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Eutectic reaction of crystallisation – as the way of increasing tribotechnical characteristics of alloys

K e y w o r d s

Eutectic crystallisation, structure, properties, wears, coatings, PVD sputtering, iron-based, interstitial phases.

S u m m a r y

Laws of the formation of properties eutectic gas-plasma coating on an iron-base containing interstitial phases depending on a degree of nonequilibrium conditions are established. It is shown that, after high-temperature diffusion annealing, eutectic coatings work on deterioration in a pair with the couched steel better than up to annealing. A conclusion is drawn on self-organising structure and properties of the investigated coatings during friction and wear processes.

Eutectic alloys have long been considered as a simple mechanical mix of phases owing to the absence of chemical interaction on interphase borders. In the case of realisation, a eutectic reaction between metal and composition, which essentially differs from it on properties, during crystallisation the natural composite material, in which interaction on interphase border physical is formed. At high speeds of cooling from a liquid when diffusion processes are

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limited in time, in a eutectic alloy, there can be new conditions with unusual properties. Such conditions are created, in particular, at deposition coatings by physical methods with a high concentration of the density of the power of energy carriers. They can increase in eutectic coatings in a condition thermodynamically nonequilibrium, but can be steady and stable under operating conditions at rather low temperatures. In this case, coatings are capable of retaining acquired properties for a long time. Besides, using eutectic reactions for the realisation of strongly nonequilibrium conditions opens ample opportunities for structural self-organising of a coating during work.

Special interest in this approach is in conditions of external destructive influence, which arises during friction. The change of the structure of alloys eutectic systems in strongly nonequilibrium conditions is dependent on external influence.

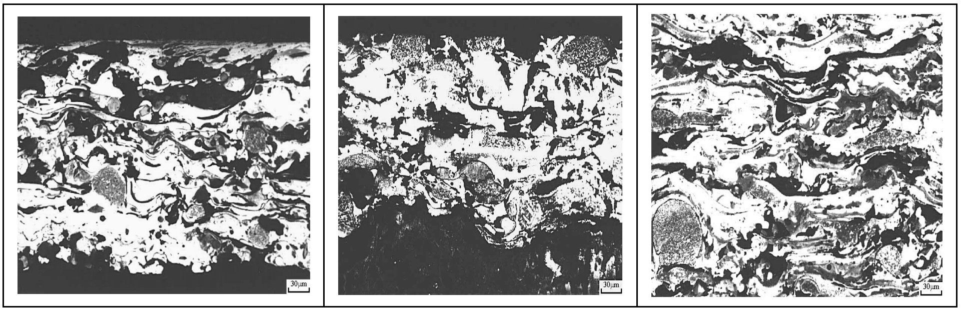
Thus, there is a self-organising of eutectic structure that leads to the formation of its optimum properties.

Such an approach, when the predisposition of the system to self-organising under operating conditions is considered, obtains increasing recognition [1, 2]. In particular, by the development of wear-resistant alloys, it is considered useful to create obviously nonequilibrium conditions from which the alloy passes in intermediate, more equilibrium conditions. Thus, according to the theory developed by scientists of Kostetskogo`s B.I. school, there is an adaptation of the structure to concrete investigation of friction conditions [3].

In early works [4-11], it has been shown that eutectic alloys of iron-base with interstitial phases in a cast condition combine a soft, plastic metal matrix with firm, refractory thermodynamic stability interstitial phases [queasy - third eutectic multi-component systems: (α-Fe)-VC-TiB_2; (γ-Fe)-TiB_2-CrB_2; (α-Fe)-VC]. Owing to such a structure, alloys possess high values of physical and mechanical properties.

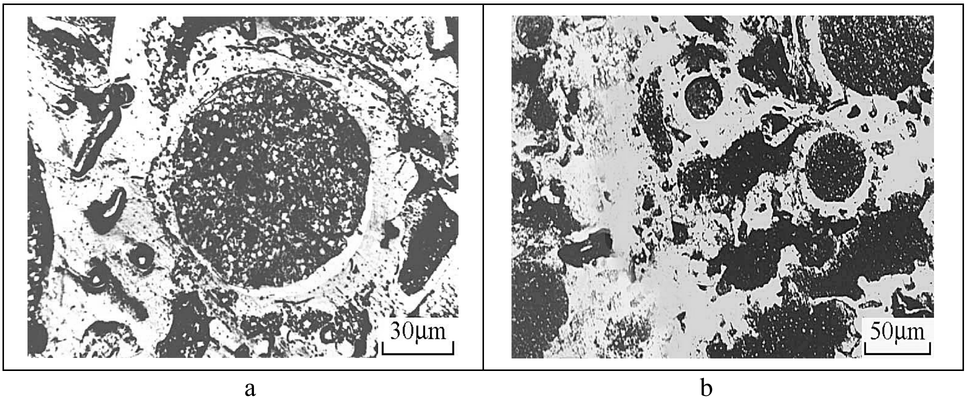
However, to operate the properties cast eutectic alloys, it is a little opportunities owing to the big stability of crystallisation reaction.

Essential opportunities of the management of properties of a specified eutectic open at the use of nonequilibrium conditions, which arise during the rapid crystallisation of solids in gas-plasma (PVD) coatings. Thin phases conglomerate in the structure of coatings at high speeds of cooling ($\sim 5 \cdot 10^5$K/c) are (Fig. 1) [12], which occupies the basic volume of a coatings and is formed in the thermodynamic nonequilibrium eutectic. This structural component in many respects determines the properties of all coating. On Fig.1 and 2, the thin conglomerate phases is looked like white layers possessing high corrosion resistance and, practically, is not pursued in the chemical reactants usually applied in metallography. On Fig. 2, deposition particles in the initial eutectic as a powder in the form of spheres of the correct form are not visible.



a b c

Fig.1. Wight layers – think phase conglomerate in structure gas-plasma eutectic coatings: a – (γ-Fe)-VC-TiB_2 system; b – (γ-Fe)-TiB_2-CrB_2 system; c – (α-Fe)-VC system.



a b

Fig. 2. The structure of gas-plasma eutectic coatings: a – (γ-Fe)-VC-TiB_2; b – (α-Fe)-VC. The cross section is parallel to coating surface.

After high-temperature diffusion annealing ($0.8T_m$) structure (Fig. 3) and properties of a thin phase conglomerates are changed: microhardness (Table 1) decreases, microplasticity (Fig. 4) increases, corrosion resistance decreases, and the oxidising ability in air increases. Such a change of properties leads to essential change in tribotechnical characteristics (Fig. 5-7). The comparative analysis of the resulted dependencies shows that, in initial (not annealing) conditions, strong deterioration of a counter-body is observed due to friction about a coating. After annealing, deterioration of a counter-body essentially decreases, as well as annealed at small times of a coating. The increase of annealing time leads to an increase in the deterioration of a coating. Here the optimum mode annealing is when total deterioration of pair friction will be minimal. Such optimum exists in all examined eutectics and differences consist only in absolute values of the characteristics of properties.

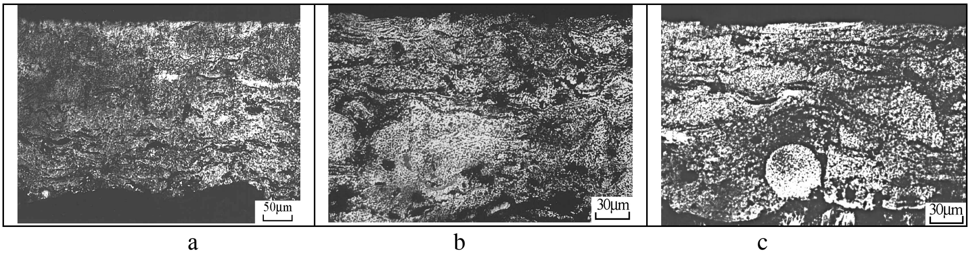


Fig. 3. The macrostructures when annealing ($0.8T_m$) gas-plasma coating: a – (γ-Fe)-VC-TiB_2, ($54\cdot10^2$c); b – (γ-Fe)-TiB_2-CrB_2, ($54\cdot10^2$c); c – (α-Fe)-VC, ($18\cdot10^2$c).

Table 1.

Eutectic coating of system:	Micro-hardness Before annealing, МПа	Micro-hardness after annealing, МПа, Annealing time, c			Lead
		18x10^2	54x10^2	18x10^3	
(γ-Fe)-VC-TiB_2	12510	6880	5800	5630	P = 0,49H
(γ-Fe)-TiB_2-CrB_2	12330	6010	4140–5690	3960–6350	P = 0,49H
(α-Fe)-VC	6740– 11760	5720–6740	4890–7070	3900–6830	P = 0,49H

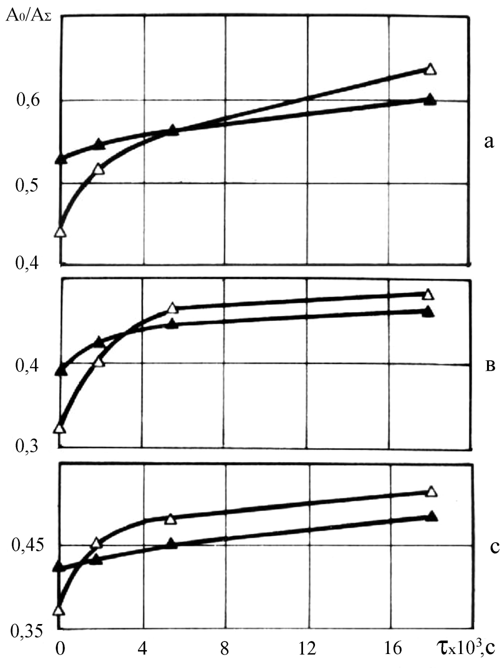


Fig. 4. The dependence micro-plasticity of weight layers (Δ) and fields with colonial structure ($\blacktriangle$) from annealing time (T_{an}=0,8T_m). a - (γ-Fe)-VC-TiB_2; в - (α-Fe)-VC; c - (γ-Fe)-TiB_2-CrB_2.

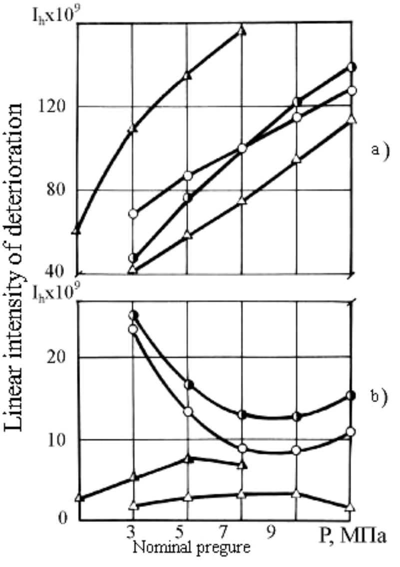


Fig. 5. The change linear intensity of deterioration: a) – contra-body (quenched under hardness 56–60 HRC high carbon steel У8) and b) – gas-plasma coating (γ-Fe)-VC-TiB_2 as a dependence nominal pressure: ▲– before annealing coating; Δ, o, ● – after annealing for $18{\cdot}10^2$, $54{\cdot}10^2$, $18{\cdot}10^3$ c a coating agreeably (under V = 0.25 м/с)

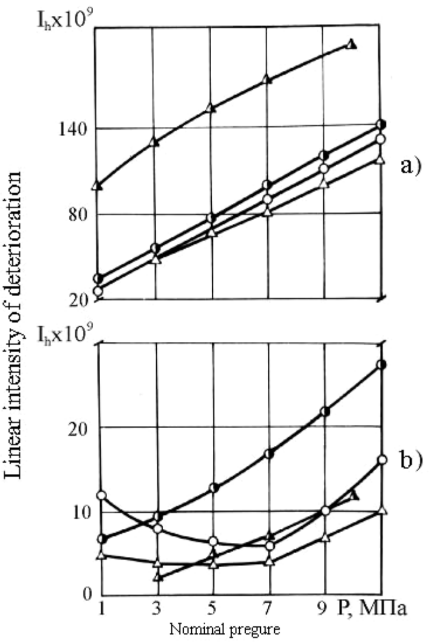


Fig. 6. The change linear intensity of deterioration: a) – contra-body (quenched under hardness 56–60 HRC high carbon steel У8) and b) – gas-plasma coating (α-Fe)-VC as a dependence nominal pressure: ▲– before annealing coating; Δ, o, ● – after annealing for $18{\cdot}10^2$, $54{\cdot}10^2$, $18{\cdot}10^3$ c a coating agreeably (under V = 0.25 м/с).

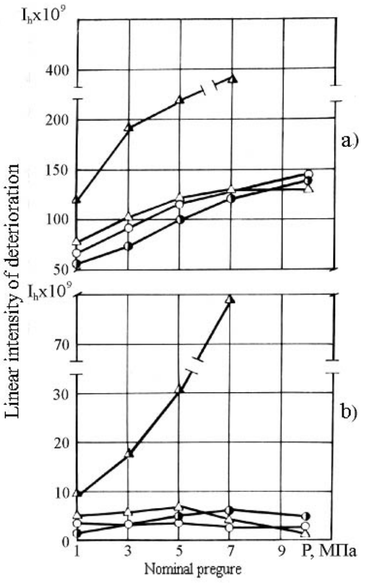


Fig. 7. The change linear intensity of deterioration: a) – contra-body (quenched under hardness 56–60 HRC high carbon steel У8) and b) – gas-plasma coating (γ-Fe)-TiB_2-CrB_2 as a dependence nominal pressure: ▲– before annealing coating; Δ, o, ● – after annealing for $18{\cdot}10^2$, $54{\cdot}10^2$, $18{\cdot}10^3$ c a coating agreeably (under V = 0.25 м/с).

High-temperature annealing leads to a decrease in corrosion resistance and the integration of particles' interstitial phases, which essentially influences tribotechnical properties. Decrease in corrosion resistance is visible when comparing the degree of etching metallographic specimen in non-annealed and annealed coatings. It is possible to assume that, during friction, non-annealed coatings, in places where high local temperatures and plastic deformations develop, diffusion processes will take place actively and lead to the same consequences as at annealing. In such a way, the zone of friction eutectic coatings adapts to external conditions, thus minimising the total deterioration of pair friction. Such a conclusion will be coordinated with forecasts of behaviour of nonequilibrium systems of friction B.I.Kostetskogo formulated in works and followers of his school.

Notice that the duration of annealing is commensurable with an operating time of pair friction on a site extra earnings - the heaviest site of work. During this period, there are the greatest deformations in the zone of friction and the highest local temperatures, and sometimes reaching temperatures of fusion develop. In such extreme conditions, nonequilibrium conditions in areas with a structure of a thin phase conglomerate change very quickly and occur at large distances (the tenths of millimetres). More equilibrium and steadier conditions which answer the given conditions of friction are better is as a result realised. For example, a decrease in the corrosion resistance, deposited eutectic coatings, promotes process of formation onside films which carry out a role of firm lubricate. Thus, total deterioration of pair friction decreases. An increase of microplasticity allows reduced stress, due to plastic deformation of local areas. In such a way, an eutectic coating as the nonequilibrium system spontaneously moves to a new more equilibrium structurally-phase condition, producing an optimum for work of pair friction in the given conditions.

The specified laws of the change of structure and properties are observed in all investigated eutectic coatings that concern the opportunity of the extrapolation of the conclusions to more eutectic alloys.

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