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UTILIZING DETONATION SPRAYING IN THE PROCESS OF FORTIFYING COMPONENTS WITHIN POWER PLANT TECHNOLOGY

Abstract: *The article addresses challenges related to enhancing the performance characteristics of power plant components. Research conducted by different authors demonstrates that when aiming to enhance the operational qualities of these parts, detonation spraying yields superior outcomes owing to its low porosity, high strength, and strong adhesion of the coatings produced. Also benefits of employing Ni-Cr-Al-based coatings as high oxidation resistant coating. The study involves the acquisition of Ni-Cr-Al-based gradient structured coatings using detonation* *spraying techniques. Investigated their phase composition and microstructures. By modifying the technological parameters during spraying, we achieved control over the properties of the resulting gradient coatings. Analysis of the elemental composition via the EDS method revealed that the Ni–Cr–Al gradient coatings possess a structured gradient, wherein the aluminum concentration progressively rises from the substrate towards the surface of the coating. The Ni–Cr–Al gradient coating thereby obtained the presence of phases NiCr with a surface of NiAl that has a high hardness and wear resistance.*

Key words: *power plant, protective coating, detonation spraying, Ni-Cr-Al coating, gradient structure.*

Introduction

Presently, various issues such as corrosion, oxidation, high-temperature oxidation, hot corrosion, and erosion afflict different parts of power plants exposed to elevated temperatures, potentially leading to their failure and undesirable termination of the installation. This predicament often stems from the utilization of low-quality fuel in power plants. Low-quality coal, primarily used in steam turbine installations due to its low cost and widespread availability, is composed of approximately 50% ash containing nearly 15% abrasive mineral rocks (such as hard quartz), intensifying the coal's susceptibility to erosion. Moreover, in a bid to mitigate greenhouse gas emissions, biomass serves as a widely adopted substitute for non-renewable fuels in thermal power plants. Agricultural waste, wood waste, and other forms of biomass are commonly employed to generate steam. Consequently, heat transfer surfaces operating on biomass tend to be vulnerable to corrosion [1].

Superalloys developed for high-temperature applications often struggle to fulfill the dual requirements of high-temperature strength along with erosion and corrosion resistance simultaneously. The deleterious effects of hot corrosion result in the degradation of these alloys. The presence of molten salts in boilers exacerbates the corrosion issue as they react with protective chromium or aluminum oxides, thereby compromising their protective properties. Aggressive salt types further subject superalloys to internal oxidation. To address these challenges, one viable approach involves applying wear-resistant coatings on the surface of superalloys that demonstrate resistance to oxidation and corrosion. Given these circumstances, the development of protective systems for safeguarding superalloy surfaces from wear and hot corrosion holds immense economic significance. Surface engineering emerges as a pivotal player in this domain. NiCrAl coatings serve as widely utilized thermal barrier coatings (TBCs) crucial for safeguarding components exposed to high temperatures, oxidation, and hot corrosion. Typically, TBC coatings contain a limited amount of aluminum, and an insufficient quantity of it stands as the primary cause for the diminished quality of NiCrAl coatings. Research indicates that the early-stage formation of Al_2O_3 and Cr_2O_3 oxides during high-temperature corrosion, along with the development of mixed Cr_2O_3–Al_2O_3 oxide during testing, amplifies the coatings' resilience against high-temperature corrosion and oxidation. Recently, substantial attention has shifted towards NiCrAl coatings featuring a gradient structure [2].

Numerous methods exist for obtaining coatings, including thermal spraying, chemical vapor deposition, and batch cementation. Among these, thermal spraying stands out as a particularly convenient process capable of effectively addressing challenges related to oxidation, hot corrosion, and erosion. Within the realm of thermal spraying techniques, detonation spraying technology emerges as notably efficient, generating coatings with minimal porosity and superior adhesion. This method yields robust, wear-resistant, and densely structured coatings, establishing itself as the premier thermal spraying technique. The detonation spraying process achieves peak temperatures of 4000 °C in the combustion chamber, with shock wave velocities reaching 3500 m/s. It results in significantly lower porosity compared to high-velocity gas-plasma spraying (HVOF) and plasma spraying methods [3].

Methods and materials

For the substrate heat-resistant low-alloy boiler steel 12Kh1MF (equivalent to 14MoV63) was chosen. The samples were grinded to achieve a uniform and flat surface. After grinding the samples were sandblasted. A mixture of 90NiCr-10Al composite powder (wt.,%) was selected as the powder.

We carried out detonation spraying using the CCDS2000 setup. The gun barrel is filled with gases using a high-precision computer-controlled gas distribution system. The process begins by filling the barrel with a carrier gas. The coatings were sprayed onto 12Kh1MF ferrite-perlite steel substrates with 50 mm diameter and 3 mm thickness. We sandblasted the substrates before spraying in order to increase surface roughness. The feedstock was a mixture of 80 wt % NiCr powder (Ni20Cr80) and 20 wt % of Al (99.99% purity). Nominal powder particle size ranged between 30 and 45 μm. A PULVERISETTE 23 planetary ball mill was used for preliminary powder mixture activation. The mechanical activation time was 2 h with a frequency of 30 Hz. Table 1 presents the process parameters used.

Table 1 – Technological parameters for obtaining Ni–Cr–Al gradient coating

Name	Ratio O_2/C_2H_2	Barrel filling volume, %	Spraying distance, mm	Shot number
Gradient Ni Cr-Al coating	1,856	50%	250	5
		40%		5
		30%		5
		25%		5

Results and discussion

In investigating how the deposition method influences the structure and characteristics of Ni–Cr–Al coatings, we devised a technique to create gradient coatings. This approach employs a detonation setup featuring a single dispenser and a composite powder primarily composed of Ni–Cr–Al; adjustments in technological parameters occur throughout the spraying process. Our procedure involved a gradual reduction in the barrel filling volume, from 50% to 25%, followed by an examination of the structure and properties of the resultant gradient coating based on Ni–Cr–Al. The goal is to generate coatings wherein the aluminum content progressively increased from the substrate to the surface. We base this on the initial assumption that the formation of the NiAl intermetallic compound on the surface, at a filling volume of 30%, offers heightened resistance to wear and corrosion, while the NiCr phase formed closer to the substrate enhances the adhesive strength of the coating [4]. Figure 1 presents the phase composition of the Ni–Cr–Al gradient coatings obtained by detonation spraying method.

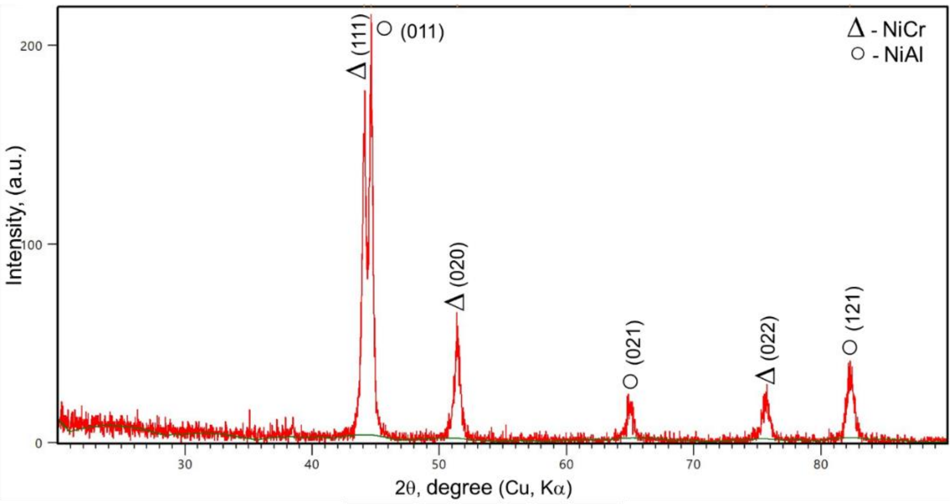

Figure 1 – Diffractograms of Ni–Cr–Al gradient coatings obtained by detonation spraying

SEM images of Ni-Cr-Al gradient coating cross-sections in Figure 2(a) show a microstructure characterized by an uneven, highly developed relief layer with a thickness of 350 microns. This layer consisting of elongated particles up to 80 microns in size with a layered structure characteristic of powders subjected to mechanical activation. The cross-sectional mapping analysis showed (Figure 2(b)) that the coating has a gradient structure. This is especially evident from Al K, which shows the distribution of aluminum over the coating depth. The aluminum concentration gradually increases from the substrate to the coating surface.

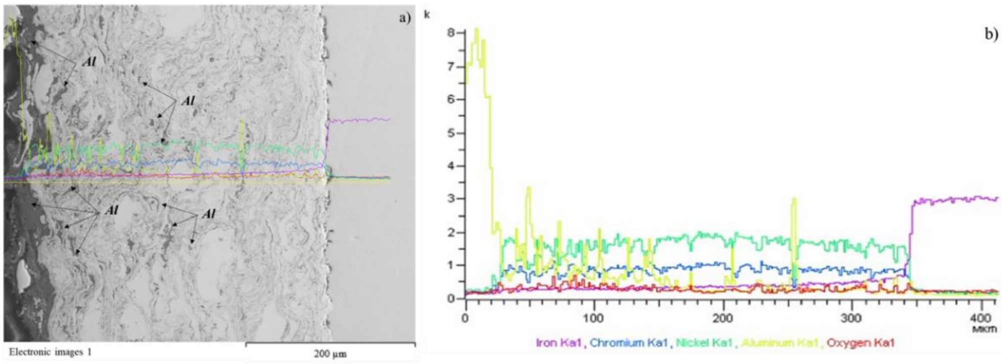

Figure 2 – SEM cross-section images (a) and element distribution (b) as a function of depth in the Ni–Cr–Al gradient coating.

Conclusion

From our investigation, the following conclusions were drawn: The article focuses on tackling challenges associated with improving the performance attributes of power plant components. The utilization of detonation spraying method offers advantages in the quest to enhance the operational features of these parts. A technique was devised to craft gradient coatings relying on Ni–Cr–Al, utilizing a detonation unit with a single dispenser. This method involves the utilization of a composite powder based on Ni–Cr–Al. By modifying the technological parameters during spraying, we achieved control over the properties of the resulting gradient coatings. Analysis of the elemental composition via the EDS method revealed that the Ni–Cr–Al gradient coatings possess a structured gradient, wherein the aluminum concentration progressively rises from the substrate towards the surface of the coating. The Ni–Cr–Al gradient coating thereby obtained the presence of phases NiCr with a surface of NiAl that has a high hardness and wear resistance.

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ЭЛЕКТР СТАНЦИЯЛАРЫНЫҢ КОМПОНЕНТТЕРІН ҚАТАЙТУ ПРОЦЕСІНДЕ ДЕТОНАЦИЯЛЫҚ БҮРКУ ТЕХНОЛОГИЯСЫН ҚОЛДАНУ

Мақалада энергетикалық қондырғы компоненттерінің пайдалану сипаттамаларын арттыруға байланысты мәселелер қарастырылады. Әр түрлі авторлардың зерттеулері көрсеткендей, бұл бөлшектердің өнімділігін жоғарылатуда кеуектілігі төмен, адгезиялық беріктігі жоғары детонациялық бүрку әдісімен жабындар алуға болады. Сондай-ақ, Ni-Cr-Al негізіндегі жабындарды тотығуға төзімділігі жоғары жабын ретінде пайдаланудың артықшылықтары қарастырылыды. Зерттеу детонациялық бүрку әдісін қолдана отырып, Ni-Cr-Al негізіндегі градиентті құрылымдық жабындарды алуды қамтиды. Олардың фазалық құрамы мен микроқұрылымдары зерттелді. Бүрку кезінде технологиялық параметрлерді өзгерту арқылы біз алынған градиент жабындарының қасиеттерін бақылауға қол жеткіздік. EDS әдісімен элементтік құрамды талдау Ni–Cr–Al градиентті жабындардың құрылымдық градиенті бар екенін көрсетті, онда Алюминий концентрациясы субстраттан жабын бетіне қарай біртіндеп көтеріледі. Осылайша, Ni–Cr–Al градиентті жабыны жоғары қаттылық пен тозуға төзімділікке ие NiAl, NiCr фазаларының түзілуін қамтамасыз етті.

Түйін сөздер: *электр станциясы, қорғаныс жабыны, детонациялық бүрку, Ni-Cr-Al жабыны, градиент құрылымы.*

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ИСПОЛЬЗОВАНИЕ ДЕТОНАЦИОННОГО ТЕХНОЛОГИИ НАПЫЛЕНИЯ В ПРОЦЕССЕ УПРОЧНЕНИЯ КОМПОНЕНТОВ ЭЛЕКТРОСТАНЦИЙ

В статье рассматриваются проблемы, связанные с повышением эксплуатационных характеристик компонентов энергетической установки. Исследования, проведенные различными авторами, показывают, что при улучшении эксплуатационных характеристик этих деталей детонационное напыление обеспечивает превосходные результаты благодаря низкой пористости, высокой прочности и крепкому сцеплению получаемых покрытий. Также рассматриваются преимущества использования покрытий на основе Ni-Cr-Al с высокой стойкостью к окислению. В рамках исследования проводится получение градиентных структурированных покрытий на основе Ni-Cr-Al с применением методов детонационного напыления, а также изучается их фазовый состав и *микроструктура. Изменяя технологические параметры во время напыления, мы добились контроля над свойствами получаемых градиентных покрытий. Анализ элементного состава с помощью метода EDS показал, что градиентные покрытия Ni–Cr–Al обладают структурированным градиентом, при котором концентрация алюминия постепенно повышается от подложки к поверхности покрытия. Таким образом, градиентное покрытие Ni–Cr–Al обеспечило наличие фаз NiCr с поверхностью из NiAl, обладающей высокой твердостью и износостойкостью.*

Ключевые слова: *энергетическая установка, защитное покрытие, детонационное напыление, Ni-Cr-Al покрытие, градиентная структура*

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