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**V.V. SHEPETOV, O.U. SYDORENKO**

***National aviation university, Ukraine***

# DETONATION COVERINGS ON BASIS OF $FeAl_2$ FOR PROTECTION OF FRICTION UNITS AGAINST WEAR PROCESSES

*The generalization of results of the laboratory researches accepted in practice, shows, that the carried out researches testify to expediency of use of the developed detonation coverings of system FeAl2-Ti-Si for increase of wear resistance and durability of the rubed interfaces working in absence of greasing. Besides, the application of the specified wearproof coverings as have shown the economic data, promote the improvement of quality and durability of the details working in conditions of friction, reduction in expenses for repair work and manufacture of spare parts, that, finally, results in significant economy of metals.*

***Key words:*** *friction, alloy, aluminide, wear resistance, tribooxidation, detonation covering.*

## Introduction

The processes of friction, wear and greasing, remain one of the most actual areas of research because they provide possibility of theoretical and applied methods of studying the questions with which are actual in daily practice.

According to modern positions of a science about friction and wear processes of materials the tribotechnics parameters which describe the contact interaction, are defined, mainly, by a condition and properties of superficial layers. And in the common complex of the actions which are directed on development of methods of increasing the efficiency of tribotechnic systems operation, the great value is got with technologies of superficial hardening. Practically in all industrial complexes the interest continuously grows to the technical opportunities of various technological methods of creation the strengthening, in particular, wearproof coverings [1,2]. Today their development and application - that focus in which concentrated the efforts of scientists, experts, organizers of manufacture. And the level of realization of their practical opportunities began not only the generalizing characteristic of a degree of the country development, but also a subject of the state prestige which reflect the scientific and technical potential.

The coating of detonation coverings is one of modern technological methods of increase the wear resistance of friction pairs. However at a choice of a material for coating, if proceed the real conditions of operation, it is necessary to take into account the technical and economic restrictions caused by requirements of manufacture, in particular, the charge of scarce and expensive components, for example, wolfram, cobalt, nickel [3].

## 1. Experimentals

In the given research which includes the development and tribotechnic tests of composite coverings, not containing scarce components, the program which includes, in generally, some facts (speed of sliding, temperature, etc.) is realized; the theoretical positions which prove the resistance to wear process of a superficial layer, were considered from positions of the structural - power theory of friction and wear [4], the coating of coverings was carried out on installation such as "Dnepr - 3" by the technology stated in the source [3].

The characteristics of metal phases of a coating layer, and also secondary structures with the certain properties essentially depend on technology of reception and a chemical compound of an initial material. So in the given research the powder structures with application of technology which allows to form structure on nanometric level, in particular, mechanic and chemistry synthesis of materials from elementary powders, which is more effective for reception of compositions with unique properties [6,7] have been received. So, as a basis of powder raw material for coverings have been used the aluminide iron ($FeAl_2$), in addition alloyed by the titan and silicon. Thus it is necessary to note the nondeficiency of initial raw material and potential low-cost of the components. The optimum contents of alloying elements corresponding to the maximal wear resistance of coating coverings is established. The injection in an initial powder the additives of the titan has caused the formation of intermetallic phases of type γ - $TiAl$, $Ti_3Al$. The additional alloying by silicon promoted the reception of strengthening connections such as $Ti_3Si$, $Ti_5Si_3$, $Fe_3Si$, $FeSi$. Besides, the interaction of aluminium and iron causes the presence of firm solutions of iron in aluminium and aluminium in iron, and also intermetallic

eutectic. The aluminides of titan, iron, as well as silicides, are characterized by sufficient durability of internuclear connections and thereof the high temperature of fusion and the raised mechanical durability. The finely divided phases of intermetallic render the significant influence on the dislocation mechanism of formation the defects of thin structure, in such way lowering a degree of activation and raising the resistance against dripping. Alloying additives substantially cause the kinetic of formations and a complex of properties of secondary structures. Varying the structures of a composite powder in a coating covering, it is possible to influence a level of structural activation, formation of superficial layers with beforehand set properties and as a result to provide minimization of tribotechnical parameters.

Operating the technological process of reception of composite powders, it was possible not only to provide a desirable chemical compound, but also to receive at coating the set structure which optimizes a complex of the properties causing, in a certain range of parameters of friction, the steady display of structural accomodation.

The tribotechnical properties of detonation composite coverings in absence of greasing were estimated at the face friction of modelling samples in a wide range of speeds, loadings, temperatures in the air environment at normal atmospheric pressure. At research of processes of friction and wear of detonation coverings of system $FeAl_2$-*Ti*-*Si* for comparison under the same conditions and under similar programs the samples with coating coverings from powders of alloy with wolfram ВК15 and on a basis of nichrome, alloyed by aluminium and a pine bor, and also samples from tempered steels 45, 30ХГСНА, antifrictional bronze БрОСЦ6-6-3 were tested. The thickness of coverings after operational development was made 0,18-0,2 mm, a roughness of surface $R_a$=0,63 … 0,32.

At disclosing interrelations between properties of a material of a covering in conditions of friction, their structure, influence of the external factors determining reliability and serviceability of friction system, the leading part is played with a choice of methods of researches. Opportunities of used techniques and equipments in many respects determines depth and reliability of representations about the processes proceeding at contact interaction of connected surfaces.

## 2. Analyses

The analysis of physical and chemical properties of coverings, the microphase analysis were carried out with the help of scanning microanalyzer "Camscan".

During research of a microstructure of the developed covering it has been established, that at coating, except for aluminide $FeAl_2$, are present aluminides of iron such as $Fe_3Al$, *FeAl* which at the presence of the titan form aluminide, alloyed by the titan (*Fe, Ti*) *Al*. The light zones contain a firm solution of components of a covering on the basis of connection *FeAl* ($H\mu$ = 9500±400Р). The intermetallic sites with disperse inclusions represent connections on a basis of $\gamma$-*TiAl*, $Ti_3Al$, and also $Ti_3Si_3$. The presence of oxide type $\alpha$-$Al_2O_3$ in firm solutions as disperse crystal inclusions is caused, probably, its oxidation in process of exothermic reactions at coating. Laws of curves of distribution of the chemical elements included in a covering on basis $FeAl_2$, correlates with character of distribution of the structural components, established on corresponding pictures in x-ray characteristic radiation. Besides, the structure of coverings represents sites of a firm solution of iron and finely divided mixes of intermetallics such as $Ti_5Si_3$, $FeSi_2$ and *TiSi*.

From the results of researching the influence of speed of sliding on intensity of wear processes it is visible, that the resistance to wear processes possess coverings of system $FeAl_2$-*Ti*-*Si*, not worse then conceding values of covering ВК15. In all a range of speeds (up to 1,0m/sec at the constant loading equal 5,0MPa) the mechanochemical wear process is the leader for developed coverings.

The condition of a superficial layer in which there are processes of activation at the friction, which influencing on intensity of oxidations and dripping, were studied by a method electron diffraction analysis on installation ЭМР-100. The electron diffraction pattern, that fixes the change of thin structure shows, that in the most thin superficial layer of a covering occurs the dispersion with a crushing of crystallite, to what the presence of maxima of intensity on diffusion auras testifies.

On the type of the leading process of wear a significant influence is rendered with properties formed superficial films which on the data of electron diffraction analysis represent the oxides $Al_2O_3$, $SiO_2$, which with the protoxide of iron form spinels such as $FeAl_2O_4$ and silicate of fielitic type such as $Fe_2SiO_4$, besides, is established the presence of β – thialitum ($Al_2TiO_3$) which carry out a role of firm greasings, as result of tribooxidation. The mechanism of formation the secondary structures of the given type is caused by plastic deformation therefore a superficial layer change structure and passes in the activated condition. In the table 1 the basic properties of the metal oxydes included in a covering are resulted.

The further formation of secondary structures, in opinion of authors, is accompanied by mechanochemical microalloying, including dispergation of surface materials, grinding the dispersoid with particles of oxydes, intermetallic and transformations of these ultradisperse phases on working surfaces of friction under ac-

tion of local temperatures and pressure in new ultradisperse structure. Distinctive feature of this structure that in particles of the small sizes the superficial layers of atoms create the superfluous pressure essentially deforming a crystal lattice and influencing energy of activation; in a result they are characterized by a complex of the new properties determining the high tribotechnic characteristics of coverings [8, 9].

Table 1

The properties of secondary structures oxydes

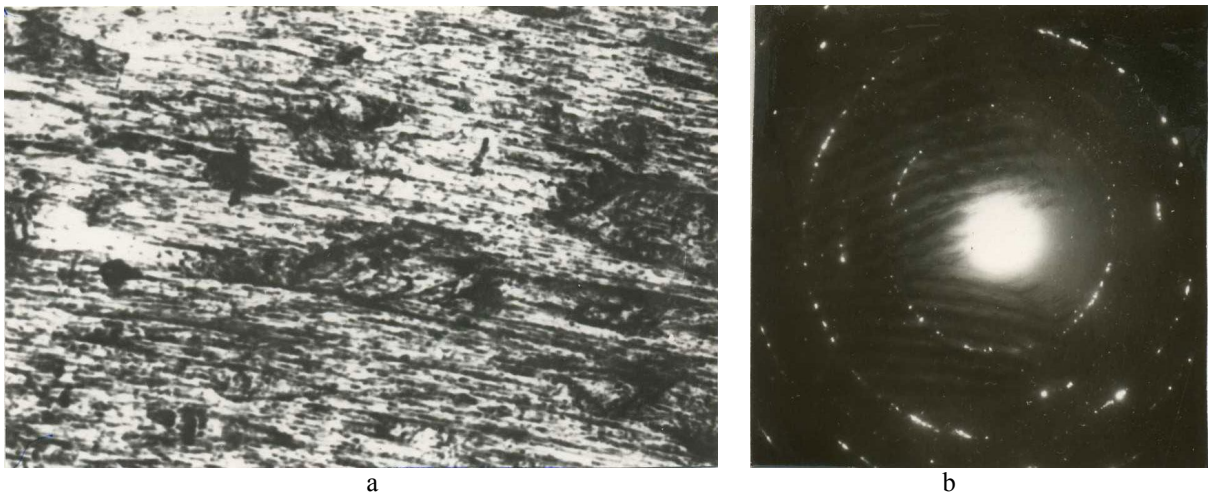
| Oxide | Syngynonum | Microhardness, MPa | Thermal factor of linear expansion·$10^6$, deg $^{-1}$ | Density, gr/sm$^3$ |
|---|---|---|---|---|
| $\alpha$-$Al_2O_3$ | hexagonal | 20673 | 9,7 | 3,97 |
| $\gamma$-$Al_2O_3$ | cubic | 24321 | 8,9 | 4,2 |
| $\alpha$-$SiO_2$ | hexagonal | 11130 | 3 | 2,26-2,65 |
| $\beta$-$SiO_2$ | - | 12356 | 4,3 | - |
| $TiO$ | cubic | 15197 | 4,2 | 4,93-5,53 |
| $TiO_2$ | tetragonal | 19614 | - | 4,17 |
| $Ti_2O_3$ | hexagonal | 12786 | 9,6 | 3,94 |
| $FeO$ | cubic | 4413 | 12,4 | 5,7 |
| $\alpha$ -$Fe_2O_3$ | hexagonal | 10787 | 14,9 | 5,24 |
| $\gamma$ -$Fe_2O_3$ | cubic | 7257 | 13,4 | 5,4 |

The character of changing the factors of friction is coordinated to the established laws of friction and wear processes. Their stability at increase of speed of sliding, testifies to high operational opportunities of coverings both on basis of $FeAL_2$, and from firm alloy BK15.

Physical basis of development the materials of coverings is providing their compatibility in friction pairs and realization of structural accomodation in working ranges for provide the durability. For research of influence of temperature on intensity of mechanochemical wear process at loading by friction, the heating of samples during the tests have been stipulated. The changing of temperature causes the intensity of diffusive processes, speed of chemical reactions, transformations in a firm phase, defines the course of plastic deformation on which the degree of structurally and thermal activation [10] depends. The tests were carried out at the constant loading equal 3,0 MPa, and speed of sliding 0,6m/sec.

## 3. Surface

The coverings of system $FeAl_2$ - $Ti$ - $Si$ have a high wear resistance under the set conditions of friction. The microstructures possess and electron diffraction pattern surfaces of friction of coverings on basis of $FeAl_2$, tested at various temperatures, are submitted in figure 1. As it has been established, the oxyde films, which formed in a zone of contact , shielding a surface of friction from mechanical and physical and chemical destruction. By the stoichiometrical structure they represents finely divided mixture of oxydes on the basis of metal components of a covering of spinel, class of silicates such as $Al_2SiO_5$. Wear resistance of system $FeAl_2$ - $Ti$ - $Si$ is determined as a structure and property of metal phases of coating layer, and a condition and properties of formed oxyde films, which, as a firm greasing, interfere with processes of contact dripping.



a b

Fig. 1. Microstructures and the electron diffraction patterns of friction surfaces of detonation coverings on basis of $FeAl_2$ tested at temperatures: a - 3000C (×320); b - (×28000)

## Conclusion

Thus, the generalization of results of the laboratory researches accepted in practice, shows, that the carried out researches testify to expediency of use of the developed detonation coverings of system *$FeAl_2$-Ti-Si* for increase of wear resistance and durability of the rubed interfaces working in absence of greasing. Besides, the application of the specified wearproof coverings as have shown the economic data, promote the improvement of quality and durability of the details working in conditions of friction, reduction in expenses for repair work and manufacture of spare parts, that, finally, results in significant economy of metals.

## Literature


*1. Інженерія поверхні / К.А. Ющенко, Ю.С. Борисов, В.Д. Кузнецов, В.М. Корж. – К.: Наук. думка, 2007. – 557 с.*

*2. Харламов Ю.А. Детонационно-газовые процессы в промышленности / Ю.А. Харламов. – Луганск: Изд-во ВУГУ, 1998. – 223 с.*

*3. Харламов Ю.А. Основы технологии восстановления и упрочнения деталей машин / Ю.А. Харламов. – Луганск, 2001. – 496 с.*

*4. Поверхностная прочность материалов при трении / Под ред. Б.И. Костецкого. – К.: Наукова думка, 1986. – 296 с.*

*5. Щепетов В.В. Повышение износостойкости детонационных покрытий путем оптимизации режимов напыления / В.В. Щепетов, А.М. Волхов // Трение и износ. – 1990. – Том 11, №5. – С. 844-848.*

*6. Середа Б.П. Получение двухкомпонентных покрытий на основе титана методом СВС / Б.П. Середа, И.В. Плеханова // Металловедение и термическая обработка металлов. – 2003. – №11. – С. 30-33.*

*7. Теория и практика газопламенного напыления / П.А. Витязь, В.С. Ивашко, Е.Д. Манойло и др. – Минск: Навука і тэхніка, 1999. – 296 с.*

*8. Восстановление и повышение износостойкости и срока службы деталей машин / Под ред. В.С. Попова – Запорожье: Изд-во ОАО "Мотор сич", 2000 – 394 с.*

*9. Газотермическое напыление покрытий. Сборник руководящих технических материалов. – К.:ИЭС им. Е.О. Патона, 1993. – 176 с.*

*10. Захарова В.Б. Термическая обработка жаростойкого газотермического покрытия / В.Б. Захарова, Т.В. Соловьёва, Б.М. Захаров // Металловедение и термическая обработка металлов. – 2001. – №4. – С. 14-17.*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**Рецензент:** д-р техн. наук, проф. А.А. Тамаргазин, Национальный авиационный университет, Киев.

### ДЕТОНАЦІЙНІ ПОКРИТТЯ НА ОСНОВІ $FeAl_2$ ДЛЯ ЗАХИСТУ ВУЗЛІВ ТЕРТЯ ВІД ЗНОСУ

***В.В. Щепетов, О.Ю. Сидоренко***

Результати лабораторних випробувань, прийнятих в практиці, вказують, що проведені дослідження свідчать про доцільність використання розроблених детонаційних покриттів системи *$FeAl_2$-Ti–Si* для підвищення зносостійкості та часу роботи тертьових сполучень, які працюють при відсутності мастила. Крім цього, використання вказаних зносостійких покриттів, як показали економічні дані, сприяють підвищенню якості і сроку роботи деталей, які працюють в умовах тертя, зниженню витрат на ремонтні роботы і виробництво запасних частин, що, в кінцевому рахунку, призводе до значної економії металів.

**Ключевые слова:** тертя, сплав, алюмінид, протизносність, трибоокислення, детонаційне покриття.

### ДЕТОНАЦИОННЫЕ ПОКРЫТИЯ НА ОСНОВЕ $FeAl_2$ ДЛЯ ЗАЩИТЫ УЗЛОВ ТРЕНИЯ ОТ ИЗНАШИВАНИЯ

***В.В. Щепетов, А.Ю. Сидоренко***

Результаты лабораторных испытаний, принятых в практике, показывает, что проведённые исследования свидетельствуют о целесообразности использования разработанных детонационных покрытий системы *$FeAl_2$-Ti–Si* для повышения износостойкости и долговечности трущихся сопряжений, работающих в отсутствии смазки. Кроме того, применение указанных износостойких покрытий, как показали экономические данные, способствуют повышению качества и долговечности деталей, работающих в условиях трения, снижению затрат на ремонтные работы и производство запасных частей, что, в конечном счёте, приводит к значительной экономии металлов.

**Ключевые слова:** трение, сплав, алюминид, противоизность, трибоокисление, детонационное покрытие.

**Щепетов Виталий Владимирович** – д-р техн. наук, проф., проф. института аэропортов, Национальный авиационный университет, Киев, Украина

**Сидоренко Александр Юрьевич** – канд. техн. наук, доцент кафедры технологий аэропортов, Национальный авиационный университет, Киев, Украина.