Response

official opponent

Doctor of Engineering Sciences

Professor Vitalii IVANOV

for a dissertation **(Du Xin)**

«Technological support of strength and durability at the manufacture and repair of component parts for branch mechanical engineering»,

applied for the degree of Doctor of Philosophy,

from the field of knowledge **13 – «Mechanical Engineering»,**

on specialty **133 – «Industrial Machinery Engineering».**

1. Relevance of the dissertation topic.

It is meaningful research to use electro-spark deposition technology to improve the surface wear resistance of engineering parts. Excessive wear of the battery box locking mechanism caused failure. It will cause a serious problem. If the surface wear of the key parts pin shaft is worn, it will not be able to return, causing the battery box to be unable to be locked. The safety of electric vehicles is significantly reduced. Products were damaged due to wear and tear, causing considerable losses to the company. Improving the wear resistance of parts has received much attention from the scientific and industrial community. Friction and wear cause huge losses every year. Europe and the United States attach great importance to the impact of wear and propose using remanufacturing methods to repair the surface of worn parts. The U.S. Department of Defense has included "new

remanufacturing technologies" as a new focus for the defense industry. Ukraine has also increased research on related issues and put forward specific results.

The remanufacturing process has various forms. Among them, the ESD process has the advantages of simple operation, lower cost of use, less environmental pollution, and less material waste. The ESD deposition process makes it easy to deposit composite coatings. The composite coating process can realize multiple functions of the metal surface. It can improve the surface's wear resistance, corrosion resistance, and anti-friction. It extends the life of the part more than a single coating. It can meet the particular requirements of long-life parts. However, the deposition mechanism of various material combinations in composite coatings is complex and requires further research to optimize their performance.

ESD technology has low pollution and low maintenance costs. It can achieve a variety of functions using composite coating technology, which has positive scientific research significance. The article proposes the composite coating process to solve the key parts of the battery box lifting components. It increases the product's service life, enhances its wear resistance, solves practical problems at a lower cost, and has strong industrial practical value.

2. Connection with scientific programs, topics, and plans.

The study was completed within the research work theme plan of Sumy National Agrarian University. The dissertation was planned and executed according to the plans of research work of the Ministry of Education and Science of Ukraine (№ 0116U002756)"Scientific methodology of parts working surfaces maintenance properties providing by energy-efficient environmentally friendly methods".

3. Scientific novelty of the obtained results.

Based on analytical, scientific, and experimental research in the dissertation for the first time:

—The electro-spark deposited steel SKH51 coating was studied as a transitional coating of WC coating. High-speed steel SKH51 material has good wear resistance and impact toughness, with fewer surface defects than WC coating.

—The abrasion width method provided a convenient assessment of the wear resistance of ESD coatings. Because there were uneven micro-textures on the ESD coating, other assessments of wear resistance can result in a significant influence by environmental factors. The wear width is measured by the microscope, which is simpler and more accurate. Abrasion width can be measured quickly and accurately by a super depth of field microscope.

—ESD coatings were evaluated with a model combining normalization and weight factor methods. Evaluation parameters with non-uniform units were normalized for deposition quality, coating thickness, and roughness. The appropriate weighting factors were selected according to the coating performance usage, and the evaluation model target values were obtained to derive the optimal solution for the deposition process.

4. Theoretical significance of the dissertation.

The theoretical significance of this dissertation is as follows:

1) The article proposes a SKH51+WC+B83 composite coating structure. SKH51 coating and WC coating were combined to form a gradient structure, which further enhanced the wear resistance and service life of the ESD composite coating. B83

material was formed as an anti-friction coating, which ensured the stability of friction force. It can further enhance the wear resistance of the parts.

2) The wear resistance of electro-spark deposited discontinuous interfaces is evaluated by the width of the abrasion marks model. This method reduces the error of measuring wear, which can achieve more accurate values.

3) Nonmetallic anti-wear coatings reduce the surface roughness of ESD coatings. The surface quality of ESD coatings is enhanced by additive manufacturing. The surface properties of the nonmetal coating are further enhanced by the excellent properties of GO nano-lubricating particles, which do not agglomerate in sodium silicate solution.

4) The theoretical importance of transition coatings is emphasized in composite coatings, and a comprehensive assessment model is established. The optimal deposition process of transition coating is obtained with the normalization and weighting factor methods.

5) Through vibration theory, RC energy theory, and spark discharge theory, continuous deposition of soft metals can be achieved, and better surface quality of ESD coatings can be obtained.

5. Practical significance of the results of the dissertation.

The results of the dissertation revolve around the fact that it is possible to improve the surface wear resistance of parts and extend their service life. The wear-resistant and anti-friction coating forms a composite coating with a better wear-resistant effect through the electric spark deposition method. In the research, composite coatings are used to improve the surface properties of key parts of the

electric vehicle lifting mechanism and extend the service life of the parts. The repair process is simple to operate, has low cost, and causes less environmental pollution. The application of this technology saves companies a lot of money at least every year, improves product reliability and safety, and saves repair costs and maintenance time. This technology can also be used for surface modification of other key mechanical parts and has strong practical significance for improving surface wear resistance and service life.

6. Number of scientific publications.

There are 21 publications related to the dissertation, including 4 articles in Ukrainian scientific journals, 2 articles in other international journals, 4 articles in international scientific journals indexed by Scopus or Web of Science databases, and 11 articles in relevant conference proceedings.

7. Complete presentation of the dissertation material in scientific publications.

The main scientific results of the dissertation have been fully presented in 21 publications mentioned in the previous chapter. The published articles meet the established requirements and reflect the main content of the thesis. Scientific results were presented and discussed at 11 international conferences.

8. The degree of validity of scientific provisions.

The research task involves the company's industrial problems and scientific projects as a background for the research. The author completes a dissertation research program at a high scientific level under the guidance of his supervisor. The dissertation was carried out based on research of 197 literature sources and

extensive experimental research studies.

The main scientific goal and conclusions presented in the dissertation are logically justified and developed based on multiple studies. The research results presented in the dissertation are not only based on professional scientific research methods, systematic theoretical studies but also published in scientific journals and conference proceedings and applied in products with the cooperation of enterprises and rigorously tested in practical applications.

Discussing the corresponding material allows for the conclusion that the validity of the scientific statements and the reliability of the research results are high.

9. The structure and content of the dissertation, its completeness, and compliance with the established requirements for design.

The introduction substantiates the choice of the dissertation topic and scientific tasks, formulates the purpose and tasks of the research, defines the scientific novelty and practical significance of the results obtained, and provides information about approval, structure, and scope of work.

In the first Chapter, the development of remanufacturing engineering was introduced. Several major remanufacturing standard processes were compared. Among them, electro-spark deposition technology was valued due to cost and convenience. This chapter provided an overview of the history of ESD, the recent research progress, and the optimization of the ESD process.

In the Second Chapter, the fundamental theories and research methods were mainly introduced. The working principle of the ESD deposition method was

introduced. Three different principles of vibrating electrodes were presented. The basic theory of coating formation by the ESD method was analyzed. ESD equipment, deposited material, experimental methods, and coating deposition processes were described.

In the Third Chapter, some methods of electro-spark deposition were researched for increasing surface abrasion resistance. Graphite deposited on the surface of 45 steel can improve the abrasion resistance of the material surface. A simple abrasion width model was developed to compare the abrasion resistance of ESD coatings. Taguchi orthogonal method was used to find out the optimum process of the graphite deposition. The SKH51 material was used as a transition layer. The normalization and weighting factors were used to obtain the optimal coating deposition process parameters. According to gradient composite coating technology and in-situ technology, various deposition schemes were used to compare wear resistance. Soft metal material can further reduce friction and wear in ESD coating. Finally, it was discovered that a composite coating scheme can significantly improve the service life. The new pneumatic electro-spark deposition process is used for low-temperature soft metal deposition to improve coating surface accuracy and deposition performance significantly. GO gel coating can improve surface accuracy and reduce friction, which reduces the machining difficulties and defects of conventional ESD-coated surfaces.

In the Fourth Chapter, the ESD process that was applied to the battery replacement equipment of electric vehicles was described. The test results of the coating for the solutions were summarized and analyzed, and the best industrial

application solution was determined based on the industrial application.

In the Conclusions, the scientific research results were summarized. General conclusions and key process solutions and data were proposed.

The research structure of the dissertation is well-sequenced and logically organized. The content and objective of the study are gradually deepened and combined to form an organic whole. The rules for planning and scientific research were followed. Advanced testing methods and processing of experimental results were used. The thesis's structure, content, and completeness fully comply with the requirements.

10. Discussion clauses, comments, and recommendations regarding the thesis content.

However, there are still some issues that have not been analyzed in detail in the thesis.

1) In the ESD process, surface defects will occur as the ESD deposition time increases, especially for WC ceramic materials. The purpose of adding transition coatings to WC coatings was not clearly analyzed. SKH51 can reduce surface cracks in WC coatings as a transition coating and improve surface deposition quality.

2) Only the effect of a single-size electrode diameter was considered in the composite coating deposition process. In the 4th chapter of the industrial application, it is necessary to consider the effect of various electrode sizes on the coating performance, which still needs to be followed up. It is more practically relevant to the industrial enterprises.

3) When GO gel coating is deposited, paint sprayers may be used instead of

brushes to improve the experimental process.

4) The curved surface deposition process differs from the plane surface deposition process. In the last chapter, multi-electrode and lathe deposition methods should improve the pin shaft deposition process.

5) The GO gel coating can further improve the performance. Adding solid lubricant powders such as Mos2 and other materials can further reduce friction.

6) No electronic measuring equipment was used to measure spark energy on soft metals deposition. What is the data basis for the calculation?

7) The authors used orthogonal experiments for electro-spark deposition. Can the experimental results be analyzed with fewer experimental groups? It allows for a better analysis of the influence of deposition factors.

8) Various deposition experiments were carried out on the composite coatings. These experimental details are insufficient, and the results can be progressively discussed and analyzed. It can even be studied more deeply.

These remarks and wishes do not reduce the overall positive impression of the dissertation work.

General conclusion

Dissertation work **(Du Xin)** "Technological support of strength and durability at the manufacture and repair of component parts for branch mechanical engineering", which was submitted for defense to the specialized academic council for obtaining the degree of Doctor of Philosophy in the field of knowledge 13 – Mechanical Engineering in the specialty 133 – Industrial Machinery Engineering according to its relevance, scientific and theoretical level, main results of validity,

main provisions and results published in professional publications, novelty statement and practical meaning meets the requirements of the Order of the Ministry of Education and Culture of Ukraine No. 40 of January 12, 2017 "On approval of requirements for the preparation of a dissertation" and Resolution of the Cabinet of Ministers of Ukraine of January 12, 2022 No. 44 "On approval of the Procedure for awarding the degree of Doctor of Philosophy and cancellation of the decision of a one-time specialized of the academic council of the institution of higher education, scientific institution on awarding the degree of doctor of philosophy" with changes introduced in accordance with Resolution of the Cabinet of Ministers No. 341 dated 03.21.2022.

Official opponent:

Doctor of Engineering Sciences, Professor,

Head of the Department of Manufacturing

Engineering, Machines and Tools of

Sumy State University Vitalii IVANOV

Підпис Іванова В.
засвідчую
пров. фах. веду відділу кадрів
Красуля