

Modification of wear-resistant coatings of Fe-Cr-C system based on the Cr₃C₂ obtained with help of SHS method

A V Shchegolev¹, V F Aulov², A V Ishkov¹, V V Ivanayskiy¹, N T Krivochurov¹

¹Altai State Agricultural University, 98, Krasnoarmeyskiy ave., Barnaul, Russia

²Federal Scientific Agroengineering Center «VIM», 5, first Institutskiy travel, Moscow, Russia

E-mail: qq681@mail.ru

Abstract. The article deals with new wear-resistant materials of the Fe-Cr-C system, designed to strengthen the working bodies of machines by high-performance inductive surfacing. Materials are presented by a mixture of powders (burden) based on high-alloy chromium-plated cast iron of type PG-USC25 (in Russian) and flux P-0.66, modified by cermet based on Cr₃C₂, obtained by the SHS method. The peculiarity of the modifier proposed by the authors is that the open pores of this ceramic are filled with the main, matrix material of the future wear-resistant coating - cast iron PG-CS-25 (in Russian), which is used in the SHS as an inert. X-ray diffraction studies of cermet and metallographic studies of surfaced coatings have been performed. It was shown that the introduction into the prepared burden for inductive surfacing up to 25% by weight specified cermet allows to increase hardness (up to 1320 HV) and wear resistance of the welded material. The effect is explained by formation in the hardening coating of up to 20% by vol. of new phase - the needle-shaped carbide Cr₇C₃ due to recrystallization and change in the composition of carbides formed from artificially introduced Cr₃C₂ and already available in matrix eutectic cast iron, chromium and carbon.

1. Introduction

Wear-resistant coatings of the Fe-Cr-C system are widely used in mechanical engineering for strengthening wear of workpieces and tools surfaces, as well as razor edges of working mechanisms of agricultural machines [1]. Various methods and technologies are used for application hardenable surfaces [2], and in particular, inductive overlaying [3]. However, in some cases, the wear resistance of such surfaces is insufficient [4].

In order to improve the wear resistance without significant changing the material composition and strengthening technology, the finished burden is modified by adding various materials (powders of refractory and wear-resistant compounds, nanoparticles, carbide particles, etc.) [5-7], which can be obtained separately. The processes of recrystallization, growth or crushing of chromium carbides are initiated in the modified materials and leads to an improvement of its mechanical properties [8, 9].

The promising technique of obtaining modifiers is self-spreading high-temperature synthesis (SHS), based on exothermicity interaction reactions of majority kinds of metals with nonmetals and formation of target products (carbides, borides, silicides and nitrides) [10-12].

The purpose of the article is modification of the surfacing material PG-US25 (in Russian) in order to improve its wear resistance, powder cermet based on Cr₃C₂, obtained by the SHS method.



2. Experimental procedure

As initial reagents was used: aluminum powder of PAP-1 mark, chromium oxide (III) reactive purity and technological graphite of GLS mark. In order to secure from oxidation of reagents and products, the synthesis was carried out in argon in a special SHS reactor, initiating combustion of burden with a nichrome coil.

Cylindrical samples with dimensions of 20×60 mm were prepared by extrusion of burden from the fractionated powders of the starting reagents and wetted in the binder- of 5% alcohol solution of boric acid.

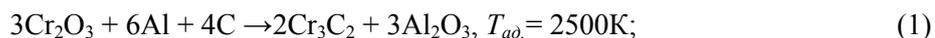
The finished products (powders, cermets, alloys) after complete cooling in a reactor in argon flow, were crushed, lixiviated with 10% aqueous alkali solution, washed and dried on a filter.

Hardening coatings were obtained by inductive overlaying of a modified burden, by weight. %: PG-UC25 (in Russian) material - 85; Flux P-0.66 (in Russian) - 15 [13] on 65G steel samples. The overlaying was carried out by the industrial HFC hardening installation ELSYT-100/75 (in Russian).

X-ray phase analysis of products was performed on a DRON-6 (in Russian) diffractometer (Cu K α radiation, $\lambda = 1.5418$ Å), phase identification was made with the help of PDWin software package using card indexes: PDF-2, ICDD [14]. The metallographic analysis of microstructures of hardening coatings was performed on a CARL ZEISS AXIO OBSERVER-Z1 M microscope and MH-6 microhardness tester according to ASTM E standard methods: 3, 407, 1558, 883, 384 [15].

3. Results and discussion

Cr₃C₂ chromium carbide used as a modifier and formed according to the known SHS reaction [16]:



It emerged that after lixiviation, product Al₂O₃ has high porosity and low density and when you add it to the known burden for inductive overlaying (mixture of PG-UC25 (in Russian) powders and flux P-0.66 (in Russian)), it appears in the metal melt and removes with slag. In order to get the effective introduction into the hardening coating a cermet based on Cr₃C₂ was obtained, pores of which are filled with surfacing material. In this case, PG-CS25 (in Russian) was used as an inert [10, 16], and injected in amounts of 5, 10, 15 and 25%, from the mass of the metal material.

Using it in SHS reaction a high-alloy nickel cast iron of the ChN mark as an inert and without further introduction into the graphite mixture, the resulting ceramic products appeared to be a mixture of two higher carbides Cr₃C₂ and Fe₃C with a small fraction of reduced iron (Figure 1).

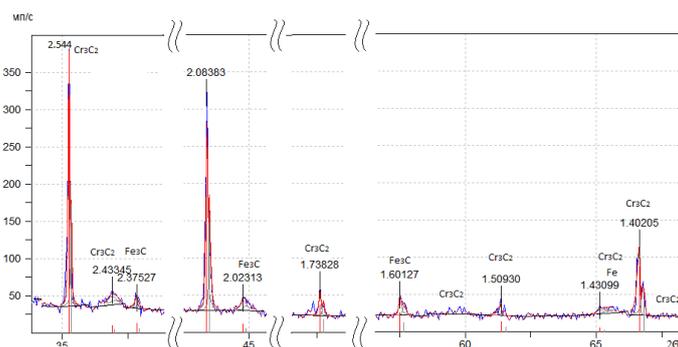


Figure 1. X-ray diffraction pattern and results of identification phases at SHS in the system Cr₂O₃ + Fe₃O₄ + Al, with the addition of 35% by weight. Inert - cast iron of ChN mark.

While using as the inertia of the main surfacing material - highly alloy cast iron of PG-USC25 (in Russian) brand, the SHS product is a cermet based on a single carbide Cr₃C₂. The introduction of the powder of this modifier in the quantity of 25% in the ready-to-fill burden was optimal and provided the maximum hardness and wear resistance of the hardening coating.

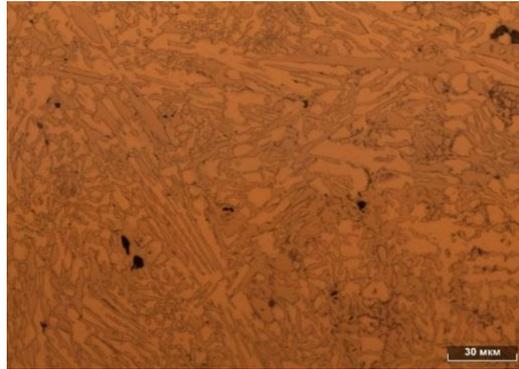


Figure 2. Microstructure of the Fe-Cr-C system deposited metal with a cermet content based on Cr_3C_2 - 25% by weight. (500 \times)

Deposited metal of this composition (Figure 2) has a complex structure of the composite, in the matrix, which consists of ledeburite and finely-divided carbides, the needle-like particles of the chromium carbide Cr_7C_3 are scattered. This carbide is formed during the inductive surfacing of the modified PG-US25 (in Russian) material from the introduced Cr_3C_2 carbide, as well as the chromium and carbon present in the carbide eutectics, the basic phase in the Fe-Cr-C system (Table 1).

Table 1. Characteristics of the structural components of the deposited material of the Fe-C-Cr system modified by the Cr_3C_2 based cermet

Structural composition	Share, %	Hardness HV (load of 100 g)
Chromium carbide	15-20	1324
Matrix (eutectics)	75-80	838
Metal average hardness	-	1081

The high wear resistance of the deposited metal is provided precisely by chromium carbide Cr_7C_3 (Figure 3), which possesses one of the highest hardness among Cr-C carbides [17] and it is the main coating phase. It is interesting to note that this carbide is formed in a deposited layer at a much lower temperature than the equilibrium one - 1766 °C [18].

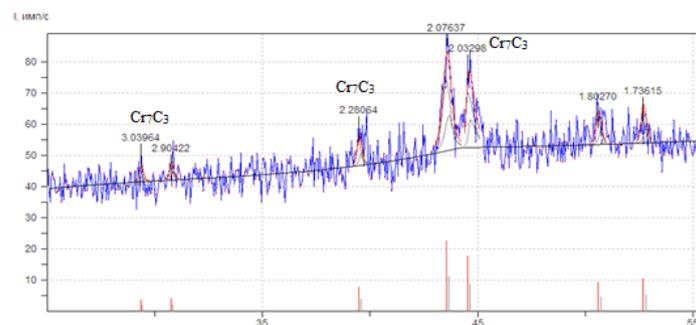


Figure 3. X-ray diffraction pattern and results of the identification phases of the deposited metal with the content of Cr_3C_2 cermet - 25% by weight

The hardness of the wear-resistant coatings of the Fe-Cr-C system is determined by the carbide formation, the hardness of the deposited layer will practically not depend on the technological factors: the temperature of the metal heating during surfacing and its cooling rate while cooling down [8, 9].

This circumstance allows us to recommend the modification of the surfacing material of PG-US25 (in Russian) cermet based on Cr_3C_2 as an effective way to increase its wear resistance.

4. Conclusion

On the basis of carried out experiments and study results of composition, structure and characteristics of deposited wear-resistant material, the following conclusions can be made:

1. It is proposed to increase the durability of surfacing material of Fe-Cr-C system (PG-UC25) (in Russian) by modifying them with cermet based on Cr_3C_2 .
2. Cermet is obtained by the SHS method, and open pores of the ceramics are filled with matrix material of the coating used as an inert for synthesis.
3. Introduction 25% modifier in the ready burden for inductive surfacing provided an increase in the hardness and wear resistance of the deposited layer due to the formation of Cr_7C_3 chromium carbide in it.

References

- [1] Laird G, Gundlach R, Röhrig K 2000 Abrasion-resistant Cast Iron Handbook. Ed. American Foundry Society Schaumburg USA 1-222.
- [2] Hasui A., Morigaki O. Surfacing and Sputtering 1985 *Mechanical Engineering*. 1-240 (in Russian)
- [3] Tkachev V N 1970. *Induction hardfacing of hard alloys* (M. Mechanical Engineering) 1-183.
- [4] Zum K and Eldis G 1980 *Abrasive Wear of White Cast Irons* Wear. **Vol. 64** 175-194.
- [5] Hou Y, Wang Y, Pan Z and Yu L 2012 *Journal of Rare Earths* **Vol. 30** 283-288.
- [6] Ryabtsev I A, Panfilov A I, Babinets A A, Ryabtsev I I, Gordan G N, Babiichuk I L 2015. *Automatic welding* **5-6 (742)** 84-88.
- [7] Albertin E and Sinatora A 2001. Effect of carbide fraction and matrix microstructure on the wear of cast iron balls tested in a laboratory ball mill. *Wear* **Vol. 250** 492-501.
- [8] Bedolla A, Arias L and Hernández B 2003 *Journal of Materials Engineering and Performance*. - **Vol. 12**. 371-382.
- [9] Liu F, Jiang Y, Xiao H and Tan J 2015 *Journal of Alloys and Compounds* **Vol. 618** 380-385.
- [10] Amosov A P, Borovinskaya I P and Merzhanov A G 2007 Powder technology of self-propagating high-temperature synthesis of materials. *M. Mechanical engineering* 1 1-567.
- [11] Gorshkov V A, Miloserdov P A, Luginina M A, Sachkova N V and Belikova A F 2017. *Inorganic Materials* **Vol. 53** 3 271-277.
- [12] Ilyushchenko A, Vitias P, Beliaev A and Talako T 2001 *Proceedings of the International Thermal Spray Conference «Thermal Spray: New Surfaces for a new millennium»* Ed. Berndt C C, Khor K A, Lugscheider E F. Publ by ACM International, Materials Park Ohio, USA 1299-1302.
- [13] *Surviving materials of the member states of the CMEA 1979 catalog* Kiev M. VINITI 1-619.
- [14] Brady J B, Newton RM and Boardman SJ 1995 New Uses for Powder X-ray Diffraction Experiments in the Undergraduate Curriculum. *Jour. Geol. Education* **Vol. 43**. № 5 466-470.
- [15] ASTM International - Standards Search: E -<https://www.astm.org/Standard/alpha-lists/E.html>
- [16] Koizumi M 1998 *Chemistry of Synthesis of Combustion*, Ed. M. Koizumi (M. World) 1-247.
- [17] Mehdi Mazar Atabaki, Sajjad Jafari and Hassan Abdollah 2012 Abrasive Wear Behavior of High Chromium Cast Iron and Hadfield Steel A Comparison. *Journal of Iron and Steel Research, International* **Vol. 19** Issue 4 43-50.
- [18] Giessen B and Wang S Alloy Phase Diagrams Ed. Bennett L H, Massalski T B and Giessen B C 1983 North-Holland (New York USA) 289-294.