ISSN 2073-2244
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AKTET
Journal of Institute Alb-Shkenca
Revistë Shkencore e Institutit Alb-Shkenca

PROCESSING OF CONVERTER SLAG IN THE PROCESS OF OBTAINING Fe-Ni IN NEWCO FERRONICELI COMPLEX L.L.C. OF DRENAS

SH. IMERI[1], N. TAHIRAJ[1], H. MEHMETI[2]
[1]Newco Ferronikeli Complex L.L.Ci - Drenas, Kosova
[2]Faculty of Mining And Metallurgy in Mitrovica, University of Prishtina.
Email: shefik.imeri@kosovo-nickel.com

ABSTRACT

The Investigation introduce processing of converters slag into the smelting process in electro- reduction furnaces with arc during the production of Fe-Ni in NewCo Ferronikeli Complex L.L.C. in Drenas. With industrial tests is proved, that this type of material can be smelted inside the electro- reduction furnaces without difficultly, indicating in this case one increase of recovery of nickel and a production of electrics furnace slag with lover smelting point and better cast ability, improving smelting process of production Fe – Ni as well. Processing of converter slag into the smelting process, has effected in considerable decreasing of Limestone into the calcinations process in rotary kilns. As result of decreasing of using Limestone , in rotary kilns, consumption of black oil has been decreased and has been achieved production of calcine with temperature above 750 C. Except improvement to the metallurgical process of obtaining Fe-Ni, has been decreased the pollution of environment as well, producing less CO_2 in rotary kilns and electro-reduction furnaces.

Key words: electric arc furnace, converter slag, electric furnace slag, crude Fe-Ni, recycling, dissociation.

PËRMBLEDHJE

Punimi prezanton riqarkullimin e zgjyrës së konvertorëve në procesin e shkrirjes, në furra elektro – reduktuese me hark elektrik për prodhimin e Fe-Ni në shkritoren e ferronikelit të ri në Drenas. Provat industriale kanë dëshmuar se ky lloj materiali mundet të shkrihet pa vështirësi në furrat elektro-reduktuese duke ndikuar në rritjen e shkallës së shfrytëzimit të nikelit si dhe në prodhimin e zgjyrave të furrave elektrike me pikë shkrirje ma të ulët dhe me rrjedhshmëri ma të mirë, duke e lehtësuar procesin e shkrirjes së prodhimit të Fe-Ni. Rikthimi i zgjyrës së konvertorëve në procesin e shkrirjes, ka ndikuar edhe në zvogëlimin e konsiderueshëm të përdorimit të sasisë së gurit gëlqeror në procesin e fërgimit në furra rrotulluese. Si rezultat i zvogëlimit të përdorimit të gurit gëlqeror, në furra rrotulluese, është zvogëluar konsumi i mazutit dhe është arritur të prodhohet materiali i fërguar me temperaturë mbi 750 ^{0}C. Përveç përmirësimit të procesit metalurgjik të përfitimit të Fe-Ni, është zvogëluar edhe shkalla e ndotjes së mjedisit, duke prodhuar më pak CO_2 në furra rrotulluese dhe furra elektro-reduktuese.

Fjalët kyçe: furrë me hark elektrik, zgjyrë e konvertorit, zgjyrë e furrës elektrike, Fe-Ni i papërpunuar, riqarkullim, disocim.

1. INTRODUCTION

The aim of this investigation was recycling of converter slag into the smelting process of obtaining Fe-Ni, in order to improve the metallurgical process of obtaining Fe-Ni and consuming this material which contain considerable amount of Ni and since 2007 was considering as sterile and valueless material and as such it has been unusable. Smelting test of converter slag has been carried out at the Smelting Complex in NewCo Ferronikeli Complex L.L.C.- Drenas.

2. CONVERTER SLAG AND ITS PRODUCTION

In order to eliminate S, Si, Cr, P,C and other impurities, as well dressing of Ni content, the crude ferronickel goes for refining in vertical converter by technical O_2. In the converter the impurities are eliminated on the basis of selective oxidation of iron by oxygen. Limestone the size 16 – 32 mm is used for desulphurisation and obtaining of slag.

Slag of converter after cooling it is subject to magnetic separation and after the electromagnetic separation, the nickel concentrate is returned back to the converter for smelting, unified with liquid metal. Remaining slag is returned back in the smelting process mixing with ores. Productions parameters of Fe-Ni for operation period January – June 2009 are presented in tables 1, 2 and 3.

Month	Charges	FeNi(tn)	Ni(tn)	Ni/charge	Nr of charges converter 1	Nr of charges converter 2	Recovery	Efectiv time(min)/charge	Total time(min)/charge
January	106	1336.4	339.9	3.21	53	53	96.84	39.57	89.95
February	113	1457.2	354.9	3.14	64	49	96.2	40.22	92.61
March	120	1690.51	435.4	3.63	75	45	98	40.05	86.88
April	118	1722.9	452.8	3.84	50	68	98	46.19	103.92
May	121	1875.0	454.5	3.76	74	47	97.43	38.66	80.6
June	140	2201.8	554.5	3.96	78	62	101.8	40.9	106.9
Total	718	10283.8	2591.98	3.61	394	324			

Table 1. Charges- commercial Fe-Ni recovery.

Month	Ni(%)	Fetot(%)	SiO_2(%)	CaO(%)	MgO(%)	quantity(TN)
january	0.236	58.3	3.28	12.94	3.77	2520
February	0.22	56.4	3.4	13.4	3.6	2500
March	0.233	59.25	2.36	13.02	3.54	2500
April	0.24	58.74	1.63	12.74	3.58	2600
May	0.255	57.99	2.93	10.54	3.18	2269
June	0.312	60	2.78	9.99	3.06	3200
TOTAL	0.2519863	58.524877	2.7229309	12.038364	3.442544102	15589

Table 2. Converter slag analysis .

Month	Ni(%)	Co(%)	S(%)	Si(%)
January	25.44	1.03	0.12	0.01
February	24.25	0.91	0.09	0.01
March	25.21	0.96	0.11	0.01
Aprile	26.28	0.97	0.12	0.01
May	24.24	0.97	0.12	0.01
June	25.2	0.93	0.12	0.01

Table 3. Commercial Fe-Ni

Bay the above mentioned parameters we can see, one electric furnace is produced around 35000 t of converter slag per year, while with two electric furnaces, around 70000t converter slag per year. This quantity of slag, despite considerable amount of Ni 0,25 – 0,35% Ni and low amount of humidity 0,6% H_2O, because of technical reason wasn't used into the smelting process of obtaining Fe-Ni.

3. Processing of converter slag in smelting process of obtaining Fe-Ni

After additional crushing up to 20-50 mm, the converter slag has been processed in smelting process of obtaining Fe-Ni.

3.1 Treatment of converter slag in rotary kiln

As typical examples of industrial treatment of converter slag into the rotary kiln, we will present two cases as it follows: - Adding of converter slag without Albanian ore. - Adding of converter slag in combination with Albanian ore.

Working parameters of rotary kiln while operation with converter slag:

Dated on 12.07.2009, rotary kiln nr2 was operating as follow:

Capacity 70t/hr
Lignite 8,5%
Limstone 2,5%,

Ore composition:
Gllavica ore 47%
Cikatova ore 37,6%
Suka 1 ore 9,4%
Converter slag 6%
ε =100%

Charge composition:
Gllavica ore 32,9t
Cikatova ore 26,32t

Suka1ore 6,58t
Converter slag 4,2t
Lignite 5,9t
Limstone 1,75t
Charge quantity 77,65t
Chemical composition of ore, calcine, temperature of material and gases are given in table 4, 5 and 6.

Ni %	Fe %	Co %	Cr_2O_3 %	CaO %	MgO %	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	H.P %	Humidity %
0,92	24,21	0,06	1,94	7,30	6,69	2,79	30,34	34,62		26,7
0,94	16,50	0,04	1,00	8,80	8,18	2,72	37,18	23,59		29,30
1,22	18,08	0,05	1,06	2,26	8,26	3,32	46,00	25,85		25,20

Table 4. Chemical composition of ore

Ni %	$Fe_{tot.}$ %	Co %	Cr_2O_3%	CaO%	MgO%	Al_2O_3%	SiO_2%	C_{fix}%	$Fe_{met.}$%	FeO %	Fe_2O_3 %
1,17	17,87	0,04	1,37	4,25	12,29	2,46	44,74				
1,06	16,08	0,03	1,10	6,15	11,14	1,30	42,27	3,50	0,19	13,14	8,15
1,18	16,62	0,04	1,16	3,33	12,50	1,93	44,16	2,40	0,19	12,42	9,72

Table 5. Chemical composition of calcine

OP – Optical Pyrometer.

Table 6. Temperature of material and gases inside rotary kiln

Working parameters of rotary kiln while the operation with converter slag and Albanian ore to:

Dated on 09.08.2009, rotary kiln nr2 was operating as follow:
Capacity 85t/hr
Lignite 8,5%
Limstone 3,5%

Ore composition:
Gllavica ore 52%
Cikatova ore 32,135%
Albanian ore 8,04%
Filipinas ore 4,02%
Converter slag 3,5% ε =100

Charge composition
Gllavica ore 44,46t
Cikatova ore 27,314t
Albanian ore 6,834t
Filipinas ore 3,417t
Converter slag 2,975t
Lignite 7,225t
Limstone 2,975t
Charge quantity 95,2t

Chemical composition of ore, calcine, temperature of calcine and gases are given in table: 7, 8 and 9.

At the first example, for capacity of the rotary kiln of 70t/hr, in the charge was adding 6% cs/hr, or 4,2 tcs/hr $\times$ 0.995 $\times$ 58,52 %Fe_{total} = 2,44 Fe_{total}/hr. The quantity of reducing $CaCO_3$ due to increasing of converter slag is 7.5% of the overall charge, or rotary kiln capacity of 70 t / hr: 70t/hr 7,5%=5,25 t $CaCO_3$ /hr, or considering the moisture of $CaCO_3$ from 0.85%, then 5,25 t $CaCO_3$ 0,9915 = 5,205t $CaCO_3$/hr. The practical results proved that≈60% of $CaCO_3$ dissociated in rotary kiln under reaction:

$$CaCO_3 \rightarrow CaO + CO_2$$

520 kg$CaCO_3$/hr x 60% = 31223 kg$CaCO_3$ x 44/100 = 1374,12 kgCO_2/hr,
Or 1374,12 kg CO_2/hr x 22,4/44 = 699,55 $m^3N CO_2$/hr.

Which means that for the capacity of 70t/hr of the rotary kiln has been produced less 699, 55 $m^3N CO_2$/hr.
For 1t dry ore has been produced less CO_2:

699,55 $m^3N CO_2$/51,056 t DO = 13,7 $m^3N CO_2$/ t DO.

Quantity of Ni which is increasing inside of rotary kiln due to converter slag for 1t dry ore (DO) is:

4,2tc. slag x 0,995/51,058 t DO = 0,082tc. Slag/t DO x 0,253%Ni = 0,000207,
or 0,207 kg Ni/t DO.

Ni %	Fe %	Co %	Cr_2O_3%	CaO %	MgO%	Al_2O_3%	SiO_2%	Fe_2O_3 %	H.P %	Humidity %
1,11	15,79	0,04	0,95	5,77	8,87	6,75	42,51	22,57		34,81
0,82	23,65	0,04	1,53	7,25	8,50	4,54	22,32	33,61		22,85
1,33	17,70	0,06	1,15	5,42	8,07	3,01	40,77	25,31		30,48

Table 7. Chemical composition of ore

Ni %	Fetot. %	Co %	Cr2O3%	CaO %	MgO%	Al2O3%	SiO2%	Cfix%	Femet.%	FeO %	Fe2O3%
1,08	20,33	0,05	1,44	4,04	11,12	2,82	44,66	1,75			
1,19	17,02	0,04	1,36	4,90	10,34	2,25	45,44	3,90	0,53	16,03	5,82
1,17	21,98	0,05	1,91	3,73	8,87	3,72	44,14	3,80	0,25	12,97	16,70

Table 8. Chemical composition of calcine.

Temp.	M8	M7	M6	M5	M4	M3	M2	M1	G7	G6	G5	G4	G3	G2	G1	G0
OP °C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
760	826	516	822	594	342	331	244	160			839	589	509	448		228
760	825	393	769	515	314	302	226	170			807	574	516	426		234
756	816	302	660	401	293	310	266	205			740	568	517	415		242

Table 9. Temperature of material and gases inside the rotary kiln

Ni %	Fe %	Co %	Cr%	Si %	Cu %	S%	C%
12,53	86,53	0,42	0,13	0,04	0,02	0,57	0,19
12,36	86,79	0,42	0,12	0,01	0,03	0,57	0,19
12,43	87,11	0,42	0,12	0,02	0,03	0,57	0,20

Table.10. Chemical composition of crude Fe-Ni

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %	MnO %	Cr2O3 %	Al_2O_3%
0,07	56,10	14,83	19,13	6,82	16,39	0,17	2,20	2,23
0,07	56,41	14,44	18,62	6,75	16,97	0,18	2,14	2,18
0,07	54,71	14,07	18,15	6,51	16,38	0,19	1,92	2,14

Table. 11. Chemical composition of electric furnace slag

Ni %	Fe %	Co %	Cr%	Si %	Cu %	S%	C%
12,53	86,53	0,42	0,13	0,04	0,02	0,57	0,19
12,98	84,46	0,48	0,32	1,18	0,03	0,57	0,41
13,32	84,08	0,48	0,30	1,83	0,03	0,60	0,38

Table 12. Chemical composition of crude Fe-Ni

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %	MnO %	Cr2O3 %	Al_2O_3%
0,06	60,89	15,17	19,56	6,48	11,68	0,35	1,54	2,24
0,08	60,69	15,74	20,30	6,37	11,40	0,37	1,51	2,23
0,07	59,15	15,15	20,31	6,26	11,25	0,37	1,48	2,20

Table 13. Chemical composition of electric furnace slag

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %	MnO %	Cr2O3 %	Al_2O_3%
0,07	56,10	14,83	19,13	6,82	16,39	0,17	2,20	2,23

Table 14. Chemical composition of electric furnace slag with increasing quantity by 5,43% F_{total}

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %
0,07	58,49	9,41	12,08	7,11	17

Table 15. Chemical composition of electric furnace slag with less of 5,43 %Fe_{total}

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %	MnO %	Cr2O3 %	Al_2O_3%
0,06	60,89	15,17	19,56	6,48	11,68	0,35	1,54	2,24

Table16.Chemical composition of electric furnace slag with increasing quantit by 3,27% Fe_{total}

Ni %	SiO2 %	Fe %	FeO%	CaO %	MgO %
0,07	61,2	11,4	14,65	6,61	11,93

Table 17.chemical composition of electric furnace slag with less of 3,27% Fe_{total}

3.2 Treatment of converter slag in electric furnace

Products of electric furnace for the first example are given in table 10, 11, while for second example in table 12, 13.

Additional quantity of converter slag, is increasing the quantity of Fe_{total} into electric furnace slag and Ni quantity in crud Fe-Ni as follow:

Chemical composition of electric furnace slag with increasing of Fe_{total} by 5,43% is given in table 14, while with less Fe_{total} by 5,43% is given in table 15.

Chemical composition of electric furnace slag with increasing of Fe_{total} by 3,27% is given in table 16, while with less Fe_{total} by 3,27% is given in table 17.

For first example:

Increasing quantity of Fe_{total} inside electric furnace slag is:

51,058t DO/hr x 88% = 44,93$t_{elec.fur.slag}$ /hr,

and 2,44t Fe_{total} /hr x 100/44,93$t_{elec.fur.slag}$ /hr = 5,43%$Fe_{total.}$

The practical results proved that≈40% of $CaCO_3$ has dissociated inside electric furnace under reaction.

$CaCO_3 \rightarrow CaO + CO_2$

520 kg $CaCO_3$ /hr x 40% = 2082 kg $CaCO_3$/hr x 44/100 = 916,08 kg CO_2/hr,

or 916,08 kgCO_2/hr x 22,4/44 = 466,368 $m^3 NCO_2$/hr

Which means that for the capacity of 70t/hr of the rotary kiln inside the electrical furnace has been produced less 466, 368 m^3 NCO_2 /hr.

For 1t dry ore has been produced less CO_2:

466,368 m^3NCO_2/51,056t DO = 9,13 m^3NCO_2/t DO.

4. RESULTS AND DISCUSSION

Results from first example: .

Increased quantity of Fe $_{total}$ /t DO: 0,0479t Fe_{total} /t DO.

Decreasing quantity of CO_2 in rotary kiln gases: 13,7 m^3NCO_2/t DO.

Decreasing quantity of CO_2 in electric furnaces gases: 9,13 m^3NCO_2/t DO.

Increased quantity of Ni from converter slag: 0,207 kg Ni/t DO.

Increased quantity of Fe_{total} in electric furnace slag: 5,43% $Fe_{total.}$

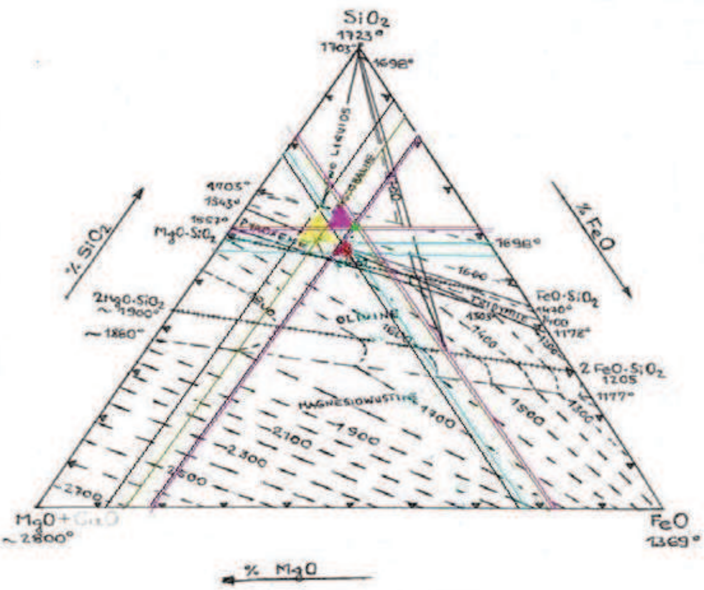

Fig 1. Three components diagram: MgO+FeO+SiO2

Results from second example:

Increased quantity of Fe_{total} /t DO: 0,028t Fe_{total} /t DO.

Decreasing quantity of CO_2 in rotary kiln gases: 12,25 m^3NCO_2/t DO

Decreasing quantity of CO_2 in electric furnaces gases: 8,16 m^3NCO_2/t DO.

Increased quantity of Ni from converter slag: 0,123 kg/t DO

Increased quantity of Fe_{total} in electric furnace slag: 3,27% Fe_{total}

From three components diagram (fig.1) we can compare the liquid temperature of electric furnace slag for 2 examples, depending from chemical composition of slag

First example – Operation only with converter slag

a). With converter slag

b).Without converter slag:

SiO_2 = 56,1%; SiO_2 = 58,49%; MgO + CaO = 16,39% + 6,82% = 23,21%; MgO + CaO = 17% + 7,11% = 24,11%; FeO = 19,13%; FeO = 12,08%; Tl ≈ 1500° C. Tl ≈ 1600° C.

Second example – converter slag and Albanian ore

a).With converter slag and Albanian ore: b).Without converter slag:

SiO_2 = 60,89%; SiO_2 = 61,2%; MgO + CaO = 11,68% + 6,48% = 18,16%; MgO + CaO = 11,93% + 6,61% = 18,54%; FeO = 19,56%; FeO = 14,65%; Tl ≈ 1650° C Tl ≈ 1680° C.

By facilitation of the process for diffusion of hot gases, through the material inside the rotary kiln has improved roasting process of calcine and has reduced quantity of sticking calcine for 50%. Such improvement of technological process of the roasting, has created condition for increasing of quantity and quality of calcine , producing more calcine, with temperature over 750°C (that in the past was around 450°C) and pre-reduction degree about 56% (that was almost 0%) that has indicated directly in decreasing of black oil consumption up to 53kg/t calcine and decreasing of electrical specific consumption in electrical furnace from 604KWh/t calcine that was in 2007 in 514KWh/t calcine in July 2009.

Is decreased additional quantity of sterile material $CaCO_3$ in charge from 10% up to 3,5%- 2,5%, that has indicated positively in increasing of percentage of Ni in calcine for o,207kgNi/t DO (in the first example), for 0,123kgNi/t DO (in the second example) and in decreasing of quantity of CO_2 in rotary kiln gases for 13,7m^3NCO_2/t DO (in the first example), for 12,25$m^3NCO_{2/}$/t DO (in second example) and in the electric furnace gases for 9,13 m^3NCO_2/t DO (in the first example) and 9,13m^3NCO_2/t DO (in second example).

By increasing quantity of Fe_{total} in electric furnace slag for 5, 43% (for first example) and 3,72% (for second example) in both cases have been created satisfactory condition, that by decreasing of acidity of electric furnace slag , to decrease the smelting point of it and such case to have a technological process so equilibrium in electric furnace, with continuous flow of slag (approximately is preserved condition: FeO + MgO + CaO ≈ 40%). In the first example:

FeO + MgO + CaO = 42,34%

and in the second example:

FeO + MgO + CaO = 37,72%

If we would operate without converter slag for two ceases, we would have these parameters:

FeO + MgO + CaO = 36,19% (for first example) and

FeO + MgO + CaO = 33,19% (for second example).

Has been increased considerably the recovery of Ni, from 57, 5% in the 2007, 91, 19% in 2008 and in July 2009 87, 3%.

5. CONCLUSIONS

Industrial investigation has been done at smelting complex of Newco Ferroniceli Complex in Drenas.

By industrial experiments has been proved, that converter slag could be treated without difficulty in metallurgical process of obtaining Fe-Ni, recycling it into the smelting process as single component or in mixture with Albanian ore.

Recycling of converter slag in smelting process of obtaining Fe-Ni, except improvement of metallurgical process has been indicated positively in decreasing of pollution for environment as well. In the future should investigate new methods for further improving of metallurgical process of obtaining Fe-Ni, eliminating at all using of CaCO3

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