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ENVIRONMENTAL AND LABOR SAFETY ASPECTS OF TECHNOLOGIES FOR ENHANCING THE WEAR RESISTANCE OF WORKING SURFACES IN MILL AND PUMP COMPONENTS

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Abstract
This article examines the environmental and occupational safety aspects of technologies used to enhance the wear resistance of working surfaces in mill and pump components. The main risk factors related to abrasive materials, thermal treatments, coating applications, and the use of chemicals are identified, along with their impacts on the working environment and operator health. The advantages of modern eco-friendly surface strengthening methods, automated enclosed systems, and effective ventilation and filtration solutions are highlighted. Recommendations are provided for implementing safe and environmentally responsible technological regimes in industrial settings involving mill and pump component maintenance and manufacturing.

Keywords: Wear resistance, mill components, pump components, surface strengthening, abrasive materials, coatings, ecology, occupational safety, ventilation, automation.

Introduction

Mill and pump components are widely used across various industries such as mining, energy, chemical processing, and manufacturing. One of the main factors influencing the quality and durability of these components is the effective

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enhancement of their working surfaces to resist wear and corrosion. Just as impurities affect metal castings, abrasive particles, corrosion products, and surface defects reduce the operational life and reliability of mill and pump parts. Therefore, strengthening the wear resistance of working surfaces is an integral technological process in extending component lifespan.

However, surface strengthening technologies are not only related to performance improvement but also directly impact environmental conditions and occupational safety. The use of abrasive materials, thermal treatments, coatings, and chemical agents often releases dust, fumes, and aerosols that pose risks to workers' health and surrounding ecosystems. Handling high-temperature equipment and materials increases these risks, requiring strict safety measures. Various methods for enhancing wear resistance differ not only in technological and economic advantages but also in their environmental footprint, the amount of dust and chemical emissions, and the potential for direct exposure of workers to harmful substances. Therefore, it is necessary to evaluate these methods not only in terms of surface quality and durability but also based on environmental and occupational safety criteria.

Research Methodology

Surface strengthening technologies applied to mill and pump components often involve the use of abrasive materials, thermal treatments, and coating agents. These processes can have significant environmental and occupational safety implications that must be carefully considered to minimize risks to workers and the surrounding environment. A considerable part of surface treatment involves the use of abrasive compounds and chemical agents, some of which may contain chlorides, fluorides, or other reactive salts. When these substances interact with high temperatures during treatment, they can release gases, fumes, and aerosols into the workplace atmosphere. These emissions may include sharp-smelling gases, fine dust from abrasives and residues, as well as chemically active aerosols. The accumulation of these particles in the air increases pollution levels within production areas and poses health hazards to workers through inhalation or skin contact. Solid waste generated from surface strengthening operations, such as spent abrasive materials, coating residues, and slag, also presents environmental

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challenges. These wastes often contain salts, oxides, and metallic particles, making their disposal problematic if treated as ordinary industrial refuse. Improper disposal in landfills or open areas can result in long-term contamination of soil and groundwater. Thus, selection of abrasive and coating materials should consider not only their technical effectiveness but also their ecological classification, emission levels, and options for neutralization or recycling of waste products. The use of inert gases, such as nitrogen or argon, is common in some thermal surface strengthening technologies to create protective atmospheres or assist in coating processes. While these gases are chemically inert and non-toxic in themselves, their production, transportation, and storage involve energy consumption and contribute indirectly to environmental impacts such as carbon footprint. Moreover, the operational handling of gas cylinders requires strict safety protocols to prevent accidents.

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Filtration and dust control technologies play a vital role in reducing airborne contaminants during surface treatments. Using ceramic or foam filters and enclosed extraction systems effectively captures solid particles without additional emissions of dust or fumes. However, the used filters become hazardous solid waste containing metal and oxide residues, requiring controlled collection, processing, or disposal in designated facilities to minimize environmental risks. Surface strengthening operations often take place at elevated temperatures, sometimes exceeding 600°C, which leads to additional occupational hazards. Workers face risks of burns, eye injuries, and skin damage due to metal splashes, hot slag volatilization, and intense radiant heat. To mitigate these dangers, stringent safety measures are mandatory. These include wearing heat-resistant protective clothing, gloves, footwear, face masks, and goggles, as well as physical barriers separating hot zones and minimizing direct worker exposure through remote handling equipment. Particulate emissions, dust, and aerosols generated especially when handling crushed abrasives, coating powders, or during slag removal can cause respiratory, eye, and skin irritation or damage. This risk is heightened when fluorine-containing compounds are involved due to their chemical toxicity. To address these challenges, several solutions have been proposed and increasingly implemented in industrial practice. The use of environmentally friendly “green” abrasive materials and low-toxicity reagents significantly reduces harmful emissions. Manufacturers now offer abrasives and coatings with reduced fluorine content or completely fluorine-free compositions, minimizing smoke and aerosol production while maintaining cleaning and strengthening efficiency. Selecting such materials should consider price, technological performance, and environmental and occupational safety classifications. Closed-system surface treatment devices and automated equipment further improve safety and environmental conditions. These systems enhance the interaction efficiency between abrasives or gases and the component surfaces while limiting erosion, metal splashing, and direct worker exposure. Enclosed chambers capture most fumes and dust, which are then expelled through sophisticated ventilation and filtration units, improving workplace air quality.

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Ventilation and gas-dust cleaning systems are crucial for maintaining air purity in workshops. Local exhaust devices, multistage filters, and gas neutralization equipment immediately capture and process airborne contaminants from treatment zones, preventing their spread throughout the working area and ensuring compliance with environmental regulations. Equally important is the continuous training of personnel in occupational safety and environmental responsibility. Comprehensive instruction programs for new employees, regular seminars for existing staff, and detailed protocols for handling abrasive materials, gas cylinders, and filters enhance safety culture. Training also includes emergency response algorithms for incidents such as metal splashes, fires, or gas leaks, which significantly reduce accident risks. Through integrated application of technical innovations and organizational measures, the environmental and occupational safety levels in surface strengthening operations of mill and pump components can be significantly improved. Such advancements not only fulfill social responsibility obligations but also enhance the competitiveness and economic efficiency of production enterprises.

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Conclusion

Technologies aimed at enhancing the wear resistance of working surfaces in mill and pump components are crucial for ensuring the durability and reliability of these parts. However, assessing these technologies solely based on surface hardness or mechanical performance is insufficient. The environmental impact and occupational safety risks associated with abrasive materials, thermal treatments, coatings, and related processes must also be carefully considered. Toxic substances contained in abrasive compounds, coating residues, and spent materials, as well as hazards related to high-temperature operations and handling of compressed gases or chemicals, can adversely affect worker health and the surrounding environment. Therefore, it is essential to adopt environmentally friendly "green" abrasives and reagents in surface treatment workshops, implement closed and automated treatment systems, use effective ventilation and dust-gas cleaning technologies, regularly train personnel, and maintain a high culture of occupational safety. Looking ahead, the development of new low-environmental-risk materials, easily recyclable or safely disposable waste products, and energy-efficient, fully automated complexes for surface strengthening will remain among the key scientific and technical priorities in this field.

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