Eurasian Journal of Physics and Functional Materials

2020, 4(3), 249-254

Influence of the detonation-spraying mode on the phase composition and properties of Ni-Cr coatings

M. Maulet[*,1], B.K. Rakhadilov[1], Zh.B. Sagdoldina[1], A.B. Kassymov[2], D.N. Kakimzhanov[3]

[1]Non-profit Limited company «Sarsen Amanzholov East Kazakhstan University», Ust-Kamenogorsk, Kazakhstan

[2]Shakarim University, Semey, Kazakhstan

[3]D.Serikbaev East Kzakhstan technical university, Ust-Kamenogorsk, Kazakhstan

E-mail: maulet_meruert@mail.ru

DOI: **10.29317/ejpfm.2020040307**
Received: 09.07.2020 - after revision

In work considers the results of studies of the phase composition and mechanical-tribological properties of Ni-Cr detonation coatings obtained at different values of the volume of filling the detonation barrel with an explosive acetylene-oxygen mixture. Analysis of the obtained experimental results indicates that the phase composition and properties of detonation coatings strongly depend on the technological parameters of spraying. When the barrel is filled with an explosive gas mixture of 40%, the coating is not dense enough, with noticeable boundaries between individual particles, which may be the result of insufficient heating and acceleration of the particles of the sprayed powder. It is determined that when the volume of filling the detonation barrel with an explosive mixture is up to 60%, there is a widening and a decrease in the intensity of the main peaks. Higher values of microhardness were obtained at 50% filling of the barrel. The results of tribological tests of coatings showed that the coating applied when filling the detonation barrel with an explosive mixture of up to 60% has a lower coefficient of friction than other coatings.

Keywords: detonation spraying, Ni-Cr, phase composition, steel 12Kh1MF, microhardness, wear resistance.

Introduction

Detonation spraying is an effective method of obtaining a coating with very low porosity and high adhesion [1]. Owing to low porosity and good adhesion, detonation spraying can effectively reduce the interior diffusion of oxygen. This provides hard, wear-resistant and dense microstructural coatings and is the best method of thermal spraying. The researchers carried out work based on the nickel coating applied by detonation spraying and studied its isothermal oxidative properties. It was found that based on the nickel coatings obtained by detonation spraying method have a favorable resistance to oxidation [2].

In the technology of spraying detonation coatings, it is essential to identify the relationship between the technological modes of spraying and the quality of the resulting coatings [3]. One of the essential technological parameters of detonation spraying that affect the temperature and speed of movement of particles of sprayed powders is the filling volume of the combustion chamber with a gas mixture. This work is devoted to the research effect of the barrel filling volume during detonation spraying on the phase composition and properties of Ni-Cr coatings applied to 12Kh1MF boiler steel.

Experimental procedure

For the substrate heat-resistant low-alloy boiler steel 12Kh1MF (equivalent to 14MoV63) was chosen. The composition of the boiler steel material is shown in Table 1. The samples were grinded using MIRKA grinding paper up to 1200 to achieve a uniform and flat surface. After grinding the samples were sandblasted.

Table 1.
Chemical composition in % of 12Kh1MF steel.

C	Si	Mn	Ni	S	P	Cr	Mo	V	Cu
0.1-0.15	0.17-0.37	0.4-0.7	until 0.3	until 0.025	until 0.03	0.9-1.2	0.25-0.35	0.15-0.3	until 0.2

The CCDS2000 detonation system was used for obtaining coatings, which has a system of electromagnetic gas valves that regulate the supply of fuel and oxygen (Figure 1), as well as control the purge of the system [4]. The volume of filling the barrel with a mixture of acetylene-oxygen varied from 40% to 60%. Nitrogen was used as a carrier gas. The experiments were provided in based on the Scientific research center "Surface Engineering and tribology" of the non-profit limited company "Sarsen Amanzholov East Kazakhstan University".

Research of the phase composition of samples were carried out by x-ray diffraction analysis using X'PertPro diffractometer using CuKα-radiation. For study the general nature of the structure was used an optical microscope «NEOPHOT-21» [6, 7]. The tribological characteristics of the coatings were studied using a friction machine according to the scheme «ball-on disk» on the tribometer TRB3. The microhardness of the samples was measured by pressing a diamond indenter on the PMT-3M device in consent with GOST 9450-76.

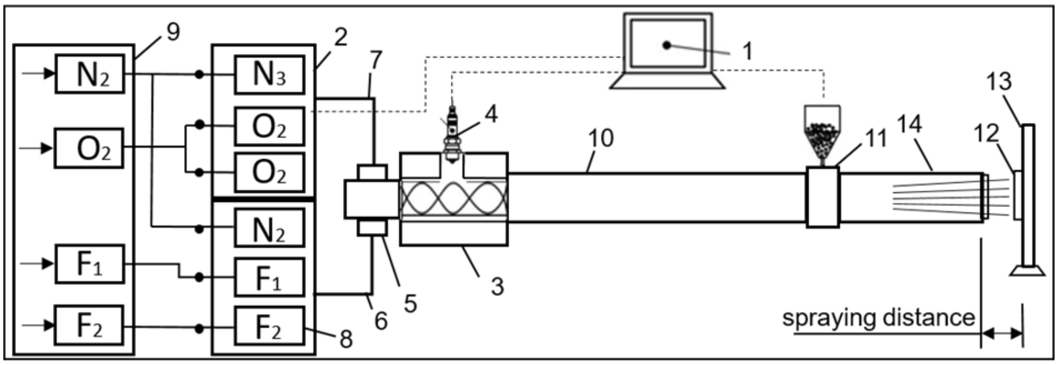

Figure 1. Principled schematic diagram of the CCDS2000 detonation complex [5]: 1 - control computer, 2 - gas distributor, 3 - mixing-ignition chamber, 4 - spark plug, 5 - barrel valve, 6 - fuel line, 7 - oxygen line, 8 - gas valves, 9 - gas supply unit, 10 - indicated part of the barrel, 11 - powder dispenser, 12 - workpiece; 13 - manipulator, 14 - the muzzle of the barrel.

Results and Discussion

Analysis of the obtained experimental results indicates that the phase composition and properties of detonation coatings strongly depend on the technological parameters of spraying. Based on the results, we found that by varying the technological parameters of coating application, such as the percentage of filling of the barrel, the ratio of the gas mixture, it is possible to control the structure and phase composition. At the same time, it is possible to determine the optimal conditions for the development of technological modes for obtaining Ni-Cr coatings. An increase in the velocity pressure of detonation products is achieved by increasing the volume of the detonating mixture (or the degree of filling of the barrel of the detonation installation), which at the time of detonation match to a decrease in the specific volume of detonation products. Increasing the velocity pressure of detonation products contributes to the overall improvement of the quality of coatings, in particular wear resistance and microhardness.

Figure 2 shows the microstructure of the surface and cross-section of Ni-Cr detonation coatings when the barrel is filled with an explosive mixture of 40%, 50% and 60%. When the barrel is filled with an explosive gas mixture of 40%, the coating is not dense enough, with noticeable boundaries between individual particles, which may be the result of insufficient heating and acceleration of the particles of the sprayed powder. With an increase in the volume of filling the barrel with an explosive mixture by 50% and 60%, there is an increase in the density of coatings.

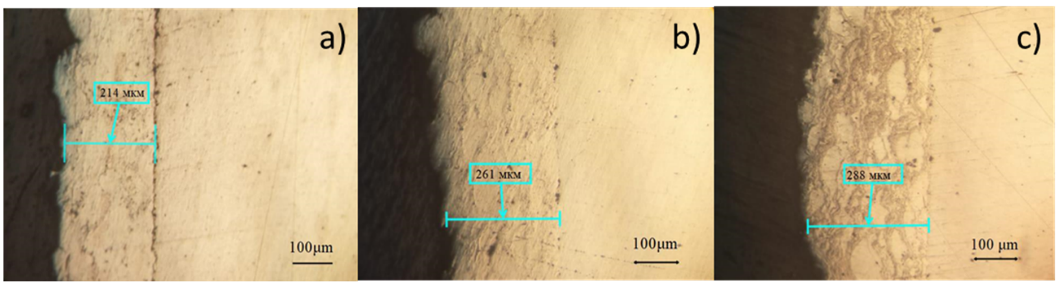

Figure 2. Microstructure of Ni-Cr detonation coatings: filling volume of barrel 40% (a), filling volume of barrel 50% (b), filling volume of barrel 60% (c).

The results of X-ray phase analysis of coatings showed that the powder and coatings consist of $CrNi_3$ phases (Figure 3). With the increases filling volume, occurs the widen all X-ray peaks of the $CrNi_3$ phase. On the diffractogram of the coating obtained when volume filling the detonation barrel with an explosive mixture up to 60%, alongside with widening, a decrease in the intensity of X-ray peaks of the $CrNi_3$ phase is occured. The increase in the intensity of all peaks may be due to the transition of a part of the substance to a nanophase or an amorphous state.

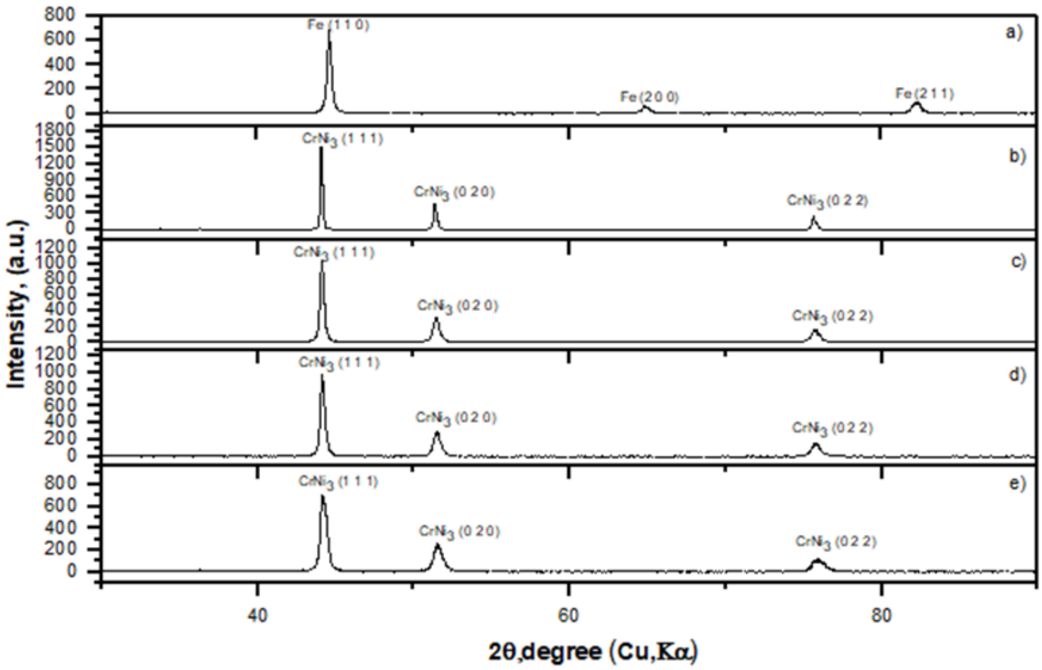

Figure 3. Diffractogram of Ni-Cr coatings: (a) initial steel 12Kh1MF, (b) powder $CrNi_3$, (c) filling volume of barrel 40%, (d) filling volume of barrel 50%, (e) filling volume of barrel 60%.

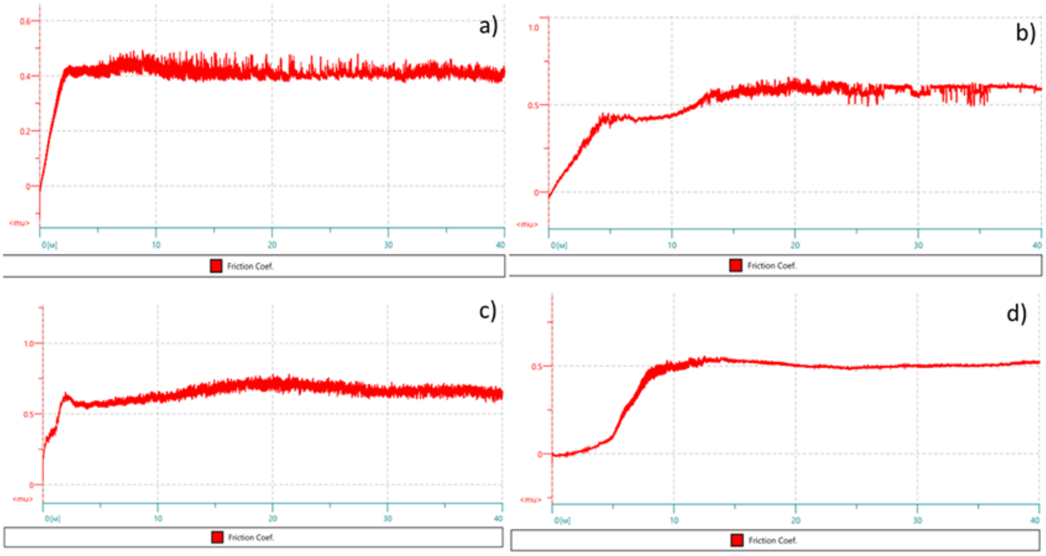

Figure 4. Coefficient of friction of coatings Ni-Cr: (a) initial steel 12Kh1MF, (b) filling volume of barrel 40%, (c) filling volume of barrel 50%, (d) filling volume of barrel 60%.

The results of tribological tests of coatings showed that the coating applied when filling volume the detonation barrel with an explosive mixture of up to

60% has a lower coefficient of friction than other coatings (Figure 4d). Coatings applied at a filling volume of 40% and 50% showed approximately the same value of the coefficient of friction (Figure 4 (b, c)).

Figure 5 shows changes in the microhardness of a 12Kh1MF coated steel sample. The Ni-Cr powder obtained by detonation coating is showed a higher microhardness when compared the main material. When the barrel is filled with an explosive gas mixture of 40%, the microhardness compose 2570 MPa, due to insufficient heating and acceleration of the particles of the sprayed powder. Higher values of microhardness were obtained at 50% and 60% filling of the barrel.

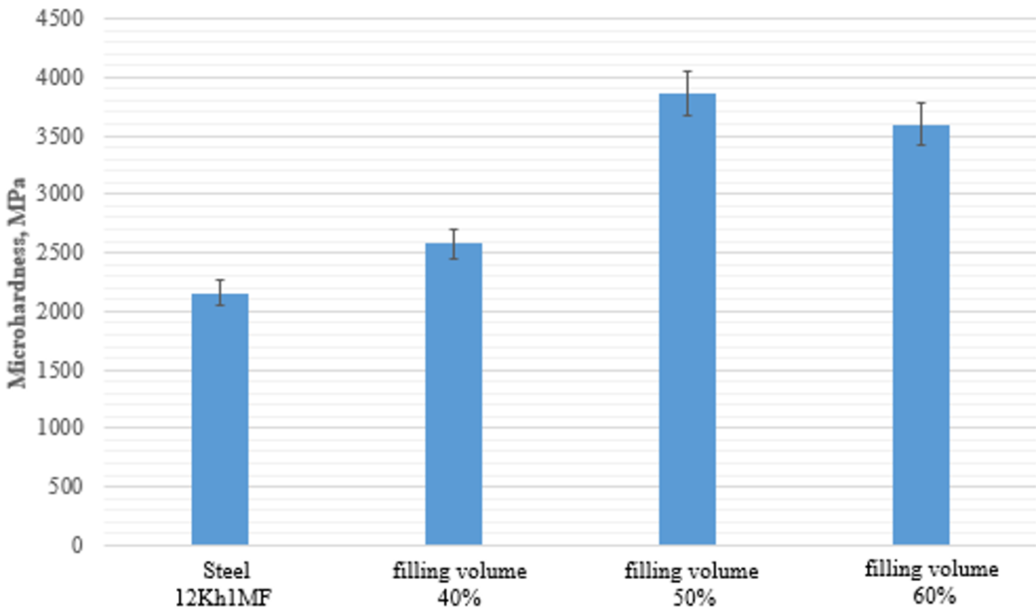

Figure 5. Graph of changes in the microhardness of Ni-Cr coatings: initial steel 12Kh1MF, filling volume of barrel 40%, filling volume of barrel 50%, filling volume of barrel 60%.

Conclusion

Thus, analysis of the obtained experimental results indicates that the phase composition and properties of detonation coatings strongly depend on the technological parameters of spraying. When the barrel is filled with an explosive gas mixture of 40%, the coating is not dense enough, with noticeable boundaries between individual particles, which may be the result of insufficient heating and acceleration of the particles of the sprayed powder. It is determined that when the volume of filling the detonation barrel with an explosive mixture is up to 60%, there is a widening and a decrease in the intensity of the main peaks. Higher values of microhardness were obtained at 50% filling of the barrel. The results of tribological tests of coatings showed that the coating applied when filling the detonation barrel with an explosive mixture of up to 60% has a lower coefficient of friction than other coatings.

Acknowledgments

The work was performed in the framework of program-targeted funding of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan for 2018-2020.

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