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Effect of Nanodiamonds Modification of Chromium Coating on Sintered Ferrous Materials

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Abstract. Chromium coatings modified with nanodiamond particles are deposited on sintered ferrous materials. NanoDiamond particles are produced by Detonation Synthesis (NDDS). The NDDS particle size is from 10 to 50 nm. The effect of the modification of the chromium coating with NDDS on the density and porosity, apparent and plane, is studied. The microstructure and microhardness are determined by metallographic methods. Optical microscope and scanning electron microscope images of the coating show that the coating material enters into the gaps of the porous metal parts and thus increases the adhesion to the base material. The influence of the alloying elements of the matrix material on the properties of the chromium and NDDS coating is evaluated. The best results are obtained with samples prepared from ferrous powders with low carbon content. It can be concluded that the composite chromium coating applied at low carbon content products has better performance.

Keywords: chromium coating, nanodiamonds, sintered ferrous products.

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1. Introduction

The modification of the chromium galvanic coatings with nanodiamond particles increases the chemical and mechanical properties of the substrate material. The research of the influence of the nanodiamond particles on the characteristics and properties of the modified chromium layer in the published studies refers to coatings on dense materials [1–3]. There is no data about electrochemical composite (chromium and nanodiamond particles) coatings on sintered ferrous products. On the other hand the sintered ferrous products have a lot of advantages – high production rates, low cost, precise dimensional tolerances in the finished product, complex shaped parts.

The objective of this paper is to study the effect of modification of chromium galvanic coating with nanodiamond particles on sintered ferrous products in relation to the properties of the coating.

It was found that the depositing of chromium on sintered ferrous products gives better results when the coating is obtained from electrolyte containing nanodiamond particles compared to coating from electrolyte without NanoDiamond particles produced by Detonation Synthesis (NDDS).

2. Experimental

The electrochemical chrome plating was carried out on sintered samples prepared from iron powders Astaloy Mo (AMo7), Distaloy AB2 (DAB2) and Distaloy AB5 (DAB5) with chemical composition shown in Table 1.

Table 1. Chemical composition of the initial ferrous powders

Components, wt%	C	Cu	Ni	Mo	MnS	Balance, Fe
Astaloy Mo	0.7	2.0	–	1.5	–	95.8
Distaloy AB2	0.2	1.5	1.7	0.5	0.5	95.6
Distaloy AB5	0.5	1.5	1.7	0.5	0.5	95.2

The samples were prepared at pressure 420, 550 and 700 MPa and sintered at 1120 °C for 30 minutes in reducing environment. The total sintering time was 150 min. Their dimensions were 12.7×31.7×10 mm.

The chromium was deposited on the surface of the sintered items by electrolytic process. The parameters of the electrolytic process were: current density – 45 A/dm^2; duration of the process – 45 min; temperature of the electrolyte – 50 °C. The electrolyte used was the traditional acidic electrolyte with CrO_3 –220 g/l, and H_2SO_4 – 2.2 g/l. The nanodiamond particles were added to the electrolyte as an aqueous suspension. Their concentration was 25 g/l. The nanodiamond particles were produced by detonation synthesis [4].

The weight is measured before and after the coating process. The increase in weight shows the yield of chromium on the surface of the sample and indirectly the average thickness of the coating. The yield and the thickness values are approximate because of the roughness of the surface and the difficulty to determine exactly the total area. The microstructure and microhardness are determined by metallographic analysis methods.

3. Results and discussion

The thickness of the coating in relation of the compacting pressure and the kind of powder are given in Table 2. The actual average coating thickness is the thickness measured on the cross-section image in the micropictures. The calculated average thickness is determined by distribution of the amount of deposited chromium per unit surface. It is clearly seen that the thickness of the coating increases with decreasing the carbon content of the matrix ferrous material.

Table 2. Thickness of the coating on samples prepared from different ferrous powders at different compacting pressure

Code of sample	Compacting pressure, MPa	Actual average coating thickness, μm (actual from micropictures)	Amount of coating material, g	Average coating thickness, μm (calculated)
AMo7 420	420	23.9	0.299	26.2
AMo7 550	550	25.7	0.319	28.1
AMo7 700	700	23.0	0.289	25.6
DAB2 420	420	49.9	0.450	52.1
DAB2 550	550	47.0	0.414	47.4
DAB2 700	700	49.1	0.420	48.4
DAB5 420	420	30.8	0.408	33.7
DAB5 550	550	31.6	0.419	35.8
DAB5 700	700	29.5	0.380	32.6

A microstructure of the cross-section of samples prepared from different powders at compacting pressure 550 MPa is shown in Fig. 1. The coating adheres strongly to the surface and follows the surface topography of the sintered product. The measured chromium yield after the electrolytic process and the respective calculated thickness of the composite chromium and NDDS coating are in good correlation with the actual average coating thickness.

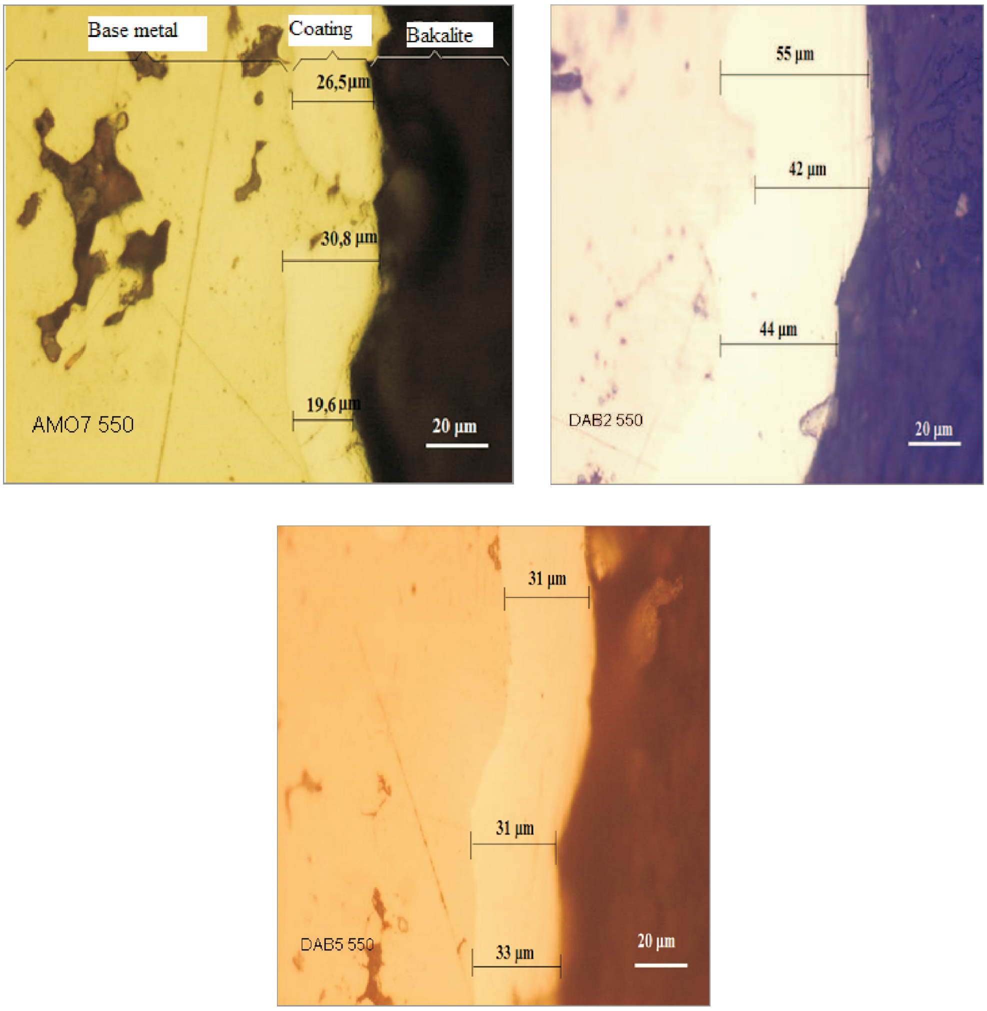

Fig. 1. Thickness of the chromium coating deposited on the surface of sintered iron samples prepared from different ferrous powders

The microhardness tests were carried out according to Vickers standard, Table 3. The microhardness increases with increasing the pressure and, respectively, with the sintered density. The difference in microhardness between the coated and uncoated samples is 4–5 times for samples prepared from both DAB2 and DAB5 powders.

Table 3. Microhardness of samples, uncoated and coated with chromium modified with ND

Initial powder	Compacting Pressure, MPa	Density, g/cm^3	Microhardness uncoated, MPa	Microhardness coated, MPa
DAB2	420	7.164	2166	10653
	550	7.196	2401	9937
	700	7.220	2450	11456
DAB5	420	7.104	2744	10868
	550	7.108	2842	10721
	700	7.111	2940	10898

The microhardness of coated and uncoated samples prepared from DAB2 iron powder was evaluated (Fig. 2). The difference in the compaction pressure did not show significant variation in the values of the microhardness of the coating.

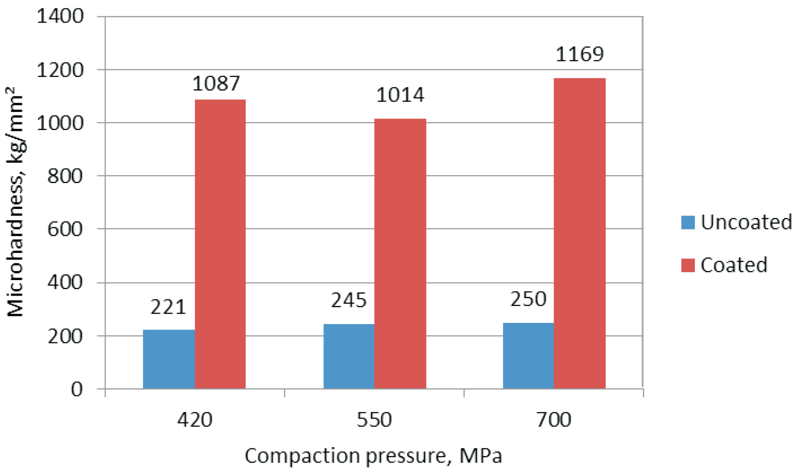

Fig. 2. Microhardness of the Cr coating and matrix for sintered iron materials

The study of the microhardness shows the high quality of the composite coating containing chromium and nanodiamond particles on sintered ferrous materials.

The best results were obtained with Distaloy AB2 (Fig. 2). The load applied on the coating was 200 g while the one on the less hard sintered iron matrix was 100 g. The measured average microhardness of the coating is 1090 kg/mm^2 which is 4.5 times higher than the measured microhardness of the matrix – 240 kg/mm^2.

4. Conclusion

- Chromium coatings, modified with nanodiamond particles, deposited on sintered ferrous materials are obtained for the first time.
- The deposition of chromium on sintered ferrous products gives better results when the coating is obtained from electrolyte containing nanodiamond particles compared to coating from electrolyte without NDDS.
- The thickness of the coating increases with decreasing the carbon content of the matrix ferrous material.
- The measured average microhardness of the coating is more than 4 times higher than the average microhardness of the iron matrix.
- The composite coating opens new technical applications of the sintered products.

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