

Improving the design of the lining of the ball mill used to improve the quality of grinding

Nosir Saidmakhamadov^{1}, Nodir Turakhodjaev¹, Sarvar Tursunbaev¹, Ruslan Zokirov¹, Nuritdin Tadjiev¹, Kamol Abdullaev², Vohid Hamroev³, Ulugbek Rakhmanov¹, and Jurabek Juraev¹*

¹Tashkent State Technical University, Tashkent, 100095, Uzbekistan

²Namangan Engineering-Construction Institute, Namangan, 160100, Uzbekistan

³National University of Science and Technology “MISIS” in Almalyk, Uzbekistan

Abstract. This article discusses the traditional ball mill lining used and the improved ball mill lining. Experimental data of the proposed and previous linings are presented. The economic effect of using a new improved ball mill lining design is shown. Also, based on the dimensions of the ores, their mechanical properties, the material and construction of the detail were selected first. It is recommended to use high-manganese steel alloy, if corrosion occurs due to friction, and chromium – molybdenum steel alloy as the material of the detail. As a result of changing the design of the part in the proposed technology, it can be seen that the ore crushing process has improved. As a result of the good ore grinding process, it became easier to extract metals and alloys from the crushed ore. In order to obtain research results, several studies were conducted using traditional and improved technology. Thanks to this technology, the economic efficiency of the production enterprise has increased due to the improvement of ore crushing, the increase of the service life of the part, the saving of resource energy, and the reduction of the time required for technical repairs.

1 Introduction

Over the past 30 years, linings have been widely adopted in practice for protection against wear of ore grinding mills on the 2nd and 3rd stages of grinding mining, as well as cement mills industry, displacing steel armour lining based on steel 110G13L. As for the 1st stage of grinding, when moving from metal on a purely rubber lining there is a drop performance and, as a rule, a decrease in service life linings. In order to maintain productivity and, at the same time, increasing service life, foreign manufacturers have developed and Rubber – metal lining of the “Unloading BMC” type is successfully used with steel inserts in the working area. As an alternative to such lining, specialists of JSC “NMMC” developed and put into operation an original modern rubber – metal lining.

The company's most experienced staff, consisting of engineers, designers and technologists, using a holistic approach, develop custom – made mill linings to ensure

* Corresponding author: anvarovichsarvar908@gmail.com

exceptionally high service life and reliability. Available in company resources provide complete control of the entire process from design before production [1-4].

2 Research methods

During operation, individual parts of mining equipment and machines work in difficult conditions caused by abrasive and dynamic effects, and as a result are subject to rapid impact and abrasive wear. Premature wear of parts leads to high energy consumption and has a detrimental effect on the operation of machines as a whole. Thus, the performance of machines is largely determined by the wear resistance of parts of working parts, mainly made by casting from chromium – molybdenum steels [5]. Based on the operating conditions of ball mills used in the conditions of JSC “NMMC”, the service life of the lining was increased by changing the design and choosing its optimal material. As a result, the production output of crushed ore of the required fraction (71 microns) has been increased.

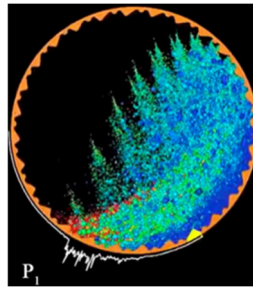


Fig. 1. Type of the working process of the mill operating in the conditions of JSC “NMMC”.

As can be seen in Figure 1, the manufactured lining made of 110G13L steel works under conditions of shock – abrasive wear [6]. The current structure of the lining in the mill works at high shock loads, and in addition, as a result of the impact of the balls on the surface of the lining under the action of a certain force, the balls are destroyed. The lining experiences a high impact load, and the balls are chipped. Due to the small contact area of grinding media, the yield of the usable (71mkm) is 85 – 89 % [7-8]. The experiments carried out at mills № 44 and № 57 at different loads, the material size class after unloading the mill and draining the HCI show that the yield of a suitable for lining with an existing chromium – molybdenum alloy structure increased to 96% (Table 1). But due to the high impact load, intensive wear of the chromium – molybdenum lining occurs. (ACT №. 04/541 of 19.12.2022, Figure 3).

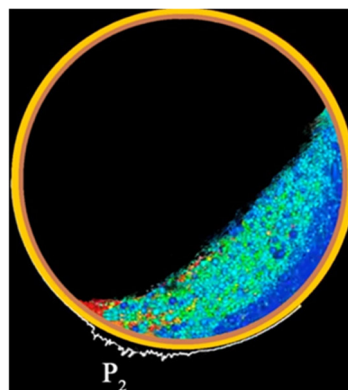


Fig. 2. Type of work process of the improved lining design proposed for JSC “NMMC”.

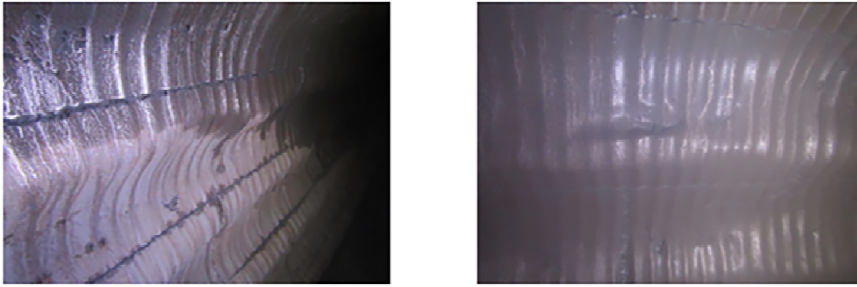


Fig. 3. View of the spent improved lining.

Based on the study, an improved lining design was developed in order to reduce the impact load and increase the friction surface between the lining and the balls (Figure 2). As a result, the yield of the usable (71 microns) will increase to 94 – 96% (Graph 1 and 2). The shown construction of the lining in Figure 1 is intended for the 110G13L alloy, since a rivet is formed upon impact. In chromium – molybdenum alloys, no cleavage is formed, which leads to their rapid wear [9]. The service life of the proposed chromium – molybdenum lining design (Figure 2) increases when it works only for abrasive wear and does not work at high impact loads.

3 Results and discussion

The average hourly processing is 165t/hour.

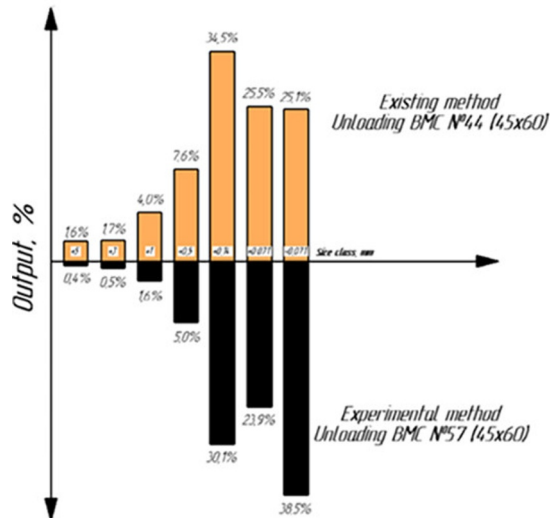


Fig. 4. Results of the study of grinding unloading of the BMC.

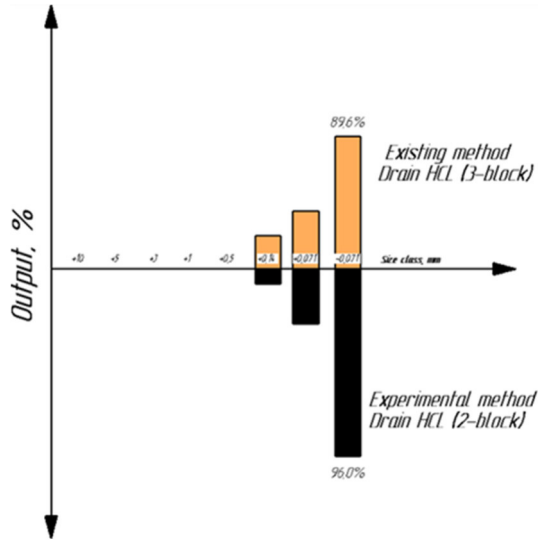


Fig. 5. Results of the study of grinding of the HCL drain.

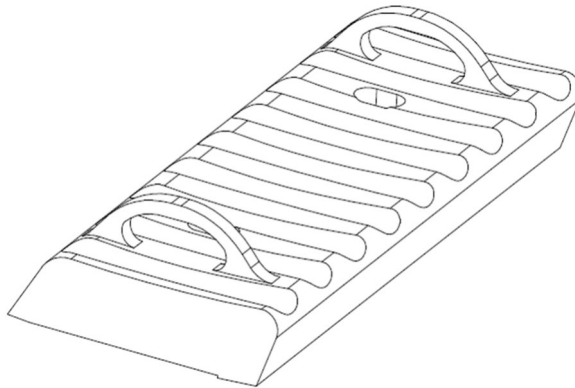


Fig. 6. General view of the proposed lining design.

Table 1. The experimental results.

Date, hours of selection	Product name	Average hourly processing, t/hour	Product density, g/l	Output, %								
				Size classes, mm								Initial
				+10	+5	+3	+1	+0,5	+0,14	+0.071	-0.071	
04.05. 23y. 6 ³⁰ pm	Uploading BMC №57 (45x60)	165	1806	-	0.4	0.5	1.6	5.0	30.1	23.9	38.5	100
	Drain HCL (3-block)		1170	-	-	-	-	0.3	3.7	96.0	100	
	Uploading BMC №44 (45x60)	165	1804	-	1.6	1.7	4.0	7.6	34.5	25.5	25.1	100

	Drain HCL (2-block)		1176	-	-	-	-	-	0.7	9.7	89.6	100
04.05. 23y. 7 ³⁰ pm	Uploading BMC №57 (45x60)	165	1827	-	0.4	0.2	1.3	4.3	31.2	24.1	38.5	100
	Drain HCL (3-block)		1161	-	-	-	-	-	0.3	3.4	96.3	100
	Uploading BMC №44 (45x60)	165	1795	0.4	0.5	0.9	3.5	7.7	34.4	25.7	26.9	100
	Drain HCL (2-block)		1141	-	-	-	-	-	0.4	6.6	93.0	100
04.05. 23y. 8 ³⁰ pm	Uploading BMC №57 (45x60)	165	1774	-	0.2	0.2	1.1	3.8	28.4	26.5	39.8	100
	Drain HCL (3-block)		1179	-	-	-	-	-	0.4	3.2	96.4	100
	Uploading BMC №44 (45x60)	160	1698	0.3	1.4	1.4	3.7	7.5	36.1	24.8	24.8	100
	Drain HCL (2-block)		1191	-	-	-	-	-	1.1	14.3	84.6	100
04.05. 23y. 9 ³⁰ pm	Uploading BMC №57 (45x60)	145	1885	-	1.0	0.5	1.6	4.6	29.5	24.1	38.7	100
	Drain HCL (3-block)		1178	-	-	-	-	-	0.6	4.3	95.1	100
	Uploading BMC №44 (45x60)	160	1819	2.7	1.3	1.5	4.0	8.1	35.2	22.3	24.9	100
	Drain HCL (2-block)		1161	-	-	-	-	-	1.1	12.9	86.2	100

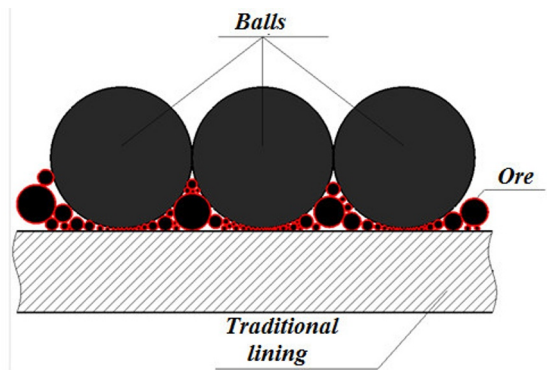


Fig. 7. Type of traditional lining in grinding processes.

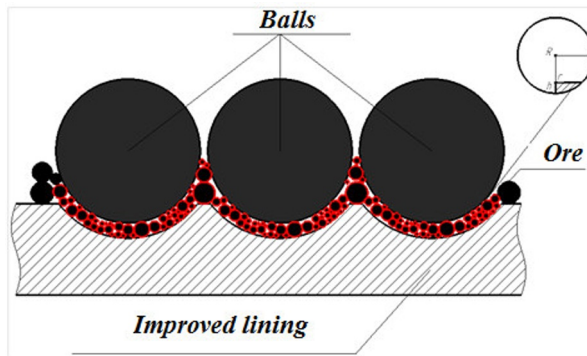


Fig. 8. View of the advanced lining design during the grinding process.

Currently, the traditional lining of mills in the conditions of “NMMC” JSC has a contact surface of the ball with ore (Figure 7) that is significantly smaller than the contact surface of the ball with ore of the proposed lining design (Figure 8).

In Figure 7, the length of the contact line of the ball with the ore is 5 mm. In Figure 8, the length of the contact line is 76 mm, the immersion depth of the ball is 14 mm, the depth of the contact zone of the ball with the lining is 35 mm, and completely follows the profile of the lining groove, which significantly increases the degree of grinding and the yield of the required fraction (71 μ m).

Based on these parameters, the area of the contact surface of the ball is calculated using the formula:

$$s = \pi(r^2 + h^2) = 2\pi Rh = 2 * 3.14 * 50 * 14.5 = 4553 \text{ mm}^2 \quad (1)$$

4 Conclusion

Considering the above indicators, based on the improved structural lining and the optimal material selected for it, the following conclusions were made:

1. The traditional mill lining used at “NMMC” JSC is made of 110G13L steel and the heat treatment cycle is 24 hours. The use of a new lining design made of 300X32H2PL cast iron does not require heat treatment, which consistently leads to a reduction in energy consumption and labor intensity.
2. As a result of using traditional lining, the yield (71 microns) is 85 – 89 %. With the recommended improved lining of a new design, the yield (71 microns) is 94 – 96 % (graph 1 and 2).
3. In the process of grinding ores, the mill balls are chipped off at a certain impact. The proposed improved new lining design prevents the ball from breaking due to the lack of impact load during operation. The impact load is 5 – 6 times less than with a traditional lining design ($P1 > P2$). This increases the service life of the lining.
4. During the operation of the mill, most of the under – crushed ore fraction leaves the unloading part of the mill, which requires additional installation of discharge mills, which leads to a decrease in efficiency. With the proposed lining of the new design, the mill does not work in waterfall or cascade mode. Therefore, the large fraction of ore is not mixed with the small fraction. The fine fraction comes out of the mill unloading, and the large part, due to the density, is further ground in the mill. Due to the output of a smaller amount of a large fraction of ore, the equipment of the technological chain (pumps, classifiers and hydro cyclones) are subjected to

less wear. The use of a new improved lining design instead of the traditional mill lining leads to a decrease in metal consumption by 13 – 14%, as well as an increase in the volume of the mill, which in turn leads to an increase in the economic efficiency of the production process.

5. When operating mills used in the conditions of JSC “NMMC”, a large fraction is 11 – 15% and their processing is required. This leads to a decrease in economic efficiency. As a result of the use of improved linings of a new design, the level of presence of a large fraction is 4 – 6 %. In the process of further processing, the service life of the equipment involved in ore dressing increases, which will lead to an increase in their efficiency.

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