MODERN REPAIR TECHNIQUES: METALLIZATION AND ITS INDUSTRIAL APPLICATIONS

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Abstract: This paper examines metallization, a modern repair technique used to restore worn components across various industries. The process involves spraying molten metal onto the surface of a part, creating a durable coating that enhances resistance to wear, corrosion, and mechanical stress while extending the component's lifespan. Key aspects of the study include the advantages of metallization, its diverse application methods (thermal spray, plasma, and electric arc), and critical parameters influencing the process, such as coating thickness and substrate preparation.

A particular emphasis is placed on its use in reconditioning hydraulic cylinders, showcasing how metallization offers an efficient and cost-effective alternative to traditional repair methods like welding or machining. Results indicate significant improvements in performance and durability, reinforcing the technique's viability for industrial applications. Additionally, challenges such as adhesion issues and operational costs are addressed, providing a comprehensive perspective on this advanced repair solution.

Keywords: Metallization, Industrial reconditioning, Metal coatings, Durability, Hydraulic cylinders

1. INTRODUCTION

Reconditioning used industrial parts represents an essential solution for maintaining functional equipment and installations, contributing to cost reduction for replacement and extending the lifespan of components. In industries such as automotive, aerospace, and energy, parts like shafts, hydraulic cylinders, or turbine rotors are subjected to high levels of wear due to mechanical, thermal, or chemical factors. The costs associated with manufacturing and replacing these components are often significant, which makes reconditioning techniques a more attractive and sustainable option.[1]

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Over time, repair technologies have evolved considerably. Traditional methods, such as welding or mechanical processing, while effective in certain situations, present limitations in terms of precision, costs, and execution time. In this context, modern technologies, such as metallization, have gained ground due to their advantages. Metallization is an innovative method that allows the application of a thin layer of metal powder onto the surfaces of worn parts, thus restoring their geometry, functionality, and resistance. The metallization process involves using specialized equipment to spray an additive material (in the form of powder or wire) in a molten or semi-molten state, so that it adheres to the substrate. This technology offers flexibility in using various materials, such as steel alloys, aluminum, copper, or nickel, adapting to the specific needs of each industrial application.

Metallization stands out due to a series of advantages that make it preferable to other reconditioning methods. The process allows the application of a wide range of metal materials, providing flexibility according to the application requirements. Controlled spraying ensures a uniform layer, which contributes to the performance of the reconditioned part. The applied layering through metallization can provide superior properties, such as wear resistance, corrosion resistance, and high-temperature tolerance. By extending the lifespan of parts, metallization significantly reduces replacement and maintenance costs. Additionally, metallization helps reduce material waste, making it an eco-friendly and economical option.

Although it offers numerous benefits, metallization technology also faces certain technical challenges. One of the biggest challenges is ensuring adequate adhesion between the metallic layer and the part's surface. Proper substrate preparation is essential to avoid delamination or cracking. Furthermore, the process involves considerable material loss during spraying, which can affect economic efficiency. While it reduces long-term costs, purchasing metallization equipment requires high initial investments. To achieve a quality layer, strict monitoring of process parameters, such as temperature, particle speed, and spraying distance, is necessary.[2,3]

A notable application of metallization is found in the reconditioning of hydraulic cylinders. These are critical components used in industrial and construction machinery, subjected to intense mechanical stress. Through metallization, the worn surfaces of the cylinders can be restored, improving wear resistance and preventing hydraulic fluid leaks. Studies show that metallization can significantly extend the operational life of these components, while also reducing the financial and environmental impact of their replacement.

This paper aims to explore the metallization technology in detail, highlighting its advantages and challenges in various industries. Through a case study applied to the reconditioning of hydraulic cylinders, the goal is to validate the process's efficiency and identify the critical parameters that influence the quality of the metallized layer. The results presented in the paper will contribute to understanding the potential of this technology and promoting its use as a sustainable and efficient alternative in industrial repairs.

In conclusion, metallization represents a promising technology in the field of industrial reconditioning. Due to its versatility, economic efficiency, and contribution to sustainability, this method proves to be a viable solution for various applications. This paper aims to deepen the understanding of metallization technology, providing a solid foundation for its widespread adoption in industry.

2. METHODOLOGY AND RESULTS

The metallization process involves several essential stages that influence the quality of the final coating. First, the surface preparation is crucial. This step begins with degreasing and cleaning the surface to remove any impurities that may hinder the bonding of the metal layer. Degreasers or industrial solvents are typically used for this purpose. After the surface is cleaned, creating roughness is the next vital step. This is usually achieved through sandblasting or mechanical processing, ensuring an optimal surface texture for better adhesion of the metal layer. It is important to note that a well-prepared surface can significantly enhance the quality of the metallized coating. Additionally, preheating the part is often done to avoid condensation and ensure an even substrate temperature.[4]

The metallization techniques themselves vary depending on the specific requirements of the application. One of the most commonly used techniques is electric arc metallization. In this method, metal wires are melted using an electric arc and then sprayed onto the surface with the help of compressed air. Another technique, plasma spray metallization, involves accelerating metal particles to supersonic speeds to achieve a high level of precision. Lastly, oxyacetylene metallization uses a flame to melt the metal and deposit it onto the surface. Each technique offers distinct advantages and is chosen based on the desired results, material compatibility, and operational conditions.

Critical parameters during the metallization process play a decisive role in the success of the procedure. For instance, the melting temperature of the metal directly affects the oxidation level and hardness of the deposited layer. Inadequate control of the temperature can lead to a poor-quality coating with compromised properties. Air pressure also plays a critical role in determining the size and speed of the particles being deposited. A high air pressure results in faster particle velocity and potentially finer coatings, while low air pressure may lead to insufficient deposition. The quality of the added material is another key parameter. It is carefully selected according to the properties required for the application, as different metals offer varying levels of wear resistance, corrosion resistance, and thermal stability.

A practical example of the application of metallization is the reconditioning of a hydraulic cylinder, a key component used in industrial machinery. The cylinder, having undergone significant wear, required a comprehensive surface preparation process before metallization. The first step in preparing the cylinder was to degrease it using industrial solvents to remove any oils and grease that could interfere with the adhesion of the metallic layer. Following degreasing, the surface was blasted with an abrasive material to create the necessary roughness, ensuring a strong bond between the metal layer and the substrate. Preheating the cylinder was also carried out to prevent condensation from forming and to guarantee an even substrate temperature during the metallization process.

Once the cylinder's surface was prepared, the metallization process itself began. For this, an electric arc metallization system was used, calibrated to ensure an even deposition of the metal layer. The chosen material for this process was a carbon steel wire, selected for its durability and wear resistance, which matched the operational conditions of the hydraulic cylinder. The thickness of the deposited layer was continuously monitored and adjusted to achieve a desired thickness of 0.5 mm. During the metallization, visual inspections and intermediate adhesion tests were conducted to detect any defects or inconsistencies in the coating.

After the metal layer was deposited, the cylinder underwent a final mechanical processing phase. This included turning and grinding the surface to bring the cylinder back to its nominal dimensions and to ensure a smooth and high-quality finish. This final processing was essential to meet the dimensional specifications and surface quality required for the hydraulic cylinder’s optimal performance. The metallized coating was subjected to rigorous testing to assess its quality and performance. Adhesion tests were conducted using a traction method, which showed an average adhesion strength of 110 kg/cm^2. Furthermore, hardness tests were performed using a portable durometer, providing values that met the technical requirements for the cylinder's operating conditions. The porosity of the deposited layer was also evaluated microscopically, revealing a significant reduction in internal defects compared to traditional reconditioning methods. This is an important finding, as the reduction of internal porosity directly contributes to the durability and performance of the coated part.

Finally, the reconditioned hydraulic cylinder was installed in an operational hydraulic system for a six-month test period. The performance of the metallized cylinder was compared to that of a new cylinder, and the results were promising. The metallized cylinder exhibited minimal wear, and its performance was almost identical to that of the new component. This confirmed the effectiveness of the metallization process and its ability to restore the functionality of critical parts while extending their operational life.

The results of this study indicate several clear advantages of metallization in industrial reconditioning. Firstly, it significantly extends the lifespan of parts by enhancing their durability and resistance to wear, corrosion, and high temperatures. Secondly, metallization reduces costs compared to replacing parts entirely or using other repair methods. The reconditioned components perform similarly to new ones, which makes metallization a cost-effective and reliable option. Furthermore, the metallization process has a lower environmental impact compared to traditional repair methods, as it eliminates the use of toxic substances often involved in other reconditioning techniques.

When compared to traditional methods, metallization offers superior quality of the deposited layer. It provides excellent adaptability to various materials and geometries, which makes it a versatile solution for a wide range of industrial applications. Moreover, it is a more sustainable option, as it minimizes waste and reduces the need for raw materials. The case study on the hydraulic cylinder demonstrated that metallization is not only an effective repair method but also a practical alternative to traditional part replacement, offering both economic and environmental benefits.

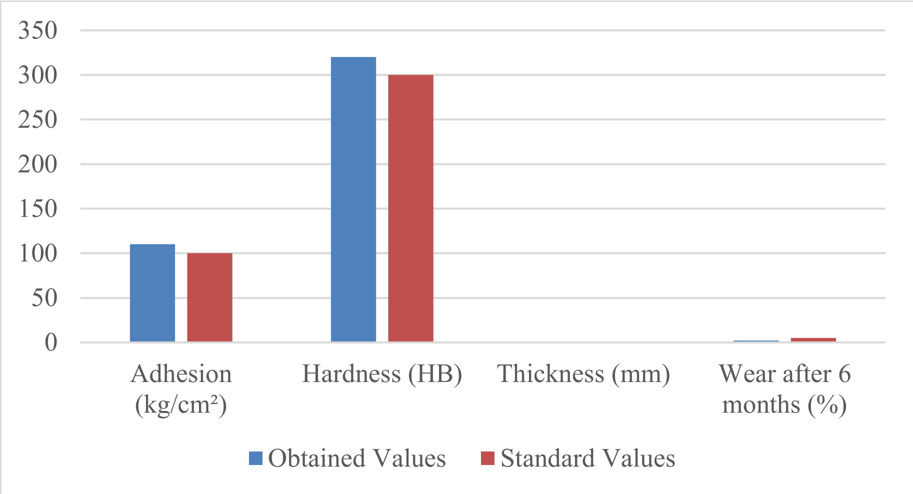

Fig.1. Comparison Between Obtained and Standard Parameters

Table 1. **Comparison Between Obtained and Standard Parameters**.

No.	Parameters	Obtained Values	Standard Values
1.	Adhesion (kg/cm²)	110	100
2.	Hardness (HB)	320	300
3.	Thickness (mm)	0.5	0.5
4.	Wear after 6 months (%)	2.3	5

3. CONCLUSIONS

Based on the analysis of the metallization process applied to the reconditioning of hydraulic cylinders, clear conclusions can be drawn regarding the efficiency and viability of this technology in various industrial applications. Metallization has demonstrated multiple advantages over traditional reconditioning methods, significantly contributing to extending the lifespan of components, reducing maintenance and replacement costs, and minimizing environmental impact. One of the most important benefits of metallization is its ability to restore worn parts, greatly improving their mechanical properties. By applying a protective metal layer, superior wear, corrosion, and high-temperature resistance is achieved, allowing the component to function optimally for a much longer period. This aspect is crucial, especially in industries that use equipment subjected to intense mechanical stresses, such as the energy, automotive, and aerospace sectors. In addition to the technical benefits, metallization is an economic and sustainable option. The reduction in part replacement and maintenance costs makes this technology an attractive alternative, particularly considering the high production and replacement costs of many industrial parts. Moreover, the metallization process helps reduce material waste and minimize the use of toxic substances, making it an environmentally friendlier solution compared to other reconditioning methods.

Regarding the challenges encountered in the metallization process, these are generally related to ensuring good adhesion between the metal layer and the substrate, as well as the need for strict control of process parameters such as temperature and air pressure. These challenges can be overcome through proper surface preparation and careful monitoring of the application process.

In conclusion, metallization proves to be a promising technology capable of addressing both economic needs and performance requirements in the reconditioning of industrial components. It represents a sustainable, efficient, and environmentally friendly solution for industries looking to optimize costs and improve the durability of their equipment.

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