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(REVIEW ARTICLE)

Application of new power fittings coating material in power grid construction

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Abstract

In the power system, a vast amount of materials are used in the construction and operation of the power grid, covering steel, aluminum, cement, as well as insulating materials and composite materials. These materials form different components such as electrical equipment, structures, and power fittings. Among them, power fittings are widely used in power grid construction and play crucial roles in connection, fixation, and protection. This paper takes power fittings as the specific research object and deeply analyzes the adaptable application of new materials in power fittings. Through combing and analyzing, it provides theoretical and data support for the subsequent research and development and practical application of new materials in the power system.

Keywords: Fittings; New Materials; Power Grid Construction; Power Fittings

1. Introduction

As power fittings bear the transmission conductors, their role is self - evident, which has prompted increasing research on power fittings by scholars at home and abroad. However, most of the research focuses on the electrical performance of power fittings, while there is relatively little research on their mechanical properties, especially the wear - resistant characteristics of UHV transmission line fittings. There is even less research that takes into account the corrosion - resistant and wear - resistant properties of connecting fittings.

Hot - dip galvanizing is the most commonly used surface anti - corrosion treatment method for connecting fittings. The zinc layer, as an anodic coating, provides anti - corrosion protection for the base materials, which include materials with certain hardness such as 20# steel and 25# steel, enabling the connecting fittings to have certain wear - resistant properties. Due to the diverse environments where power fittings are located, in areas with strong atmospheric corrosion, the hot - dip galvanized layer, as a sacrificial anode, will fail rapidly. The base material will also be accelerated in wear under the multiple actions of tensile load and galloping. Therefore, the anti - abrasion and corrosion technology for connecting fittings that takes into account both corrosion resistance and wear resistance has become an inevitable trend.

Among them, zinc - nickel alloy deposition, composite deposition, and laser alloying are important research directions of this paper. In addition, there are quenching and partitioning, zinc - infiltration composite technology, and metal surface corrosion - resistant and conductive carbon - based coating technology. This paper will introduce and explain these relatively new wear - resistant and corrosion - resistant technologies for power fittings.

This paper will focus on the introduction of these new coating material technologies for power fittings, including different aspects such as technical principles, research status, development directions, and functions.

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2. Research Status of New Power Fittings

2.1. New Technologies for Power Fittings

We first focus on three new technologies for power fittings: zinc - nickel alloy deposition, composite deposition, and laser alloying. By referring to relevant materials, the following research information can be obtained.

In the research of zinc - nickel alloy deposition, B. Veeraraghavan from the University of South Carolina prepared an amorphous Ni - Zn - P chemical coating with a high nickel content [1]. It was found that the corrosion resistance of this coating is much lower than that of zinc and zinc - nickel coatings. However, the composition of the alloy coating is affected by many factors such as temperature, pH value, and plating solution composition, which increases the instability of its controllable preparation to a certain extent. This technology provides technical support for improving the surface corrosion resistance of power fittings and on - site repair.

In the research of composite deposition, there are numerous studies on using the second - phase particles to improve the wear resistance of coatings. E. Pompei et al. in Italy prepared a Ni - BN composite coating on the surface of a brass substrate using the composite electro - deposition technology [2]. It was found that the addition of BN can reduce the wear amount of the coating to 50% of that of pure nickel, and the friction coefficient also decreases accordingly. Mehmet Uysal et al. in Turkey prepared an Ag - graphene - WC nano - composite coating through the chemical composite plating technology [3]. It was found that even a small amount of graphene addition can significantly improve the hardness and friction performance of the coating, and the synergistic effect between graphene and WC further enhances the anti - friction and wear - resistance of the composite coating. This technology provides technical support for greatly improving the surface wear - resistant performance of power fittings.

In the research of laser alloying technology, Adriano et al. in Brazil prepared a laser - nitrided layer on the surface of a Ti - 6Al - 4V alloy, and the hardness of the layer can reach 1100 HV, which improves the surface wear - resistance [4]. A. R. Hamad et al. in Libya increased the surface hardness of pure titanium by laser nitriding to improve the wear - resistance and corrosion - resistance of the alloy, and the maximum micro - hardness of the nitrided layer can reach 1920 HV0.15 [5]. J. B. Fogagnolo et al. in Brazil added Nb powder on the surface of a titanium alloy to prepare an Nb - Ti alloy coating [6], and the hardness doubled, reducing the tensile stress on the surface of the titanium alloy parts and delaying the fatigue cracking time, thus improving the fatigue strength of the titanium alloy workpieces. Previous studies have shown that the laser alloying technology can greatly improve the surface wear - resistant performance of materials.

2.2. Research Status of New Power Fittings

The corrosion and wear of power fittings have attracted the attention of power material researchers. The research on the wear - resistant performance of U - shaped shackles - adjusting rings for UHV transmission lines in reference [7] shows that the galvanized layer on the surface of power fittings undergoes plastic deformation and falls off during the wear process. Some wear debris, due to not being discharged in time, may continue to rub along with the rotation of the power fittings during the wear process. The hard wear debris that has not been discharged will cause abrasive wear along with the rotation of the power fittings. In actual working conditions, due to the harsh climate environment, once the galvanized layer of power fittings falls off, a series of side effects are likely to occur. For example, the defects caused by wear will lead to the corrosion of the steel materials of power fittings. At the same time, under the action of wind load, wear and corrosion will have a positive - correlation effect, greatly increasing the mechanical and chemical damage between the contacting power fittings and accelerating the corrosion rate. As a result, power fittings are extremely likely to be damaged, leading to accidents. He Jiang et al. from Hunan Electric Power Line Equipment Factory studied the application of wear - resistant materials in power fittings. They applied 35#, 35CrMo, Grl5, and 45Mn2 to the U - shaped rings of connecting fittings and believed that 35CrMo is the most reasonable and economical material for the U - shaped rings of connecting fittings. The Fittings Laboratory of China Electric Power Research Institute carried out wear - resistant treatment on power fittings by aluminizing, which can make the surface hardness reach 640 HV. However, the measured hardness of the hot - dip galvanized layer in this study is as high as 180 HV, which is debatable.

Currently, research on zinc - nickel alloy deposition, composite deposition, and laser alloying technologies has been carried out and developed. In the research of zinc - nickel alloy deposition, Wei Zidong et al. from Shandong University of Technology prepared a zinc - nickel alloy coating [8]. Its corrosion resistance is more than 12 times higher than that of a pure Zn coating. Considering that the cost of electro - galvanizing nickel alloy is twice that of galvanizing (that is, the price of Ni is more expensive than that of zinc), the overall economic benefit is increased by more than 6 times.

In the research of composite deposition, silver coatings and silver - graphene composite coatings were prepared through the thiosulfate system respectively. The friction - reducing and wear - resistant properties of the two coatings were characterized by a CFT - I type comprehensive material surface performance tester. The data shows that the friction coefficient of the composite coating is reduced by 80% and the wear amount is reduced by 89% compared with that of the silver coating [9].

In the research of laser alloying technology, the research team led by Yao Jianhua from Zhejiang University of Technology carried out laser alloying experiments on the surface of 40Cr steel with Co/W alloy and ultrafine WC (2 - 3μm) [10]. It was found that the micro - hardness, wear - resistance, and other properties of the alloy layer were improved to varying degrees compared with gas nitriding. The service life of the injection - molding machine screw made of 40Cr steel after laser alloying strengthening is twice that of gas nitriding. The team also used a high - power semiconductor laser to prepare a nickel - titanium surface - modified layer on the surface of TC4. The alloyed layer is mainly composed of NiTi2 and A13Ti0.8V0.2, and the wear - resistance of the coating is 8 times higher than that of the substrate, and the cavitation - erosion resistance is 2.7 times higher.

Sun Guifang et al. from Northeastern University applied the laser alloying technology to high - nickel - chromium infinitely chilled alloy cast iron rolls [11], prepared an alloyed layer with an average thickness of 0.2875 mm, and the average micro - hardness was 1001 HV0.05, which is 1.53 times that of the base material (656 HV). The research team led by Professor Chen Chuanzhong from Shandong University prepared a B - C - N multi - element laser alloyed layer on the surface of a Ti - 6Al - 4V substrate [12]. The micro - hardness range is 1196 - 1452 HV0.2, which is about 4 times that of the substrate hardness, and the wear - resistant performance has also been significantly improved.

3. Social and Economic Benefits

3.1. Economic Benefits

In terms of economic benefits, the economic losses caused by corrosion in the power industry cannot be underestimated. These losses include direct losses and indirect losses. Indirect losses usually consist of factors such as reduced equipment service capabilities, environmental pollution, and resource waste caused by corrosion. Due to the complexity of these factors, it is difficult to quantify and calculate, so they will not be discussed here for the time being. Direct losses mainly include three parts: power outage losses caused by corrosion, equipment losses and replacement costs caused by corrosion, and maintenance and repair costs related to corrosion.

For the first point, power outage losses caused by corrosion. The interruption of power supply will bring industrial production to a standstill and hinder commercial operations, causing serious impacts on the social economy. Secondly, equipment damage caused by corrosion and subsequent replacement costs. Frequent equipment replacement not only consumes a large amount of funds but also causes resource waste. Finally, maintenance and repair costs related to corrosion are also a considerable expense over the long term.

By systematically analyzing the differences between different new materials and zinc - nickel alloys in the above - mentioned direct loss items, it is possible to clearly evaluate the significant benefits brought by the adoption of new materials in reducing direct losses and controlling costs. Take the zinc - nickel alloy deposition technology as an example. With its excellent corrosion resistance, it effectively slows down the corrosion rate of power fittings, greatly reduces the replacement frequency due to corrosion, and significantly reduces equipment replacement and maintenance costs. The composite deposition technology improves the wear - resistant performance of power fittings by adding hard phases such as ceramic particles to the metal matrix, further reducing equipment losses caused by wear and lowering the operation and maintenance costs of the power grid. This enables power enterprises to save a large amount of funds in long - term operations.

3.2. Social Benefits

From the perspective of social benefits, once the connecting fittings fail, it is very likely to cause a sudden power outage of the entire transmission line. This will not only bring great inconvenience to residents' lives and affect the normal production and living order but also pose a serious threat to some key fields that rely on electricity, such as medical care and transportation. The wide application of the achievements of power fitting anti - abrasion and corrosion technologies can not only reduce equipment operation and maintenance costs and lower the replacement frequency of corresponding components but, more importantly, reduce the failure risk of connecting fittings. For example, by using new anti - abrasion and corrosion technologies to treat power fittings and improve their stability and durability, it is possible to effectively reduce the number of sudden power outages of equipment lines caused by the failure of connecting fittings and ensure the safe and stable operation of the entire power system. A stable power supply provides a solid guarantee for the smooth development of society, facilitating the orderly operation of various fields in society and greatly improving the overall social operation efficiency and reducing potential social risks caused by power outages.

4. Conclusion

This paper mainly focuses on the field of power fittings and deeply explores the application of new materials in it. The research shows that current research on power fittings mainly focuses on electrical performance, while research on their mechanical properties, especially wear - resistant characteristics, is relatively scarce. Improving the corrosion - resistant and wear - resistant properties of power fittings in complex environments has become a key requirement. New technologies such as zinc - nickel alloy deposition, composite deposition, and laser alloying show unique advantages. Although zinc - nickel alloy deposition faces certain challenges in the controllable preparation of coatings, its corrosion - resistant performance is significantly improved, providing strong technical support for the surface anti - corrosion of power fittings and on - site repair. Composite deposition greatly improves the surface wear - resistant performance of power fittings. The laser alloying technology can significantly enhance the surface hardness of materials and effectively improve the comprehensive properties such as wear - resistance, corrosion - resistance, and fatigue strength, achieving good results in the surface treatment of different materials.

In the future, in the research of new materials and technologies for power fittings, it is necessary to further optimize existing technologies, improve the stability and controllability of coating preparation, deeply explore the synergistic effects of different material combinations in composite deposition, and expand the application of laser alloying technology to more power fitting materials. At the same time, it is necessary to strengthen the research on the long - term performance of power fittings under complex working conditions and establish a more perfect evaluation system to more accurately guide the application of new materials in power grid construction and promote the sustainable development of the power industry.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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