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FERROSILICON OBTAINING USING IRON-SILICATE –FAYALITE

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ABSTRACT

The use of by-products stimulates the circular economy by reducing the footprint on the environment and the use of natural raw materials. In the copper industry, iron-silicate fines, also called fayalite, are generated as a result of flotation processes in the production of copper concentrates. The bulk of this material is landfilled. The material contains about 46% iron and about 27% silicon dioxide. For the production of ferrosilicon FeSi, quartzite, carbon reducer, and iron chips are used as standard. In the present paper, an attempt has been made to partially replace quartzite and iron chips with iron silicate-fayalite.

The quantitative ratio between the components for the production of ferrosilicon alloy was determined on the basis of the calculated material balance. The composition and amount of the alloy and slag were determined. The Gibbs energy for the different temperature retentions was calculated and an experimental equation for ΔG= f (T) in the temperature range 1250-1433K was derived. Ferrosilicon is used for oxidation, alloying, and modification in extractive metallurgy.

Keywords: *iron-silicate - fayalite, ferrosilicon, material balances, thermodynamics*

EXPERIMENTS

Globally, the landfill of fayalite in annual terms is about 50 million tons, of which in Bulgaria alone about 1 million tons. Ferrosilicon alloys include a large group of ferroalloys from the Fe-Si system and contains 20 to 90% silicon. For the production of FeSi, quartzite, and iron chips are used as standard. Ferrosilicon is usually smelted in closed submerged arc furnaces with a power of 22 to 93 MVA. The composition of FeSi45 alloy by standard is: **Si: 41-47 %, Mn: 2,0 %, Cr: 0,5 %, P: 0,05 %, S: 0,02 %, Al: 2,0 %.** The density of the alloy is ~3,27g/cm^3, melting point 1330–1350^{o}C.

The aim of the present work is to obtain a ferrosilicon alloy using iron silicate as an alternative raw material.

Table 1 - Chemical composition of charge materials, %.

%	iron-silicate	quartzite	coke	A^C coke	electrode mass	A^E electrode mass
SiO_2	27,18	99,2	-	47,52	-	50
Fe_2O_3	Fe_2O_3 -11,26 FeO- 51, 55	0,17	-	9,67	-	14
Al_2O_3	3,76	0,31	-	30,78	-	23
CaO	2,32	0,14	-	6,3	-	8,1
MgO	1,19	0,19		2,4	-	3
P_2O_5		-		0,58	-	-
ZnO	1,69	-	-	-	-	-
PbO	0,53	-	-	-	-	-
Cu	0,47	-	-	-	-	
MnO	0,06	-	-	-	-	-
S	-	-	0,5	-	-	2
C	-	-	85	-	80	-
A^C	-	-	10,92	-	7	-
W	-	0,18	2,45	-	-	-
V^C	-	-	1,63	-	13	-

Iron-silicate fines - fayalite contains iron oxide over 60% and 27% silicon dioxide. Particles with a size below 70 µm are about 80%, pycnometric density is 3,6 t/m^3, bulk density - 2,4 t/m^3, humidity - 10%. The material is finely dispersed.

Table 2 - Quantity and chemical composition of the obtained FeSi45 alloy

elements	Fe	Si	Al	Ca	Mg	Cu	Total
kg	49,46	46,87	2,31	1,03	0,23	0,47	101,31
%	49,29	46,69	2,30	1,03	0,23	0.47	100,00

Table 3 - Quantity and chemical composition of the obtained slag.

oxides RxOy	FeO	SiO_2	Al_2O_3	CaO	MgO	Total
kg	0,624	2,001	1,863	1,439	1,124	7,051
%	8,85	28,38	26,41	20,41	15,94	100,00

Table 4 - Material balance of ferrosilicon process.

Input charge materials			Output products		
	mass (kg)	%		mass (kg)	%
quartzite	75,00	30,65	alloy FeSi45	95,67	39,10
coke	65,60	26,81	slag	7,05	2,88
iron-silicate	100,0	40,87	gas	135,88	55,53
electrode mass	2,70	1,10	red.elements	5,30	2,17
Fe furnace shell	1,40	0,57	unbound	0,80	0,32
Total	244,70	100,00	Total	244,70	100,00

In the heating process, the change of the electromotive force (EMF) on the principle of galvanic cell with solid electrolyte ZrO_2 (CaO) and a reference electrode Mo-MoO$_2$ was registered.

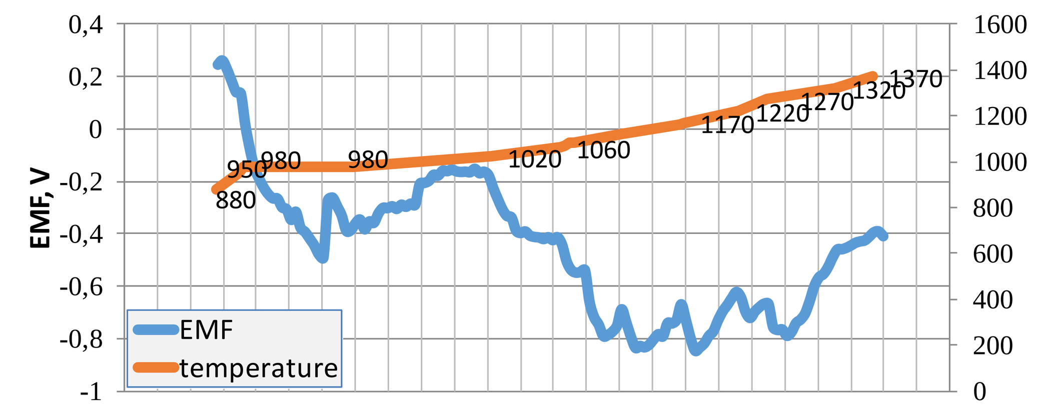
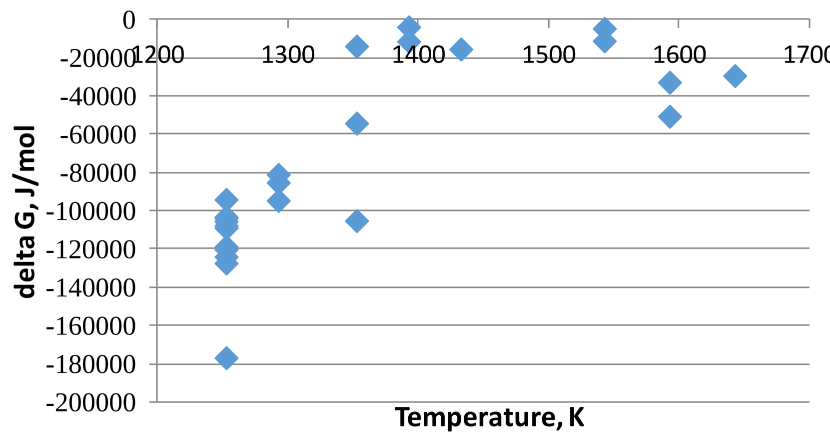


Figure 1 - EMF and temperature depending on time



$$E = \frac{R.T}{n.F}\left(\lg P''_{O_2} - \lg P'_{O_2}\right)$$

ΔG= -886801+616,7. T, J/mol

R^2=0,9308

Figure 2 - Dependence of ΔG=f(T)

During this period the reactions took place are

$3Fe_2SiO_4$ (s)+ O_2(g) → $2Fe_3O_4$(s) + $3SiO_2$ (s)
ΔG=-471750+160,06.T J/mol (1080T1340K)

Fe_3O_4(s)+CO=3FeO(s)+CO_2(g)
$ΔG^0$= 35 380- 40,16 T J/mol.

Equilibrium in this system is achieved at temperatures 1369 - 1661K.

CONCLUSIONS

A material balance was calculated, including a quantitative ratio between the components for the production of ferrosilicon FeSi45, using a by-product of copper production - iron silicate. Heating of the investigated charge was performed experimentally and EMF was registered. An equation for ΔG= f (T) in the temperature range 1250–1433 K was derived. The results of theoretical calculations show that it is possible to obtain FeSi45 according to the standard.

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