хрома, которые обусловливают эффективное взаимодей-

ствие смазки и покрытия за счет сил физической и химической природы. Повышенная твердость слоев обеспечивается карбидной фазой. Для поверхности такого покрытия свойственны существенные колебания твердости с невысокими ее значениями на отдельных протяженных участках, сформированных в основном связующим материалом

Ключевые слова: *процессы плазменного напыления, порошковые композиции, плазменное напыление на воздухе, металлические сплавы на основе м-кролей, эксплуатационные характеристики, морфология и структура.*

1. Introduction

The processes of friction and wear of parts significantly affect the performance of machines and units. When machines fail and are repaired, the problem of replacing worn parts made of expensive alloy materials often arises. To solve this problem, various technologies are increasingly being used to restore the size and shape of worn surfaces by applying compensating coatings that simultaneously perform protective functions. The experience of the CIS countries, Switzerland, Germany, Japan and others indicates that an effective way to apply wear-resistant protective coatings is plasma spraying [1-3]. Its main advantage is the ability to spray materials of various compositions and properties, the number of which is constantly increasing. In this case, research into the technology of plasma deposition of the created materials is necessary. The purpose of the proposed research is to develop a technology for restoring the size and shape of worn parts by plasma spraying of composite coatings [5-10]. The research concerns coatings on parts operating under friction conditions with boundary, imperfect lubrication. Such conditions are typical for many critical tribo-interfaces, for example, an internal combustion engine. The object of research is coatings obtained by plasma spraying of NiCrAlY-40% TiC and FeCrAlY-40% TiC composite powders. The composition of the powders was selected taking into account the following prerequisites [2]:

- the oil-retaining ability of the applied coatings is ensured by the Ni, Cr, Fe component. The number of ion-dipole bonds between metal ions and oil dipole groups increases, the oil-holding capacity of the metal surface and its wear resistance increase;
- the hardness of the applied coatings is ensured by carbide inclusions. At the same time, the degree of deformation of the friction surface of the coatings and the area of actual contact of the run-in tribo-couplings decreases. Conditions are created to improve the antifriction properties of friction pairs;
- the combination of components in powders ensures the formation of sawn coatings with a structure favorable for friction from hard carbide inclusions distributed in a relatively soft matrix.

2. Research methodology

When developing a technology for restoring the size and shape of worn surfaces by plasma spraying of composite coatings, the following technological parameters were optimized: plasmatron arc current; spraying distance; flow rate of plasma-forming gas-nitrogen; consumption of transport gas - nitrogen. The optimization criteria are the coefficient of use of sprayed powder materials (CPM) and the structure of the applied coatings. The utilization coefficient makes it possible to estimate the number of applied particles that did not form a coating due to insufficient ductility and flight speed. This, in turn, makes it possible to evaluate the degree of particle heating, distance and other spraying modes. Optimized modes are those with maximum values of the instrumentation factor, which correspond to increased cohesive and adhesive strength of coatings. The coefficient of powder utilization was determined on samples in the form of a steel sheet measuring 200x200x2 mm, which had undergone jet-abrasive preparation, cleared of abrasive and having a clearly marked spraying zone of 80x80 mm in the center. Jet-abrasive preparation was carried out with grains of solid electrocorundum 22000-26000 MPa. The surface roughness of the sample after preparation should be Ra 12.5-25 µm. In parallel, a series of experiments was carried out with the application of coatings with a thickness of 0.4-0.5 mm on flat steel samples measuring 30x15x3 mm. At the same time, the structure of the coatings was studied when changing the modes of their plasma spraying. The structure was analyzed on thin sections of the cross section of the deposited layers using a Nanolab-7 scanning electron microscope (Germany) and a Unimet light microscope (Japan). The analysis took into account that to increase the cohesive strength and wear resistance of coatings, a dense structure of sawn materials is required. Plasma spraying was carried out in air, the particle sizes of the applied powder materials were in the range of 40-100 microns. To increase the adhesion strength of the coatings, a sublayer of NiCr adhesive was preliminarily applied to the steel substrate. Sputtering was carried out using a UPU-3D installation.

3. Research results and discussion

The technological parameters for the restoration of worn parts by plasma spraying of composite coatings, optimized based on research results, are presented in Table. 1 и on figure 1-4. The structure of coatings obtained using optimal technology consists of a solution (binder, matrix) and carbide inclusions, Fig. 5. This structure is characterized by oil-retaining ability and hardness, which create the prerequisites for wear resistance and improved anti-friction properties of th even forces of physical and chemical nature. The increased hardness of the layers is provided by the carbide phase. The surface of such a coating is characterized by significant fluctuations in hardness with low values in certain extended areas formed mainly by the binder material. When the protective coating is used under friction conditions, these areas are easily deformed by the tribo-coupling counterbody with the formation of closely adjacent conjugate zones, which are prone to micro-contact seizure and scuffing. The performance of the wear-resistant coating and the friction unit as a whole decreases.

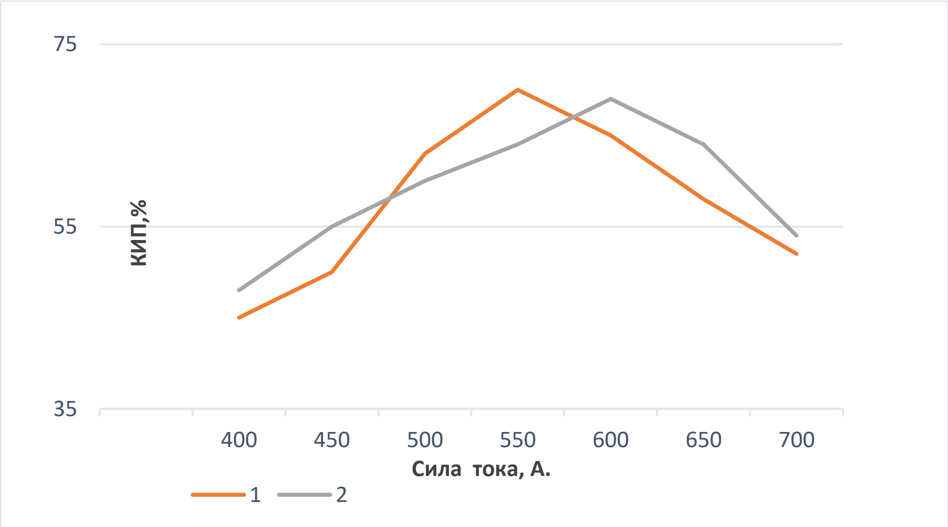


Figure 1. The influence of the values of the current supplied to the plasma torch (I, A) on the obtained KIM indicators, % for powder materials 1- NiCrAlY -40% TiC, 2-FeCrAlY-40% TiC (powder fraction 50...63 µm, L=110 mm, R por.=4.0 kg/hour, RN2 =55 l/min).

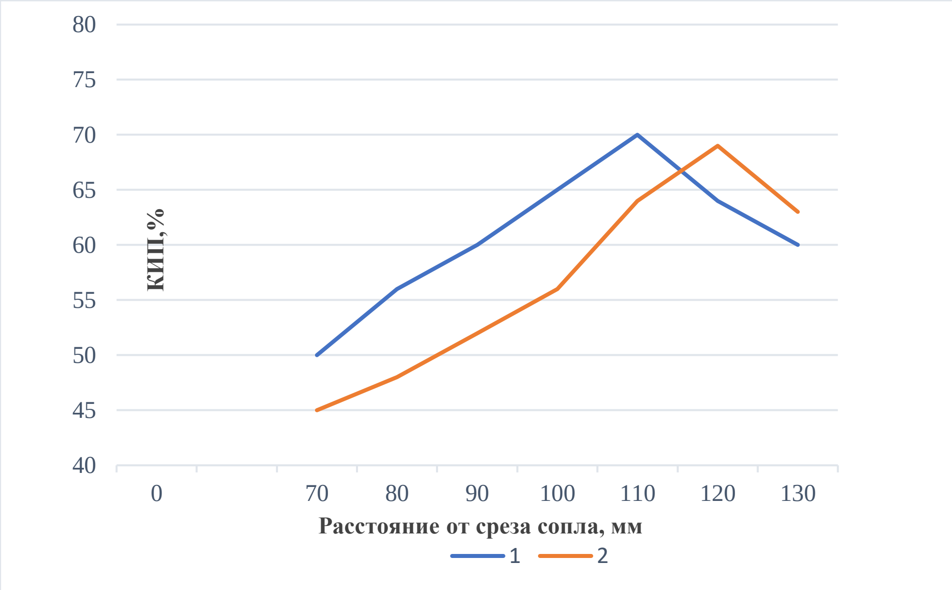


Figure 2. The obtained dependence of the values of the KIP, % on the applied distance of the spraying process L, mm for the applied powder material 1- NiCrAlY -40 % TiC (powder fraction 50...63 µm, I=550 A; R por.=4.0 kg/hour, RN =55 l/min), 2-FeCrAlY-40 % TiC (powder fraction 50...63 µm, I=600 A, R por.=4.0 kg/hour, RN =60 l/min).

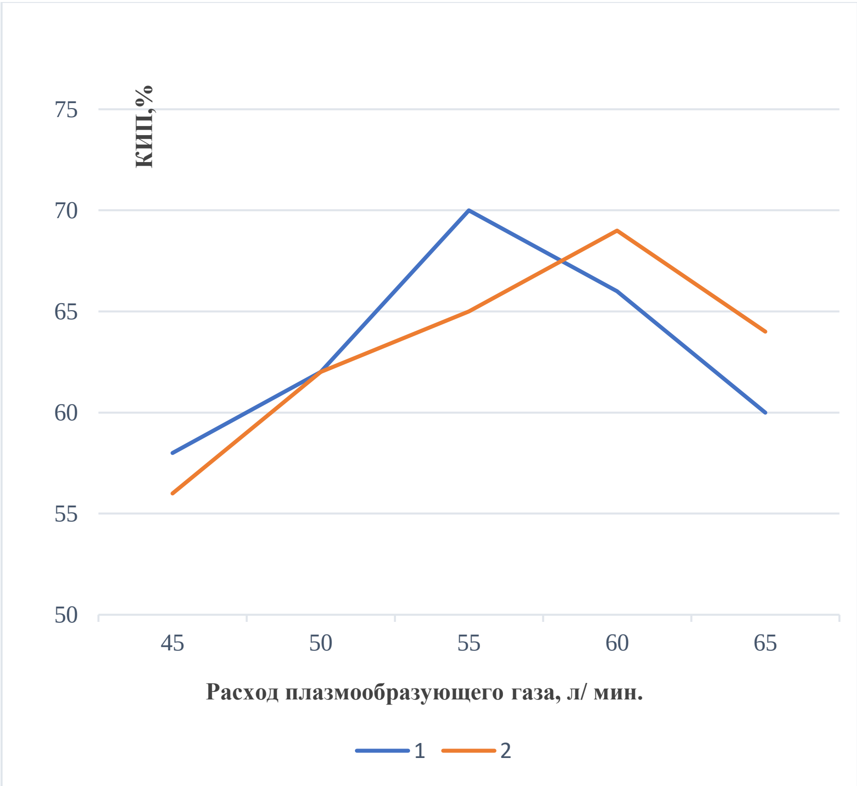


Figure 3. The obtained values of the instrumentation and control, % of the consumption of the plasma-forming gas nitrogen for the applied powder material 1- NiCrAlY -40 % TiC (powder fraction 50...63 µm, I=550 A; R por.=4.0 kg/hour, L=110 mm), 2-FeCrAlY-40 % TiC (powder fraction 50...63 µm, I=600 A, R por.=4.0 kg/hour, L=120 mm).

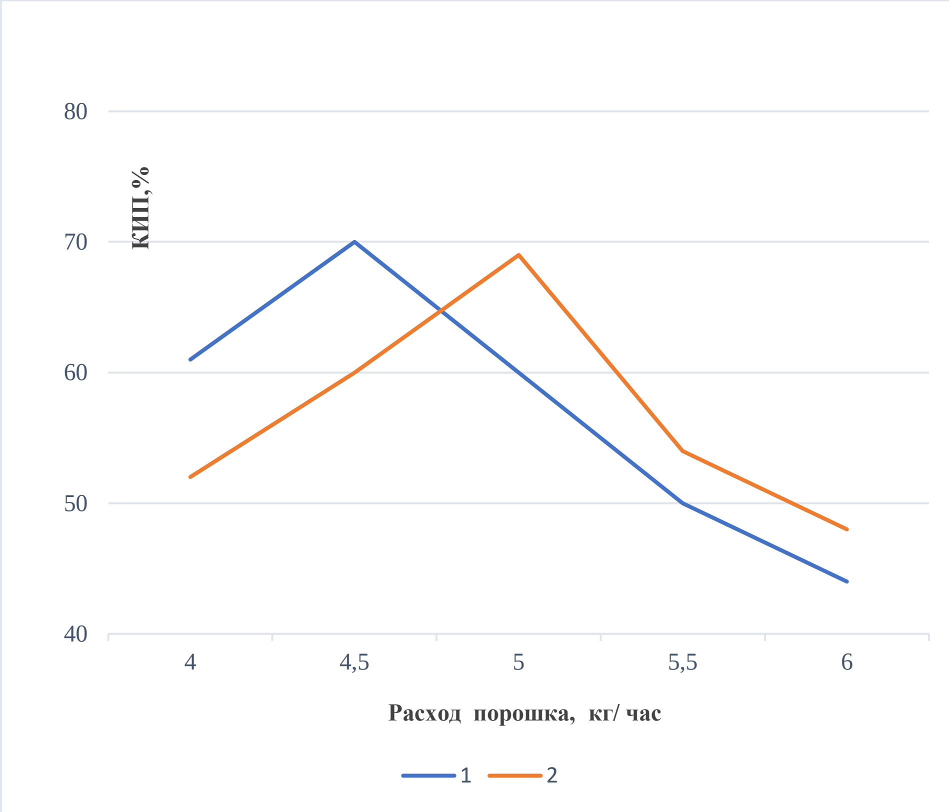
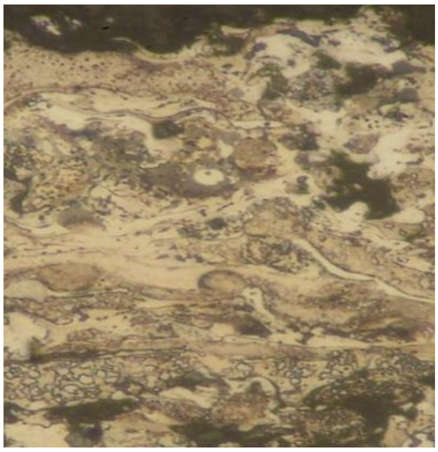


Figure 4. Obtained values of the instrumentation and control, % of powder consumption for the powder material used in the spraying process: 1- NiCrAlY -40 % TiC (powder fraction 50...63 μm, I=550 A; R N2=55 l/min, R por.=4.5 kg/hour, L=110 mm), 2-FeCrAlY-40 % TiC (powder fraction 50...63 μm, I=600 A, R por.=5.0 kg/hour, R N2=60 l/min, L=120 mm).

Table 1. Technological parameters for restoring worn partse surface restored by spraying.

Sprayed powder material	Spray modes				
	Plasmatron arc current, A	Arc voltage, V	Consumption of plasma-forming gas - nitrogen, l/min	Consumption of sprayed powder, kg/h	Spraying distance, mm
NiCrAlY -40 % TiC	550	55	55	4,5	110
FeCrAlY-40 % TiC	600	65	60	5,0	120

a



b

Figure 5. Structures obtained after plasma spraying at different values of plasma-forming nitrogen gas: a-NiCrAlY -40% TiC, b-FeCrAlY-40% TiC.

The photograph of a thin section of the coating is characterized by an increased number of dark areas of complex shape, which are zones of chipping of the carbide phase and pores, Fig. 1. This is due to the technology of manufacturing sections and an excess of the carbide phase in the coatings.The surface of such a coating is characterized by significant fluctuations in hardness with low values in certain extended areas formed mainly by the binder material. When the protective coating is used under friction conditions, these areas are easily deformed by the tribo-coupling counterbody with the formation of tightly adjacent mating zones, which are prone to micro-contact seizure and scuffing. The performance of the wear-resistant coating and the friction unit as a whole decreases. The photograph of a thin section of the coating is characterized by an increased number of dark areas of complex shape, which are zones of chipping of the carbide phase and pores, Fig. 1. This is due to the technology for preparing sections and the excess of the carbide phase in the coatings.Laboratory tests on an Armsler type machine confirmed the wear resistance of the coatings under consideration under boundary lubrication conditions. The resulting compositions are characterized by maximum wear resistance and antifriction properties. For example, the wear resistance of such coatings is 2-3 or more times higher than the same parameter for steel 45 with a hardness of 484-544 HV (48-52 HRC).

3. Conclusion

A technology has been developed for restoring and strengthening worn surfaces of parts by plasma spraying of composite coatings. At the same time, the technological parameters of applying materials in the form of initial composite powders NiCrAlY-40% TiC and FeCrAlY-40% TiC were investigated and optimized. The optimization criteria were the utilization rate of the sprayed powder and the coating structure. The following optimal spraying modes have been established: plasmatron arc current – 550-600 A; spraying distance – 110-120 mm; consumption of plasma-forming gas – nitrogen – 55-60 l/; consumption of sprayed powder – 4.5-5.0 kg/h. The coatings are characterized by maximum wear resistance, which is 2-3 or more times higher than the same parameter for steel 45 with a hardness of 484-544 HV (48-52 HRC). It is advisable to use the developed coating technology for the restoration and strengthening of machine parts operating under friction conditions with boundary, imperfect lubrication.

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