ANNOTATION

for the dissertation work towards the degree of Doctor of Philosophy (PhD) in the educational program "6D073200 – Standardization and Certification"

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Improving the quality of depozition of self-fluxing high alloyed metal surfacing powders

The annual losses of the global economy due to corrosion are estimated at more than $2.5 trillion, which is about 3-4% of global GDP. According to experts, the introduction of effective corrosion management strategies can reduce these losses by 25-35%.

Currently, there are a number of trends in Kazakhstan that require the development and modernization of infrastructure. In Kazakhstan's transition period from a planned to a market economy, its mineral resources are becoming extremely important.

The failure of the vast majority of machine parts, mechanisms, equipment, tools and technological equipment is associated with the wear and destruction of their surface layers, that is, a gradual change in the size and shape of their working surfaces. Traditionally, the fight against wear is based on the construction of parts from bulk-alloyed materials followed by heat treatment or electrochemical coatings.

This approach is complicated by the scarcity and reduction of the range of materials for manufactured metal products, their excessively high cost, high energy consumption for thermal or chemical heat treatment, and environmental problems.

Relevance of the research

The creation of a technology for flame and plasma surfacing of machine parts during wear is an important design and technological task that makes it possible to obtain a surfaced layer with high strength and adhesion, which will extend the life of repaired parts resistant to wear two or more times.

Despite the successes achieved, theoretical problems remain unresolved in the field of flame deposition, as well as practical difficulties in the application of plasma technologies using plasmatrons. The choice of optimal technological parameters of the process requires consideration, as well as the selection of a rational composition of powder materials, including highly alloyed components, to form a wear-resistant and durable deposited layer. Based on the conducted research, there is a need to develop a standard for the technology used. In this regard, the research of gas-thermal surfacing of machine parts, as well as the creation of engineering methods for calculating its parameters and characteristics, using high-speed and plasma tools

are an urgent task, the solution of which will increase the efficiency of gas-thermal surfacing processes.

The developed self-fluxing powder surfacing material based on iron with a strengthening additive is intended for the restoration of machine parts and equipment operating under conditions of abrasive wear, corrosion, at elevated temperatures or aggressive environments.

Research objectives and tasks

The aim of the work is to improve the quality of application of self–fluxing surfacing powders from high-alloy metals, which makes it possible to create a repair technology using new alloyed alloys. To achieve this goal, the following tasks were solved::

1. To select and justify the optimal composition of metal powders resistant to wear and adhesion based on standards;
2. To create a regulatory and technical methodology for obtaining powder material aimed at standardizing the manufacturing process of a new composite material;
3. To develop a regulatory and technical document regulating the technological process of coating a new powder material;
4. To form a standard defining the requirements for the composition, properties and quality of composite powder material.

Scientific basis and content of the work

The scientific novelty of the work consists in improving the quality of application of self-fluxing high-alloy surfacing powders.

It was found that the introduction of 10% CrB_2 ligature into the surfaced PG-Z40 alloy is optimal for achieving the hardness of the deposited metal in the 450-600 HV range. Based on the results of X-ray diffraction analysis, it was revealed that with such a CrB_2 content, an iron-nickel matrix with evenly distributed borides and carbides of iron, chromium and nickel is formed after mechanical alloying and melting. This fact is confirmed by an increase in the microhardness of the deposited layer from 495.55 to 549.96 HV.

A new anticorrosive protective coating is proposed that is corrosion resistant to hydrogen sulfide (H_2S), sulfuric (H_2SO_4) acids (acidic media). The level of corrosion resistance is not less than the V NACE MR 0175 ISO 15156 level.

Regulatory and technical documents have been developed:

- Standard for composite powder material;
- Technological process of production of composite powder material;
- Technological regulations for the application of this powder material.

Key findings

1. The developed powder material, which provides a hardness of the deposited metal in the range of 450-600 HV, is formed by introducing up to 10% CrB_2 ligature into the PG-Z40 alloy. Such alloying leads to the formation of an iron-nickel matrix with evenly distributed borides and carbides, which provides an increase in the microhardness of the deposited layer to 549.96 HV;

2. The developed regulatory and technical document, which establishes a methodology for obtaining powder material with the addition of CrB_2 for protective coatings of equipment in the oil and gas and uranium industries, provides standardization of the manufacturing process of a new composite material.;

3. The developed regulatory and technical document is the technological process of supersonic gas thermal spraying of anticorrosive protective coating of equipment for the oil and gas and uranium industries. The document regulates the process of applying a new powder material;

4. The developed standard of the enterprise ensures the unification of requirements for the composition, characteristics and quality of composite powder material, which leads to increased reproducibility of the properties of the applied coatings, stability of the technological process of supersonic flame spraying and guaranteed corrosion and wear resistance of protective layers on equipment of the oil and gas and uranium industries.

Scientific Novelty

1. It is proved that a new powder material based on the PG-Zh40 alloy with the introduction of up to 10% CrB_2 ligature, which ensures the formation of an iron-nickel matrix with a uniform distribution of borides and carbides, which makes it possible to increase the microhardness of the deposited layer to 549.96 HV and provide hardness in the range 450-600 HV.

2. A regulatory and technical document has been created that establishes a methodology for obtaining powder material with the addition of CrB_2, which ensures the standardization of manufacturing technology for a new composite material.

3. A regulatory and technical document has been developed regulating the technological process of supersonic gas-thermal spraying of an anticorrosive coating, which ensures reproducible application of a new powder material and stability of the properties of the formed protective layer.

4. An enterprise standard has been formed that unifies the requirements for the composition, characteristics and quality of composite powder material, which ensures increased reproducibility of the properties of the applied coatings, process stability and guaranteed corrosion and wear resistance of protective layers of equipment in the oil and gas and uranium industries.

Practical significance

The developed composite powder material and regulatory and technical documents can be used in the following industries:

1. Mechanical engineering – restoration of shafts, necks, bearing seats, surfacing worn gear teeth, guides, cylinders.

2. Oil and gas and uranium industry – surfacing of drill bits, chisels, rotors, hardening of pumping and compressor equipment, restoration of pipe threads and landing surfaces.

3. Agricultural machinery – restoration of working bodies of plows, cultivators, harvesters, welding of axles, shafts and transmission parts.

4. Mining industry – restoration of excavator buckets, welding of crushing plates, knives, rotors, reinforcement of wear surfaces of mining equipment.

The main advantages of the technology are high wear resistance of the coating, strong adhesion to the base metal, precise localization of hardening, high corrosion and heat resistance of coatings.

Conclusion

The conducted studies of powder coating technology have shown that the use of the developed new powder material ensures obtaining the desired hardness. Its composition is formed by introducing up to 10% CrB_2 ligature into the PG-Z40 alloy. This alloying provides an increase in the microhardness of the deposited layer to 549.96 HV.

A regulatory and technical document has been developed regulating the method of obtaining powder material with the addition of CrB_2 for the formation of protective coatings. The document provides standardization of the manufacturing process of a new composite material.

A regulatory and technical document has been created that establishes the technological process of supersonic gas-thermal spraying of an anticorrosive protective coating.

A standard has been developed that ensures the unification of requirements for the composition, characteristics and quality of composite powder material. Its implementation increases the reproducibility of the properties of protective coatings, stabilizes the technological process of supersonic flame spraying and guarantees the required corrosion and wear resistance of the layers.

Approbation of the dissertation

The results of the dissertation research have been published in the following sources. Articles published in journals indexed in international scientific databases such as Thomson Reuters and Scopus:

1. **Yermekov D.**, Povetkin V., Rutkuniene Z., Nurmukhanova A., Bukayeva A. Development of a technology of gasflame application of powders to increase wear resistance and adhesion strength//Eastern-European Journal of Enterprise Technologies. – 2021. – ISSN 1729-3774 № 3/12. – P. 111 DOI: 10.15587/1729-4061.2021.235578. Quartile Q3

2. Kenzhaliev B.K., Mironov V.G., Shilov G.T., Ilmaliyev Zh.B., **Yermekov D.K.** The study of the effect of chromium boron (CrB2) hardening additive on the developed pg-z40 surfacing powder// Bulgarian Chemical Communications. – 2018. – Vol. 50, Special Issue G. – P.140 – 145 DOI:10.17580/cisisr.2018.02.11

Scientific articles published in journals recommended by the Committee for quality assurance in the field of education and science of the Ministry of Science and Higher Education:

1. **Ермеков Д.К.**, Поветкин В.В., Руткуниене Ж. Состояние оборудований и технологий для нансения износостойких покрытий на технологические оборудования//ВЕСТНИК КАЗАХСТАНСКО - БРИТАНСКОГО ТЕХНИЧЕСКОГО УНИВЕРСИТЕТА. – 2019. – Vol. №1. – С.7-15.

2. Bukayeva A. Z., Povetkin V. V., Bektibay B. Zh., Nurymov Ye. K., **Yermekov D. K.** Intensification of combustion fuel mixture in petrolair thermal tools with ejector nozzle//NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN SERIES OF GEOLOGY AND TECHNICAL SCIENCES. – 2020. – ISSN 2224-5278. – Vol. 3. – Number 441. – P. 40 – 47 DOI:10.32014/2020.2518-170X.52.

3. **Ермеков Д.К.**, Поветкин В.В., Руткуниене Ж. Влияние коррозионной среды на физико-химическое изнашивание деталей оборудования с износостойким покрытием// Вестник Казахстанско-Британского технического университета. – 2020. - Vol.№1(48). – С. 7-15.

Publications in collections of abstracts of reports on the results of International scientific conferences:

1. Поветкин В.В., Нурмуханова А.З., **Ермеков Д.К.**, Букаева А.З., Исаева И.Н. Упрочняющие газопламенные технологии и оборудование // Сборник трудов XXVII международной научно – технической конференции «Машиностроение и техносфера XXI века» в г.Севостополе 14-20 сентября, 2020.. – Донецк: ДонНТУ, 2020. - с. 315-319. ISSN 2079-2670

2. **Ермеков Д.К.**, Поветкин В.В., Руткуниене Ж. Испытание методов нанесения износостойких порошков с заданными свойствами для повышения качества нанесения покрытии на детали оборудовании // Международная научная конференция студентов и молодых ученных «ФАРАБИ ӘЛЕМІ» 6-9 апреля 2020 года.

3. **Ермеков** Д.К., Поветкин В.В., Руткуниене Ж. Линейные параметры качества деталей оборудовании при восстановлении износостойкими материалами//Международная научная конференция студентов и молодых ученных «ФАРАБИ ӘЛЕМІ» 8-11 апреля 2019 г. – Р. 154

Utility model patent

Patent No. 6718 of the Republic of Kazakhstan. The impeller of a centrifugal ground pump / Bukayeva A. N. Z. N., Povetkin V. N. V. N., D. Yezekov. Kn., Seitkhanov A. N. M. N. G. N.O. N.; publ.: 08/12/2021 - p. 1.