HARDENING HEAT TREATMENT OF WEAR-RESISTANT CARBIDE PARTS MADE BY CASTING ACCORDING TO GASIFIED MODELS

Tilabov B.K.[1], Normurodov U.E.[2], Guzashvili K.V.[2], Mirzarakhimova Z.B.[2], Abdurakhmonova M.Kh.[2]
[1]Mechanical engineering technology, Almalyk branch of Tashkent State Technical, Uzbekistan University named after Islam Karimov
[2]Materials Science department, Tashkent State Technical University, Uzbekistan
Email: begalibektemirov94@gmail.com

Abstract - This article presents the theoretical and practical basics of manufacturing cast parts of tillage and agricultural machinery and mechanisms by casting gasified models. Technology has been developed for producing polystyrene foam models of various types of products and manufacturing cast parts of machines with a wear-resistant carbide coating of the sormite type. A technique for applying wear-resistant carbide coatings to the working surfaces of foam models - parts when casting according to gasified models has also been developed. A method for forming the casting of parts with a carbide coating up to three mm thick has been created. The quality of the casting of parts and the thickness of the applied wear-resistant carbide coatings have been checked. The macro-and microstructures of carbide coatings obtained by casting on expanded polystyrene gasified models have been studied. The thickness of the carbide coating on specially prepared grinds cut from the casting of parts with a coating thickness of 2,0-2,5-3,0 mm has also been studied. The thickness of the coating was determined using an optical metallographic microscope MIM-8M and Neophot-21 with various magnifications from x 100 to x1000. At the same time, the microstructure and phase composition of the hard alloy was studied. The hardness, microhardness, and depth of the carbide coating were determined on samples and parts obtained by casting on a polystyrene foam gasified model, on the working surface of which a powdered hard alloy of the sormite type was applied. Optimal modes of heat treatment with double phase recrystallization for these cast parts of machines and mechanisms have been developed. It is proved that heat treatment with double phase recrystallization of such products increases abrasive wear resistance and durability 2-3 times higher than serial products. The present developed technology has been tested and implemented in one of the largest giant enterprises of "Uzbekistan Metallurgical Combine" JSC with the best economic effect.

Keywords: Gasified model casting, Powder hard alloy with a binder, Carbide coating thickness, Hardness and micro hardness.

1. Introduction

Most parts of tillage and agricultural machinery and mining and metallurgical equipment work under severe conditions of exposure to an abrasive environment. Therefore, the working surfaces of such parts are subjected to surface hardening by applying wear-resistant carbide coatings by casting according to gasified models. The application of a carbide coating is carried out by melting the coating metal on the surface of the part.

The structural state of the carbide coating is formed during the solidification and cooling of the product. The final operation in most cases is a vacation. The use of parts with carbide coatings without special heat treatment is not effective enough, since the possibilities of increasing abrasive wear resistance are not fully realized due to insufficient hardness and instability of the structure.

It is advisable to obtain small-sized parts with carbide coatings on working surfaces at the same time when casting on expanded polystyrene gasified models [1]. In this case, a powdered hard alloy together with a binder, in the form of a paste, is applied to the working surface of the foam model of the product. The foam model is molded into a casting flask-a container with dry quartz sand. When pouring liquid metal through the gate system, the foam model burns out, the resulting cavity is filled with liquid metal [2]. Upon contact of the liquid metal with the cold walls of the mold, a hard crust is formed, on which a powdered hard alloy of the sormite type melts and connects with the hard crust of the solidifying casting.

There are a large number of compositions of cast hard alloys that are used as wear-resistant coatings. These are mainly high-carbon and high-chromium alloys of eutectic or hypereutectic compositions, which can be additionally alloyed with nickel, manganese, silicon, tungsten, vanadium, and titanium [3]. These alloys, upon crystallization, form quenching structures with a significant amount of stable residual austenite.

A cast hard alloy with such a structure is poorly processed by cutting (when necessary) and has insufficient wear resistance due to reduced hardness.

In this paper, the problem of increasing the abrasive wear resistance and durability of carbide parts obtained by casting according to gasified models is solved by using optimal heat treatment modes with double phase recrystallization.

2. Research Methodology

For research, the composition of a sormite-type hard alloy was selected, which does not have a large number of scarce alloying elements, ensuring the completeness of phase transformations during heat treatment (during annealing to reduce hardness, during quenching to obtain the highest hardness).

Table 1 shows the chemical composition of the powdered hard alloy.

Table 1. Chemical composition of the hard alloy

The content of the elements, in % (by weight)								
C	Si	Mn	S	P	Cr	Ni	W	Mo
3,0	1,5	0,8	0,04	0,04	22,0	1,2	0,2	0,08

The objects of research were samples obtained by casting 35GL steel according to gasified models. A paste-like paint containing a powdered hard alloy of the specified composition with a binder - a 4% solution of polyvinyl butyral in alcohol - was applied to the working surface of the model. The thickness of the paste was up to 3 mm. After drying the paste-like paint, the foam model was molded with dry quartz sand. After installing the gate system, liquid metal was poured. On the working surface, the powdered hard alloy melted, and when the entire casting was cooled, it crystallized to form a cast carbide coating.

The finished samples were cut across the coating and the macro and microstructure were studied, the hardness of the samples was determined, as well as the change in microhardness along with the coating depth. The phase composition and the state of the fine structure of the metal base of the coating were studied by X-ray [4].

The heat treatment of the samples included the following:

- low annealing at 700-720^{0}C;
- quenching with heating temperatures 900-920^0, 1000^0, 1100^0, 1150^{0}C;
- hardening at temperatures 200-250^{0}C.

Part of the samples was thermally treated with double phase recrystallization – the first quenching from different heating temperatures, intermediate tempering at 600-650^{0}C, - the second hardening 900-920^{0}C, tempering 200-250^{0}C. According to studies [5,6], such heat treatment strengthens the metal base of the alloy due to an additional increase in the density of dislocations.

Tests for abrasive wear were carried out on the PV-7 device when the polyurethane screw was rubbing on the surface of the test sample in the presence of quartz sand [7].

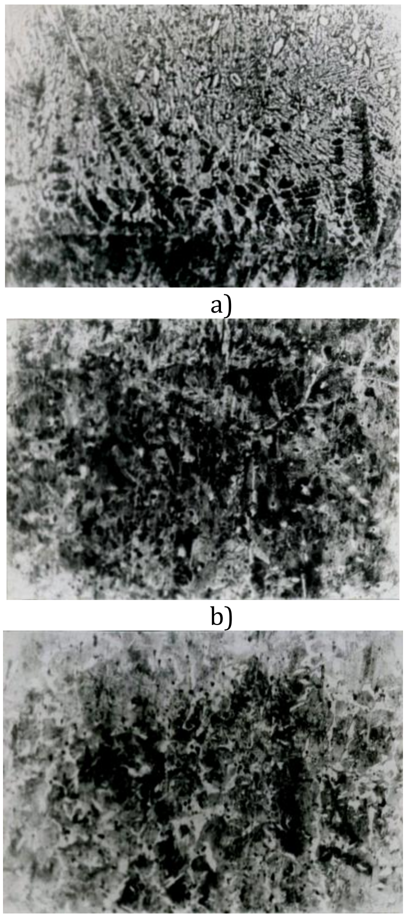
3. Research Results and Discussion

Micro-studies have shown that the resulting wear-resistant coating has a different composition and structure in depth (Fig.1). At the surface of the coating, a hypereutectic structure is formed with excess carbides of hexagonal and prismatic shapes. Further along with the depth of the layer are zones of eutectic and trans-eutectic compositions with a sharp transition to the structure of the trans-eutectoid and eutectoid steel of the metal base.

The formation of a high-carbon sublayer under the carbide coating is associated with the diffusion of carbon from the powder coating into the crust of the solidified metal, as well as carburization by the combustion products of the foam model. The total thickness of the carbide coating was 2.5-3.0 mm.

Phase X-ray structural analysis of the surface of the samples showed the presence of carbides of type M_7C_3, $M_{23}C_6$ and the presence of α-γ phases of iron. The microhardness of the layer varies widely in depth from the surface, which is due to the presence of various structural components (Fig.2).

When hardening samples from a heating temperature of 900-920^{0}C, the location, and shape of primary carbides do not change, however, the lower values of microhardness in the band of their values from HV $720 \cdot 10^{-1}$ MPa and up to HV $840\text{-}1100 \cdot 10^{-1}$



a)

b)

c)

Figure 1: Microstructures of the carbide coating were obtained by casting a 35GL steel part according to a gasified model: a) hypereutectic structure; b) eutectic and trans-eutectic compositions; c) the structure of the trans-eutectoid and eutectoid steel

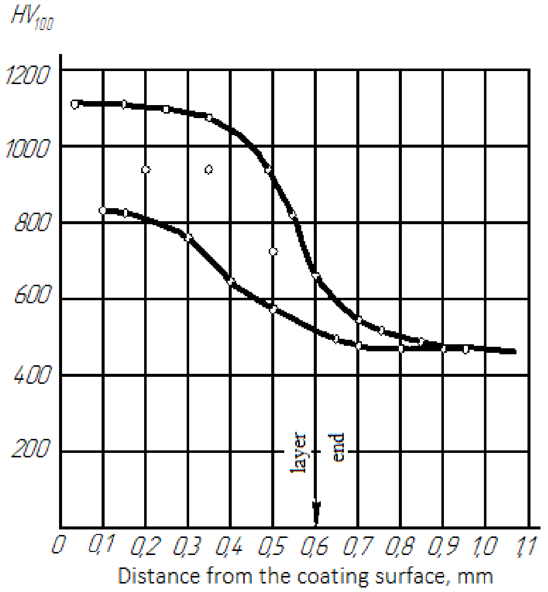


Figure 2: Change in the microhardness of the carbide coating in depth from the surface of the 35GL steel samples obtained by casting according to the gasified model.

MPa significantly increase. At higher heating temperatures for quenching, secondary carbides are dissolved in austenite. Due to the high alloying of the solid solution in a zone with a depth of 0.5-0.6 mm, an increased amount of residual austenite is detected and microhardness decreases. At a depth of 0.7-0.95 mm from the coating surface, the metal base of the alloy has only a martensitic structure. Microhardness increases again. Further, along with the depth of the high-carbon sublayer, a monotonous decrease in microhardness is observed. The total depth of the layer with a hardness of at least HV_{100} $500 \cdot 10^{-1}$ MPa (the hardness of medium-carbon steel martensite) reaches 1.9 mm.

It is known that the wear resistance of high-chromium alloys largely depends on the state of the fine structure of the metal base. The level of defects in the crystal structure is judged by the density of dislocations, which was found by the physical width of the X-ray line (211) of the α-phase [4]. The results of the studies are shown in Table 2.

Table 2. The dislocation density in the crystal lattice of the metal base (α-phase) of the wear-resistant carbide coating from the quenching temperature, $\rho \cdot 10^{11} \cdot 1/cm^2$

Hardening temperature, ^{0}C	900-920	1000	1100	1150
Dislocation density	0,35	3,49	4,82	1,98

As can be seen from Table 2, the dislocation density level depends on the hardening temperature and has an extremum at 1100^{0}C. However, when hardening from high heating temperatures, the amount of stable residual austenite increases, which reduces wear resistance. The use of heat treatment with double phase recrystallization makes it possible to eliminate this disadvantage. The first phase recrystallization takes place with heating to an extreme temperature. Quenching ensures the formation of a structure with a high level of dislocation density. The intermediate release stabilizes the dislocation structure. Repeated phase recrystallization (in this case with heating 900-920^{0}C) takes place under conditions of inheritance of elements of the original substructure, but with a minimum amount of residual austenite. The results of the studies are shown in Table 3.

The microstructure of all samples after repeated phase recrystallization at 900-920^{0}C is coagulated primary and finely dispersed secondary carbides in a finely ground martensitic base with an insignificant amount of residual austenite.

Table 3. The dislocation density in the crystal structure (α-phase) of the metal base of a wear-resistant carbide coating depending on the pre-hardening temperature, $\rho \cdot 10^{11} \cdot 1/cm^2$

Pre-hardening temperature, ^{0}C	900-920	1000	1100	1150
Dislocation density	2,24	2,33	3,63	2,33

4. Conclusions

The introduction of heat treatment into the technology of creating carbide coatings significantly increases their wear resistance [8]. Laboratory tests show that the resistance to abrasive wear is in good agreement with the structural condition of the coatings. The research results show that the amount of residual austenite and the state of the fine structure of the metal base simultaneously affect the amount of abrasive wear resistance. By adjusting the parameters of the structure of the carbide coating (in this case, obtained by casting a part according to a gasified model) by heat treatment, it is possible to significantly increase wear resistance [9]. Only the introduction into the manufacturing technology of cast parts with a wear-resistant carbide coating quenched with 900-920^{0}C increases wear resistance by almost 1.8 times, and the use of heat treatment with double phase recrystallization [10,11] increases the wear resistance and durability of cast parts 2-3 times higher than serial products. The developed technology for manufacturing cast parts of machines with a wear-resistant carbide coating by casting gasified models has been introduced into the production of JSC "Uzbekistan Metallurgical Combine " with the best economic effect.

Acknowledgements

This work was supported by Tashkent State Technical University (TSTU), Uzbekistan and also "Uzbekistan Metallurgical Combine" JSC.

References

[1] Mukhamedov, A.A., Farmanov, A.K. Tilabov, B.K.; Povishenie iznosostoykosti litih detaley s tverdosplavnimi pokritiyami metodom termicheskoy obrabotki [Increasing the wear resistance of cast parts with carbide coatings by heat treatment] // Gorniy jurnal, Moskva – Almilik, №8, Pp:95-97, 2009.

[2] Tilabov, B.K.; Novie tehnologii izgotovleniya litih detaley selskohozyaistvennih mashin s tverdosplavnim iznosostoikim pokritiem metodom litya po gazificiruemim modelyam i perspektivi ih razvitiya [New technologies for manufacturing cast parts of agricultural machines with a hard-alloy wear-resistant coating by casting gasified models and prospects for their development] // nauchno-tehnicheskii i proizvodstvenniy jurnal Selskogo hozyaistva Uzbekistana, Tashkent, №2. – Pp: 41-43, 2008.

[3] Hrushev, M.M. et al.; Iznosostoikost i struktura tverdih naplavok [Wear resistance and structure of hard surfacing], Mashinostroenie, 1989. - 94 s.

[4] Umanskiy, Y.S. i dr.; Kristallografiya, rentgenografiya i elektronnaya mikroskopiya [Crystallography, radiography and electron microscopy], Metallurgiya, p629, 1988.

[5] Mukhamedov, A.A.; Vliyanie termicheskoy predistorii na strukturu i svoistva stali [Influence of thermal background on the structure and properties of steel]. Fizika metallov i metallovedenie, Moskva, №11, Pp: 92-99, 1992.

[6] Tilabov, B.K.; Vliyanie termicheskoy obrabotki na dolgovechnost litih detaley s iznosostoikimi pokritiyami [The effect of heat treatment on the durability of cast parts with wear-resistant coatings]. Tolyattinskiy gosudarstvenniy universitet (TGU), RF. Trudy - II Mejdunarodnoy nauchno-tehnicheskoy konferencii. Chast I. Rossiya. – Tolyatti, Pp: 145-148, 2008.

[7] Tenenbaum, M.M., Bershtein, D.B.; Modelirovanie processa abrazivnogo iznashivaniya [Modeling of the abrasive wear process] // sb. Modelirovanie treniya i iznosa. NIIMash, Pp: 82-89, 1989.

[8] Tilabov, B.K.; Heat treatment of wear resistant hard alloyed coating of the details obtained by casting on gasified models. Journal of Technical University of Gabrovo. Bulgaria. Vol.49, Pp; 11-14, 2015.

[9] Karimov, Sh.A., Mamirov, Sh.Sh., Khabibullayeva, I.A., Bektemirov, B.Sh., Khusanov, N.; Friction and wear processes in tribotechnical system. International Journal of Mechatronics and Applied Mechanics, Issue 10, Vol. I, ISSN: 2559-6497, Pp: 204-208, 2021.

[10] Tilabov, B.K.; Improving working efficiency and durability of cast parts of tilling machines. European Science Review. «East West» Association for Advanced Studies and Higher Education GmbH. Vena. Austria, Volume 7, Issue 8, Pp: 23-27.

[11] Normurodov, U.E., Tilabov, B.K., Ergashyev, M., Sadullayev, Z.Sh., Sherbo'tayev, J.A.; Choice of material and thermal hardening of surface layers of casting steel parts of soil processing machines and mechanisms // Solid State Technology Blind Peer Review Referred Journal Volume: 63 USA, Pp: 186131-18639.

[12] Bektemirov, B. S., Ulashov, J. Z., Akhmedov, A. K., & Gopirov, M. M.; (2021, June). TYPES OF ADVANCED CUTTING TOOL MATERIALS AND

THEIR PROPERTIES. In *Euro-Asia Conferences* (Vol. 5, No. 1, pp. 260-262).

[13] Norkudjayev, F. R. Alikulov, A. Kh. Abdurakhmonov, Kh. Z. Tursunov, T. Kh.; Examination of Thermophysical Processes in the Creation of Metal Layered Compositions. International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-2S10, September 2019. Pp: 361-366, 2019.

[14] Nokhudjayev Fayzulla Ramazonovich, Mukhamedov Azad Anvarovich, Teshaboyev Abduvakhob Marifovich, Usmonov Jasur Muminaliyevich, Parmonov Sarvar Toshpulatovich; Resource-saving manufacturing technologies and thermal hardening of machine parts and tool. International Journal of Mechatronics and Applied Mechanics (IJOMAM), Issue 9, and ISSN: 2559-6497, Pp: 137-145, 2021.

[15] F.R. Norkhudjayev, A.A. Mukhamedov, Nabiyev B.N., Khodjimukhamedova M.M., R.F. Norkhudjayeva; International Journal of Mechatronics and Applied Mechanics (IJOMAM), Issue 10, and ISSN: 2559-6497, Pp: 168-174, 2021.

[16] Ziyamukhamedova U.A., Bakirov L.Y., Rakhmatov E.A., Bektemirov B.Sh. Structure and Properties of Heterocomposite Polymeric Materials and Coatings from them Obtained by Heliotechnological Method. International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-8, Issue-3S, October 2019. P 399-402.

[17] Umidjon Mardonov, Muhammad Turonov, Andrey Jeltukhin, Yahyojon Meliboyev; The difference between the effect of electromagnetic and magnetic fields on the viscosity coefficients of cutting fluids used in cutting processes, International Journal of Mechatronics and Applied Mechanics, Issue 10, Volume 1, 2021.

[18] Umarov, E., Mardonov, U., Abdirakhmonov, K., Eshkulov, A., & Rakhmatov, B. (2021). Effect of magnetic field on the physical and chemical properties of flowing lubricating cooling liquids used in the manufacturing process. IIUM Engineering Journal, Volume 22, Issue 2, Pp: 327-338,2021.doi:https://doi.org/10.31436/iiumej.v22i2.1768