CONTENT

# INTRODUCTION

Actuality of the topic.

Increasing the reliability and lifetime of modern machines has led to the need for widespread use of coatings from materials and alloys with a complex of elevated physical and mechanical properties. Recently, active research has been carried out in the field of the creation of gas-thermal coatings of special purpose type on the metallic and ceramic basis - cermet coatings, which combine the heat capacity and strength of ceramics with the plasticity and thermal conductivity of metals.

Composite powders used in the form of mechanical blends of metal and ceramics or as powder alloys have been used for such coatings. But the technology of applying cermets involves the use of a large amount of metal particles up to 70% in the coating. Along with this catastrophically reduced reserves of the main alloying metals, which are part of the coatings, and many of which begin to pass into the category of acute deficiencies (tungsten, molybdenum, nickel, cobalt, copper.).

A possible solution to this is the use of special compositional powders. The structural feature of which is the presence of thin coatings (films) of a polycrystalline structure, non-equilibrium, disperse or nanosized phases, which have a radical effect on the properties of gas-thermal coatings.

Creating such a composition of composite powders requires the development of new methods, techniques and technologies for the formation of components.

Among the large number of composite powders forming technologies that would most fully meet the requirements for the creation of nanostructured phases are vacuum methods. These methods allow to create a coating of a wide range of inorganic materials - metals, alloys, chemical structures of regulated structure with high rates of deposition to the surface.

The method of forming coatings from the fluxes of a metallic plasma of a vacuum arc due to its technological capabilities is most promising in depositing

coatings of a special structure on the surface of powders of different granulometric composition. It differs in the simplicity of the implementation of evaporation and the condensation of the vapor of the material on the surface and thanks to the high ionization of the plasma flow, it can be applied to various structural materials, significantly improving the performance of these materials, and provides them with new physico-mechanical properties.

Thanks to such properties of powder materials, a new level of technology for applying gas-thermal coatings can be achieved and the requirements set by new developments in aerospace engineering, internal combustion engines, energy converters, petrochemical, glass and instrumental industries are achieved.

At the same time, the problem of obtaining vacuum coatings of a new composition, nanostructured phases on powder materials, both in scientific and technical terms, is far from completely solved. No conditions are defined for which the maximum condensation velocity on individual particles of a powder is provided, which depends on the velocity of evaporation and distance to the substrate, and the conditions at which the best properties and the structure of the coating are provided, which in turn depends on the degree of ionization of the atoms of the evaporating material.

Available in the periodical literature data on the application of vacuum coatings to various materials and products, as well as the issue of the theory of evaporation of metals in vacuum in relation to the technology of coating, illuminated insufficiently detailed and are, as a rule, applied, it does not allow to determine general recommendations on the technology of application coverings of various alloys and metals. Many issues related to the peculiarities of the process of ion-plasma deposition are not yet fully understood. In particular, it is not known which part of the evaporated atoms is ionized; what is the concentration of excited atoms in the plasma and how it changes when changing the basic parameters of the ion deposition process: gas pressure, substrate potential, vacuum arc discharge current, distance from the evaporator to the substrate.

In this regard, the study on the improvement and optimization of the technological processes of ion-plasma deposition of films on powder materials is relevant and aimed at creating a qualitative new deposited powder material for its further use, including for gas-thermal coating of coatings of various functional purposes.

The aim of thesis. The aim of the master's thesis is to analyze the factors that influence the quality and efficiency of the powder coating process by the vacuum-arc method for choosing the optimal regime parameters for coating the powders.

To achieve this goal, the following tasks are defined:

- to study, based on the literature data, the structure of composite powders, methods of obtaining coatings on powders, their properties and applications;
- to find dependencies which allow to determine the optimal time of metallization, necessary for reaching the powder particle on the surface of a given temperature and obtaining a metal film of the required thickness;
- to analyze the influence of the choice of the material of the ceramic basis for the deposited particle on the performance of the metallization process;
- to study physical and chemical processes on the surface of powder particles
- to analyze the effect of the thickness of the coating of the worn powder particles on the regime
- parameters of application of functional gas-thermal coatings;
- to develop the basic requirements for labor protection, fire and environmental safety

The object of research is the technological process of vacuum-arc coating of metal coatings on ceramic powders.

The subject of research is the efficiency of vacuuming powder coating by vacuum-arc method.

Methods of research - methods of mathematical analysis using computational software packages MathCad, Mathematica. Computer simulation of

plasma spray processes in the CASPSP software package. The processing of the results was carried out using the software of personal computers (Excel).

Approval of the results of work. According to research results, abstracts and articles have been published:

1. Єлисєєв М.Є. Нагрів плакованих частинок в процесі плазмового напиленні покриттів / М.Є. Єлисєєв, І.В. Смирнов // Інженерія поверхні. Комплексний підхід: Матеріали четвертої всеукраїнської науково-технічної конференції студентів, аспірантів та наукових співробітників (25.05.17). - К.: КПІ ім. Ігоря Сікорського, ТОВ "Фастпринт", 2017. – 37 с.

2. Єлисєєв М.Є. Підвищення ефективності плакування порошку вакуумно-дуговим методом / М.Є. Єлисєєв, І.В. Смирнов // Інженерія поверхні. Комплексний підхід: Матеріали четвертої всеукраїнської науково-технічної конференції студентів, аспірантів та наукових співробітників (16.05.18). - К.: КПІ ім. Ігоря Сікорського, ТОВ "Фастпринт", 2018. – 30 с.

3. Andreytsev A. Modeling of the heating for cladded powder in plasma jet at spraying of coating / A. Andreytsev, I. Smirnov, A. Chornyi, M. Yelysieiev, N. Dolgov // DSMIE – 2018 (12.06.18 – 15.06.18) Sumy. – Springer International publishing.

# GENERAL CONCLUSIONS

1. In the master's dissertation, on the basis of literary data, the types of composite materials, conditions for the formation of clad materials, their properties and applications are investigated. It is revealed that the most widespread use is the use of deposited powders on the basis of ceramic materials coated with more melting metals (Al, Cu, Ti, etc.). The analysis of the basic methods of obtaining clad powders has been made, from which it is concluded that it is more promising to obtain coatings on powders by vacuum-arc spraying methods, since in comparison with others it is possible to cover a larger range of coating materials.

2. According to the results of work, mathematical models were proposed that allow to determine the time of achievement on the surface of powder particles of a given temperature, as well as the duration of the metallization process to obtain a film of a certain thickness for three different materials ($Al_2O_3$, $ZrO_2$, WC), which allows to adjust the technological regimes vacuum - metallic metallurgy, depending on the weight of the loaded powder, its fractions and evaporator performance. On the basis of mathematical calculations, an analysis of the influence of the choice of the base material for the deposited particle on the performance of the metallization process and the growth of the thickness of the coating at the same powder volumes and time of spraying was carried out. It was established that with the same volume of powder and metallization time, the growth rate of the thickness of the coating is greater in WC than in $ZrO_2$ and $Al_2O_3$. This is due to the fact that, with the same volume of powders and different densities, the WC particles in comparison with other materials are less and correspondingly one particle has more coating material.

3. An analysis of the physico-chemical processes occurring on the surface of the trapped particle was performed and the chemical interaction of the material of the nucleus of the trapped particle and the coating material was investigated. According to the results of the study, the oxygen and aluminum concentration, corresponding to 8.4% and 5.6% for titanium and 2% and 2.5% for copper, were

determined. It has been found that at the temperature of 573 K the calculated values of the concentration of oxygen and aluminum in copper are very small compared with the solubility of these components in titanium.

4. Investigation of the dependence of the thickness of the coating of the deposited particle and the temperature parameters of the gas-thermal spraying was carried out. A mathematical model has been developed, according to which, for a particle of aluminum oxide with a diameter of 50 microns of clad copper, the thickness of the coating at which the particle acquires the maximum temperature corresponds to 1.5 microns. By mathematical calculations, the change in the maximum particle temperature was studied by changing the thickness of the coating and its corresponding change in the temperature of the plasma stream.

5. The master's thesis provides the basic requirements for labor protection, fire and environmental safety when working with vacuum equipment. Developed measures and facilities for the creation of safe working conditions on a research facility.