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Choosing the Mass of an Ingot of a Rational Shape for Bloom Rolling

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Abstract: This article focuses on enhancing technological processes to elevate the quality of the final product, specifically by optimizing the weight and configuration of the ingot. The aim is to bolster the durability and performance of critical components in industrial equipment units, such as rolls, beds, and universal spindles. By meticulously selecting the optimal weight and shape of the ingot, the study endeavors to fortify the structural integrity and operational efficiency of these equipment parts. Through innovative technological advancements and meticulous design considerations, the research aims to address key challenges associated with material strength and performance durability. The overarching goal is to enhance the overall quality and reliability of industrial equipment units, ultimately contributing to improved productivity and operational efficiency in various industrial sectors. Through this article, insights are provided into the innovative approaches and methodologies employed to optimize ingot weight and configuration for enhanced performance and durability in industrial applications.

Keywords: spindle, ingot, bloom, universal spindle, wire rod

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1. Introduction

Rolling conditions and ingot configuration significantly affect the stress-strain state and the surface quality of the ingots. Metals undergo complicated stress-strain states during rolling, which causes strain zones to emerge and need a large amount of energy [1]. Since early residual stresses have little effect on the plastic strain distribution during rolling, it is crucial to comprehend the dynamic changes brought about by the rolling process [2]. The surface quality of ingots is greatly impacted by the stress-strain state parameters, whereas surface fracture development during upsetting operations is influenced by the stress states [3]. Furthermore, the ultimate quality of the ingot is significantly influenced by the distribution of electric current density during operations such as vacuum arc remelting (VAR) [4].

Studies on the creation of surface markings on aluminum alloy ingots to improve surface quality have concentrated on the impact of casting speed [5] in the context of ingot quality. Moreover, the quality and fracture toughness of ingots are greatly influenced by the grain size and refiners, especially for aviation applications [6]. Controlling segregation during the solidification process is crucial because it has a direct impact on the quality of steel ingots and the final products that follow [7].

To increase the degree of deformability of the ingot, its shape must provide the most favorable stress state pattern during the rolling process. These requirements are satisfied by the convex shape of the side surface of the ingot with an arrow of convexity of 7-10% of the width of the face [8]. This convex configuration can lead to a stress state that is conducive to deformation during rolling, thereby improving the overall deformability of the ingot. By optimizing the shape of the ingot to have a convex side surface, the stress distribution during rolling can be managed more effectively, potentially resulting in better deformability and surface quality of the final product.

Furthermore, it makes it possible to approximate the quality of blooms rolled using the first edging pattern after the fourth pass and the quality of blooms rolled using the edging pattern after the second pass. Research has indicated that the mechanical characteristics of rolled material can be greatly influenced by the number of accumulative roll bonding passes [9]. Vickers microhardness, for example, tends to increase with the number of passes in accumulative roll bonding, suggesting that material strength and quality may be improved. Moreover, a systematic comparison of the microstructure and properties arising from the rolling process has been conducted, demonstrating the variations in the material characteristics with each pass [10]. Additionally, accumulative roll bonding can reveal the anisotropic behavior of materials like Al1050, shedding light on how the material's characteristics change during the rolling process and providing a framework for assessing the caliber of rolled goods [11].

Likewise, a great deal of research has been done on how the rolling process affects a material's mechanical qualities and ability to withstand corrosion. A good example of how different rolling circumstances may affect the final product's quality is the way that low-temperature rolling affects the mechanical characteristics and corrosion resistance of CrCoNi medium entropy alloy [12]. Furthermore, extra low carbon steel's ultimate tensile strength may be affected by adjusting the rolling process for particular textures and recrystallization patterns. This information can be used to evaluate the quality of rolled products according to the required mechanical qualities [13].

In addition, the convex shape of the ingot faces improves heating conditions and reduces the temperature difference across the cross section. It has been investigated how to regulate the pull-in effect and concavity on the lateral sides of the ingot by using convex molds in direct chill casting. In order to control solidification flaws such as concavity, shape optimization is essential [14]. In a similar vein, convex-faced tablet design has demonstrated potential advantages in improving tablet quality in pharmaceutical compaction studies [15].

Through the optimization of cooling conditions and interface features, simulations have shown that modifying the thermal gate movement rate may increase the convexity of the m-c interface and the center cooling condition of silicon ingots during solidification, therefore improving ingot quality [8]. Furthermore, studies on weight-compatible design stress how crucial it is to keep the ingot and mold in optimal contact in order to facilitate effective heat transfer and solidification [16].

2. Method

The paper uses quantitative techniques to determine the optimal ingot mass for bloom rolling, emphasizing sensible form factors. To create a theoretical framework, the method entails a thorough literature assessment. The deformation of the ingot during rolling is then simulated mathematically, and the ideal ingot mass required to achieve the required bloom dimensions and mechanical qualities is predicted. The mathematical models are then verified by laboratory-scale rolling mill trials, and the efficiency of different ingot masses in achieving the desired bloom dimensions and qualities is evaluated. The experimental data is subjected to statistical analysis in order to identify connections between ingot mass, rolling parameters, and bloom qualities. This procedure finally identifies the ideal ingot mass in order to improve process quality and efficiency. Ultimately, in order to find the ingot mass that maximizes production and product quality while minimizing energy use, material waste, and processing time, optimization approaches are used. The study seeks to offer useful insights for improving the bloom rolling process's efficacy, economy, and quality through the use of this scientific methodology.

3. Results and Discussion

3.1. Definition of preliminary investigation

One of the main parameters characterizing the ingot is the specific height of the ingot, which is the ratio of its height L to the reduced thickness of the average B_{roll}

$$N_{beat} = L / V_r, \tag{1}$$

Where $B\sqrt{H_{med} \cdot B_{med}}$; (2)

$$H = \frac{H_B + H_H}{2}; \tag{3}$$

$$B_{roll} = \frac{B_B + B_H}{2} \tag{4}$$

The highest productivity of a crimping mill is achieved when, as the mass of the ingot increases, its specific height increases [17].

Figure 1 shows the change in height *(1)*, thickness *(2)*, taper *(3)*, and specific height *(4)* depending on the mass of the ingot [18].

With increasing mass, the height and cross-sectional dimensions of the ingot increase, but previously performed calculations showed that the reduced thickness of the ingot grows faster.

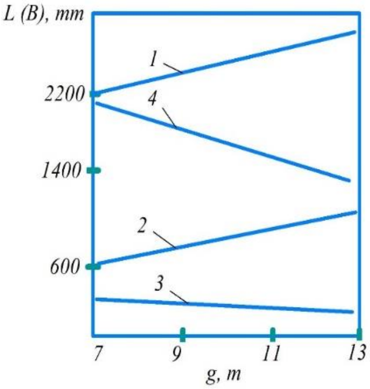

Figure 2. Change in height L (*1*), thickness B (*2*), taper (*3*) and specific height (*4*) depending on the ingot *g*

When the mass increases to 12.5 tons, rolling such an ingot in 11 passes causes an increase in the load on the equipment and dangerous slipping. Therefore, rolling 12.5 t ingots is carried out in 13 passes, the productivity is lower than when rolling 11 t ingots in 11 passes [19].

This is due to the fact that when the compression intensity decreases, the proportion of pauses increases significantly [18].

We accept an ingot m = 10.7 tons.

$$\frac{835\times735}{930\times830}\times2330,\ N_{beat} = 2.8 \tag{5}$$

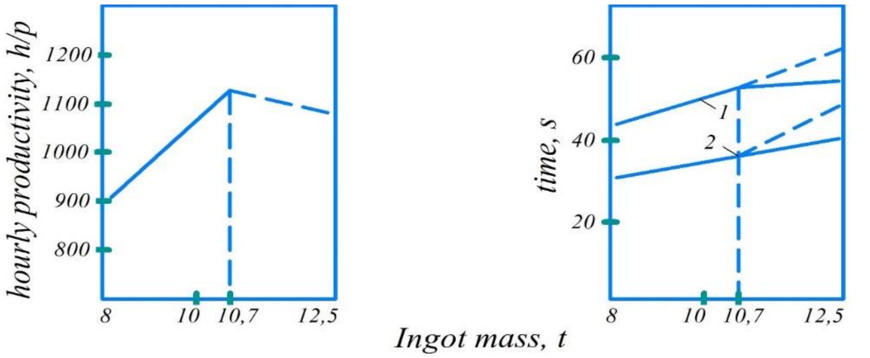

Figure 2. Dependence of productivity, machine time (*1*) and pauses (*2*) on the mass of the ingot. Dotted line – rolling in 13 passes

Analysis of Figure 2 shows that the productivity of an ingot weighing 10.7 tons. increases compared to existing ingots weighing 12.5 tons.

Ingots of medium and high-carbon unalloyed and low-alloy steel are cast into a widening towards the bottom of the casting with insulation of the head part [20].

When producing such ingots with a flat bottom base, the amount of shrinkage of this part during the rolling process is significant and the trim amounts to 3-5% of the length of the roll. Therefore, one of the main issues when choosing the optimal shape of an ingot is determining the configuration of this part, widened towards the bottom of the ingot.

4. Conclusion

This article provides for the improvement of technology in order to improve the quality of finished products. Reducing the weight of the ingot made it possible to roll the ingots in fewer passes (11 passes). At the same time, the modernized mill increased annual productivity by 21% with the same energy costs and the same operating time of the mill.

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