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DETONATION COATINGS BASED ON TiAl INTERMETALLICS WITH ADDITIONS OF NON-METALLIC REFRACTORY COMPOUNDS

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ABSTRACT

The results of producing and examination of structure and phase composition of detonation coatings from composite powders (CP) based on TiAl intermetallics and non-metallic refractory compounds (B_4C , BN, SiC, Si_3N_4) are presented. Detonation spraying with CP was carried out using the automatic detonation complex "Perun-S". As working gases, the mixture "propane-butane-oxygen" and as diluent and transporting gas air were used. CP for detonation spraying was produced by the method of mechanochemical synthesis (MChS) with a subsequent conglomeration. The size of CP particles was 40–80 μm . It was revealed that the main changes in the phase composition of detonation coatings as compared to the source CP consist in the appearance of a large number of oxide phases; in the composition TiAl- B_4C - TiO_2 , Ti_3O_5 ; TiAl-BN- Ti_3O_5 , TiO, TiO_2 ; TiAl-SiC- TiO_2 , Ti_3O_5 , SiO_2 ; TiAl- Si_3N_4 - TiO_2 , TiO, SiO_2 . The most dense and homogeneous structure was obtained in the coatings with CP TiAl-SiC i TiAl- Si_3N_4 .

KEYWORDS: Ti–Al system intermetallics, non-metallic refractory compounds, detonation coatings

INTRODUCTION

Due to low density, high specific strength, good mechanical properties at elevated temperatures and resistance to environmental influence, TiAl intermetallics are already used for some components of the automotive and aircraft industry, including for turbochargers or low-pressure turbine blades. However, some drawbacks inherent in TiAl alloys, such as low plasticity and low impact toughness are still inhibiting their wider use as a bulk material. On the other hand, TiAl can be used as a protective coating, for example, for titanium alloys. The main advantages of TiAl coatings consist in the fact, that they have a density lower than MCrAlY alloy coatings, good compliance with titanium alloys in terms of thermal and mechanical properties, as well as the ability to form a strong adhesion with a metal base due to interdiffusion at a lower tendency to brittle phase formation. In addition, adding alloying elements can reduce the rate of oxidation and improve the mechanical properties of TiAl binary alloy. To provide TiAl alloy with a high strength, rigidity and wear resistance SiC, TiB_2 , B_4C , TiC, Al_2O_3 , etc. are used [1–4].

TiAl-based coatings can be produced in several ways, among which thermal spraying [5, 6] and aluminizing have become most widespread [7].

Among the different methods of thermal spraying of TiAl coatings, most studies were focused on plasma, high-velocity oxygen fuel (HVOF), cold, detonation and electric arc surfacing.

As for the coatings produced by detonation spraying, the research data are mainly referred to TiAl [8–13], Ti_3Al [12, 14] and TiAlCr [15].

In [10, 11, 14], in addition to intermetallics, in the coatings small amounts of titanium carbide, nitride and oxide were found. These secondary phases are located on the boundaries or inside the lamellas, depending on the mechanism of formation. The formation of such inclusions of the secondary phase is sometimes carried out consciously, as they provide or enhance the specific characteristics of coatings. For example, titanium nitride was included in the composition of TiAl-coatings to increase the tribological properties of these coatings [14]. Titanium aluminide coatings deposited using hydrogenated titanium [16] was distinguished by a higher hardness, heat resistance and oxidation resistance as compared to the coatings deposited from the source titanium aluminide [12]. The process of detonation spraying can be used to produce nanostructured aluminotitanium coatings with a higher microhardness than appropriate plasma coatings. Producing multilayer aluminotitanium coatings from conventional and nanostructured powders with alternating layers from partially molten nanostructural material are presented in [11]. In [14] the results of studying the composition of the coatings produced by the method of detonation spraying from Ti_3Al powders in environments of different chemical composition are presented by changing the ratio of O_2/C_2H_2 . In these coatings, along with Ti_3Al , TiN and Ti_2N were revealed, which are formed as a result of the reaction of heated particles with nitrogen used to transport the powder. In addition, the studies showed that in the conditions of detonation spraying, a strong oxidation of Ti_3Al occurs, which contributes to the loss of aluminium.

In [11, 12] the authors revealed that from the mechanically alloyed Ti powder, 50 at.% Al a ceramic coating based on Al_2TiO_5 compound can be produced by the oxidizing

effect of the working gas environment on the powder. Titanium aluminide coatings based on TiN inclusions can be formed at the influence of the working gas environment (air, nitrogen) on the powder. At the same time, when using cast TiAl (γ) powder, its phase composition is inherited by the coating. Thus, the coatings produced from mechanically alloyed and cast powders are different both in structure and phase composition. The use of powders produced by mechanoalloying allows not only to vary the phase composition of coatings due to a high chemical activity of a nanostructural X-ray amorphous sprayed material, but also provides new opportunities for creating the optimal coating structure.

The aim of the work was to study the processes of coating formation during spraying by detonation method from composite powders based on TiAl intermetallics with additions of non-metallic refractory compounds (B_4C , BN, SiC and Si_3N_4).

CHARACTERISTICS OF SOURCE MATERIALS AND RESEARCH PROCEDURE

As the source materials to produce coatings by the method of detonation spraying, TiAl intermetallics powder was used containing (wt.%): 62.5 Ti and 37.5 Al (T65Yu35) and composition powders (CP) based on it with the introduction of non-metallic refractory compounds (NRC) such as B_4C , BN, SiC, Si_3N_4 into their composition.

The composite TiAl/NRC powders were produced by the method of mechanochemical synthesis (MChS) in the high energy reactor "Activator 2SL" at 1.5 h of processing. The technology of producing CP of this type is described in detail in [17]. For powder conglomeration, polyvinyl alcohol (PVA) in the amount of 3 % was used.

To study the source powders and sprayed coatings, the methods of metallographic, X-ray structural phase and microdurometric analysis with the construction of variational curves of microhardness were used.

SELECTION OF DETONATION SPRAYING MODE

The coatings were sprayed in the detonation installation "Perun-S". As working gases, a mixture of "propane-butane-oxygen", and as a diluent and transporting gas air were used.

When choosing a detonation spraying mode, a series of experiments was performed with an assessment of the effect of the degree of filling the barrel of a detonation installation with a working gas on the quality of coating, determining the optimal spraying distance, optimal process cyclogram, as well as the consumption of transporting gas and the thickness of the coating, which is formed in a one cycle.

To study the effect of the degree of filling of the barrel on the quality of coatings, the air consumption in the mixture (from 0.4 to 1.15 m³/s) was changed at a con-

stant ratio of working gases (propane-butane and oxygen) consumption being 1:3 and a distance of spraying of 100 mm, which corresponds to the change in connection with this degree of filling the barrel from 58.3 to 76 %. The most optimal ratio for producing quality coatings was the ratio of working gases (propane-butane+oxygen+air) being 1:3, 1:1.3 for spraying coatings from Ti-Al powder with the particles size of 40–100 μ m and the degree of filling the installation barrel being 64 %.

When changing the spraying distance, the 4 distances from the muzzle barrel of the installation to the base with an interval of 40 mm (70, 110, 150 and 190 mm) was chosen. It was found that during spraying at a distance of 70 mm, the coating is dense with a clearly defined border, but both the base and the coatings have temper colors, probably caused by overheating of the base and the coating. In addition, at a small spraying distance, the base may deform and in the coating microcracks may appear under the action of thermal stresses. During spraying at a distance of 110 mm, the coating is dense, the powder particles of all sizes are involved in the formation of the coating: in small-sized particles the temperature and velocity have not been already reduced, the border of the coating is slightly blurred, the temperature of the base and the coating is ~ 300 °C. The coating at a spraying distance of 150 mm is formed by medium- and large-sized powder particles, and small-sized particles lose velocity and temperature at this distance. The coating spot is larger than the diameter of the barrel, the border is blurred, the porosity of the coating is increased. At a spraying distance of 190 mm, the coating is formed of large-sized particles that have not lost their velocity and temperature. The coatings of large powder particles have a considerable porosity, the border of the spot is blurred, on the base it is possible to see traces of ricochet of large particles. As the spraying distance increases, the temperature and velocity of the spraying particles decreases, which leads to the formation of a loose coating and reduction in the adhesion strength, which can lead to delamination of the coating from the base. Thus, according to the results of the coatings produced during spraying at different spraying distances, a distance of 110 mm was chosen.

To produce a quality coating, it is necessary that the sprayed powder particles interacting with the products of detonation acquired the required energy characteristics, i.e. the temperature of 0.8–0.9 from the melting point of the powder material, the velocity of the powder particles is 600–1000 m/s at the exit from the barrel. Obtaining such characteristics is achieved by the optimal value of powder loading into the barrel — the distance between the edge barrel and the location of the material portion being sprayed at the moment of mixture explosion. The size of the powder portion load is regulated by the cyclogram.

The cyclogram provides a pulse of transporting gas to supply the portion (cloud) of the powder to the desired place of the barrel at the moment of initiation of the gas mixture explosion. The choice of the cyclogram should be coordinated with the degree of filling the barrel with a mixture of working gases so that the powder cloud does not go beyond the mixture. In the "Perun-S" installation, 8 cyclograms (four per each dispenser) are provided, which can be used to deposit coatings of powder materials with different density and different sizes of particles. To supply the powder to the desired place of the barrel (at this degree of filling), the cyclogram 2-2 (dispenser 2) is installed, which is intended for spraying powders with a density of 3–9 g/cm³ and particle size of 10–50 μm, which provides the location of a powder cloud with a length of 200 mm at a distance from the barrel edge to the front part of the cloud being 150 mm. The generation frequency during spraying of coatings was 6.6 s⁻¹.

The amount of transporting gas consumption is used to regulate the amount of a portion of the powder to produce a certain thickness of the coating per 1 cycle. For this detonation installation with a barrel length of 550 mm and a barrel diameter of 20 mm, a portion of powder (most of the sprayed materials) is optimal, during spraying of which the thickness of the coating per 1 cycle is 4–6 μm. Increasing the portion of powder (and the thickness of the coating) causes non-uniform heating of moving particles in the center and on the periphery of the metallization flow. Reduction of a powder portion leads to a decrease in the thickness of the coating, which is not economically feasible.

For TiAl powders with a density of 3.0–3.8 g/cm³, the consumption of composite powders in the installation Perun-S was 0.9–1.2 kg/h.

Thus, for spraying coatings from TiAl-based powders with a melting point of the base being 1200 °C and particle size of 40–100 μm, a mode with the ra-

tio of working gases 1:3, 1:1.3 and their consumption: propane-butane of 0.5 m³/h, oxygen — 1.55 m³/h, air — 0.65 m³/h was selected. The degree of filling the barrel was 64 %. To supply the powder to the desired place of the barrel (at this degree of filling), the cyclogram 2-2 (dispenser 2) was installed. The consumption of transporting gas for powders with the density of 3.0–3.8 g/cm³ and particles with the size of 40–100 μm was 0.15–0.3 m³/h. The spraying distance is 110 mm.

RESEARCH RESULTS AND DISCUSSION

Using the XRD method, in the source powder T65Yu35 TiAl, the phases of TiAl (γ -phase) and Ti₃Al were revealed (Figure 1, *a*). After grinding in the planetary mill, an expansion of diffraction lines and a decrease in their intensity (Figure 1, *b*) occurs, which indicates a partial amorphization of powder.

To find out the mechanism of physico-chemical interaction of components in CP in the conditions of the detonation spraying method, the coating of three types from TiAl powder without NRC additives was first investigated: 1) from the source powder in as-delivered state; 2) from the powder subjected to processing in the planetary mill for 1.5 h; 3) from the powder subjected to processing in the planetary mill with a subsequent conglomeration.

The study of the structure of detonation coatings from TiAl powder of all three types showed that the produced coatings are dense, without cracks and delaminations from the base, they contain large dark gray oxide lamellas, a small number of thin light lamellas and deformed light particles (Figure 2). In the coating from a grinded and conglomerated powder, the structure is more fine-dispersed with the most uniform distribution of light and dark lamellas (Figure 2, *c*). Microhardness in the coating from the source powder is 5330 ± 800 MPa, and in the coatings of grinded powder and that processed in the planetary mill with a subsequent conglomeration has almost no difference (average values are respectively 3990 ± 800, 4190 ± 630 MPa), and the most probable (Figure 3) are 3975 and 4010. The XRD method found that in the coatings from TiAl powders of all three types, the main phases are TiO₂, Al₂O₃ and TiO (Figure 4). The content of TiAl and Ti₃Al intermetallic phases from the conglomerated powder coatings are slightly increased relative to the coating from the source powder (traces). Regarding the quantitative phase composition, it is necessary to note the presence of more intensive peaks of intermetallic phases on X-ray patterns from grinded powders; in addition, judging by the intensity of X-ray lines, the content of TiO₂ is higher in the coating from the source TiAl powder (in Figure 4, *a*), than in the coatings of grinded powders (Figure 4, *b, c*), moreover, in the grinded powders, traces of Ti₃O₅ oxide were found. These differences may be associated with the

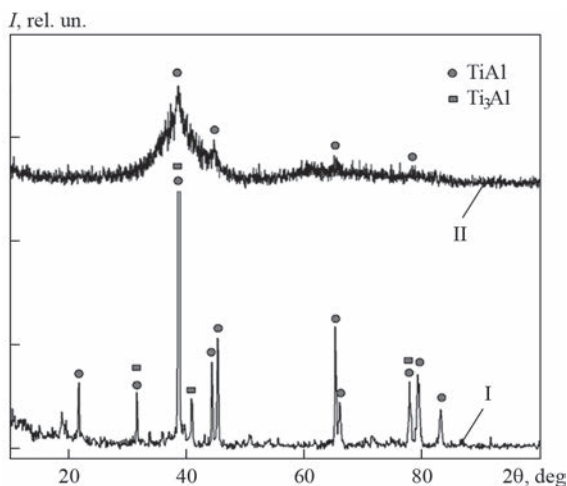


Figure 1. X-ray patterns of source TiAl powder (*a*) and TiAl powder after mechanical grinding in the planetary mill (*b*)

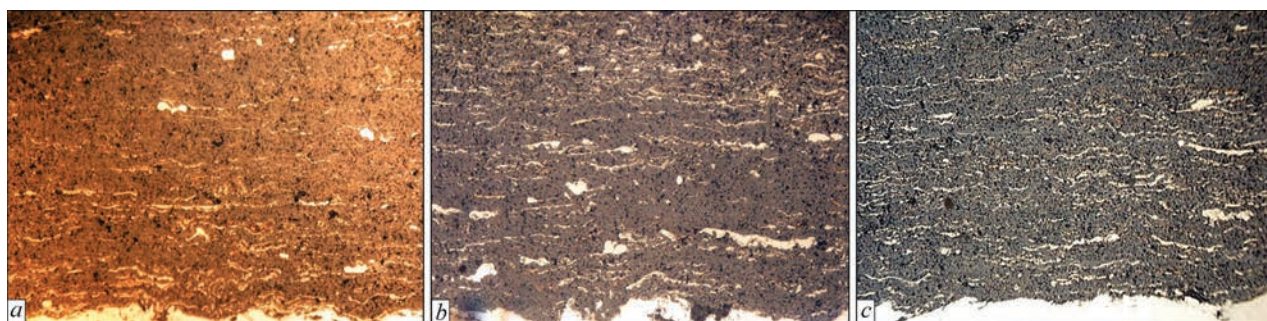


Figure 2. Microstructure ($\times 400$) of detonation coating from TiAl powder: *a* — source powder; *b* — powder produced by grinding in the planetary mill for 1.5 h; *c* — powder produced by grinding with a subsequent conglomeration

dispersion of sprayed powder particles (Table 1). The higher sizes of particles of 2nd and 3rd type as compared to the 1st one are explained by the formation of larger particles due to the welding processes during mechanical processing of powder in the planetary mill and in the future during conglomeration.

On the basis of the analysis of the results of the conducted investigations (Table 1), to produce composite powders and coatings from them, TiAl-powder of two types were selected: the powder processed in the planetary mill for 1.5 h; the powder processed in the planetary mill for 1.5 h with a subsequent conglomeration.

To deposit detonation coatings, the composite TiAl/NRC powders were used produced by the MChS method both in the initial state as well after additional processing-conglomeration (Table 2). At the same time, some differences in the structure and phase composition of the produced coatings were identified.

The examination of the structure of detonation coatings from composite TiAl/B₄C powder showed

that the structure from a non-conglomerated powder (Figure 5, *a*) is dense, without cracks and delaminations, lamellar, consists of dark gray and has a small number of thin light lamellas. In the structure of the coating produced from a conglomerated powder (Figure 5, *b*), a larger number of light lamellas and non-melted particles with small dark gray inclusions is observed. The microhardness of the coating from the powders of both types differs slightly. The average values are 5550 ± 1080 and 4760 ± 950 MPa, respectively (most probable are 5090 and 5200) (Figure 6). When comparing the phase composition of the coatings (Figure 7) with the source powder (Table 2), it is possible to note an increase in the number of boride and carbide phases — products of interaction of CP components in the process of spraying and the appearance of oxides, first of all, of titanium as a result of interaction of CP particles with detonation flow in the process of spraying. At the same time, it can be noted that the coating from a conglomerated pow-

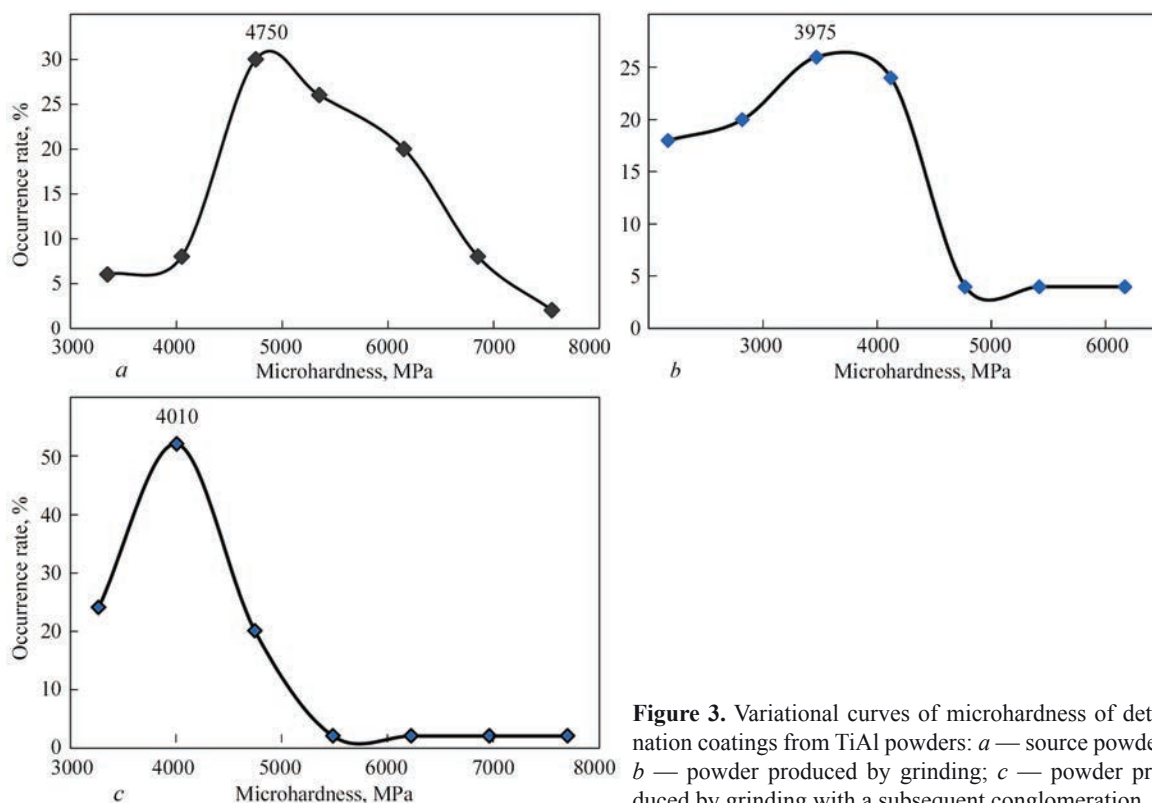


Figure 3. Variational curves of microhardness of detonation coatings from TiAl powders: *a* — source powder; *b* — powder produced by grinding; *c* — powder produced by grinding with a subsequent conglomeration

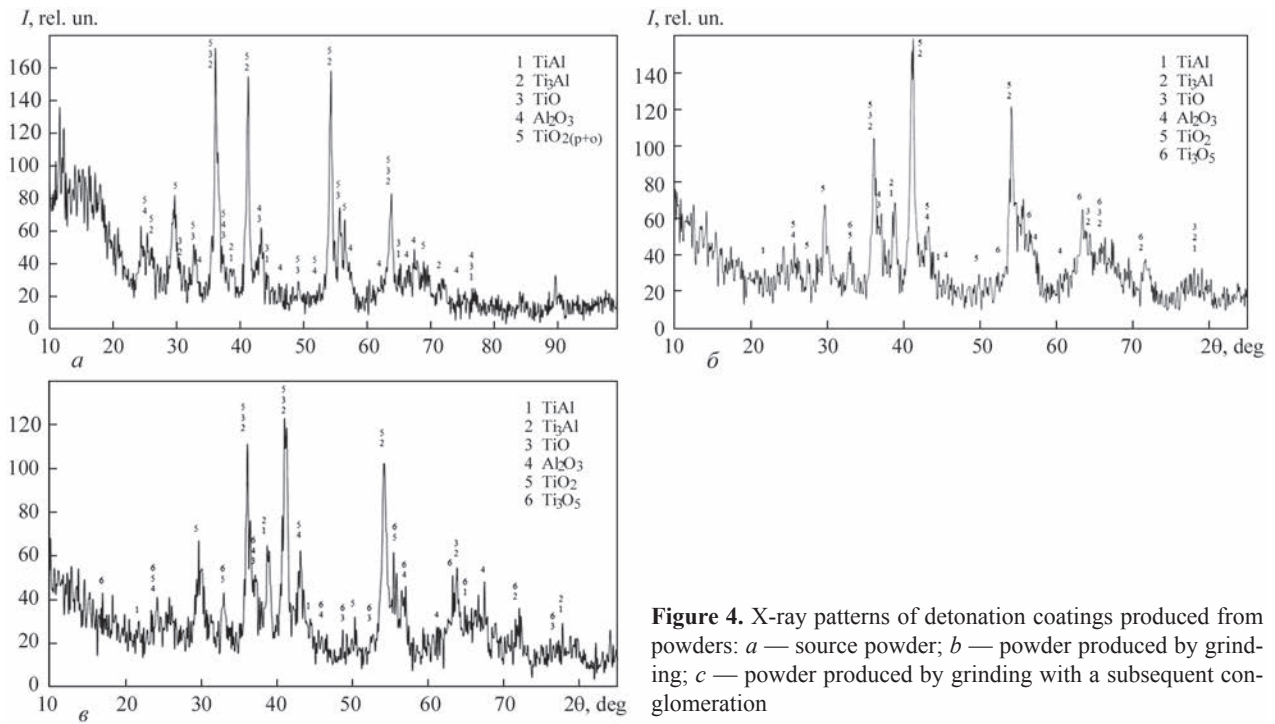


Figure 4. X-ray patterns of detonation coatings produced from powders: *a* — source powder; *b* — powder produced by grinding; *c* — powder produced by grinding with a subsequent conglomeration

der contains a lower amount of oxide phases, which is associated with a smaller specific particle surface that contacts the environment. On the other hand, the process of interphase interaction in the particles of a conglomerated powder proceeds more actively, which affects the phase composition — a number of interaction of TiAl products with B₄C increases, and the content of TiAl and Ti₃Al decreases.

In the detonation coatings from the composite powders of TiAl/BN while making the section, chipping of individual areas of the coating occurs, which indicates the brittleness of the formed phases (Figure 8). The coating produced from MChS powder, is strongly oxidized, has a dark gray color with small thin light lamellas (Figure 9, *a*). In the coating from the powder produced by MChS with the further conglomeration (Figure 9, *b*), more light lamellas and non-melted particles is observed. The microhardness of the coating from MChS powder is 4880 ± 1200 MPa, and from MChS powder with a subsequent conglomeration it is

4040 ± 850 MPa. The reduction of microhardness of the coatings from CP TiAl/BN of conglomerated powders was also noted on the variational curves (Figure 9).

The XRD method found that in the coating from MChS powder, a number of intermetallic phases (TiAl, Ti₃Al) is lower as compared to the source powder. The main phase in this coating is Ti₃O₅ oxide, the traces of TiN, TiB₂, AlB₂ and AlN phases and oxides TiO₂ and TiO (Figure 10, *a*) were also found in the coating. XRD method found, that in the coating from MChS powder with a subsequent conglomeration, the coating is less oxidized as compared to the coating from MChS powder, it contains a small amount of TiAl, Ti₃Al, in the coating an increase in the content of TiN, TiB₂, AlB₂ and AlN phases was revealed and except of Ti₃O₅ and TiO₂ oxides, in the coating a high-temperature oxide Al₂TiO₅ phase is present (Figure 10, *b*).

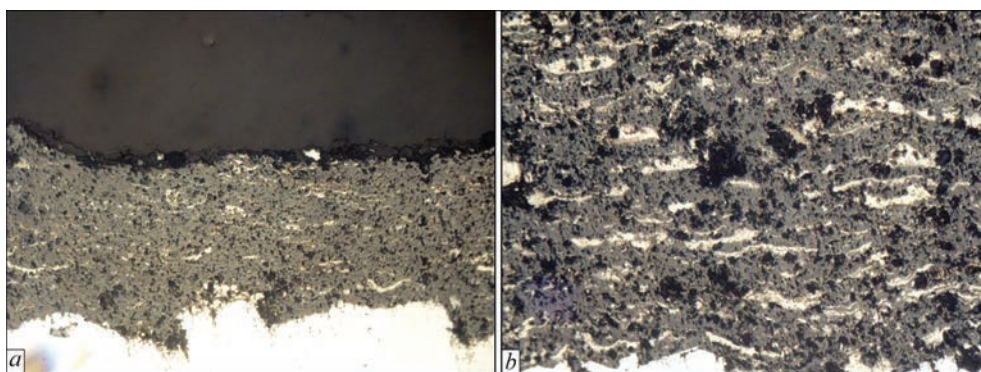
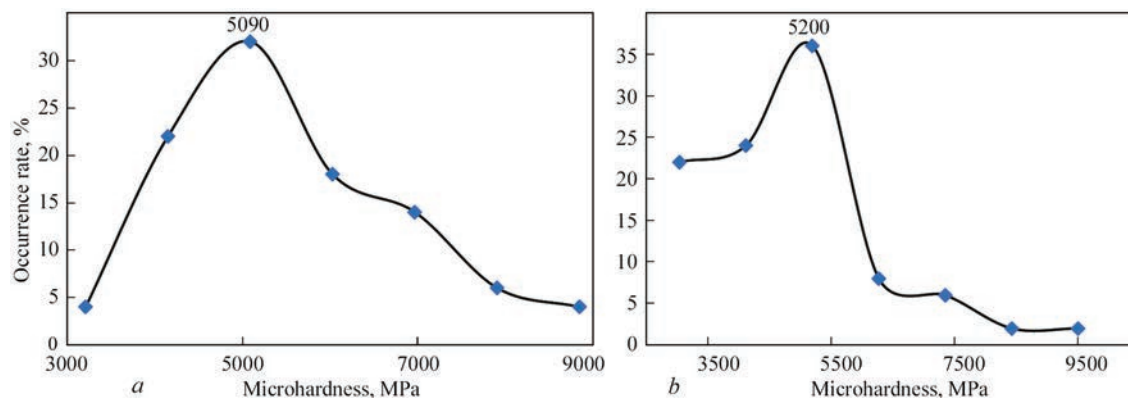
The structure of detonation coatings from composite TiAl/SiC powders is dense, without cracks and delaminations from the base, with large dark-gray oxide

Table 1. Characteristics of TiAl powders and detonation coatings from them

Powder			Coating			
			Microhardness, MPa (<i>P</i> = 50 g)		Porosity, %	Phase composition
Type	Particle size, μm	Phase composition	Average	Most probable		
Source (1 st type)	≤20	TiAl, Ti ₃ Al	5330 ± 800	4750	0.8	TiO, TiO ₂ , Al ₂ O ₃ , traces TiAl, Ti ₃ Al
Processed in the planetary mill for 1.5 h (2 nd type)	4–80		3990 ± 800	3975	2.2	TiAl, Ti ₃ Al, TiO ₂ , TiO, Al ₂ O ₃ , traces Ti ₃ O ₅
Processed with a subsequent conglomeration (3 rd type)	40–80		4190 ± 630	4010	2.6	

Table 2. Characteristics of detonation coatings produced from composite powders

Characteristics of powder				Characteristics of coating				
Composition of mixture for CP, wt. %	Method of producing	Size of powder particles, μm	XRD	Thickness of coating, μm	Microhardness, MPa ($P = 50 \text{ g}$)		Porosity, %	MChS
					Average	Most probable		
TiAl B ₄ C (16 % B ₄ C)	MChS, 1.5 h	≤ 22	TiAl, Ti ₃ Al, TiB ₂ , TiC	175 ± 25	5550 ± 1084	5090	4	TiAl, Ti ₃ Al, TiC, TiB ₂ , AlB ₂ , TiO ₂ , Ti ₃ O ₅ , traces Al ₂ O ₃
	MChS, 1.5 h + conglomeration	40–100		460 ± 30	4760 ± 1060	5200		
TiAl + BN (18 % BN)	MChS, 1,5 год	≤ 19	TiAl, Ti ₃ Al, TiB ₂ , AlB ₂ , TiN, AlN, BN	215 ± 15	4880 ± 1200	5700	3	Ti ₃ O ₅ , TiO, TiO ₂ , TiN, TiB ₂ , AlB ₂ , traces TiAl, Ti ₃ Al
	MChS, 1.5 h + conglomeration	20–80		440 ± 30	4040 ± 850	4300	12	Ti ₃ O ₅ , TiO ₂ , TiN, TiB ₂ , AlB ₂ , Al ₂ TiO ₅ , traces TiAl, Ti ₃ Al
TiAl + SiC (16 % SiC)	MChS, 1.5 h + конгл.	≤ 19	TiAl, Ti ₃ Al, SiC, TiC, Ti ₅ Si ₃	410 ± 70	4230 ± 750	5000	4	TiC, Ti ₅ Si ₃ , TiO ₂ , Ti ₃ O ₅ , SiO ₂ , traces Ti ₃ Al, TiAl,
	MChS, 1.5 h + conglomeration	40–100		480 ± 46	5250 ± 800	5700	2.9	
TiAl + Si ₃ N ₄ (18 % Si ₃ N ₄)	MChS, 1.5 h	≤ 14	TiAl, Ti ₃ Al, TiN, Si ₃ N ₄ , Ti ₅ Si ₃ , AlN	385 ± 50	4010 ± 670	4000	2.1	Ti ₃ Al, TiN, Ti ₅ Si ₃ , Al ₂ O ₃ , TiO ₂ , SiO ₂ , Al ₂ TiO ₅ , traces AlN, TiAl
	MChS, 1.5 h + conglomeration	40–100		500 ± 20	5440 ± 970	4975	4.4	


Figure 5. Microstructure ($\times 400$) of detonation coatings from composite TiAl/B₄C powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

Figure 6. Variation curves of microhardness of detonation coatings from composite TiAl/B₄C powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

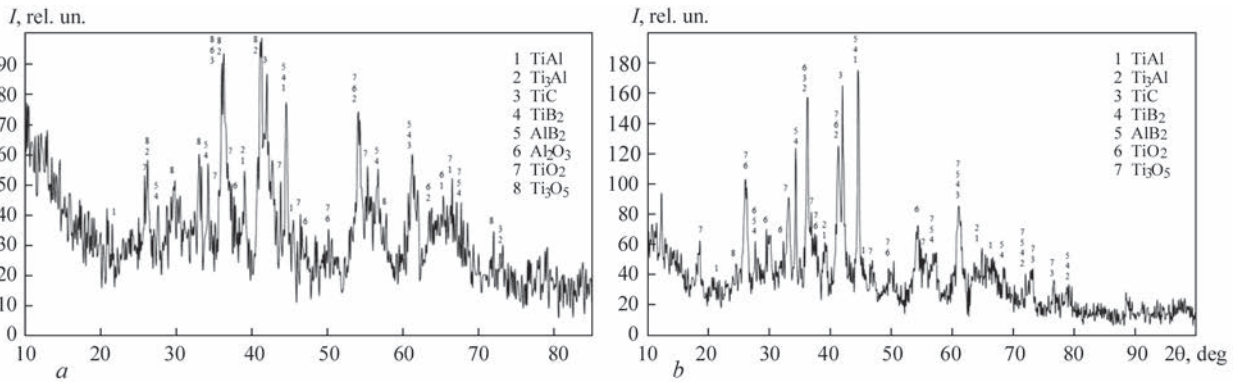


Figure 7. X-ray patterns of detonation coatings from composite TiAl/B₄C powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

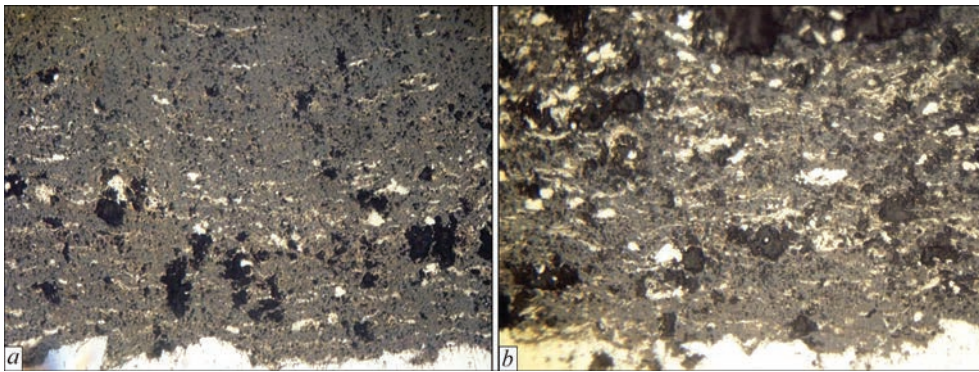


Figure 8. Microstructure ($\times 400$) of detonation coatings from composite TiAl/BN powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

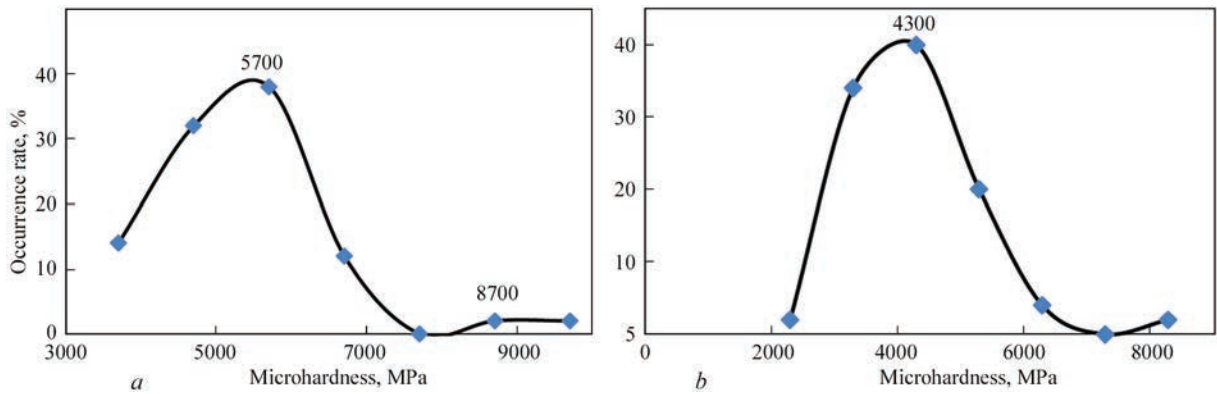


Figure 9. Variation curves of detonation coatings from composite TiAl/BN powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

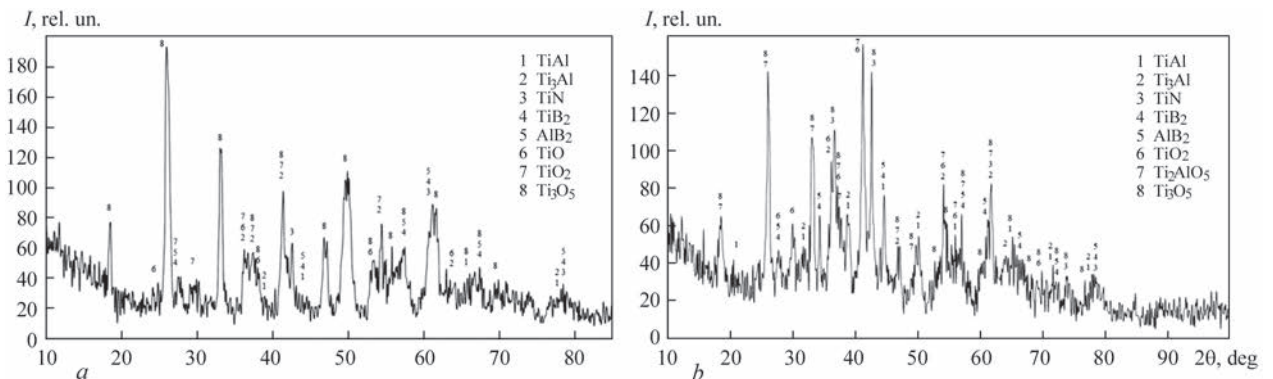


Figure 10. X-ray patterns of detonation coatings from composite TiAl/BN powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

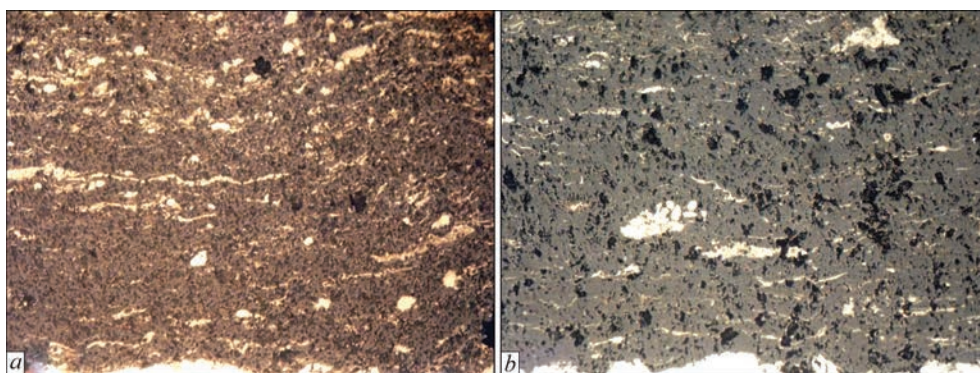


Figure 11. Microstructure of detonation coatings from composite TiAl/SiC powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

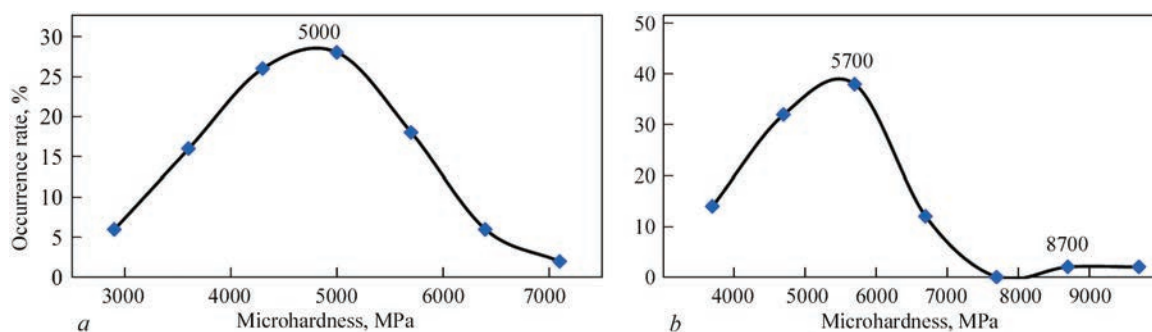


Figure 12. Variational curves of detonation coatings from composite TiAl/SiC powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

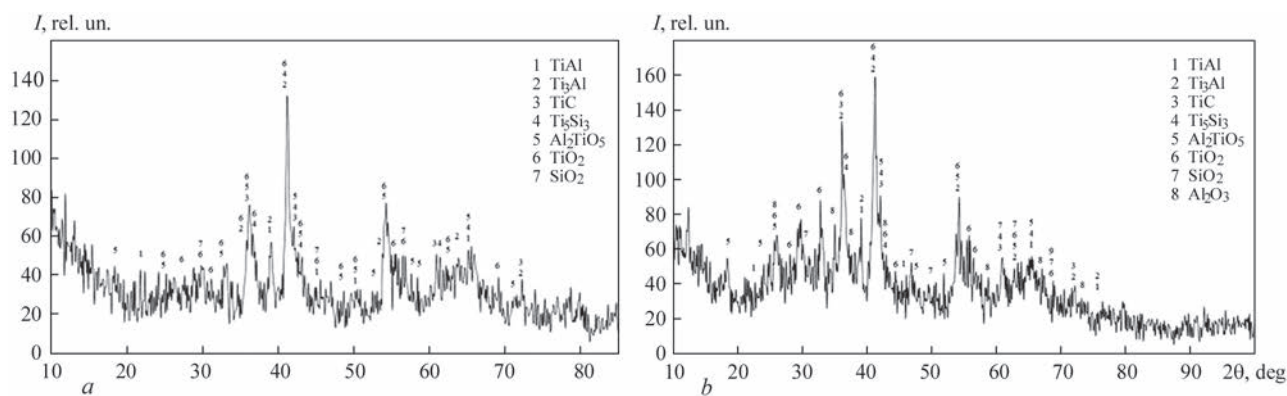


Figure 13. X-ray patterns of detonation coatings from composite TiAl/SiC powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

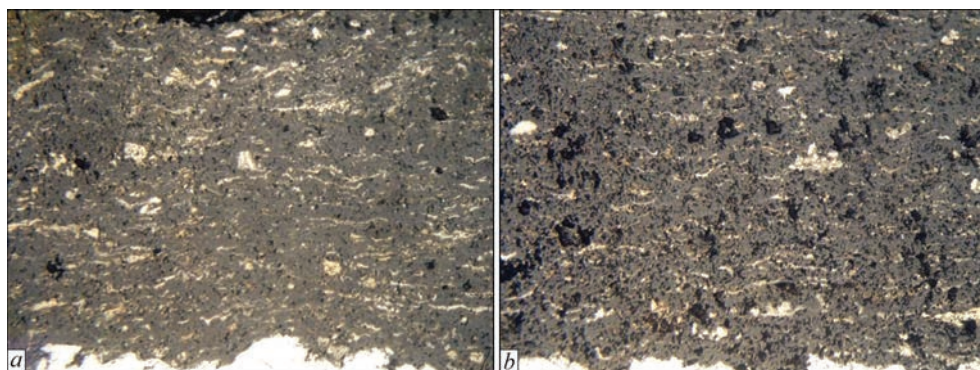


Figure 14. Microstructure of detonation coatings from composite TiAl/Si₃N₄ powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

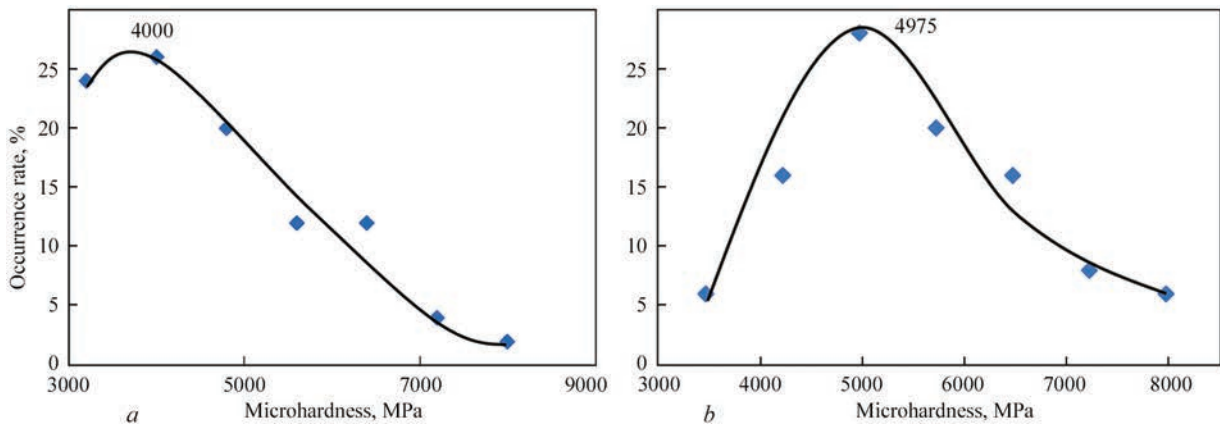


Figure 15. Variation curves of detonation coatings from composite TiAl/Si₃N₄ powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

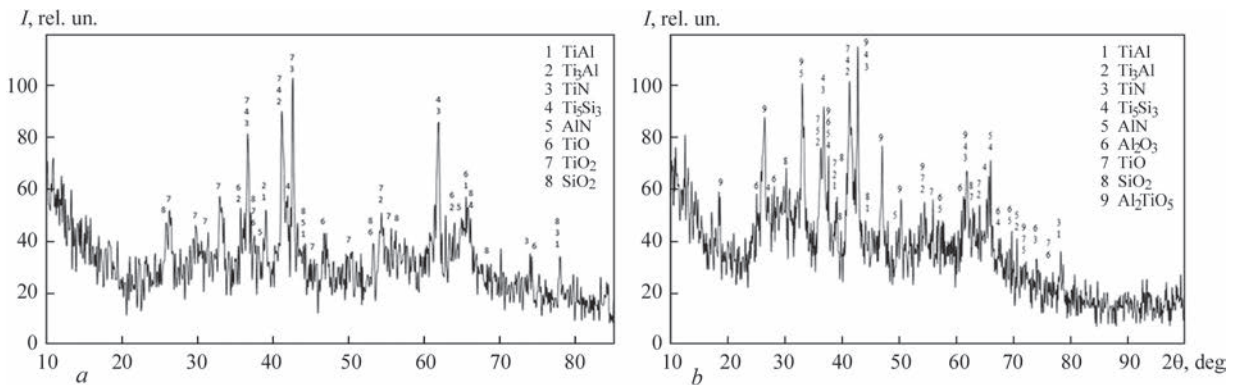


Figure 16. X-ray patterns of detonation coatings from composite TiAl/Si₃N₄ powders produced by the methods: *a* — MChS; *b* — MChS with a subsequent conglomeration

lamellas and thin light lamellas (Figure 11). The average value of microhardness of the coating from MChS powder is lower than in the coating from MChS powder with a subsequent conglomeration (4230 ± 750 and 5250 ± 800 MPa, respectively), which is associated with a denser structure of the coating from MChS powder with a subsequent conglomeration. The lower values of microhardness were obtained on the variational curves (Figure 12) for the coatings made of non-conglomerated powder.

On the X-ray patterns of the coatings (Figure 13), in addition to the main phases of TiAl, Ti₃Al, TiC and Ti₅Si₃, which are present in the powder, the oxides TiO₂, SiO₂, Al₂TiO₅ and Ti₃O₅ were found.

The structures of detonation coatings from the composite powders of TiAl/Si₃N₄ are similar to the structures of coatings from the composite powders of TiAl/SiC: they are dense, without cracks and delaminations from the base, with large dark-gray oxide lamellas and thin light lamellas (Figure 14). Microhardness of MChS powder coatings is lower than in the coating from MChS powder with a subsequent conglomeration (4010 ± 670 and 5440 ± 970 MPa, respectively), which as in the case of CP TiAl/SiC is associated with a denser structure of the coating from MChS powder with a subsequent conglomeration. The same regularity was

marked for the most probable values of microhardness on the variational curves (Figure 15).

On the X-ray patterns (Figure 16, *a, b*) both the main phases characteristic of the source powder TiAl, Ti₃Al, TiN, Ti₅Si₃, AlN, as well as oxides TiO₂, SiO₂, TiO were revealed, which are present in the coating from MChS powder.

CONCLUSIONS

1. As a result of studying the impact of technological parameters on the formation of detonation coatings from TiAl intermetallics and composite powders on its base with the additives of non-metallic refractory compounds (B₄C, BN, SiC, Si₃N₄), the mode of producing high-quality coatings, distinguished in a high density of structure and absence of defects at the border with the base, was revealed.

2. During detonation spraying from TiAl powder, the oxidation of its particles with the formation of titanium (TiO, TiO₂, Ti₃O₅) and aluminium (Al₂O₃) oxides occurs. The content of oxides in the coating depends on the dispersion of the powder. Thus, it is lower in the coatings from conglomerated powders than in the coating from powders subjected to grinding only.

3. When forming detonation coatings from CP of TiAl/NRC, both oxidation of sprayed particles as well

as processes of interphase interaction of its components occur. Thus, in the coatings from CP of TiAl/B₄C oxides TiO₂, Ti₃O₅ and Al₂O₃ were revealed as well as increased content of TiC, TiB₂ and AlB₂ as compared to source CP. In the coatings from CP of TiAl/BN, the main phases are TiO, TiO₂, and Ti₃O₅ oxides, TiB₂ and AlB₂ borides and TiN nitride. When depositing coatings from TiAl/SiC and TiAl/Si₃N₄, oxidation occurs less actively than in the previous cases, and in CP of TiAl/Si₃N₄, the process of interphase interaction runs less active.

4. Comparing the structure and phase composition of detonation coatings from MChS powders and powders produced by MChS method with a subsequent conglomeration shows that in the second case, a decrease in the content of oxides for all compositions is observed, and the content of products of interphase interaction between TiAl and inclusions of non-metallic refractory compound grows.

5. The structure of coatings of all compositions is lamellar, consists of dark-gray (oxide) and light (metal-like) lamellas. In the coatings produced from MChS powders with a subsequent conglomeration, it is more dense and homogeneous than in the coatings from powders not exposed to conglomeration. The confirmation of a higher degree of homogeneity of the structure and phase composition is also the distribution of microhardness on the variational curves.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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