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Article

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INFLUENCE OF CAST IRON VACUUMING ON THE LEVEL OF MECHANICAL CHARACTERISTICS OF THE MATERIAL OF THE WORKING LAYER OF DOUBLE-LAYER CHROMIUM-NICKEL ROLLS

The object of research is chromium-nickel cast iron of the working layer of two-layer sheet-rolling rolls of the LPKhNd design. At present, chromium-nickel cast iron is widely used for the manufacture of rolls for sheet and section rolling mills. One of the ways to improve the operational properties of products made of chromium-nickel cast iron is the refining of molten metal by vacuum. The existing problem is that information on the effect of vacuuming on the performance of chromium-nickel iron is very limited.

Rolls with the most characteristic concentration of alloying elements for LPKhNd performance were selected for the study. When evaluating the properties of vacuumed cast iron and cast iron by traditional technology, the level of strength, hardness, as well as special properties were determined, the study of which is caused by the peculiarities of the operation of rolling rolls (thermal wear resistance and crack resistance).

It has been established that there is no significant difference in the structures of rolls made of vacuumed and non-vacuumed cast iron. The structure of the rolls consists of martensite, bainite and carbides. With an increase in the content of graphite-forming elements (C, Si, Ni), graphite inclusions appear in the structure, and with their decrease, individual troostite colonies appear. The physical and mechanical properties of vacuumed and non-vacuumed cast iron are on the same level. The crack resistance of the chilled zone of vacuum cast iron is 12.35 % higher than that of cast iron of the traditional production method, and the transition zone is 11.96 %. The thermal endurance of the chilled zone of the roll material increased by 14.95 % as a result of vacuuming of the molten metal, and the transition zone – by 14.56 %. An increase in crack resistance and heat resistance can help reduce the chipping of the working layer of chromium-nickel rolls of sheet mills during operation and increase their resource indicators.

The obtained results of research indicate a positive effect of vacuuming on individual indicators (crack resistance and heat resistance) of the working layer of the forming tools of sheet rolling mills.

Keywords: *chromium-nickel cast iron, vacuuming, working layer, physical and mechanical properties, crack resistance, thermal resistance, rolling shafts.*

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1. Introduction

At present, chromium-nickel cast iron is widely used for the manufacture of rolls for sheet and section rolling mills. One of the ways to improve the operational properties of products made of chromium-nickel cast iron is the refining of molten metal by vacuum. This is due to the fact that vacuum treatment of molten metal contributes to its mixing and purification from non-metallic inclusions and impurities, and also increases the operational characteristics of products [1–3].

Despite the fact that the first publications concerning the effect of degassing on the technical characteristics of cast irons were presented as early as the early sixties of the last century [4–6], information on the effect of degassing on the performance characteristics of chromium-nickel cast iron is very limited.

It was noted in [7] that as a result of vacuuming of chromium-nickel cast iron, the microhardness of pearlite in the bleached cast iron of LPKhNd rolls increases by $H_{\lozenge 50}$=150–160, and in SPKhN by $H_{\lozenge 50}$=70–75. The authors also note an increase in the proportion of the carbide phase in the structure of the working layer of chromium-nickel rolls.

Additional studies of the effect of vacuuming on the quality of rolling rolls [8] showed that as a result of pro-

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cessing, the hydrogen content in the metal can decrease by 20–60 %, oxygen by 10–30 %, and nitrogen by 10–25 %.

The performed analysis of scientific publications indicates that information on the degassing of molten metal is more relevant to steel processing [9–11]. This does not give a complete picture of the effect of vacuuming during the casting process on the quality and structure of the metal of rolling rolls, and their service life.

Thus, *the object of research* is chromium-nickel cast iron of the working layer of two-layer sheet-rolling rolls of the LPKhNd design. *The aim of research* is to study the effect of vacuuming on the main indicators of the quality of the working layer of two-layer chromium-nickel rolls of the LPKhNd design.

2. Research methodology

Rolls with the most characteristic concentration of alloying elements for LPHND performance were selected for the study.

To determine the chemical composition of cast iron (Si, Mn, Cr, Ni), a PGS-2 spectrograph (Germany) was used.

The total carbon content was determined with an AN-7529M gas analyzer (Belarus), sulfur was determined by the coulometric method using a DF-7012 analyzer (Belarus), and phosphorus was determined by the photometric method with hydroxylamine.

When evaluating the properties of cast iron, the level of strength, hardness, as well as special properties, the study of which is caused by the peculiarities of the operation of rolling rolls (thermal wear resistance and crack resistance), were determined.

The tests were carried out on tangential specimens cut from rings taken from the lower casting ends of the barrel and neck, real rolls. Tensile strength (σ_t) was evaluated according to GOST 1497. The determination of temporary tensile strength in static bending (σ_{bend}) was carried out on samples 10×10×60 mm in size with a distance between supports of 40 mm on an Amsler model machine (Germany).

The susceptibility of the metal to brittle fracture was evaluated by impact bending test according to GOST 9454 on standard specimens without a notch at a temperature of +20 °C.

Hardness tests were carried out on Brinell (GOST 9012, at P=7350 N, d_{sh}=5 mm and P=29400 N, d_{sh}=10 mm) and Rockwell devices (GOST 9013).

In previous studies, it was found [1] that one of the main reasons for the failure of the two-layer rolling rolls of sheet mills is the chipping of the working surface. The level of destruction of this type depends on the crack resistance and thermal resistance of cast iron. The index K_{IC} (critical stress intensity factor, MPa) was chosen as the crack resistance parameter, and N_c (number of cycles to failure) was chosen as the thermal resistance parameter.

The thermocyclic endurance of the material under study was evaluated by the number of cycles to failure of the samples tested on the facility and according to the method developed at the Ukrainian Research Institute of Metals (Kharkiv, Ukraine) in relation to the operating conditions of hot rolling rolls [12]. Induction heating of the sample was carried out from room temperature to 600 °C, cooling was performed with a water jet. The temperature was controlled by a contact thermocouple welded to the surface in the central part of the sample. Samples were tested with pinched ends at a load of 176.4 N.

The static crack resistance of the material was evaluated by the critical fracture intensity factor K_{IC} according to GOST 25.506 [13].

3. Research results and discussion

Previous studies [14] on the operational stability of the rolls of the mill 2000 versions LPKhNd-63, LPKhNd-71, LPKhNd-74, made by stationary casting showed that the highest operational parameters are typical for rolls of the LPKhNd-74 design. The lowest performance indicators in the finishing group of stands are for rolls of the LPKhNd-63 design. The operational characteristics of the rolls of the LPKhNd-71 design are higher than those of the rolls of the LPKhNd-63 design, but are inferior to those of the rolls of the LPKhNd-74 design. Based on the fact that the rolls of the LPKhNd-74 design are somewhat more expensive than the LPKhNd-71 design and almost 1.8 times more expensive than the LPKhNd-63 design, and also taking into account the profitability indicators of the sheet-rolling mills, rolls of the LPKhNd-71 design were chosen for research. The chemical composition of the studied materials is given in Table 1, and the properties of the material of the working layer are presented in Table 2.

The study of the working layer of chromium-nickel rolls of the LPKhNd-71 design showed that there is no significant difference in the structures of the rolls made from vacuumed and non-vacuumed cast iron. The structure of the rolls consists of martensite, bainite and carbides. With an increase in the content of graphite-forming elements (C, Si, Ni), graphite inclusions appear in the structure, and with a decrease, individual troostite colonies appear.

Table 1

The chemical composition of the material of the investigated rolls

Conditional roll number	Contents of elements, %							Processing method
	C	Si	Mn	P	S	Cr	Ni	
1	3.0	0.43	0.73	0.47	0.10	0.76	4.0	vacuuming
2	2.76	0.50	0.65	0.50	0.09	0.92	3.6	vacuuming
3	3.4	0.70	1.0	0.50	0.10	1.1	3.8	vacuuming
4	3.2	0.45	0.60	0.47	0.09	1.2	3.7	vacuuming
5	3.1	0.65	0.50	0.49	0.09	1.0	4.0	without processing
6	3.0	0.48	0.62	0.48	0.10	1.1	3.9	without processing
7	2.81	0.64	0.73	0.49	0.10	0.95	3.6	without processing
8	3.0	0.58	0.85	0.50	0.09	0.98	3.8	without processing

Table 2

Physical and mechanical properties of the working layer of rolls of the LPKhNd design before and after vacuuming

Conditional roll number	Distance (depth of working layer), mm	Mechanical characteristics				Stress intensity factor, K_{IC}, MPa	Heat resistance, N_c, number of cycles to failure
		σ_t, MPa	σ_{bend}, MPa	K_C, J/cm^2	Hardness, HRC		
1	0–10	260	430	2.5	50	58	2041
	10–20	260	380	2.2	46	62	2077
2	0–10	320	460	2.7	53	60	2087
	10–20	300	440	2.3	48	62	2095
3	0–10	280	430	3.0	52	63	2078
	10–20	270	390	2.4	48	63	2098
4	0–10	290	450	2.6	54	64	2015
	10–20	290	420	2.2	47	63	2041
5	0–10	300	440	2.8	55	54	1765
	10–20	290	400	2.3	48	55	1800
6	0–10	270	440	3.0	52	58	1715
	10–20	260	430	2.5	46	59	1818
7	0–10	300	460	2.9	51	51	1801
	10–20	290	440	2.4	46	55	1727
8	0–10	310	450	2.8	53	50	1711
	10–20	300	420	2.4	46	52	1756

Data in the Table 2 show that the tensile and bending strength, impact strength and hardness of vacuumed and non-vacuumed cast irons are on the same level.

There are differences in the indications of crack resistance and heat resistance. The crack resistance of the chilled zone of vacuum cast iron is 12.35 % higher than that of cast iron of the traditional production method, and the transition zone is 11.96 %.

The thermal endurance of the chilled zone of the roll material increased by 14.95 % as a result of vacuuming of the molten metal, and the transition zone – by 14.56 %.

An increase in crack resistance and heat resistance can help reduce the chipping of the working layer of chromium-nickel rolls of sheet mills during operation and increase their resource indicators.

The obtained results of the study indicate the positive effect of vacuuming on individual indicators (crack resistance and heat resistance) of the working layer of the forming tools of sheet-rolling states.

But it should be noted that for the industrial application of degassing of chromium-nickel cast iron, additional studies should be carried out to determine the parameters of degassing for the formation of performance indicators for the working layer of two-layer rolling rolls, namely:

– vacuum level;
– vacuuming time;
– temperature of molten iron before vacuuming;
– lowering the temperature of molten cast iron during vacuuming;
– volume of slag plug formation on the surface of the liquid metal bath.

4. Conclusions

As a result of the research carried out, it was established:
– vacuuming of the molten metal does not have a significant effect on the structure of the working layer of chromium-nickel rolls of the LPKhNd-71 design;
– physical and mechanical properties of vacuumed and non-vacuumed cast iron are on the same level;
– crack resistance in the chilled zone of vacuumed cast iron is 12.35 % higher than that of cast iron of the traditional production method, and the transition zone is 11.96 % higher;
– thermal endurance of the chilled zone of the roll material as a result of vacuuming of the molten metal increased by 14.95 %, and the transition zone – by 14.56 %;
– an increase in crack resistance and heat resistance can help reduce the chipping of the working layer of chromium-nickel rolls of sheet mills and increase their resource indicators.

Conflict of interests

The authors declare that they have no conflict of interest regarding this study, including financial, personal nature, authorship or other nature that could affect the research and its results presented in this article.

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