



Improvement of Resistance of Structural Metal Ceramics of Fe-C-Mn-Mo-Cr Type by Boron Nonmetallic Coatings

I. Mitev

Department of Machinery and Equipment
Technical University of Gabrovo
4, H. Dimiter str.
Bulgaria

Abstract: During the last years the development of powder metallurgy is connected with constant search and elaboration of new materials to improve mechanical properties of workpieces. Such type of materials are structural powder materials of the system Fe-C-Mn-Mo-Cr, which are elaborated on the basis of "Astaloy" powders. The elaboration work studies the wear resistance of this type of materials in the process of priction after chemical and thermal treatment with boron nonmetal coatings (B-C, B-Si) during 2, 3 and 4 hours at 950°C. It presents graphic relations that show the changes of microhardness along the cross-section of the models tested as well as such ones that show their resistance in the process of dry friction depending on their density and the type of their chemical and thermal coating.

Keywords: "Astaloy" powders, boronizing, boron carburizing; boronsiliconizing; thermochemical treatment.

I. Introduction

During the last years the development of powder metallurgy is connected with constant search and elaboration of new materials to improve mechanical properties of workpieces. Such type of materials are structural powder materials of the system Fe-C-Mn-Mo-Cr, which are elaborated on the basis of "Astaloy" powders.

For all workpieces, made of construction material, wear resistance is an important technological indicator. It specifies to considerable extent the effective life of the material. The nature of wear resistance upon their operation surface depends mainly on the speed of material's relative (specific) displacement, pressure and temperature conditions for operation in the area of the contact surface.

The complicated and tense conditions for operation of construction work pieces condition development of different by nature destructive processes in their surface layers. For that reason the use of a chemical-heat treatment can be rather effective for the failures over the operation surface. To this effect, carbonization, nitride hardening etc. is used [1,2], and during the last years such treatments as boronization, chromium plating, silicification and a number of complex processes of saturation become very popular [2,4,5,6,7,8].

II. Technical requirements

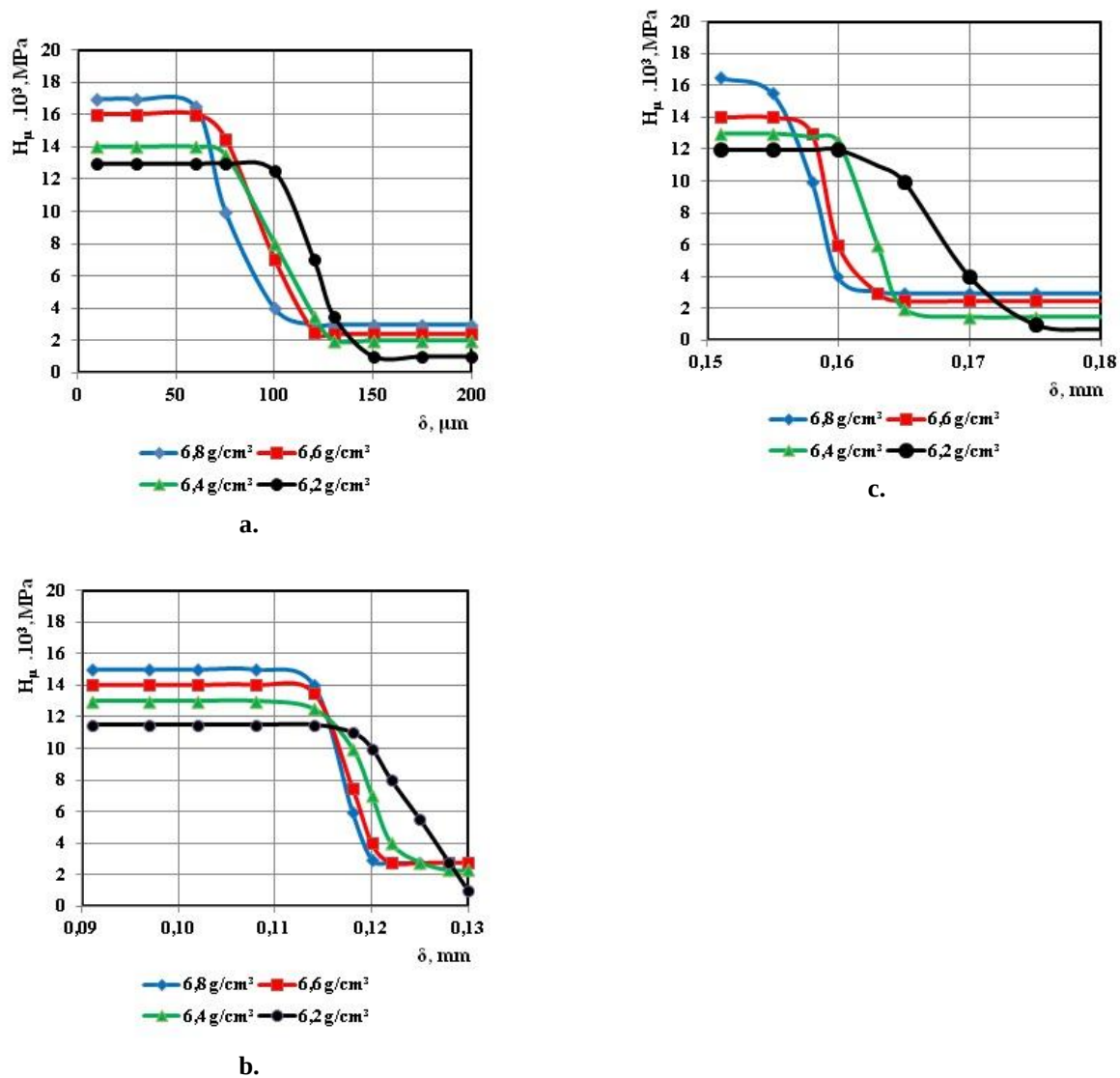
The purpose of the present research is to improve the surface hardness of metal-ceramic construction workpieces from the system Fe-C-Mn-Mo-Cr, through a surface diffusive concentration using boron, carbon and boron non-metal coating of the type B-C ; B-Si and so study their influence over the wear resistance of powder-metallurgical materials in the condition of dry friction and their failure at high loading and low speeds.

To the test were put metal-ceramic materials containing 0,35%C+3,75%Cr+1%Mn+1,35% Mo and the rest part to 100% iron. They were sintered during 1 hour at the temperature of 1250°C. The density of the samples is 6,2; 6,4; 6,6 and 6,8g/cm³. They were put to diffusive concentration in liquid saturating mediums for boronizing, boroncarburizing and boronsiliconizing of powdered construction steels developed at "MTM"-Technical University Gabrovo Department at the following temperature of saturation 800°, 850°, 900°C during 2, 3, and 4 hours.

To the saturated by this way samples, a metallographic analysis has been made by a metallographic microscope – "Neophot- 2,0" and their microhardness has been measured with the help of "D-32" accessory for microhardness.

The graphic interpretation of the results received is presented on fig. 1.

Figure 1. Distribution of microhardness in construction powder-metallurgical workpieces of type: Fe-C-Mn-Mo with a density of 6,2 ; 6,4; 6,6 and 6,8g/cm³ after: boronizing – a; boronsiliconizing - b and boroncarburizing – c.



From the figures can be seen that at the homogenous boronizing as well as the boronsiliconizing and boroncarburizing samples, the maximum microhardness is fixed upon their surface and its values are nearly invariable in the area of boride phases. The range of variance of microhardness for samples put to a homogenous boronization is within the limit 13700-17100MPa, as the higher values are registered at samples having a density 6,8g/cm³, and the lower ones have density 6,2g/cm³. The high microhardness of the formed boride coating is a result of the hardness of the boride phases - FeB 16000÷20000MPa and Fe₂B 15700÷18600 MPa, of which the coatings are constructed and it is conditioned by the formation of a stable electronic configuration of sp³-d³ type in their structure [9]. Stability of this configuration is one of the reasons heating the surface in the process of operation.

The higher values of microhardness at the samples having higher density are result of a decreased quantity of pores in the surface layer as well as of the easier formation of the high-boride phase – FeB at the denser materials [2].

When comparing the result of microhardness at the boronizing and boroncarburizing samples - fig. 1a and 1b, it seems that the formed diffusive layer has nearly the same microhardness - 13000-16000 MPa, but in contrast to the homogenous boronization, the formed layer is much thicker reaching 0,15-0,16mm, as a result of anticipatory diffusion of the carbon.

At the boronsiliconizing samples the diffusive layer is within the limits of 0,11-0,12mm depending on the density of the samples tested and the hardness is lowered in compared to the boron-carbonization and varies between 12000-14700MPa - fig. 1c. This lowering of hardness at B-Si can be explained with the specific

distribution of Si along the depth of the diffusive layer. Situating between the borides, pins it is combined with the ferrite, forming, by this way, areas of lower hardness.

When increasing the duration of saturation from 2 to 4h at equal other conditons, the distribution of microhardness does not change after boroncarburizing and boronsiliconizing. It is not observed any change of the maximum values of microhardness within the limits of the layers formed, but only increase of their depth – fig. 2.

When decreasing the temperature of saturation from 900^o to 800^o C, decrease of the values of microhardness is found out, where at the boron- carbonized samples this decrease is 1800-2300 MPa, and at the boron-silicificated samples- 2000-2700 MPa, which is a result of the difficult formation of the high-boride phase at lower temperatures of saturation – fig.3.

As in the studied by case the matrix is complexly alloyed, parallel processes of redistribution of alloying elements in the matrix proceed in the process of diffusive concentration as well. This has an essential influence microhardness in the sub-layer of workpieces.

Figure 2. Distribution of microhardness in construction powder-metallurgical workpieces of type: Fe-C-Mn-Mo-Cr with a density of 6.8 g/cm³ after boroncarburizing

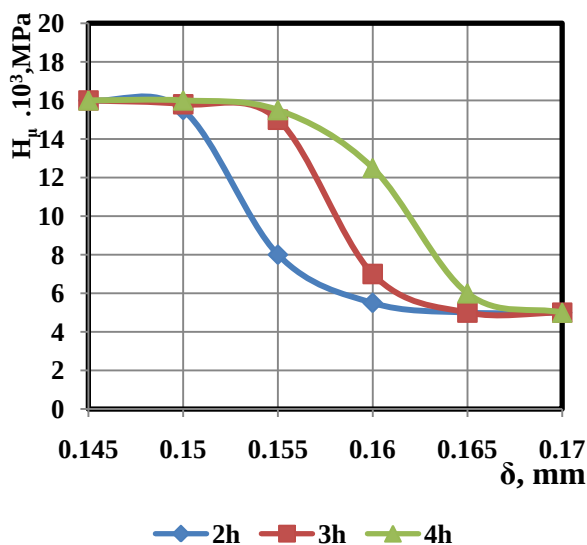
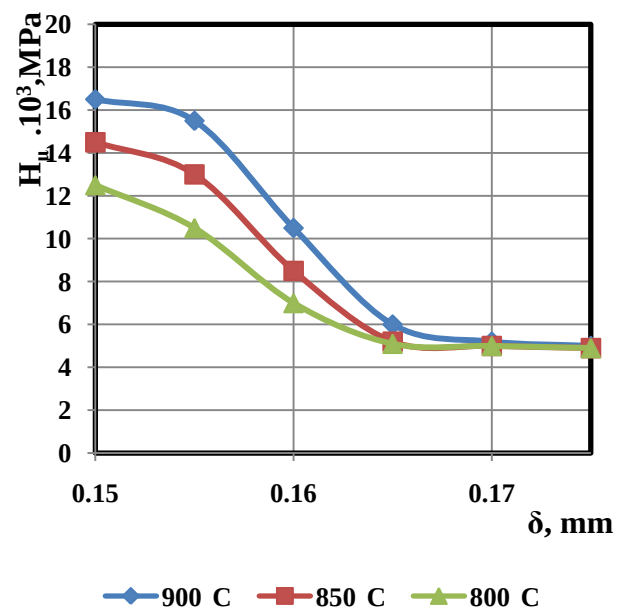


Figure 3. Distribution of microhardness in construction powder-metallurgical workpieces of type: Fe-C-Mn-Mo-Cr with a density of 6.8 g/cm³ after boroncarburizing



Molybdenum and carbon practically do not dissolve in borides, as a result of which during the process of saturation they pushed into the sub-layer and regroup in the sub-boride area. In parallel to that, they make difficult the diffusion of boron towards the core, as a result of which the formed over the samples of Fe-Cu powdered materials at equal other conditions [5,9].

In order to define the wear resistance of saturated samples an apparatus is used, developed in the Laboratory of Metal Testing at the Technical University of Gabrovo. As a criterion of the wear the coefficient “n” is used, which is calculated by the formula (1):

$$n = \Delta P / (s \cdot \tau) \text{ [g/m}^2 \cdot \text{h]} \quad (1)$$

where: ΔP – loss of weight for a certain time – g;

τ – time of wear – h;

s – wear surface – m².

Graphic interpretation of the results received at the research in coordinate change of weight reduced to a unit of surface and wear duration are shown on fig.4.

From the figures can be seen that the greater wear is observed at samples having lower density independently on the type of chemical-heat treatment. This can be explained with the reduced adhesion of particles from these samples and their fast removal from the workpieces surface in the process of friction – a sample and a metal disk.

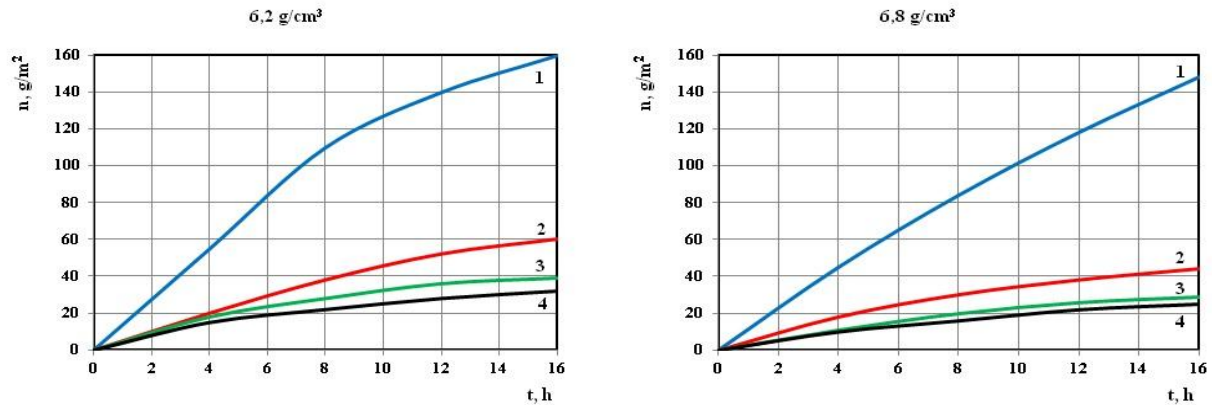
Increasing of density from 6,2 to 6,8 g/cm³ leads to reducing of the loss of weight, where for samples put to homogenous boronizing, after a wear during 14h, the weight loss for density 6,8 g/cm³ lower, compared to the samples having density of 6,2 g/cm³. After testing the boroncarburizing samples, a wear is observed upon the denser (6,8 g/cm³) samples, which is 17-20 g/m² lower than the samples having a density of 6,2 g/cm³.

Analogical results are received at the boronsiliconizing samples at which the denser ones are worn out 10-15 g/m^2 less than the non-denser ones.

For all types of thermochemical treated workpieces the wear resistance is greater than the unsaturated ones at equal other conditions - density, time of a wear and so on.

At the samples put the homogenous boronizing this difference is about 6 times, and the boroncarburizing and boronsiliconizing – 4÷5 times. It is known from the literature that the wear, process of shear of microvolumes on the workpieces surface proceed.

Figure 4. The wear resistance change of samples depending on the duration of friction workpieces of type Fe-C-Mn-Mo-Cr - 1 and after boroncarburizing - 2; boronsiliconizing -3 and boronizing - 4 $t_s=4\text{h}$, $T_s=900^\circ\text{C}$



Some authors claim that decreasing of the wear resistance is due to the decreased hardness of the friction surfaces [9], and other researchers prove that the hardness of the friction surfaces do not predetermine the extent of material's wear, and that it depends on the structural-power state of the surfaces before and after diffusive processes [10,11].

Comparing the results from the metallographic analysis it has been found out that at the different types of boride coating the basic layer is built up of the phases Fe_2B , FeB . It has been established that in the cases when FeB forms a dense layer on the surface of the saturated samples, they have a lower wear resistance compared to the cases where this phase is under the guise of separate inclusions. The reason for that is because in spite of the fact that FeB has much greater hardness, it has a lower wear resistance and respectively lower speed of wear as they do not depend on hardness of the formed diffusive layer but on the mechanical and physical characteristics of materials as well, including their brittleness.

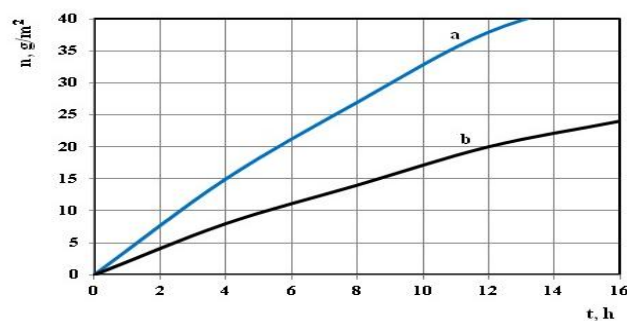
Increasing the temperature of saturation from 800°C to 900°C at the boronizing contributes to the increase of wear resistance of layer as its depth increases, and as a result of this the content of boride in it too. When increasing the temperature of saturation above 1000°C , the increase of FeB is considerable - a dense layer of a high boride phase is formed, which leads to increasing the brittleness and decreasing the wear resistance of the coatings – fig. 5.

Wear resistance of the layers not containing FeB is lower than those containing inclusions of this phase. The greater wear of the samples having lower density- $6.2\text{g}/\text{cm}^3$ is a result of the weaker adhesion of particles as well as of the slower increase of the concentration gradient over the saturated surface caused by the greater porosity.

The presence or absence of FeB over the surface of the samples saturated is defined by the conditions of proceeding of diffusive processes - temperature, duration of saturation, type of the saturating medium etc.

At the complex boride coating the presence of alloying elements in FeB causes considerable changes of the characteristics of surface layers of the diffusive upgraded materials including their wear resistance.

Figure 5. The wear resistance change of samples depending on the duration of friction with density- $6.4\text{g}/\text{cm}^3$, $t_s=2\text{h}$, $T_s = 900^\circ\text{C}$ - a, $T = 1050^\circ\text{C}$ - b.



Comparing the results from the wear of boroncarburizing and boronsiliconizing samples it is seen that in spite of their lower microhardness- fig. 1, boronsiliconizing samples possess better wear resistance - fig. 4. It is due to the fact that at boronsiliconizing of low – alloyed and medium - alloyed powder-construction materials, coatings are formed which contain a great quantity of a brittle FeB phase. In this case the wear resistance of the diffusive hardened surface increase in return for a considerable reduction of the brittle separated sections of boride coating in the process of the wear.

III. Conclusion

From the research made about the wear resistance of powder- metallurgical construction materials of the system Fe-C –Mn- Cr- Mo after coating of boron and boron-non-metal coatings, it was found that more essential improvement of the wear resistance is reached when forming a layer Fe₂B and inclusion FeB on the surface of the saturated products. However, improving the wear resistance by boron and boron-non-metal coatings can be made only in these cases when the workpieces are not break off and fall between the friction surfaces under the guise of abrasive pallets and contribute to the faster wear of workpieces.

The results, received from the experiment, corroborate the theory of the link between the structural-power state of the system and its wear resistance. In the studied by us case boronization of powder-metallurgical samples of the system Fe-C-Mn-Cr-Mo, maximum wear resistance is received not in cases when the layer has a maximum hardness - at a dense layer FeB, but when the power state of the system is optimal.

IV. References

- [1] Бельский, Е.А. Химико-термическая обработка инструментальных материалов. Минск, Наука и техника, 1986.
- [2] Ворошнин, Л.Г. Борирование промышленных сталей и чугунов. Минск, Белорус, 1981.
- [3] Митев, И., К. Попов, Химикотермично обработване на проникнаеми прахови конструкционни материали, Машиностроене и машинознание, кн.№17, 2012, с.74÷77, ISSN 1312-8612
- [4] Митев, И., К.Попов, Съвместяване процесите синтероване и химико-термично обработване при прахови материали на Fe основа, МНТК „УНИТЕХ‘ 12”, Габрово, 2012, том II, с. 135÷140, ISSN 1313-230X
- [5] Митев, И., И.Винев, Технология для идготовления антифрикционных материалов на основе Fe-Cu, 17÷19 September, 2008,Uzice, Serbia, p.137÷142
- [6] Mitev, I., Kinetics of Diffusion Processes in Carbonizing Iron – Copper Powder – Metallurgie Materials, Ohrid, September, 16÷17, 2004, p. 115÷120
- [7] Mitev, I., Siliconizing of Fe-C-Mn- Cr-Mo Sintering Structural Materials , IV International Congress “ Mechanical Engineering and Technologis – 04” , September 23÷25, 2004, Varna, Bulgaria, p. 175÷179, ISSN 1310 – 3946
- [8]. Mitev, I., M. Georgieva, Influence of Mn over the Structure after Sintering of Fe-C-Cr-Mn–Mo Powder-Metallurgic Materials, “Unitech – 04”, 18÷19 November, 2004, volume II, p. 197÷203, ISBN 954 – 683 – 304 – 5.
- [9] Mitev, I., Determining Carbon Diffusiviti in Copper Alloyd Austenite of Structure Cermet, 31.08÷04.09.2004, Zlatibor, Serbia and Montenegro, p.232÷239