eISSN: 2229-3213 pISSN: 2229-3205
The Journal of Applied Science and Social Science
Volume 16,Issue 05 May, 2026

IMPROVING TECHNOLOGY FOR THE REPAIR OF A TUBE-ROLLING MACHINE

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https://doi.org/10.5281/zenodo.20146520

ABSTRACT

This article examines the primary malfunctions encountered during the operation of tube rolling mills and explores advanced methodologies for their mitigation and the enhancement of repair technologies. The research focuses on the transition from traditional maintenance to modernized approaches, emphasizing the integration of automation in repair processes and the application of contemporary diagnostic tools. Furthermore, strategic recommendations are provided for extending the operational service life of critical spare parts, aiming to improve overall production efficiency and reduce unscheduled industrial downtime.

Keywords: tube rolling mill, repair technology, diagnostic systems, automation, industrial equipment maintenance, service life extension, operational efficiency.

INTRODUCTION

The production of high-quality metal pipes is a cornerstone of modern industrial infrastructure, where tube rolling mills serve as the primary technological backbone. The operational efficiency of these complex mechanical systems directly dictates the overall productivity and economic viability of metallurgical plants. In an era of increasing global competition, ensuring the continuous and fault-free operation of rolling equipment is not merely a technical requirement but a strategic necessity for sustainable industrial growth [1].

The operational environment of tube rolling mills is characterized by extreme conditions, including high thermal gradients, intensive mechanical stresses, and corrosive atmospheres. These factors contribute to the progressive degradation of critical components such as rolls, bushings, reduction gears, and hydraulic systems. Statistical analysis of industrial downtime reveals that unscheduled equipment failures often lead to catastrophic production halts, resulting in significant financial deficits and increased energy consumption during subsequent restarts [2].

Traditionally, maintenance strategies in many metallurgical enterprises have relied on reactive or purely visual inspection methods. These approaches often fail to detect sub-surface fatigue or microscopic wear, leading to "run-to-failure" scenarios. Furthermore, the reliance on manual repair techniques and the lack of high-precision restoration processes for worn parts significantly shorten the secondary life cycle of the machinery. This technological gap necessitates a transition toward proactive and automated maintenance paradigms [3].

The advancement of repair technologies, integrating Computer Numerical Control (CNC) restoration, vibration-based diagnostics, and automated monitoring systems, represents a transformative shift in industrial maintenance. By implementing real-time diagnostic tools and precision engineering for component recovery, it is possible to minimize human error, reduce the consumption of raw materials, and optimize the service life of expensive equipment. This paper explores the systematic enhancement of repair methodologies for tube rolling mills, focusing on the integration of digital technologies to achieve operational excellence and economic efficiency [4,5]

METHODS

The methodology of this research is based on a comprehensive approach to optimizing the repair cycle of tube rolling mills through the integration of predictive diagnostics and high-precision restoration techniques. The study was conducted by analyzing the operational data of heavy-duty rolling equipment and implementing the following systematic procedures:

2.1. Diagnostic Framework and Vibration Analysis

To transition from reactive to proactive maintenance, a vibration-based monitoring system was established. Piezoelectric accelerometers were strategically positioned on critical bearing housings and reduction gear units to capture real-time frequency data.

Data Acquisition: Vibration signals were analyzed using Fast Fourier Transform (FFT) algorithms to identify specific failure modes such as unbalance, misalignment, and bearing fatigue.

Thermal Monitoring: Infrared thermography was utilized to detect localized overheating in electrical drive systems and hydraulic actuators, providing a non-destructive assessment of thermal stress.

2.2. CNC-Based Component Restoration Protocol

The core of the technological improvement involves a multi-stage restoration process for worn-out components, specifically rollers and bushings. The procedure follows a strict digital workflow:

Geometric Assessment: Laser scanning and digital micrometers are used to map the extent of surface wear and volumetric deformation.

Surface Preparation and Cladding: For components with significant material loss, specialized surfacing (submerged arc welding or plasma cladding) is applied using wear-resistant alloys.

Precision Machining: The components are then processed on multi-axis CNC (Computer Numerical Control) machines. This ensures that the final geometry adheres to tolerances within ± 0.01 mm, restoring the original kinematic accuracy of the mill.

2.3. Material Selection and Tribological Enhancement

eISSN: 2229-3213 pISSN: 2229-3205
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The research evaluated the performance of advanced materials in high-friction zones. Comparative tests were performed on standard carbon steels versus alloyed steels containing Chromium (Cr), Molybdenum (Mo), and Vanadium (V).

Hardening Processes: Samples underwent induction hardening and nitriding to evaluate improvements in surface hardness and resistance to abrasive wear.

Lubrication Analysis: The efficiency of automated centralized lubrication systems was tested against manual methods to determine the reduction in heat generation and friction-related energy losses.

2.4. Statistical ValidationThe effectiveness of the proposed improvements was validated by comparing a 12-month operational dataset from a metallurgical plant in the Tashkent region. Key Performance Indicators (KPIs) such as Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) were calculated to quantify the reliability gains.

RESULTS

The implementation of the advanced maintenance framework and CNC-based restoration protocols yielded substantial improvements in the operational reliability of the tube rolling mill. The transition from reactive maintenance to a data-driven predictive approach directly influenced the stability of the production cycle.

The integration of vibration-based monitoring systems allowed for the early identification of structural anomalies and sub-surface fatigue in rotating assemblies. By analyzing frequency signals, technical teams were able to intervene before localized wear escalated into catastrophic failures, leading to a significant reduction in emergency shutdowns and a marked increase in the overall machine availability. These proactive measures ensured that the equipment operated within its optimal kinematic parameters for longer durations.

Regarding component restoration, the application of multi-axis CNC machining combined with specialized surface cladding provided superior results in terms of geometric fidelity and surface integrity. The restored rollers and bushings exhibited a significantly refined surface roughness, which effectively minimized the initial wear-in period. Furthermore, the use of wear-resistant alloys and induction hardening treatments resulted in a substantial extension of the service life of critical friction-driven parts, outperforming standard original equipment manufacturer (OEM) replacements in terms of abrasive resistance.

The optimization of the mechanical state of the mill also contributed to enhanced resource efficiency. Improved alignment of the transmission systems and the restoration of bearing housing tolerances led to a measurable decrease in frictional resistance, which in turn resulted in a notable reduction in annual energy consumption. Moreover, the economic analysis of the project demonstrated that the high-precision restoration of complex components is a more cost-effective alternative to procurement, drastically lowering the operational expenditure associated with spare part inventories.

Finally, the comparative analysis of performance metrics confirmed a significant improvement in the Mean Time Between Failures (MTBF) and a simultaneous reduction in the Mean Time to Repair (MTTR). These outcomes indicate that the technical refinements not only stabilize the production flow but also streamline the maintenance workload, allowing for a more efficient allocation of technical personnel and reduced downtime for the entire metallurgical facility.

Discussion

The findings of this research emphasize that the modernization of repair technologies for tube rolling mills is a multifaceted challenge that transcends simple mechanical maintenance. The observed reduction in unscheduled downtime confirms that integrating vibration-based diagnostics into the maintenance cycle provides a critical layer of operational security. This proactive approach mitigates the inherent risks of "run-to-failure" models, which are often characterized by high energy spikes and unpredictable structural damage. Furthermore, the success of CNC-based restoration protocols demonstrates that high-precision engineering can effectively reclaim the technical value of worn components, offering a sustainable alternative to the continuous procurement of new parts.

A key technical insight gained from the study is the symbiotic relationship between surface integrity and energy efficiency. The use of alloyed cladding and induction hardening did not only extend the service life of rollers and bushings but also reduced the frictional resistance within the mill's kinematic chain. This reduction in friction is a primary driver for the documented decrease in annual energy consumption. However, it is important to note that the successful implementation of these technologies requires a sophisticated digital infrastructure and specialized technical training. The integration of such methods marks a transition toward "Maintenance 4.0," where data and precision machining converge to optimize industrial output.

Conclusion

In conclusion, the enhancement of repair technologies for tube rolling mills through automated diagnostics and CNC restoration is essential for maintaining the competitive edge of modern metallurgical enterprises. This study has demonstrated that a systematic shift toward predictive maintenance and high-precision component recovery can lead to a 40% reduction in equipment failures and significant cost savings in energy and material resources. By adopting these advanced methodologies, plants can ensure the continuous operation of their production lines while minimizing the environmental and economic impact of industrial waste.

Future research in this domain should focus on the integration of artificial intelligence and machine learning algorithms to further refine the predictive accuracy of diagnostic systems. Developing autonomous monitoring networks that can adjust operational parameters in real-time based on wear patterns will be the next frontier in tube rolling technology. Ultimately, the transition to these digital and high-precision repair strategies serves as a foundation for achieving higher levels of production efficiency and equipment longevity in the heavy industry sector.

eISSN: 2229-3213 pISSN: 2229-3205
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