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ISSN 0543-5846
METABK 58(3-4) 283-286 (2019)
UDC – UDK 666.79:541.4:539.41:544.4:666.88=111

STUDYING REFRACTORY BRICKS STRUCTURE IMPACT ON THEIR PERFORMANCE PROPERTIES

Received – Primljeno: 2018-06-28
Accepted – Prihvaćeno: 2018-12-20
Preliminary Note – Prethodno priopćenje

The refractory bricks structure impact on such operational properties as slag resistance and heat resistance is considered. Chamotte brick used in the RK metallurgical plants and refractory brick made according to the new technology with the use of non-stationary pressure have been used as samples. The products porosity has been studied. It has been shown that porosity, slag resistance and heat resistance of products manufactured using non-stationary pressure is higher than those of the reference.

Key words: refractory brick, chemical composition, non-stationary pressure, porosity, slag resistance

INTRODUCTION

The performance properties of refractory bricks used as the lining determine largely not only the productivity of metallurgical units (melting furnaces and furnaces for heat treatment, ladles, baths, etc.), but also the quality of the finished products. The destruction of the lining made of refractory bricks leads:

- firstly, to the forced downtime of metallurgical aggregates caused by repair work, which negatively affects the production cost;
- secondly, to the clogging of the smelted metal with nonmetallic inclusions of both exogenous and endogenous origin, mechanical impurities, etc.

Thus, the properties of refractory bricks used in metallurgical aggregates as the lining determine both the quality and the cost of finished metallurgical products.

Therefore, all activities aimed at improving the operational properties of refractory bricks are relevant.

One of the main operational properties of refractory bricks used as the lining of smelting furnaces is their slag resistance and heat resistance. In this case slag resistance means the depth of slag penetration into the lining; heat resistance means the number of the refractory immersions into the melt without destroying it. Both indicators depend on the chemical composition of the melt (slag) and the structure and composition of the refractory itself [1].

It is obvious that the optimal refractory structure in terms of these properties is its dense structure that will prevent the melt from penetrating into the lining body and thereby reduce the risk of destruction. On the other hand, a completely non-porous article has a significant mass, which is also undesirable. Consequently, the ideal structure of the refractory for ensuring the optimum performance properties will be the closed type porous structure that, on the one hand, provides the minimum mass of the product, on the other hand, it prevents the melt penetration and prevents its destruction.

Previous studies of the effect of the pressing and sintering mode made it possible to determine the mode [2] that provides the structure that is close enough to ideal. It is proposed to use alternating pressure as the pressing mode, which makes it possible to form a fairly homogeneous structure that, with a properly selected sintering mode, provides the closed type porosity. Based on the results of the studies, the parameters of the technology for manufacturing refractory chamotte bricks with optimal porosity and high thermal stability have been determined. The composition of the non-pressurized mass is as follows: fractions 2,5 - 3 mm chamotte: 55 %, fractions 0,1 - 0,3 mm chamotte: 5,5 %, clay suspension: 39,5 %. The moisture content of the mass is 3 - 4 %. Pressing should be performed within 12 seconds, the basic (initial) pressure is 22 MPa, after 7 - 8 seconds it increases to 27 MPa. Sintering is carried out at the temperature 1 250-1 270 °C within 12 hours.

Studying the porous structure of refractories have been carried out by the method of mercury porosimetry on porosimeter of the PascalPoreMaster 60 system. The results of the studies are shown in Figure 1.

EXPERIMENTAL STUDIES
Equipment and tools

The comparison of the porous structure of the refractory used at present (reference) and the structure of the refractory obtained according to the proposed compressing and sintering mode speaks in favor of the latter.

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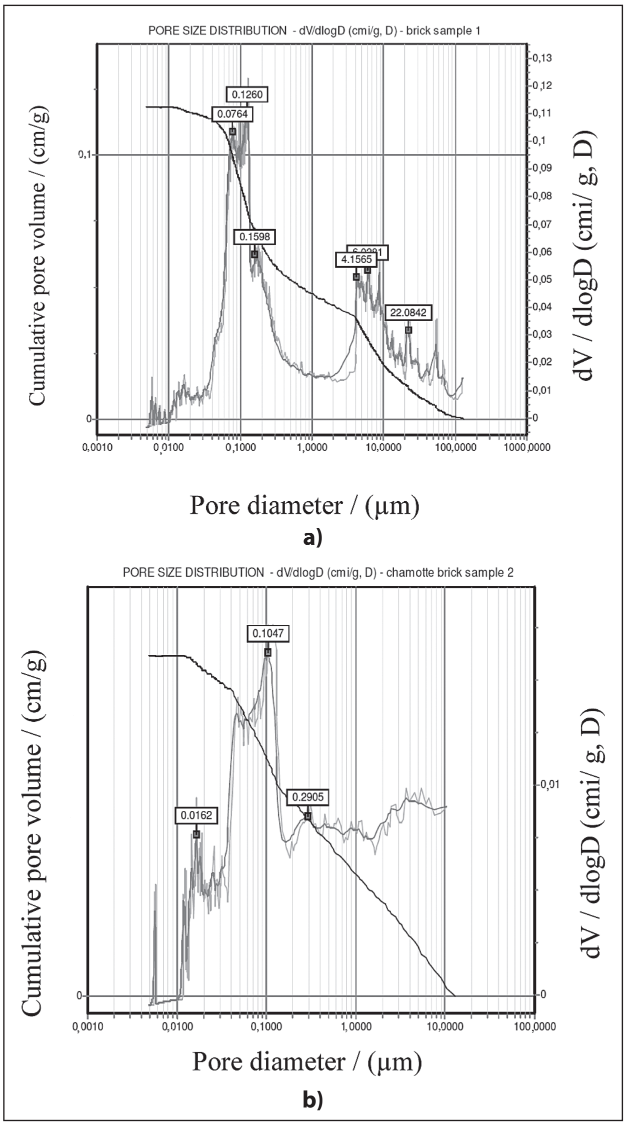

a)

b)

Figure 1 Pore distribution in chamotte bricks obtained using: a) a usual mode (reference); b) a variable load

Figure 1 shows that the nature of the pore distribution varies depending on the nature of the applied load. With a variable load the pore size distribution curve shifts towards smaller pores. The studies have shown that the largest pore volume when a variable load is applied is in the range of 0,1-0,3 µm, while for the reference this value is 0,7-1,0 µm. It is obvious that decreasing the average pore size and redistributing the pore volume towards the fine pores is a favorable factor, since it will help reducing the flow of slag into the pores and thereby increasing the refractory slag resistance.

The obtained test samples and the reference have been used for preparing samples to determine slag resistance. For this purpose cylindrical holes with the 15 mm diameter and 35 mm depth have been made in the samples. These holes have been filled with slag after smelting 35HMFL grade steel in the arc steel furnace. For comparison the same operation has been done with the reference. Then the samples have been placed in the NaberthermLHT furnace and kept at the temperature of 1 550 °C (the slag has been in the molten state) within 4 hours. After complete cooling the samples have been cut with the cross section (010) and the depth of penetration of the slag has been studied with magnification X50. The slag penetration has been determined at five points, the data of the studies are given in Table 1. The points for determining the penetration depth have been located radially around the central point.

Table 1 – **Determining the depth of slag penetration / mm**

No.	point 1 (center)	point 2 (10 cm from the center)	point 3 (10 cm from the center)	point 4 (10 cm from the center)	point 5 (10 cm from the center)	average number
Reference	4, 14	3, 87	3,98	3,81	3, 76	3,91
Experimental sample	2, 26	2, 19	2,16	2,17	2,17	2,19

The data in Table 1 show that the depth of the slag penetration in the reference sample is higher and averages 3,91 mm. For the experiment this value is reduced and makes 2,19 mm. Thus, this indicator is improved by almost 40 %.

The principal difference between the reference and the experiment is also the nature of changing the brick slag resistance depending on the site of sampling. For the reference the difference between the depth of penetration in the center and the periphery is about 9 %; at the same time for the experiment this value is only 4 % (Figure 2).

Such a difference in the depth of penetration in the center of the sample and at the periphery is due to the uneven structure of the brick. For the reference (obtained at constant compression pressure) non-uniform distribution of density and pore volume is characteristic, while in the test sample the difference in density and porosity between the center and periphery is leveled by the use of non-stationary pressure.

The same tendency has been observed when the slag produced during the melting of cast iron of the GCI25 grade has been used as the penetrating melt. For the reference the slag average penetration depth into the sample was 1,14 mm, for the test sample 0,95 mm. And for

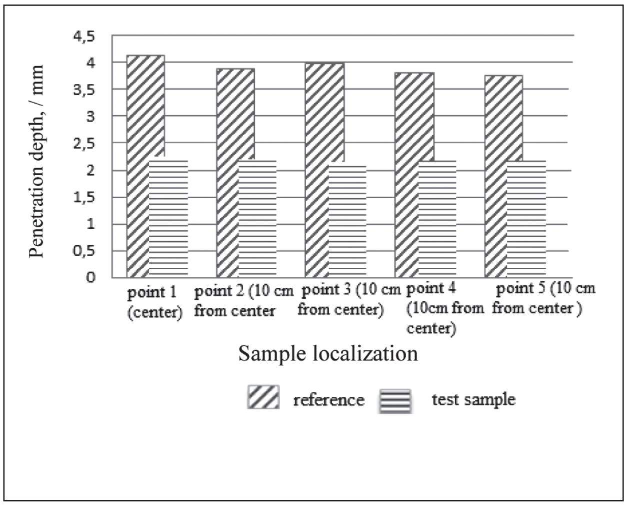

Figure 2 Diagram of changing slag resistance depending on the site of sampling

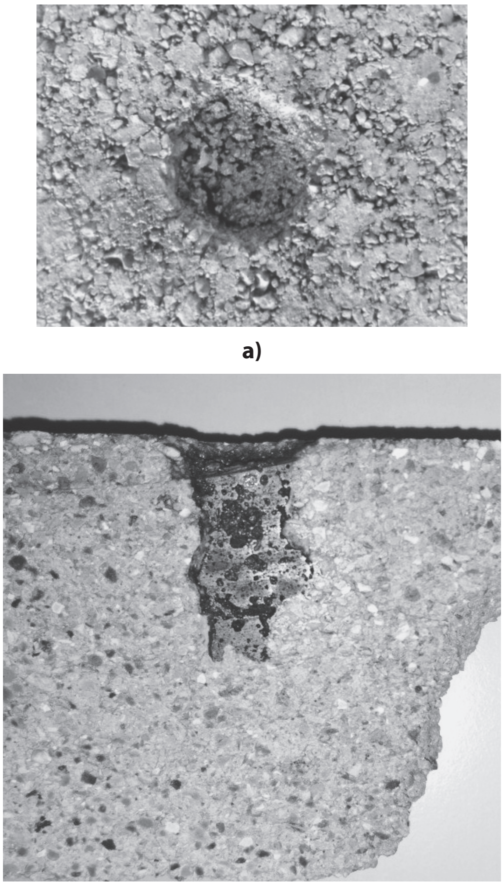
a)

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Figure 3 A sample after testing for slag resistance: a – sample surface, b – slag penetration into depth

Table 2 **Chemical composition of the melts used for determining brick slag resistance**

No.	1	2	3
Grade	GCl25	40	35HMFL
C	3,2-3,4	0,36- 0,44	0,3- 0,4
Si	1,4-2,2	0,17- 0,37	0,2- 0,4
Mn	0,7-1,0	0,5-0,8	0,4- 0,9
S	0,15	0,035	0,04
P	0,2	0,035	0,03
Fe	rem.	rem.	rem.
Ni	-	0,2	0,3
Cr	-	0,8- 1,1	0,8-1,1
Cu	-	0,3	0,2
Mo	-	-	0,08- 0,12
V	-	-	0,06- 0,12

Figure 4 A sample after several immersions

the reference the difference in the depth of penetration between the center and the periphery has been about 8 %, for the experiment 3 %.

The carried out studies of slag resistance and porosity have shown that reference samples made at constant pressure contain on the surface significantly larger pores than the test sample. This leads to easier and deeper penetration of the slag. Consequently, the use of a variable load during pressing helps reducing the size and the amount of open pores, which in turn leads to increasing slag resistance.

It is known [3, 4] that the thermal stability of the lining is affected not only by the quality of the lining itself, but also by the nature of the melt. In this connection experiments have been carried out to study the effect of the melt composition on heat resistance of bricks made using non-stationary pressure. For this the samples have been immersed in melts of various compositions (Table 2).

The test samples have been cylinders 80 mm in height and 30 mm in diameter (Figure 4). The samples have been formed in special sleeves using non-stationary pressure in accordance with the above-mentioned mode, then sintered at the temperature of 1 250 °C. The temperature resistance of the samples has been determined by the number of immersions into the melt at the temperature of 1 450 °C without destroying the integrity of the sample. The sample has been kept in the melt within 15 minutes, after which the sample has been removed. After cooling to the room temperature the sample has been again immersed in the melt. Separation of bricks into its components has meant the limit of heat resistance. Table 3 gives the data of the test sample heat resistance depending on the nature of the melt.

Table 3 **Sample heat resistance depending on the melt nature**

Sample No.	Melt grade	Number of immersions
1	GCl25	26
2	40 or carbon steel	21
3	35HMFL	18

The data of Table 3 show that the sample that is immersed in the melt No. 3 has the least heat resistance. It should be noted that at the experimental temperature the melts under study have different fluidity. It is obvious that fluidity has a great impact on heat resistance, because high fluidity promotes the melt flowing into the pores of the lining. Therefore, probably when we speak of the melt composition effect on heat resistance, in fact we speak of the fluidity impact.

CONCLUSION

Using non-stationary pressure during the proposed pressing and sintering mode in the process of manufacturing refractory bricks used for lining of smelting furnaces allows obtaining a uniform porous structure of closed type, a uniform density that increases the product slag resistance.

At this stage of the study it can be stated that at the same temperature the melt of the alloyed steel has a less negative effect on the refractory heat resistance than cast iron or carbon steel. The question which of the factors, composition or fluidity, has a greater impact on the refractory heat resistance is the subject of further research.

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Note: The responsible for England language is Nataliya Drag, Karaganda Kazakhstan