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THE INFLUENCE OF CARBON CONTENT ON THE CORROSION OF MGO-C REFRACTORY MATERIAL CAUSED BY ACID AND ALKALINE LADLE SLAG

VPLIV VSEBNOSTI OGLJIKA NA KOROZIJO OGNJEVZDRŽNEGA MATERIALA MGO-C V KISLI IN BAZIČNI PEČNI ŽLINDRI

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This paper describes an investigation of the influence of increasing carbon content on the corrosion of MgO-C refractory material by molten slag. The refractory material contained mass fraction of 98 % MgO, approximately 2 % Fe_2O_3, and graded quantities from 3 % to 18 % C. The corrosion was investigated in melts of reduction ladle slags at a temperature of 1600 °C in laboratory conditions. A sample of refractory material with dimensions of 10 × 10 × 100 mm was submerged into the molten slag and exposed to the corrosive effect of the slag for 60 min. After the expose of the refractory material the slag was cooled down and submitted to a chemical analysis. After a comparison of the MgO content in the slag before and after the corrosion test the amount of MgO content in the melt was determined and the degree of corrosion of the refractory material was quantified. The experiments were realised using final slags from the ladle furnace (LF), strongly alkaline slag $w(CaO)/w(SiO_2) = 4.43$, and also acidic slags $w(CaO)/w(SiO_2) = 0.94$ with different contents of CaF_2. The work was carried out within the frame of the projects EUREKA E!3580 and IMPULS FI-IM4/110.

Keywords: MgO-C refractory material, corrosion of refractory material, ladle slag

V članku so predstavljene raziskave vpliva naraščanja vsebnosti ogljika na korozijo MgO v raztaljeni žlindri. Ognjevzdržni material je imel masni delež 98 % MgO, okoli 2 % Fe_2O_3 in od 3 % do 18 % C. Kororzija je bila raziskana v laboratoriju v redukcijskih žlindrah pri temperaturi okoli 1600 °C. Vzorec ognjevzdržnega materiala z velikostjo 10 x 10 x 100 mm je bil potopljen 60 min. v žlindro, nato je bila žindra ohlajena in analizirana. S primerjavo vsebnosti MgO pred preskusom korozije in po njem, je bila opredeljena intenziteta korozije. Za preizkuse smo uporabili končno žlindro iz ponovčne peči (LF): močno bazično žlindro $w(CaO)/w(SiO_2) = 4.43$ in kislo žlindro $w(CaO)/w(SiO_2) = 0.94$ z različnimi dodatki CaF_2: Raziskava je bila izvršena v okviru projektov EUREKA E!3580 in IMPULS FI-IM4/110.

Ključne besede: ognjevarni material MgO-C, korozija ognjevarnega materiala, ponovčna žlindra

RESULTS

The chemical composition of the slags before the exposure is given in the **Table 1**.

Table 1 shows that the acidic slag contains very little of the CaF_2 (w = 0.82 %), and that the alkaline slag contains 7.18 % CaF_2, added to increase its fluidity.

The MgO content of the slags after exposure to the refractory material is shown in **Tables 2 and 3**. The tables also contain increments of the MgO content and the increments related to the initial MgO content in the slags (η_{MgO}). The six tested samples of refractory material differed only in terms of the carbon content, graded from 3 % to 18 %. However, sample 5 % contained 15 % C in addition to an antioxidant.

Figures 1 and 2 show the change of the MgO content in slags with respect to the carbon content in the refractory material.

In order to enable a comparison of the quantitative effect of carbon content in the MgO-C refractory material on its corrosion intensity by acidic and alkaline slag, the changes in the MgO and carbon contents in **Tables 1 and 2** were transformed according to Equations (1) and (2).

$$\bar{x}_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (1)$$

Table 1: Chemical composition and alkalinity of the slags used for the corrosion test
Tabela 1: Kemična sestava in bazičnost žlinder, ki sta bili uporabljeni za preizkuse korozije

Slag	Σ Fe	SiO_2	Al_2O_3	CaO	MgO	CaF_2	B1	B2
	(w/%)						(1)	
acidic	1.58	41.1	7.0	38.8	8.0	0.82	0.94	0.80
alkaline	0.75	13.7	13.5	60.7	5.6	7.18	4.43	2.23
$B_1 = \frac{w(CaO)}{w(SiO_2)}$ $B_2 = \frac{w(CaO)}{w(SiO_2) + w(Al_2O_3)}$								

Table 2: Changes to the MgO content in an acidic slag for different carbon contents in the refractory material
Tabela 2: Spremembe vsebnosti MgO v kisli žlindri pri različni vsebnosti ogljika v ognjevzdržnem materialu

Refractory material	ACIDIC SLAG				
	Carbon contents, $w(C)/\%$	$w(MgO)/\%$			$\eta_{MgO}/\%$
		Before the corrosion test	After the corrosion test	$w(\Delta MgO)$	
1	3		19.8	11.8	147.5
2	6		14.0	6.0	75.0
3	10	8.0	15.0	7.0	87.5
4	15		12.5	4.5	56.3
5	15 + antioxidant		12.8	4.8	60.0
6	18		12.1	4.1	51.2

$$\eta_{MgO} = \frac{w(MgO)_{po} - w(MgO)_{pred}}{w(MgO)_{pred}} \cdot 100\%$$

Table 3: Changes to the MgO contents in an alkaline slag for different carbon contents in the refractory material
Tabela 3: Spremembe vsebnosti MgO v bazični žlindri pri različni vsebnosti ogljika v ognjevzdržnem materialu

Refractory material	ALKALINE SLAG				
	Carbon contents, $w(C)/\%$	$w(MgO)/\%$			$\eta_{MgO}/\%$
		Before the corrosion test	After the corrosion test	$w(\Delta MgO)/\%$	
1	3	5.6	9.7	4.1	73.2
2	6		7.1	1.5	26.8
3	10		6.2	0.6	10.7
4	15		6.3	0.7	12.5
5	15 + antioxidant		6.3	0.7	12.5
6	18		6.7	1.1	19.6

$$\bar{y}_i = \frac{y_i - y_{min}}{y_{max} - y_{min}} \qquad (2)$$

where:

$\bar{x}_i$ is the transformed form of the independent variable of the quantity lg $w(C)$, 1

$\bar{y}_i$ is the transformed form of the dependent variable of the quantity lg $w(\Delta MgO)$, 1

x_i is the concrete value of the independent variable of the quantity lg $w(C)$, 1

y_i is the concrete value of the dependent variable of the quantity lg $w(\Delta MgO)$, 1

x_{max}; x_{min}, y_{max}; y_{min} are the maximum or minimum values of the variable quantities lg $w(C)$ and lg $w(\Delta MgO)$, 1

The quantities thus transformed were analysed with linear regression and the equations of the straight lines, shown in **Figures 3 and 4**, were obtained.

Figures 3 and 4 indicate that the similarities of the dependencies expressed by the correlation coefficient are, in both cases, close, and the value of P is even lower

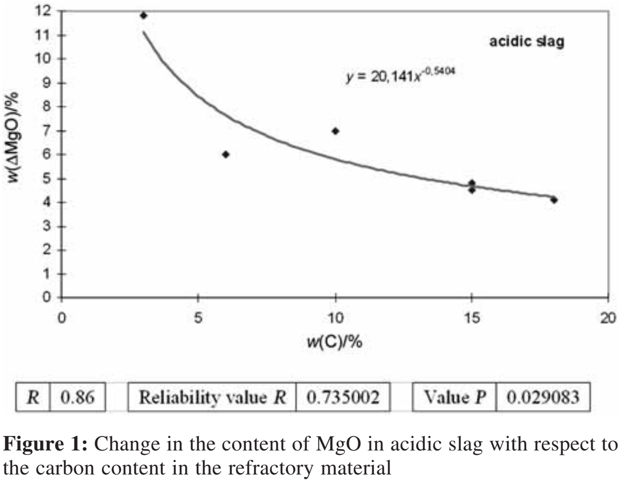

Figure 1: Change in the content of MgO in acidic slag with respect to the carbon content in the refractory material
Slika 1: Spremembe vsebnosti MgO v kisli žlindri v odvisnosti od vsebnosti ogljika v ognjevzdržnem materialu

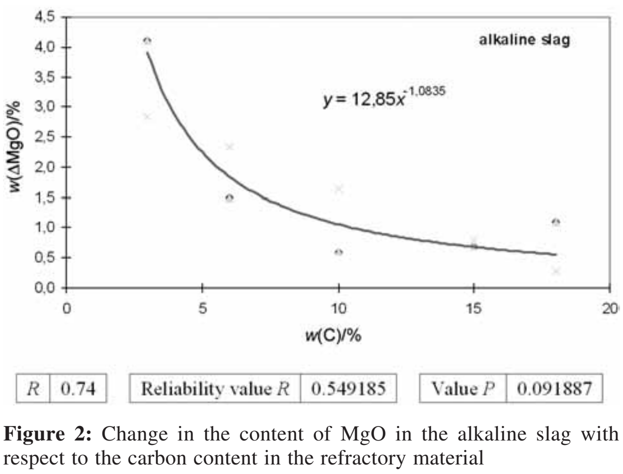

Figure 2: Change in the content of MgO in the alkaline slag with respect to the carbon content in the refractory material
Slika 2: Spremembe vsebnosti MgP v bazični žlindri v odvisnosti od vsebnosti ogljika v ognjevzdržnem materialu

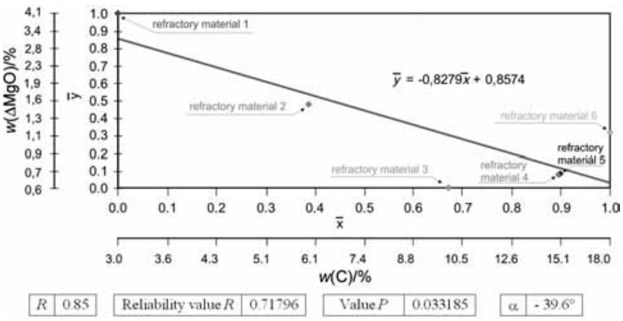

Figure 3: Dependence of w (ΔMgO) in the acidic slag on the carbon contents in refractory material after linear regression of the experimental data

Slika 3: Odvisnost ΔMgO v kisli žlindri pri različni vsebnosti ogljika v ognjevzdržnem materialu, linearna regresija eksperimentalnih rezultatov

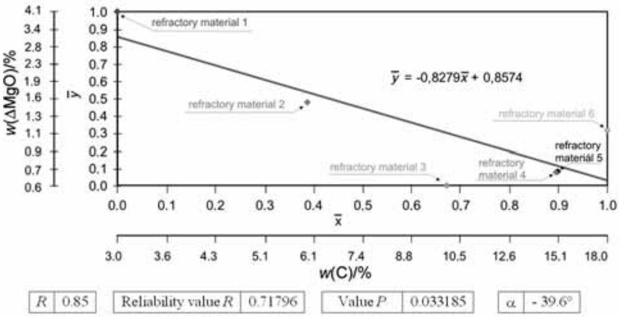

Figure 4: Dependence of w(ΔMgO) in the alkaline slag on the carbon contents in refractory material – evaluated by linear regression of the experimental data

Slika 4: Odvisnost ΔMgO v bazični žlindri pri različni vsebnosti ogljika v ognjevzdržnem materialu, linearna regresija eksperimentalnih rezultatov

than 0.05. The value P indicates the statistical significance of the tested factor. A value of $P < 0.05$ means that the tested factor has a statistically significant impact on the values of the given parameter. The effect of increasing the carbon content on reducing the wear of the MgO-C refractory material is significant for both types of slags – this is clearly evident from the slope of the straight line and the corresponding angle α, which approaches 45°. For the acidic slag the scatter of the values is smaller and the slope of the dependence is greater.

CONCLUSIONS

The acidic slag (B_1 = 0.94) dissolves a great deal more MgO-C refractory material, i.e., within the range 4.1–11.8 % MgO. The relative change of the MgO content in the slag is in the range η_{MgO} = 51.2–147.5 %.

The alkaline slag (B_1 = 4.43) dissolves significantly less MgO-C refractory material, i.e., within the range 0.6–4.1 % MgO, and the relative change of the MgO content is η_{MgO} = 10.7–73.2 %

The favourable effect of carbon in MgO-C refractory material on delaying the corrosion is stronger, particularly above 10 % C, for both slags, but more in the acidic slags with low contents of easily reducible oxides.

The dependence $w(\Delta MgO) = f(w(C))$ is hyperbolic and shows a good correlation with the experimental data.

The possible effect of an antioxidant was not detected, probably because the tests were performed with reduction ladle slags.

LITERATURE

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