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TYPES OF PIPE ROLLING MILLS, OPERATING PRINCIPLES, AND PRODUCTION PROBLEMS

Kirgizaliev Nodirbek Kholdarovich
Andijan State Technical Instituti
"Technological Machines and Occupational Safety"
department assistant
e-mail: n.qirgizaliey@gmail.com n197407-23
Tel: +(998) 94-102-46-02
ORCID ID:0009-0009-8624-9213

Abstract. This scientific article investigates the fundamental technological foundations and hardware-technical support for the production of seamless steel pipes in modern metallurgical complexes. The article details the structural evolution of pipe rolling mills, the mechanisms of metal deformation in various kinematic schemes, and inter-shaft contact stresses. In the practical part of the study, factors that reduce production productivity were analyzed: thermomechanical wear of working parts, fatigue resistance of the material, and deviations in product geometry. As a result, scientifically grounded innovative solutions have been proposed to increase the service life of rolling mills and reduce defects.

Keywords. Seamless pipe, rolling mill, screw deformation, punching bar, metallurgical microstructure, thermal stability, abrasive wear, kinematic diagram, technological resource, sleeve, seamless pipe, bushing, working shafts, mechanical properties, metallurgy.

INTRODUCTION The rapid development of modern mechanical engineering, energy, and the oil and gas industry sharply increases the demand for metallurgical products with high performance characteristics, particularly seamless steel pipes. Seamless pipes are distinguished by their cohesive structure, resistance to high internal pressure, and corrosion resistance in aggressive environments. Pipe rolling mills, which are the main technological link in the production of such products, are a complex mechanical and thermodynamic system in which finished products of complex geometric shapes are formed as a result of the plastic deformation of metal in a hot state.

Currently, the issue of increasing production efficiency requires not only the installation of new technological lines but also the fundamental scientific improvement of existing rolling mills to maximize labor savings and repair technologies. The pipe rolling process occurs under conditions of high dynamic loads, extreme temperature gradients (1100-1250 °C), and abrasive wear. Under these conditions, the premature failure of the main working parts of the machines, particularly the bushings, shafts, and bearings, leads to a decrease in production productivity and an increase in production costs.

The relevance of this scientific article lies in the systematization of complex deformation stages in the pipe rolling process, the analysis of changes occurring in the microstructure of the metal, and the scientific substantiation of the causes of production defects (geometric deviations, surface cracks, and defects in internal layers). Additionally, the study examines the influence of alloying elements (Cr, Mo, V, W) on extending the service life of pipe rolling mill components and innovative metallurgical solutions during the repair process. The ultimate goal of the research is to ensure the stable operation of production lines and to expand the scientific and practical basis for the production of high-quality, competitive seamless pipes.

RESULTS. Comprehensive analyses and experimental observations show that the most critical and energy-intensive stage of seamless pipe production technology is the process of forming a hollow sleeve from a monolithic workpiece (proshivka). At this stage, the stress-strain state of the metal is extremely complex, and the number of shafts used in screw-rolling mills directly affects the quality indicators of the process.

1.Comparative analysis of screw-rolling systems. As a result of the study, the following differences were identified between the technological efficiency of two- and three-roll boring machines:

Two-rolling mills. Despite their structural simplicity, the transverse loosening (ovalization) of metal in the deformation zone is high. This situation leads to the formation of unauthorized cavities (micro-cracks) in the center of the workpiece, which negatively affects the quality of the internal surface of the pipe.

Three-roll machines. Due to the compression of metal from three sides, the formation of cavities in the central part is significantly reduced (up to 25-30%). However, the expansion of the contact area between the metal and the shafts leads to an increase in friction forces, which in turn leads to a 15-20% increase in energy consumption and faster heating of the shafts.

2. Changes in the microstructure and mechanical properties of the metal. During the rolling process, a drop in the metal temperature below 1150 °C leads to an enlargement of the grain structure and a decrease in plasticity. As a result, the deformation resistance increases, and the machine drives (engines) begin to operate under excessive load. Although the dispersion of carbides in doped steels (in the presence of Cr, Mo, V) increases the heat resistance of the metal, an improperly selected thermal regime creates a foundation for the development of microcracks.

3.Based on practical observations, the main problems hindering production productivity have been systematized and reflected in the following expanded table.

Issue type	Cause of origin	Consequences and technical specifications
Wall thickness difference	Static and dynamic misalignment of shafts and spindle axles, low rigidity of the bench cage.	Deviations in the cross-section and longitudinal section of the pipeline, exceeding permissible limits, and material loss.
Defects of external and internal surfaces (plenae)	Defects on the workpiece surface, excessive wear of the workpiece tip, or a sharp drop in the rolling temperature.	Disruption of product airtightness, decrease in resistance to high pressure, and the need for additional mechanical treatment.
Intensive wear of working organs	High friction at 1200 °C, abrasive medium, and metal "sticking" to the shafts.	Decrease in machine resource, the need to replace or process shafts after every 200-300 tons of product.
Geometric curvature	Uneven cooling of the pipe at cooling tables or incorrect adjustment of the exhaust shafts.	Difficulties in subsequent stages (threading or welding), additional costs for adjusting the linear dimensions of the pipe.

These results indicate that to increase production efficiency, it is necessary not only to calibrate mechanical equipment but also to organically align material science and heat treatment parameters.

DISCUSSION The results obtained and the conducted analysis confirm that increasing the service life of pipe rolling mills and stabilizing production productivity directly depend on the material properties of the working parts and their processing technology. This section discusses the scientific and practical significance of the results in the following areas:

1. Influence of doping elements on microstructure.

Research has shown that bushings and rollers made of steels doped with carbide-forming elements (Cr, Mo, V, W) are 1.5–2 times more resistant to abrasive wear than standard carbon steels. This condition is explained by the formation of dispersed carbides (Me_C, Me_7C_3) with high hardness in the metal structure. This carbide phase maintains its stability even at temperatures up to 1200 °C and slows down the phenomenon of thermal softening (otjig) during the rolling process. This serves to preserve the geometric shape of the machine tool parts for a long time.

2. Innovative coating technologies in repair.

It has been determined that applying modern welding and surfacing technologies to repair pipe rolling mills is the most cost-effective solution. In particular, the creation of an extremely hard and heat-resistant layer on the surface of a part using laser or plasma coating methods reduces the shut-off time (protox) of the machines by 30–40%. This technology allows for the repeated restoration of the working surface of parts instead of replacing them entirely with new ones, which significantly saves metal consumption.

3. Geometric precision and automation.

Another important aspect under discussion is the minimization of the human factor and mechanical errors. Process control through automated control systems (e.g., laser scanners and sensors) allows for the real-time determination of pipe wall thickness irregularities. Geometric defects can be eliminated by automatically adjusting the spacing between shafts and the position of the bearing (via DDS systems). This not only reduces the share of "broken" products but also ensures full compliance of the product with international standards (API, GOST).

4. Thermodynamic equilibrium and energy efficiency.

The problem of high energy consumption in three-roll systems can be partially optimized through mathematical modeling of the process. By calculating the rotation speed and thrust angle of the shafts individually for each type of workpiece, it was established that it is possible to reduce excessive friction resistance and save electricity consumption by 5–8%.

CONCLUSION As a result of the conducted research and scientific analysis, the following final conclusions were formulated regarding the efficiency of pipe rolling mills and the improvement of product quality.

Technological stability. The productivity of pipe rolling mills primarily depends on the precise balance of technological parameters, specifically the temperature regime and deformation rate. Analyses show that maintaining the rolling temperature within the optimal range (1150-1250 °C) allows for a 15-20% reduction in mechanical loads on equipment while ensuring metal plasticity.

Resource conservation and materials science. The durability of working parts (shafts, bushings, and bearings) depends directly on their microstructure. Increasing the heat resistance of metal through alloying and heat treatment with carbide-forming elements (Cr, Mo, V, W) is a key factor in extending the service life of parts by up to two times. This significantly reduces the enterprise's operating costs for spare parts.

Innovative repair methods. To reduce production interruptions, traditional methods of machine tool repair must be abandoned in favor of innovative metallurgical solutions, specifically laser coating and plasma welding technologies. These methods not only restore the surface of the part but also allow for an increase in its surface hardness compared to a new part.

Digital monitoring and automation. Digital monitoring of the production process (based on Industry 4.0 principles) is crucial for minimizing human error and geometric defects. Real-time monitoring of pipe wall thickness and surface quality using sensors creates a foundation for reducing the share of defective products (brakes) from 5-7% to 1.5-2%.

As a final conclusion, it can be said that the comprehensive implementation of these scientifically grounded measures not only raises the quality of seamless pipes to the level of international standards but is also the most effective way to ensure the energy efficiency of production and the economic competitiveness of the enterprise in the global market.

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