https://doi.org/10.52676/1729-7885-2025-4-113-118
УДК 537.533.7

INVESTIGATION OF STRUCTURE AND PROPERTIES OF COATINGS OBTAINED BY ELECTRIC ARC METALLIZATION AT DIFFERENT WIRE FEED RATES

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This study investigates the effect of wire feed rate on the structure and properties of coatings produced by electric arc metallization using 30KhGSA wire. The coatings were deposited onto 65G steel substrates at feed rates of 5, 7, and 9 cm/s using supersonic arc spraying. A comprehensive characterization was performed, including microstructural analysis, EDS mapping, X-ray diffraction, and evaluation of coating thickness, hardness, and porosity. The results indicate that an increase in wire feed rate leads to greater coating thickness but reduces structural homogeneity. At 5 cm/s, the coating exhibited a uniform microstructure and low porosity, though with limited thickness. The intermediate feed rate of 7 cm/s provided optimal properties, including balanced thickness (up to 220 µm), reduced porosity (4.3%), and high hardness (up to 720 HV). At 9 cm/s, further thickness growth was accompanied by turbulent deposition, resulting in increased porosity and structural defects. These results confirm that wire feed rate is a decisive factor in coating quality, and its optimization is essential for achieving durable and reliable protective layers.

Keywords: *porosity, electric arc metallization, coating, steel, structure, steel wire.*

Introduction

The development of materials with improved properties (wear resistance, oxidation resistance, thermal stability) for parts operating under intensive loads is a topical issue in modern materials science. Accelerated wear and degradation of material properties significantly reduce the service life of critical components. As an alternative to costly fully alloyed steels, it is often more practical to use low-alloy steels in combination with protective coatings [1]. Steel 65G, while strong and widely used, exhibits limited oxidation resistance and is therefore in need of protective enhancement. One promising solution is to apply coatings from wear- and corrosion-resistant steels such as 30KhGSA to increase the durability and performance of 65G-based parts [2–5]. Electric arc metallization (EAM) is an efficient and cost-effective method of applying such coatings. It enables the formation of dense layers with good adhesion by melting wire feedstock with an electric arc and propelling the molten droplets onto the surface using compressed air. The quality of the resulting coating is significantly affected by parameters such as arc voltage, current, and wire feed rate. Compared to other coating deposition methods such as HVOF (High-Velocity Oxy-Fuel) and plasma spraying, electric arc metallization offers several advantages, including lower equipment cost, operational simplicity, and the ability to coat large components without complex surface preparation. While HVOF and plasma-sprayed coatings generally provide higher density and better structural homogeneity, EAM remains a practical and cost-effective method, especially for industrial and agricultural equipment subject to abrasive wear. Thus, the use of EAM is justified where economic feasibility and sufficient wear resistance are prioritized.

This study focuses on the influence of wire feed rate (5-9 cm/s) on the structure and performance of 30KhGSA coatings applied to a 65G steel substrate under fixed current and air pressure. The investigated parameters include porosity, microhardness, surface roughness, and friction coefficient.

The scientific novelty of this work lies in the comprehensive analysis of the effect of wire feed rate on coatings obtained by electric arc metallization using 30KhGSA wire, which has not been previously studied in detail. The study employs a supersonic arc spraying technique to form high-performance coatings and explores a wide range of characteristics, including microstructure, adhesion, and tribological behavior. Notably, it was found that a medium wire feed rate of 7 cm/s provides an optimal balance between structural integrity and functional properties, challenging the common assumption that higher feed rates yield better results. These conclusions are supported by SEM, EDS, and XRD analysis, offering practical insights for improving the wear resistance of machine parts operating under abrasive conditions [6].

The aim of this study is to evaluate the effect of wire feed rate on the morphology and performance characteristics of coatings. Since the 30KhGSA/65G steel combination has not been sufficiently studied in the context of arc metallization, this research addresses a relevant gap in both scientific and industrial contexts, especially for applications involving intensive abrasive wear.

Materials and methods of research.

The substrate material used was 65G steel, a high-carbon, low-alloy steel with approximately 0.65% carbon content. The substrates were cut into rectangular plates measuring 25 × 25 × 10 mm. Prior to coating, the surface of the samples was carefully prepared. Initially, they were sanded with progressively finer sandpaper, starting from 100 grit and moving to 360 grit, which ensured the necessary smoothness while removing oxide layers and contaminants. Following this, sandblasting was carried out using an electrocorundum abrasive on a Nordberg NS3 machine to achieve the desired surface roughness, enhancing the coating's adhesion.

Table 1. Composition of chemical elements of steel (by mass, %)

C	Si	Mn	Ni	S	P	Cr	Cu
0.62–0.7	0.17–0.37	0.9–1.2	to 0.25	to 0.035	to 0.035	to 0.25	to 0.2

For the experiments, steel wire of 30KhGSA grade (AISI 1330 equivalent), with a diameter of 1.4 mm and manufactured in compliance with GOST 10543-98 standards, was used as electrodes. The chemical composition of 30KhGSA steel is presented in Table 2.

Table 2. Chemical composition of steel 30KhGSA (by mass, %)

C	Si	Mn	Ni	S	P	Cr	Cu
0.28–0.34	0.9–1.2	0.8–1.1	to 0.3	to 0.025	to 0.025	0.8–1.1	to 0.3

Coating was carried out using the SX-600 supersonic arc metallizer (Guangzhou, China), a sophisticated system that includes a power supply, arc spray gun, control unit, and compressed air supply module. The process involves melting metal wires with an electric arc, after which the molten metal is atomized by a stream of compressed air [7]. The molten particles then deposit onto the target surface, forming a continuous coating. The thickness of the applied layer is controlled by adjusting the number of passes of the metallizer and its movement speed relative to the surface. The device features guides that ensure a continuous feed of two metal wires, with an electric arc generated between their ends. Compressed air, reaching speeds exceeding 100 m/s, is directed through a nozzle to pull molten particles off the wire ends and deposit them on the substrate, creating a coating with strong adhesion and low porosity [8–12].

During the experiments, 65G steel was used as the substrate material, and 30KhGSA alloy was used as the coating. The study was conducted under several sputtering modes, in which the wire feed rate was varied in the range from 5 to 9 cm/s, while the voltage, compressed air pressure, sputtering distance and other parameters remained unchanged. During operation of the equipment, it was found that varying the wire feed speed had a direct effect on the amperage. This speed range was selected as the optimum range to ensure a stable sputtering process and a high-quality coating. Detailed parameters of spraying modes are presented in Table 3.

The phase composition of the coatings after metallization was analyzed using an X'Pert Pro X-ray diffractometer (PANalytical, Netherlands), enabling both qualitative and quantitative identification of crystalline phases. Measurements were conducted at wire feed rates ranging from 5 to 9 cm/s, under a voltage of 45 kV and a current of 40 mA, using Cu-Kα radiation within a 2θ angular range of 20° to 90°, with a step size of 0.02°.

Table 3. Spray parameters for high-speed arc metallization using the SX600 machine.

Sample Name	Wire feed speed, cm/s	Current strength, A	Voltage, V	Compressed air pressure, atm	Spraying distance, cm
W1	5	200	30	9	40
W2	7	200	40	9	40
W3	9	200	45	9	40

To examine the microstructure of the coating cross-sections, scanning electron microscopy (SEM) was employed. The analysis was performed on a Tescan Vega 4 SEM (Tescan, Brno, Czech Republic) equipped with an energy-dispersive spectroscopy (EDS) system for elemental composition analysis.

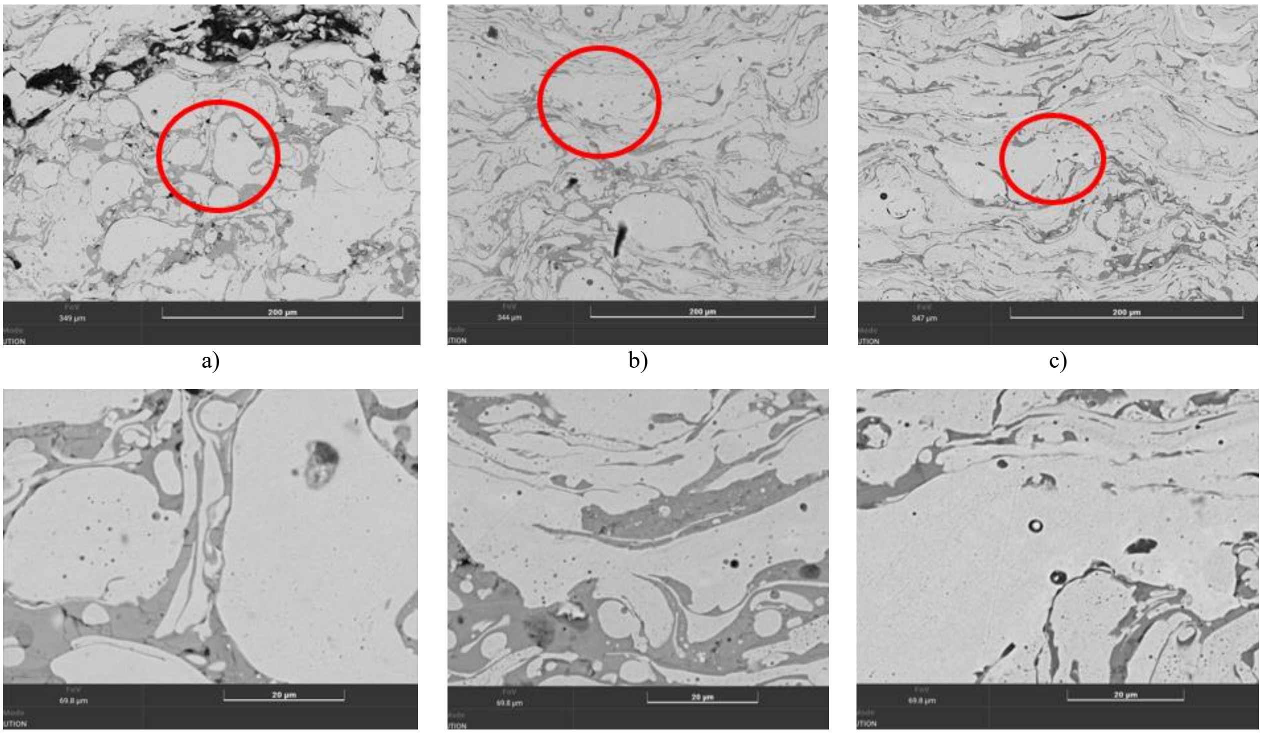
Microhardness testing was conducted using the Vickers method on a Metolab 502 device (Metolab, Russia). The measurements were taken under a load of 0.2 N with a dwell time of 10 seconds, using a diamond pyramid indenter with a face angle of 136°.

Tribological performance was evaluated on a TRB3 tribometer (Anton Paar GmbH, Austria) using the ball-on-disk method. A 3 mm diameter steel ball made of ShH15 steel served as the counterbody. The tests were carried out under a 10 N normal load, with a linear sliding speed of 3 cm/s and a wear track radius of 1.50 mm, resulting in a total sliding distance of 70 meters.

RESULTS AND DISCUSSION.

In general, metallization is one of the key areas of our work, which we have been engaged in for a long time. As in previous studies, we conducted a number of tribological, corrosion and microstructural tests. Several series of experiments were carried out using 65G steel and the most optimal variant was selected based on the data obtained. Coatings formed by electric arc metallization result from the rapid deposition and solidification of molten metal droplets, creating a multilayered structure visible in SEM images (Figure 1). This layered structure, present under all process conditions, enhances wear and corrosion resistance [13]. This structure prevents the propagation of cracks and penetration of aggressive substances, which increases the service life of the protective layer.

Despite their advantages, the coatings contain defects such as pores and oxide inclusions. As noted by Li et al. [14–16], pores form due to air entrapment during the cooling of molten particles and can reduce corrosion resistance by allowing corrosive agents to reach the substrate. SEM images (Figure 1) show that porosity varies with the wire feed rate (5-9 cm/s). In addition to the general SEM images, Figures 1a', 1b', and 1c' show enlarged fragments of the corresponding samples, allowing for a more detailed analysis of the particle distribution, porosity, and possible defects in the coating structure.



a) b) c)

a') b') c')

Figure 1. The microstructure of the coatings obtained by the SEM method: (a), (b), (c) is a general view of the surface structure of the coatings corresponding to samples W1, W2, and W3, respectively; (a'), (b'), (c') are enlarged fragments demonstrating porosity and particle distribution in local zones

Thus, although the 9 cm/s regime (W3) provides the highest hardness and lowest porosity, the increase in friction coefficient and decrease in adhesion indicate reduced stability during operation. The 7 cm/s coating (W2) demonstrates an optimal balance between thickness, hardness, adhesion, porosity, and tribological behavior. Therefore, this feed rate can be considered the most effective for producing wear-resistant and reliable coatings under abrasive conditions.

At the minimum wire electrode feed rate of 5 cm/s (sample W1), the porosity of the coating at the level of 3.5% is recorded, and its structure is characterised by irregularity. The microstructural images obtained by SEM show fluctuations in the thickness of individual layers and their density. This is explained by the insufficient energy of the melt particles deposited on the substrate, as a result of which the degree of interparticle bonding is reduced, which favours the formation of pores. Studies [17], indicate that at reduced sputtering rates, lower deposition rates are observed, increasing the probability of void formation and reducing the adhesion between layers.

At a feed rate of 7 cm/s (sample W2), the porosity decreases to 2.7% and the structure becomes more uniform. SEM images confirm that the microdroplets are deposited more uniformly, improving the density and uniformity of the coating. The paper [18], indicates that increasing the feed rate improves the coating density, reducing porosity and increasing corrosion resistance, since fewer pores limit the penetration of corrosive agents.

At the maximum wire feed rate of 9 cm/s (sample W3), the obtained coating is characterised by the lowest level of porosity – about 1.3%, and its structure is characterised by high density and uniformity. The increased kinetic energy of molten particles in this mode favours their deeper penetration into the substrate and improves adhesion between successive layers. As a result, a uniform layer with strong internal bonding is formed. As noted in the study [19], such dense coatings effectively prevent the penetration of aggressive media, which positively affects the anti-corrosion and wear resistance characteristics of the material. Microstructure analysis using SEM confirms the presence of an almost continuous coating with pronounced interlayer cohesion.

In addition to porosity, oxide inclusions are often observed in coatings produced by arc metallisation. They are formed as a result of the interaction of molten particles with air oxygen both during flight and at the moment of contact with the substrate. These inclusions are predominantly concentrated in the pores and at the boundaries between the layers, indicating that the oxidation intensity is related to the deposition modes. As noted in [20], excessive oxide content can lead to a decrease in the strength characteristics of the coating. At the same time, a moderate amount of oxides can have a positive effect – for example, some studies [21], demonstrate that the presence of oxide phases in $FeAl/Cr_3C_2$ type composite systems contributes to improved wear resistance and increased adhesion between coating layers [21].

X-ray phase analysis showed the presence of oxides (Fe_3O_4, Fe_2O_3) in the samples. The highest amount of them was found in sample W1 and the lowest in W3. This is due to less development of oxidation processes at higher wire feed speed.

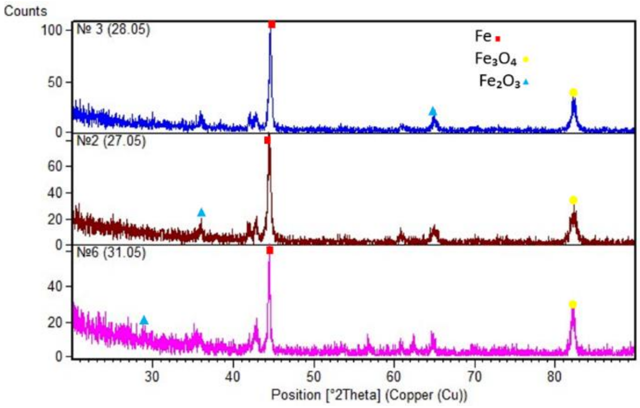


Figure 2: Results of X-ray phase analysis

Table 4 shows data on physical and mechanical characteristics of coatings obtained at different wire feed rates, including microhardness values (Vickers at HV0.1/10 load). The analysis of the obtained results demonstrates a stable dependence between the increase in feed rate and microhardness growth. Thus, at the minimum feed rate of 5 cm/s (sample W1) the lowest value of microhardness was recorded – 258 HV, which is associated with increased porosity and less dense structure of the layer. This is due to insufficient particle energy, which reduces the interlayer bonding strength. In contrast, at a maximum feed rate of 9 cm/s (sample W3), the microhardness increases to 305 HV. This increase is attributed to the more intense impact of molten particles, which favours the formation of a dense and uniform coating with improved interlayer cohesion [22].

Table 4. Summary physical and mechanical properties of coatings at different wire feed rates

Samples	Hardness (HV)	Porosity, %	R_a, µm	Friction Coefficient
W1	258	3.5±0.25	10.9	0.46±0.06
W2	278	2.7±0.27	16.2	0.42±0.05
W3	305	1.3±0.06	25.4	0.53±0.02

The variations in the structure and properties of the coatings with changes in the wire feed rate are primarily attributed to the changes in kinetic energy and thermal balance in the spray zone. At lower feed rates (5 cm/s), the amount of molten material is reduced, and the droplets have lower kinetic energy, resulting in weaker flattening upon impact with the substrate. This leads to higher porosity, less cohesion between splats, and a looser microstructure. Increasing the feed rate (to 7 cm/s) improves particle energy and volume, leading to better pore filling, enhanced splat bonding, and denser coatings. However, at excessively high feed rates (9 cm/s), turbulence and partial cooling of particles before reaching the substrate may occur, which can reduce adhesion and increase residual stresses [23–24]. Thus, the observed variations in coating properties reflect a balance between kinetic, thermal, and structural factors in the deposition process.

Figure 3 shows the dynamics of the coefficient of friction for three coating samples (W1, W2, W3) obtained at different wire feed speeds as a function of the traveled distance. All samples show an initial sharp increase in the coefficient of friction (up to 20 m) due to surface adaptation, reaching ~0.4 for W1 (low speed) and W2, and 0.5 for W3 (maximum speed, denser structure). The coefficient then stabilizes at levels of ~0.46 (W1), ~0.42 (W2), and ~0.53 (W3), indicating the formation of a stable contact layer. The dense structure of W3 provides higher wear resistance but also a higher coefficient of friction [25]. The initial stage involves the destruction of spray microdefects, after which the particles are compacted to form a stable, cohesive and wear-resistant layer.

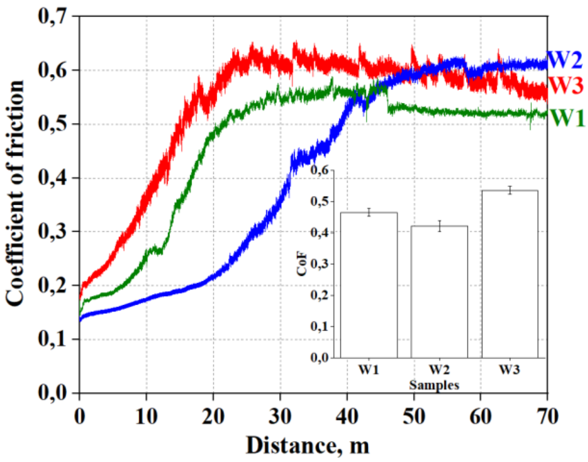


Figure 3. Dependence of friction coefficient

CONCLUSION

For coating application we used a supersonic arc metallization unit SX-600 (Guangzhou, China), in which the wire is melted using an electric arc, and then the atomized melt is transported by air flow to the surface to be treated [25]. This method allows to form a dense adhesion layer (see Figure 1). In the course of the experiment, the influence of the wire feed speed in the range from 5 to 9 cm/s on the characteristics of the obtained coatings was studied.

The influence of wire feed speed (5-9 cm/s) was analyzed, revealing the following:

- Increased feed speed enhances the coating microstructure due to higher particle kinetic energy.
- At 9 cm/s, the coating demonstrates the lowest porosity (1.36%) and highest microhardness (297 HV).
- At 5 cm/s, porosity rises to 3.58%, reducing corrosion resistance due to structural defects.

Higher feed rates result in denser coatings with improved wear and corrosion resistance, though they also lead to a slightly increased coefficient of friction.

Acknowledgments
This research is funded by the Committee of Science of the Ministry of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21882370).

REFERENCES

1. Rakhadilov, B.; Zhurerova, L.; Sagdoldina, Z.; Kenesbekov, A.; Bayatanova, L. Morphological Changes in the Dislocation Structure of Structural Steel 20GL after Electrolytic-Plasma Hardening of the Surface // J. Surf. Investig. X-Ray Synchrotron Neutron Tech. – 2021. – Vol. 15. – P. 408–413.
2. Wielage, B.; Wank, A.; Rupprecht, C. Tailoring of Wire Feedstock and Processing Conditions in High Velocity Combustion Wire Spraying. In Proceedings of the ITSC2006-ASM International, Seattle, WA, USA, May 15-18, 2006. – P. 1009–1014.
3. Gornik, M.; Jonda, E.; Latka, L.; Nowakowska, M.; Godzierz, M. Influence of spray distance on mechanical and 4. tribological properties of HVOF sprayed WC-Co-Cr coatings // Mater. Sci.-Pol. – 2021. – Vol. 39. – P. 545–554.
4. Boinovich, L.B.; Domantovsky, A.G.; Emelyanenko, A.M.; Emelyanenko, K.A. Synergism of Arc Spraying, Laser Processing, and Hydrophobization for Long-Lasting Corrosion Protection of MA8 Magnesium Alloy // Adv. Eng. Mater. – 2024, Early View. https://doi.org/10.1002/adem.202401708
5. Qiang, W.; Kang, M.; Liu, J.; Ndumia, J.N. Microstructure and Wear Performance of High-Velocity Arc Sprayed FeMnCrNiBNbAl Coating // Coatings. – 2024. – Vol.14. – P. 428. https://doi.org/10.3390/coatings14040428
6. Szymański, K.; Hernas, A.; Moskal, G.; Myalska, H. Thermally Sprayed Coatings Resistant to Erosion and Corrosion for Power Plant Boilers-A Review // Surf. Coat. Technol. – 2015. – Vol. 268. – P. 153–164. https://doi.org/10.1016/j.surfcoat.2014.10.046
7. Wielage, B.; Pokhmurska, H.; Student, M.; Gvozdeckii, V.; Stupnyckyj, T.; Pokhmurskii, V. Iron-Based Coatings Arc-Sprayed with Cored Wires for Applications at Elevated Temperatures // Surf. Coat. Technol. – 2013. – Vol. 220. – P. 27–35.
8. Romankov, S.E.; Sagdoldina, Z.B.; Kaloshkin, S.D.; Kaevitser, E.V. Fabrication of Ti-Al composite coatings by the mechanical alloying method // Phys. Met. Metallogr. – 2008. – Vol. 106. – P. 67–75.
9. Tabieva, E.E.; Zhurerova, L.G.; Baizhan, D. Influence of electrolyte-plasma hardening technological parameters on the structure and properties of banding steel 2 // Key Eng. Mater. – 2020. – Vol. 839. – P. 57–62.
10. Popova, N.A.; Zhurerova, L.G.; Nikonenko, E.L.; Skakov, M.K. Effect of plasma electrolytic nitrocarburizing on phase composition of 0.3 C-1Mn-1Si-Fe steel // Inorg. Mater. Appl. Res. – 2017. – Vol. 8. – P. 130–135.
11. Kakimzhanov, D.N.; Rakhadilov, B.K.; Tyurin, Y.N.; Kolisnichenko, O.V.; Zhurerova, L.G.; Dautbekov, M.K. Influence of pulsed plasma treatment on phase composition and hardness of Cr_3C_2-NiCr coatings. Influence of pulsed plasma treatment on phase composition and hardness of Cr_3C_2-NiCr coatings // Eurasian J. Phys. Funct. Mater. – 2021. – Vol. 5. – P. 45–51.
12. Ramezani, M.; Mohd Ripin, Z.; Pasang, T.; Jiang, C.P. Surface engineering of metals: Techniques, characterizations and applications // Metals. – 2023. – Vol. 13. – P. 1299.
13. Kengesbekov, A.; Rakhadilov, B.; Sagdoldina, Z.; Buitkenov, D.; Dosymov, Y.; Kylyshkanov, M. Improving the efficiency of air plasma spraying of titanium nitride powder // Coat. – 2022. – Vol. 12. – P. 1644.
14. Rakhadilov, B.; Pogrebnjak, A.; Sagdoldina, Zh.; Buitkenov, D.; Beresnev, V.; Mukhamedova, A. Effect of Bilayer Thickness and Bias Potential on the Structure and Properties of (TiZr/Nb) N Multilayer Coatings as a Result of Arc-PVD Deposition // Mater. – 2022. – Vol. 15. – P. 7696. https://doi.org/10.3390/ma15217696
15. Rakhadilov, B.K.; Baizhan, D.R.; Sagdoldina, Z.B.; Buitkenov, D.B.; Maulet, M. Phase composition and structure of composite Ti/HA coatings synthesized by detonation spraying // AIP Conf. Proc. – 2020. – Vol. 2297. – P. 010001.
16. Rakhadilov, B.K.; Kenesbekov, A.B.; Kowalevski, P.; Ocheredko, Y.A.; Sagdoldina, Z.B. Development of air-plasma technology for hardening cutting tools by applying wear-resistant coatings // News Natl. Acad. Sci. Repub. Kazakhstan. – 2020. – Vol. 3. – P. 54–62.
17. Yu, H.L.; Zhang, W.; Wang, H.M.; Ji, X.C.; Song, Z.Y.; Li, X.Y.; Xu, B.S. In-situ synthesis of TiC/Ti composite coating by high frequency induction cladding // J. Alloys Compd. – 2017. – Vol. 701. – P. 244–255.
18. Sidorov, S.A.; Mironov, D.A.; Khoroshenkov, V.K.; Khlusova, E.I. Surfacing methods for increasing the service life of rapidly wearing working tools of agricultural machines // Weld. Int. – 2016. – Vol. 30. – P. 808–812.
19. Sun, R.; Shi, Y.; Pei, Z.; Li, Q.; Wang, R. Heat transfer and temperature distribution during high-frequency induction cladding of 45 steel plate // Appl. Therm. Eng. – 2018. – Vol. 139. – P. 1–10.
20. Hui, R.; Wang, Z.; Kesler, O.; Rose, L.; Jankovic, J.; Yick, S.; Ghosh, D. Thermal plasma spraying for SOFCs: Applications, potential advantages and challenges. Thermal plasma spraying for SOFCs: Applications, potential advantages, and challenges // J. Power Sources. – 2007. – Vol. 170. – P. 308–323.
21. Chahal, H.K.; Matthews, S.; Jones, M.I. Fabrication of calcium phosphate coatings by the inflight reaction of precursor feedstocks using plasma spraying. J. Therm. Spray Technol. – 2023. – Vol. 32. – P. 1465–1481.
22. Qadir, D.; Sharif, R.; Nasir, R.; Awad, A.; Mannan, H.A. A review on coatings through thermal spraying // Chem. Pap. – 2024. – Vol. 78. – P. 71–91.
23. Liao, X.J.; Zhang, L.; Sun, Y.Q.; Luo, X.T.; Li, C.X.; Yang, G.J.; Li, C.J. Effect of Inter-Splat Bonding Quality on the Dependence of Wear Behavior of Plasma-Sprayed Stainless Steel Coating on Applied Load // J. Therm. Spray Technol. – 2024. – Vol. 33. – P. 1–11.
24. Abdivakhidov, K.; Sharipov, K. Corrosion-resistant protective coatings for metals: A review of metallic and non-metallic coatings // AIP Conf. Proc. – 2024. – Vol. 3045. – P. 060011.
25. Rakhadilov, B.K.; Buitkenov, D.B.; Apsezhanova, A.K.; Kakimzhanov, D.N.; Nabioldina A.; Magazov, N.M.; Selection of Optimal Process Parameters for Arc Metallization // Coatings. – 2025. – Vol. 15(3). – P. 300. https://doi.org/10.3390/coatings15030300

СЫМ БЕРУ ЖЫЛДАМДЫҒЫ ӘРТҮРЛІ БОЛҒАН ЖАҒДАЙДА ЭЛЕКТР ДОҒАЛЫ МЕТАЛДАНДЫРУ ӘДІСІМЕН АЛЫНҒАН ЖАБЫНДАРДЫҢ ҚҰРЫЛЫМЫ МЕН ҚАСИЕТТЕРІН ЗЕРТТЕУ

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Бұл жұмыста 30ХГСА маркалы сымды пайдалана отырып, электр доғалық металлизация әдісімен алынған жабындардың құрылымы мен қасиеттеріне сым беру жылдамдығының әсері зерттелді. Жабындар 65Г болат негізінде 5, 7 және 9 см/с жылдамдықпен жоғары жылдамдықты доғалық бүрку технологиясы арқылы алынды. Микроструктуралық талдау, ЭДС-карталау, рентгенфазалық талдау, жабындардың қалыңдығы, қаттылығы, кеуектілігі мен адгезиясы зерттелді. Нәтижелер көрсеткендей, сым беру жылдамдығын арттыру жабын қалыңдығының өсуіне әкелді, бірақ құрылымдық біртектілігіне де әсер етті. 5 см/с кезінде жабын жақсы адгезияға және біркелкі құрылымға ие болды, бірақ жұқа болды. 7 см/с кезінде ең оңтайлы нәтижелер байқалды: қалыңдығы 220 мкм дейін, кеуектілік – 4,3%, қаттылық – 720 HV дейін. 9 см/с кезінде қабат қалыңдады, бірақ кеуектілік артты, ал адгезия төмендеді. Осылайша, сым беру жылдамдығы жабын сапасына елеулі әсер етеді және оны оңтайландыру жабынның пайдалану қасиеттерін басқаруға мүмкіндік береді.

Түйін сөздер: *кеуектілік, электр доғалы металдандыру, жабын, болат, құрылым, болат сым.*

ИССЛЕДОВАНИЕ СТРУКТУРЫ И СВОЙСТВ ПОКРЫТИЙ, ПОЛУЧЕННЫХ МЕТОДОМ ЭЛЕКТРОДУГОВОЙ МЕТАЛЛИЗАЦИИ ПРИ РАЗЛИЧНЫХ СКОРОСТЯХ ПОДАЧИ ПРОВОЛОКИ

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В работе исследовано влияние скорости подачи проволоки на структуру и свойства покрытий, полученных методом электродуговой металлизации с использованием проволоки 30ХГСА. Покрытия наносились на подложки из стали 65Г при различных скоростях подачи (5, 7 и 9 см/с) с применением технологии сверхзвукового дугового напыления. Проведены микроструктурный анализ, ЭДС-картирование, рентгенофазовый анализ, измерения толщины покрытий, твёрдости, пористости и адгезии. Результаты показали, что увеличение скорости подачи проволоки приводит к увеличению толщины покрытия, однако влияет и на его однородность. При 5 см/с наблюдалась хорошая адгезия и равномерная структура при меньшей толщине. При 7 см/с достигнут оптимальный результат: толщина до 220 мкм, пористость 4,3%, твёрдость до 720 HV. При 9 см/с толщина возросла, но также увеличилась пористость и снизилась адгезия из-за турбулентного распыления. Таким образом, скорость подачи проволоки существенно влияет на качество покрытий, а её оптимизация позволяет управлять эксплуатационными характеристиками покрытий для применения в условиях повышенного абразивного износа.

Ключевые слова: *пористость, электродуговая металлизация, покрытие, сталь, структура, стальная проволока.*