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PRODUCTION OF GRADIENT-LAYERED COMPOSITE MATERIALS BY THE METHOD OF INDUCTION SURFACE

Masanskii O.A.[1], Tokmin A.M.[1], Kazakov V.S.[1], Gilmanshina T.R.[2], Lytkina S.I.[1], Khudonogov S.A.[3], Kaposko I.A.[1] and Stankeev V.V.[4]
[1]Department of Materials Science and Materials Processing Technologies, Polytechnic Institute, Siberian Federal University, Krasnoyarsk, Russia
[2]Department of Engineering Baccalaureate CDIO, Institute of Non-Ferrous Metals and Materials Science, Siberian Federal University, Krasnoyarsk, Russia
[3]Department of Applied Mechanics, Polytechnic Institute, Siberian Federal University, Krasnoyarsk, Russia
[4]Department of Innovative Shipbuilding and shelf development technology, Sevastopol state University, Sevastopol, Russia
E-Mail: Omasansky@sfu-kras.ru

ABSTRACT

Modernization and development of modern production is associated with the introduction of new generation equipment and innovative technological solutions. Increasing the wear resistance and durability of products subject to various types of wear during operation: abrasive, shock-abrasive, shock, cavitation, and others, requires the creation of new materials that provide high wear resistance. Obtaining composite materials with a gradient-layered structure makes it possible to form a given set of properties, due to the control of the processes of structure formation, leading to the production of maximum nonequilibrium structures which, under certain conditions, can provide a combination of the required set of properties. The use of induction heating technology allows the use of materials of a given composition to form the required set of properties, taking into account the nature of wear. The main difference between such heating and heating by external heat sources is that heating occurs directly in the metal due to the electromagnetic field created by the inductor. The aim of this work is to obtain composite materials with a gradient-layered structure by induction surfacing with a given set of physical and mechanical properties. In the course of the work, a composite material with the required structure and properties was obtained using metal powders of a given composition. The complex of studies carried out showed that the use of a surfacing charge consisting of 85% PGS-27 metal powder and 15% PR-Ni73Cr16Si3B3, the chemical composition of which is given in Table-1, makes it possible to increase the wear resistance of the material under the influence of shock and shock-abrasive loads by 10 15%, due to the combination of high hardness (55-57 HRC) with sufficient toughness, which is provided by the formation of a high-alloyed nickel austenitic matrix of the deposited layer.

Keywords: composite materials, induction heating, wear resistance.

INTRODUCTION

Modernization and development of modern production is associated with the introduction of new generation equipment and innovative technological solutions. Increasing the wear resistance and durability of products subject to various types of wear during operation: abrasive, shock-abrasive, shock, cavitation, and others, requires the creation of new materials that provide high wear resistance. Obtaining composite materials with a gradient-layered structure makes it possible to form a given set of properties, by controlling the processes of structure formation leading to obtaining the most nonequilibrium structures which, under certain conditions, can provide a combination of the required set of properties [1-6].

It is known that the use of induction technology makes it possible to control the processes of structure formation of the material, and, therefore, makes it possible to ensure the formation of a given set of physical and mechanical properties, depending on the nature of wear, using the weld mixture of the same composition [4, 6, 7-13].

Therefore, the purpose of this work is to obtain composite materials with a gradient-layered structure by induction surfacing with a given set of physical and mechanical properties.

MATERIAL AND METHODS

Based on the results of the analysis of materials used to increase wear resistance under various operating conditions, to obtain a composite material, the composition of the surfacing charge was determined, consisting of 85% PGS-27 metal powder and 15% PR-Ni73Cr16Si3B3 self-fluxing powder. Self-fluxing is ensured by the introduction of boron in the amount of 2, 3-3, 0%. The chemical composition of metal powders is given in Table-1. The use of a surfacing mixture of the specified composition provides an increase in wear resistance under conditions of shock and shock-abrasive wear [6-9].

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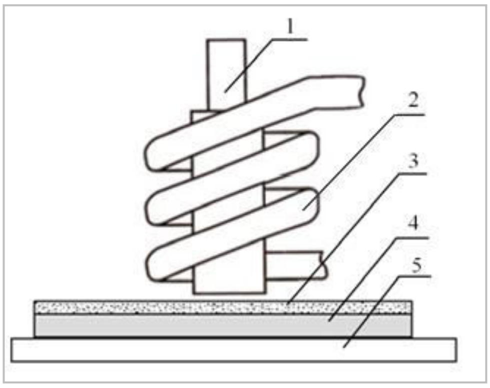
Table-1. Chemical composition of metal powder.

Alloy grade	Chemical composition, %						
	C	B	Si	Ni	Cr	Fe	Mn
PR-Ni73Cr16Si3B3	0,6-0,9	2,3-3,0	2,7-3,7	Basis	15,0-17,0	До 5,0	-
PGS-27	2,5-3,5	-	2,8-4,2	3,0-5,0	25,0-31,0	Basis	0,5-1,5

The production of a composite material with a gradient-layered structure was carried out using a UVG 2-25 high-frequency transistor induction unit. The operating frequency range was 44-66 kHz. General view and diagram of the technological process for obtaining a composite material are shown in Figure-1 [4].

(a)



(b)

1- ferrite core;
2 -coil inductor;
3 -charge;
4 - component base;
5 - table.

Figure-1. Obtaining a composite material on a UVG 2 - 25 high-frequency induction unit: a - general view; b - diagram.

The study of the structure and properties of the obtained composite material was carried out using the following techniques and research equipment:

- metallographic - by electron microscopy using electron microscopes JEOL JSM 7001F, "HITACHI TM-1000" and optical microscopy using a light microscope "Carl Zeiss Axio Vision";
- energy dispersive and chemical analysis in a JEOL JSM 7001F scanning electron microscope equipped with an energy dispersive spectrometer from Oxford Instruments;
- X-ray phase studies were carried out on a T8-ADVANCE diffractometer;
- tests by the dry friction method, to determine the wear resistance under the condition of abrasive wear;
- hardness analysis on the TK-2M device by the Rockwell method.

The research results showed the influence of technological modes on the formation of the structure of the properties of the composite material obtained with the use of PGS-27 metal powder [3, 4]. The introduction of the PR-Ni73Cr16Si3B3 metal powder, containing 72-77 % nickel, into the composition of the deposited charge is due to the production of a highly nickel-alloyed austenite matrix of the deposited layer, which is characterized by a combination of high strength and toughness, which has a positive effect when exposed to impact loads.

The X-ray phase studies of the obtained layer (Figure-2) showed the presence of several intensity peaks, the analysis of which indicates the presence of carbides of the $(Cr, Fe)_7C_3$ type and austenite highly alloyed with nickel in the structure of the deposited layer. Carbides provide an increase in hardness and, as a result, wear resistance under conditions of abrasive wear. Highly nickel-alloyed austenite is characterized by a combination of strength and toughness, which serves as an indirect estimate of the increase in wear resistance when exposed to impact loads. The large width of the peaks can be due to both the high level of internal stresses in the corresponding phase and its fine-crystalline structure.

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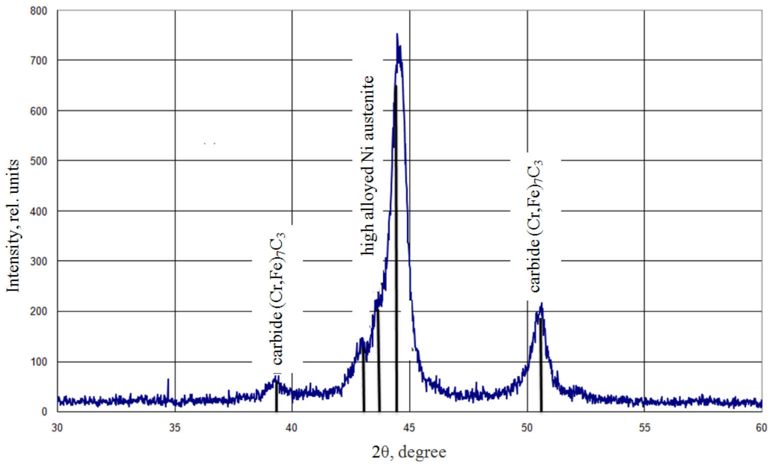

Figure-2. X-ray of the resulting layer.

The results of the energy dispersive analysis of the bulk spectra (Figure-3), which correspond to different regions of the obtained layer, are shown in Table-2. The results obtained show that spectra 1 and 3, in which the presence of a dispersed structure is clearly observed, contain an increased amount of chromium and carbon, and in spectrum 2 - increased nickel content. This difference in chemical compositions makes it possible to assume that the structure of spectra 1 and 3 contains the main fraction of the carbide phase, and spectrum 2 corresponds to a matrix highly alloyed with nickel. It is also worth noting that the microstructure of sections corresponding to spectra 1 and 3 is similar to the initial microstructure of the PGS-27 powder (Figure-4), and the region in which the spectra are located has a spherical shape. Such data may indicate that the melting process of the charge begins with the melting of the self-fluxing powder PR-Ni73Cr16Si3B3, while the PGS-27 powder has partial surface melting.

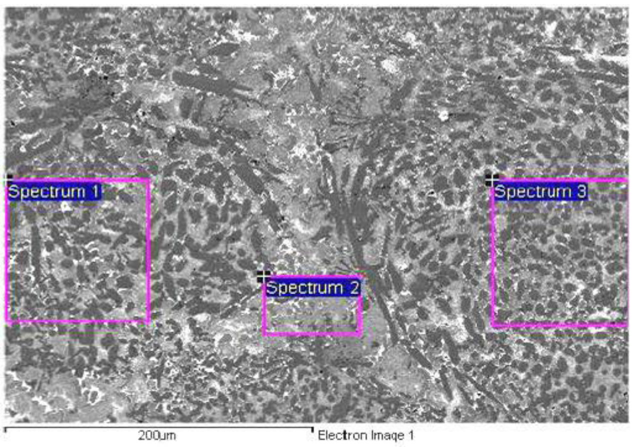

Figure-3. Volume spectra for determination chemical composition.

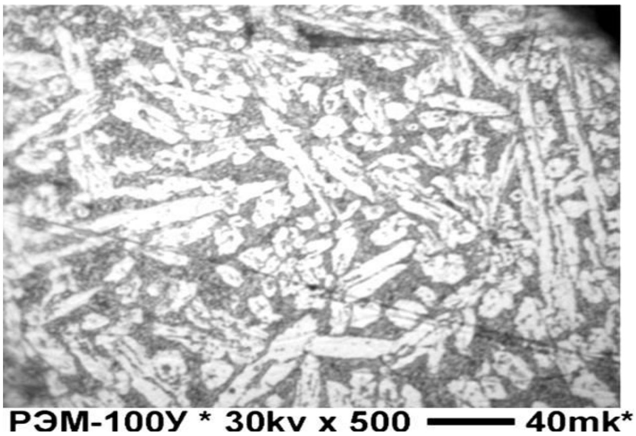

Figure-4. Microstructure of PGS-27 powder.

Table-2. The chemical composition of the bulk spectra.

No Spectrum	Ni, %	Cr, %	C,%
Spectrum 1	36,45	32,89	6,05
Spectrum 2	57,38	11,16	1,21
Spectrum 3	35,82	33,40	6,33

The results of the energy dispersive analysis of sample point spectra (Figure-5) are shown in Table-3. The results obtained show the presence of a large amount of chromium (55, 46 %) and carbon (9, 00 %) in the first spectrum and an increased content of nickel (66, 34 % and 49, 35 %) in spectra 5 and 12, respectively. Such a difference in chemical compositions may indicate the presence of a carbide phase and an austenitic, highly nickel-alloyed matrix of the resulting composite material.

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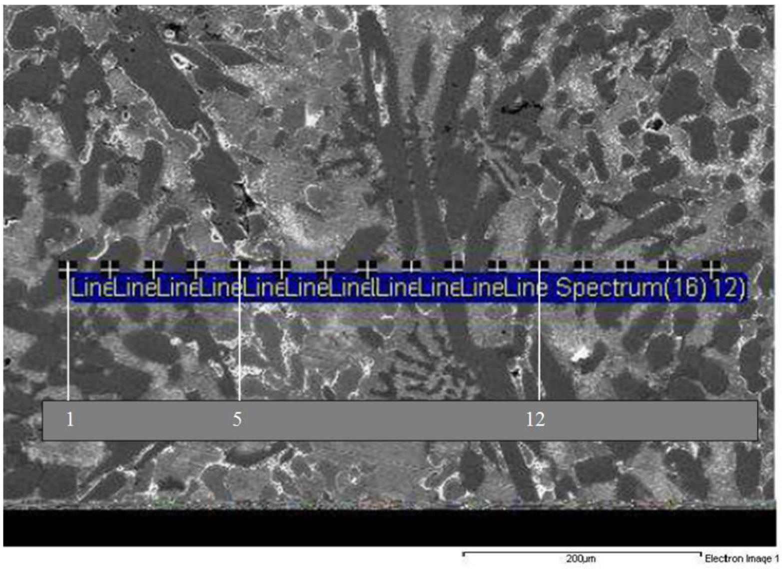

Figure-5. Point spectrum line.

Table-3. Chemical composition of point spectra.

No Spectrum	Ni, %	Cr, %	C,%
Spectrum 1	3,63	55,46	9,00
Spectrum 5	66,34	5,82	0,56
Spectrum 12	49,35	15,32	0,93

The change in hardness, depending on the deposition rate and layer thickness, is shown in Figure-6. It is shown that a decrease in the deposition rate and an increase in the thickness of the formed layer promote a decrease in hardness, which is similar to the results obtained in [3, 4]. The obtained results of the analysis of hardness show that the introduction of PR-Ni73Cr16Si3B3 metal powder into the composition of the deposited charge does not reduce the hardness of the deposited layer, in relation to the layer deposited with the use of PGS-27 metal powder.

The relative value of the increase in wear resistance (W, %) of the obtained experimental samples, depending on the layer thickness, in relation to the reference sample made of 65G steel (0, 65% C, 0, 9-1, 2 Mn), was determined by the dry friction method, at specified speeds of rotation of the abrasive wheel and the load on the test sample. The relative value of increase in wear resistance (W, %) is calculated by the expression:

$$W = 100 - \frac{\Delta m}{\Delta m_0} \cdot 100, \%$$

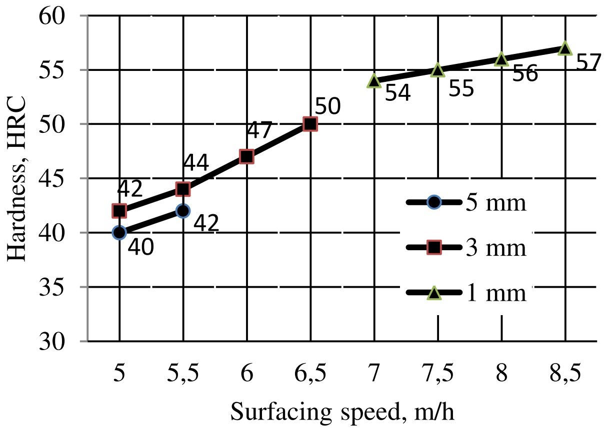

Figure-6. Hardness graphs depending on on deposition rate and thickness of deposited layer.

where, Δm - wear of the obtained sample, mg; Δm_0 - wear of the reference sample, mg.

As the studies have shown, the effect of increasing wear resistance begins to manifest itself when the thickness of the obtained layer is more than 1 mm (Figure-7). When a layer with a thickness of less than 1 mm is applied, a slight increase in wear resistance is observed. It should be noted that the change in the value of

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wear resistance (W, %) is nonlinear. With a layer thickness of more than 4, 0-4, 5 mm, the intensity of increase in wear resistance sharply decreases, which is explained by a significant decrease in hardness.

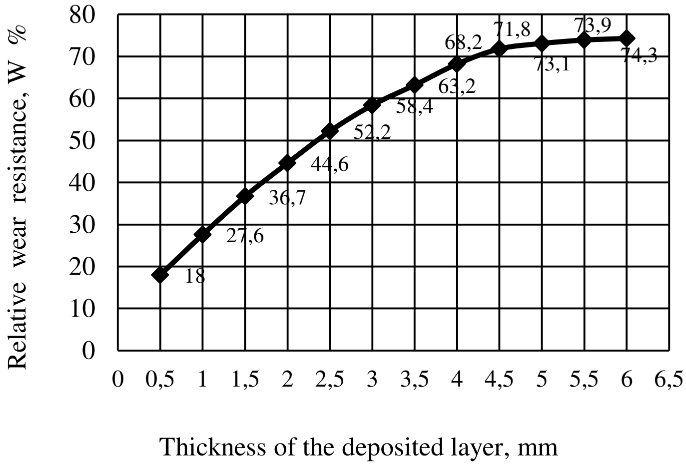

Figure-7. Change in the value of relative wear resistance, depending on the thickness of the deposited layer.

CONCLUSIONS

The complex of studies carried out testifies to the expediency of using a surfacing charge, which contains 85% PGS-27 metal powder and 15% PR-Ni73Cr16Si3B3. Analysis of the phase composition showed that the formed layer consists of a strengthening carbide phase of the (Cr, Fe) 7C3 type and a highly nickel-alloyed austenite matrix, which is characterized by a combination of sufficient strength and impact toughness. The results of the analysis of wear resistance by the method of dry friction showed that the introduction of the metal powder PR-Ni73Cr16Si3B3 into the composition of the welded mixture does not reduce the value of the relative wear resistance under the condition of abrasive wear, in relation to the layer obtained without the guidance of the metal powder PR-Ni73Cr16Si3B3, and the presence of an austenite matrix makes it possible to increase the wear resistance composite material when exposed to impact loads.

REFERENCES

[1] Preparation of metal powders from silver melt for 3d printing by melt dispersion method, 2020 Masanskii O.A., Tokmin A.M., Kazakov V.S., Bezruchko A.B., Gilmanshina T.R., Lytkina S.I., Kaposko I.A., Khudonogov S.A. ARPN Journal of Engineering and Applied Sciences. (V15 / 7): 909-914.

[2] Physicochemical processes in induction surfacing of wear-resistant materials, 2010 Masansky O.A., Svechnikova L.A., Tokmin A.M. Dynamic and technological problems of mechanics of structures and continuous media: Proceedings of the XVI International Symposium named after A.G. Gorshkov. (2): 68-70.

[3] Study of the structure and properties of a layer obtained by induction surfacing of metal powders, 2008 Tokmin A.M., Teremov S.G. Engineering technology. (9): 15-18.

[4] Relationship between the parameters of induction surfacing and the structure and properties of the deposited layer, 2011 Masansky O.A., Tokmin A.M., Svechnikova L.A. Welding production (5): 9-13

[5] Surfacing materials and surfacing technology to improve wear resistance and restoration of machine parts, 2015 Livshits L.S. Welding production. (1): 15-17.

[6] Vinogradov V.N. 1990. Abrasive wear / V.N. Vinogradov, G.M. Sorokin, M.G. Kolokolnikov - M. Mechanical engineering. p. 224.

[7] Wear-resistant steels for various operating conditions, 2010 Kamyshina K.P., Petrov Yu. N., Smirnov G.P. Foundry. (7): 4-8.

[8] Influence of the phase composition of the matrix on the wear resistance of white chromium cast iron, 2001 Filipov M.A., Plotnikov G.N., Lhagvadorzh P. Izvestiya of higher educational institutions. Ferrous metallurgy. (6): 75-76.

[9] Relationship between structure and properties of high-chromium cast irons, 2003 Komarov O.S., Sadovskiy

V.M., Urbanovich N.I. Metallurgy and heat treatment of metals. (7): 20-23.

[10] Influence of induction surfacing modes on the structure and properties of the deposited metal, 2004 Pulka Ch. V., Shabliy O.N., Pismennyy A.S. Automatic welding. (10): 19-21.

[11] The structure of the interface between the melted coating - steel, 2011 Rudenskaya N.A., Shveikin G.P., Kopysov V.A., Rudenskaya V.M. Reports of the Academy of Sciences. (441/4): 495-498.

[12] P.A. Gorbachev 2002. Investigation of physical-mechanical and operational properties of wear-resistant alloy IChKh15G4NT / P.A. Gorbachev, Yu.G. Rusin. - EKSTU, Ust-Kamenogorsk, river 44.

[13] Structure and properties of high-carbon iron-based alloys for surfacing, 2003 Perepletchikov E.F., Ryabtsev I.A., Vasiliev V.G. Metallurgy and heat treatment of metals. (5): 36-40.