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ANALYSIS OF THE EFFECT OF THE COMPOSITION AND PHYSICAL-MECHANICAL PROPERTIES OF COATED ELECTRODES ON THE QUALITY OF WELDED JOINTS

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Abstract. This article presents a scientific and technical analysis of the composition and physical-mechanical properties of coated electrodes and their influence on the quality of welded joints. During the study, the structural characteristics of the electrode core and coating layer, the metallurgical and technological properties of electrodes, the mechanisms of weld formation, and their operational performance were investigated. In addition, the effects of mineral and alloying components contained in the electrode coating on arc stability, weld quality, and the physical-mechanical properties of the weld metal were evaluated. Based on the research results, scientific principles for electrode selection in welding processes and technological recommendations aimed at improving quality indicators were developed.

Keywords: coated electrode, welding, electrode coating, physical and mechanical properties, weld joints, metallurgical process, alloying elements, corrosion resistance, thermal-physical properties.

INTRODUCTION

In modern industrial production, welding technology is considered one of the main technological directions for manufacturing metal structures, performing repair operations, and ensuring operational reliability. In particular, the increasing demand for high-quality welded joints in mechanical engineering, energy, metallurgy, transportation, and construction industries has created the need to improve the composition and performance of welding materials. In this process, coated electrodes are regarded as one of the key factors determining weld formation and the final quality characteristics of welded joints.

During the electric arc welding process, coated electrodes perform not only the function of consumable filler material but also protect the welding zone from atmospheric effects, control metallurgical reactions, and participate in the formation of the weld metal structure. The components contained in the electrode coating ensure stable arc burning, protect the molten metal from oxidation, and provide mechanical strength to the welded joint. Therefore, the scientifically based selection of electrode composition is considered one of the essential tasks of modern welding technology.

n recent years, the increasing application of high-strength steels and special alloys has intensified the need for a deeper analysis of the physical and mechanical properties of coated electrodes. Selecting the optimal ratio of mineral, gas-forming, and alloying components in electrode coatings has a significant influence on weld quality and operational performance.

The purpose of this study is to scientifically analyze the composition and physical-mechanical properties of coated electrodes and evaluate their influence on the quality of welded joints, as well as to substantiate effective technological solutions for improving welding performance and weld quality.

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ATERIALS AND METHODS

During the study, methods of theoretical analysis, structural evaluation, materials science analysis, and technological comparison were applied. Various grades of coated electrodes used in industrial applications were selected as the research object, with particular attention given to their structural configuration, coating composition, and technological characteristics during welding.

The evaluation of the physical and mechanical properties of the electrodes focused on coating composition, arc stability, the transfer characteristics of metal droplets, heat distribution, and the quality of the resulting weld. The main components of electrode coatings were classified and analyzed into four groups: slag-forming, gas-forming, alloying, and ionizing components.

The research methodology was carried out according to the following sequence:

Stage 1 – analysis of the electrode core and coating composition;

Stage 2 – determination of the functional roles of coating components;

Stage 3 – evaluation of the influence of physical and mechanical properties on weld quality;

Stage 4 – comparison of technological efficiency and development of practical recommendations.

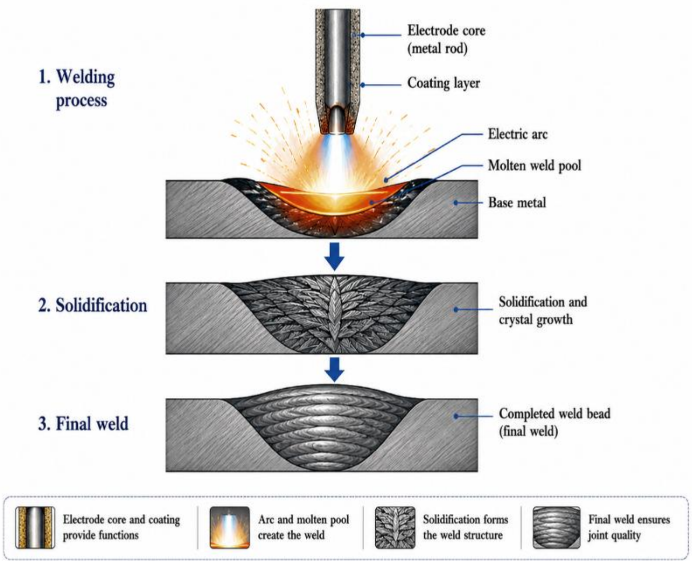

Figure 1. Structure of a Coated Electrode and Functional Diagram of the Welding Process

The presented diagram illustrates the relationship between the components of the electrode composition and their functional interaction during the welding process. As shown in the diagram, the coating composition simultaneously performs protective, metallurgical, and technological functions within the welding zone and contributes to the formation of the final weld quality.

RESULTS

The results of the study demonstrated that the composition and physical-mechanical characteristics of coated electrodes have a direct influence on the quality of welded joints. The conducted analysis revealed that the optimal selection of mineral, gas-forming, deoxidizing, and alloying components in the electrode coating contributes to improving weld strength, corrosion resistance, and operational reliability.

During the welding process, the components of the electrode coating perform several technological functions simultaneously: stabilizing the electric arc, protecting the molten metal from atmospheric gases, forming slag, and controlling the microstructure development of the weld metal. In particular, rutile coatings based on titanium dioxide were found to provide easy arc ignition and stable arc performance, whereas basic coatings produced welded joints with superior mechanical strength and enhanced structural integrity.

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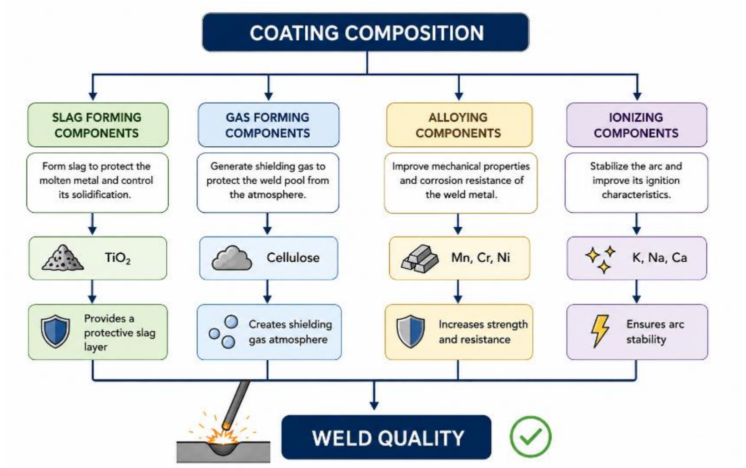

Figure 2. Structural Components of Electrode Coating and Their Functional Effects

The analysis of the diagram demonstrated that each component contained in the electrode coating performs a specific technological function during the welding process and collectively contributes to the final quality of the weld.

The evaluation results of the physical and mechanical properties of the electrodes revealed a strong relationship between these properties and their constituent elements. Alloying additives based on manganese and nickel improved the impact resistance of the weld metal, while silicon reduced the oxygen content in the metal and enhanced weld density. Components based on fluorite and calcium carbonate created a protective environment within the welding zone, thereby reducing the probability of internal defect formation and improving the overall quality of the welded joint.

The presented diagram illustrates the formation of the weld structure as a result of the interaction between the electrode material and the coating components during the welding process.

The results of the technological evaluation showed that the proper selection of coated electrodes makes it possible to increase welding productivity, reduce metal consumption, and extend the service life of welded joints. At the same time, it was determined that protecting electrodes from moisture and applying them under recommended operating conditions are important factors in ensuring high weld quality and minimizing defects.

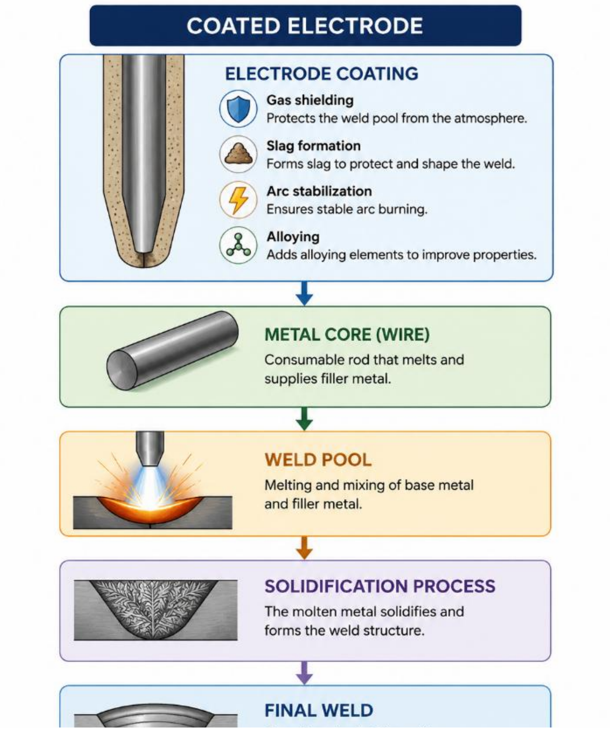

Figure 3. Schematic Representation of Weld Formation Using a Coated Electrode

DISCUSSION

The obtained results confirmed that the composition and physical-mechanical properties of coated electrodes have a significant influence on the technological efficiency of the welding process and the quality of the final welded joint. Based on the research findings, it was determined that electrode coating is not merely a protective layer but functions as an active technological system that controls the metallurgical processes occurring within the welding zone.

The analysis showed that mineral and gas-forming components contained in the coating ensure stable arc burning and protect the weld pool from atmospheric effects. At the same time, the presence of alloying elements plays an important role in forming the microstructure and operational characteristics of the weld metal. In particular, additives based on manganese, chromium, and nickel were observed to improve mechanical strength, impact toughness, and corrosion resistance [1, 2].

Among the technological characteristics of coated electrodes, arc stability, the transfer behavior of metal droplets, and slag detachability were evaluated as the main criteria. The research results indicated that rutile-coated electrodes provide greater technological convenience and ease of operation, whereas basic-coated electrodes are preferred for high-responsibility structural applications [3, 4].

Furthermore, it was determined that the operating conditions of electrodes also significantly influence the final welding results. Under the influence of moisture, the hydrogen content in the coating may increase, leading to the formation of internal defects in the weld. Therefore, proper storage conditions and thermal treatment of electrodes should be considered an integral part of the technological process [5].

Based on the obtained results, it was substantiated that optimizing the chemical composition of coated electrodes, scientifically selecting the proportion of coating components, and applying modern alloying additives represent promising approaches for improving welding quality and enhancing the operational performance of welded joints.

CONCLUSION

The results of the conducted research demonstrated that the composition and physical-mechanical properties of coated electrodes are among the main factors directly affecting the quality of welded joints. The analysis of the functional roles of the components contained in the electrode coating showed that they collectively influence arc stability, metal protection, and the weld formation process.

According to the research findings, the optimal selection of slag-forming, gas-forming, deoxidizing, and alloying components in electrode composition makes it possible to improve weld strength, corrosion resistance, and operational reliability.

In addition, improving the physical and mechanical characteristics of coated electrodes contributes to increasing welding productivity, reducing production costs, and extending the service life of metal structures.

The results of this study may serve as a methodological basis for developing scientific and practical recommendations for the design, selection, and efficient industrial application of coated electrodes.

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