KOMBINIRANI METODI ZA NISKOPROCENTNI NIKLONOSNI LATERITI

COMBINED PROCESSING METHOD OF LOW-GRADE NICKEL BEARING LATERITES

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Abstrakt

Kombinacijata na sovremeni trendovi i razvoj ja naglasuvaat superior-nosta na sulfidnite minerali, no mo`at istovremeno da sugeriraat za novi istra`uvawa i proektirawe za dobivawe na nikel od lateriti. Listata na sovremeni operacii ili postapki za niklonosni lateriti e sledna: Topewe do feronikel, Topewe do niklov kamenec, Redukcisko pr`ewe-amonija~no lu`ewe i lu`ewe pod visok pritisok so sulfurna kselina.

Nasporoti ovie spomnati metodi, postojat golem broj na obidi za razvoj na postapki kako alternativni procesi koi vklu~uvaat: Lu`ewe so azotna kiselina; Lu`ewe so halogenidi, osobeno procesot na Segregacija i drugo.

1. Introduction

In the meantime none of these progressed past the bench or pilot plant scale because of various technical, economic or environmental factors or problems. Nevertheless, the renewed interest in laterites in nineties has sprawned a number of new possibilities and hopefuls, as well as a revival of interest in some older ones.

The same is the interest and perspective of the segregation process. The previous investigations in the field of the metal compounds chlorination, esspecialy the chlorination of the refractory nickel minerals: garnierite and nontronite, by the chlorine, HCl or NaCl or $CaCl_2$, were determined directions, confirming the perspective of the mentioned process for the treatment of the low grade and complex minerals-laterites. The principal scheme of the segregation process following by the classical concentration methods - flotation or magnetic separation and hydrometallurgical treatment - ammonia leaching is shown on the figure 1. The combined methods for enriching of the oxide-silicate nickel ores are these through which by heating the ore with coke and $CaCl_2$ at high temperature metal nickel is formed on the present coke, or on the silicates which are the component parts of the ore. There are the following steps, as it's shown on the scheme: the formation of the HCl and H_2; the chlorination of the Ni-ferite and Ni-silicates to Ni-chlorides, Fe-chlorides and the reaction of reduction to Ni-metal on the coke parts or quartz parts. The next steps are flotation, magnetic separation or ammonia leaching of the formed Ni-metal.

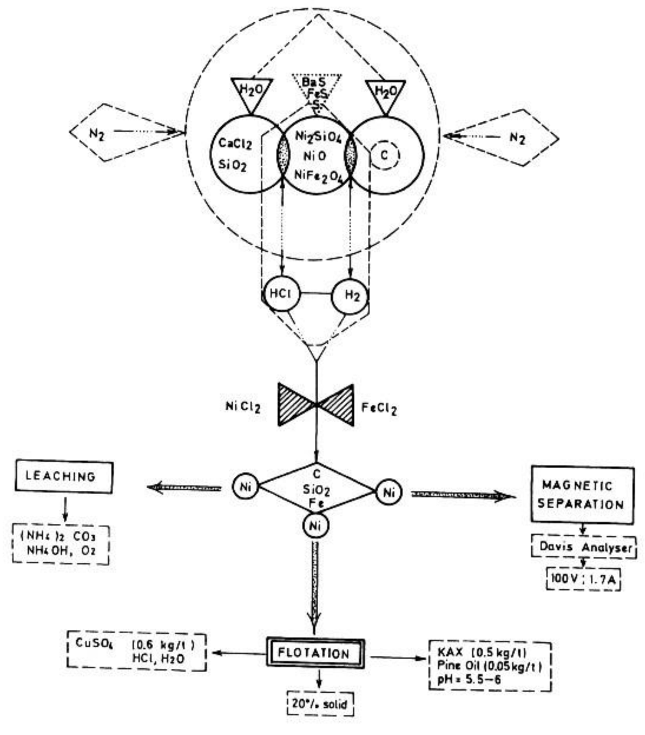

Fig. 1 Principal scheme of segregation process

Serpentine: $Mg_6 (Si_4O_{10}) (OH)_8$

Fe^{2+}; Fe^{3+} Al; Cr	Fe^{3+}; Al; Cr

$(Mg, Fe^{2+}, Ni)_{6-x} (Fe^{3+}, Al, Cr)_x / Si_{4-x} (Fe^{3+}, AL, Cr)_x O_{10} / (OH)_8$

Talc: $(Mg, Ni)_3 (Si_4O_{10}) (OH)_2 H_2O$

Fe^{3+}, Fe^{2+}	Al

$(Mg, Ni)_3$ / $Si_{3,75}$ $Al_{0,25}$ O_{10} / $(OH)_2$ H_2O - chlorite (saponit)

The following chemical reactions have explained the scheme and complex segregation high temperature process:

$$CaCl_2 + H_2O = CaO + 2HCl$$
$$CaCl_2 + H_2O + SiO_2 = CaO.SiO_2 + 2HCl$$
$$CaCl_2 + ½\ Al_2O_3.2SiO_2.2H_2O = CaO.Al_2O_3.2SiO_2 + 2HCl$$
$$CaCl_2 + H_2O + MgO.SiO_2 = CaO.MgO.SiO_2 + 2HCl$$
$$CaCl_2 + H_2O + Fe_2O_3 = CaO.Fe_2O_3 + 2HCl$$

$$NiO + 2HCl = NiCl_2 + H_2O$$
$$NiSiO_3 + 2HCl = NiCl_2 + H_2O + SiO_2$$
$$Ni_2SiO_4 + 4HCl = 2NiCl_2 + 2H_2O + SiO_2$$
$$NiFe_2O_4 + 6HCl = NiCl_2 = 3H_2O + 2FeCl_2$$

$$2NiO.SiO_2 + 6HCl + BaS\ (FeS) = 2NiCl_2 + BaCl_2\ (FeCl_2) + 2SiO_2 + 2H_2O + H_2S$$
$$NiFe_2O_4 + 8HCl + BaS\ (FeS) = NiCl_2 + BaCl_2\ (FeCl_2) + 2FeCl_2 + 3H_2O + +H_2S + ½\ O_2$$

$$NiCl_2 + H_2 = Ni + 2HCl$$
$$NiCl_2 + H_2O + C = Ni + 2HCl + CO$$
$$NiCl_2 + H_2O + CO = Ni + 2HCl + CO_2$$
$$NiCl_2 + Fe = Ni + FeCl_2$$

The thermodynamic characteristic of the above mentioned reactions are performed using the standard isobaric potential and for working on the kinetic characteristic of the chlorination - segregation process have used the equations which describe the reaction controlled by three-dimensioned surfaces advancement (diffusion-controlled reactions and reaction-controlled reactions).

2. The general behaviour of the nickel bearing minerals

For the metallurgical calculation Ni in the oxide-silicated minerals may be shown by means of the general formula:

$$NiSiO_3.mMgSiO_3.nH_2O$$

or by possible transformation:

$$(Si_2O_5)^{2-} \Rightarrow (SiO_4)^{2-} \Rightarrow (SiO_3)^{2-}$$

$$NiO.2SiO_2 \Rightarrow 2NiO.SiO_2 \Rightarrow NiO.SiO_2$$

$$\Downarrow \qquad \Downarrow$$

olivine *piroxen*

the amorphus crystal structure ⇒⇒⇒ the stable crystal structure

The iron in these Ni - bearing minerals and ores is appeared as $Fe_2O_3.nH_2O$ and as a nontronite $(Fe,Al)_2(Si_4O_{10})(OH)_2.nH_2O$.

The oxide-laterite ores are with low nickel content. The generaly, nickel and iron are as Ni-Fe-limonite $(Fe,Ni)O(OH).nH_2O$ or in the talc form.

3. The experimental investigations from the nickel synthetic mixures by segregation process

The segregation process of the synthetic nickel mixures (NiO, $NiO.Fe_2O_3$, $2NiO.SiO_2$) with gangue mineral's compounds (CaO,MgO, Fe_2O_3,SiO_2) and chlorination addition $CaCl_2.2H_2O$, reduction coke is conducted at the temperature (1023-1223^oK) with retaining time (20-120 min) in the atmosphere of N_2.

Table 1. Chemistry composition of the synthetic mixtures

Compounds	Synthetic mixures (%)		
	I	II	III
NiO	1.36	–	–
Ni_2SiO_4	–	1.91	–
$NiFe_2O_4$	–	–	4.28
Fe_2O_3	20.00	20.00	20.00
SiO_2	56.00	56.00	56.00
Al_2O_3	5.00	5.00	5.00
CaO	1.00	1.00	1.00
MgO	6.14	5.59	3.22
$CaCl_2$	7.50	7.50	7.50
C	1.00	1.00	1.00
BaS	2.00	2.00	2.00
Total	100.00	100.00	100.00
Ni (%)	1.07	1.07	1.07

Table 2. Result obtained from segregation - flotation - magnetic separation -ammonia leaching

Mixture	T (^{0}C)	t (min)	Flotation	Magnetic sep.	Leaching
			R_{Ni} (%)	R_{Ni} (%)	R_{Ni} (%)
		20	1.62	1.50	1.70
	750	40	3.41	3.05	3.65
		60	3.89	3.20	4.10
		20	8.43	7.80	8.70
I	850	40	17.66	16.50	18.25
NiO +		60	25.43	21.25	27.10
2% BaS		120	45.40	42.30	46.50
		20	28.32	25.10	30.05
	950	40	40.78	37.20	42.45
		60	44.78	40.00	5.75
		120	60.98	56.70	65.10
		20	1.90	1.70	2.15
	750	40	3.82	3.25	4.20
		60	5.48	4.85	6.10
		20	14.36	12.10	16.10
II	850	40	25.17	22.10	27.10
Ni_2SiO_4 +		60	37.40	33.45	40.00
2% BaS		120	55.60	51.50	56.50
		20	36.85	32.40	39.60
	950	40	47.24	43.70	50.00
		60	58.73	55.10	64.05
		120	76.35	71.35	78.40
		20	2.18	1.70	2.55
	750	40	3.82	3.25	4.20
		60	6.84	5.25	7.65
		20	17.55	16.50	18.25
III	850	40	28.40	25.05	30.00
$NiFe_2O_4$ +		60	44.65	40.00	46.00
2% BaS		120	58.60	55.00	61.30
		20	33.42	30.15	35.10
	950	40	50.41	44.10	52.05
		60	59.25	56.00	65.00
		120	80.70	76.40	82.10

4. The experimental investigations from the nickel natural ores by segregation process

The experimental investigations by the addition-activator 2% (BaS,FeS,S or $BaSO_4$) influence on the metallurgical indicators from combined processes **segregation-flotation-magnetic separation-ammonia leaching** are shown about the ore samples from various deposits. The partial chemistry composition from the ore samples (100% - 0,150mm and 100% - 0,100mm) are from 0,85%Ni Studena voda, 0,97%Ni Rzanovo (both in Macedonia), 1,2%Ni and 1,86%Ni Rudjinci I & II (both in Yugoslavia).

Table 3. Results obtained from segregation - flotation of the ore samples (100% -0.150mm)

Ore sample	BaS (%)	Recovery (%), R_{Ni}		
		Flotation	Magnetic separat.	Leaching
St. Voda	0.0	36.50	34.70	37.20
	2.0	45.45	42.85	46.10
	3.5	60.70	55.60	62.35
Rzanovo	0.0	36.85	35.30	87.60
	2.0	47.10	46.60	48.20
	3.5	62.30	60.70	65.10
Rudinci I	0.0	42.50	40.25	43.10
	2.0	48.60	45.30	50.20
	3.5	65.00	63.20	66.75
Rudinci II	0,0	46.00	41.75	47.05
	2,0	68.00	65.30	70.20
	3,5	78.00	73.60	80.30

Table 4. Results obtained from segregation - flotation - magnetic separation - ammonia leaching of the ore samples (100% -0.150mm)

Ore sample	Addition (%)	Recovery (%) R_{Ni}		
		Flotation	Magnetic separat.	Leaching
Studena Voda	2.0% FeS	47.00	44.35	48.35
	3.5% FeS	60.70	56.70	62.75
	2.0% BaS	47.05	44.35	50.10
	3.5% BaS	61.10	57.00	63.25
	2.0% $BaSO_4$	45.20	42.30	47.05
	3.5% $BaSO_4$	60.10	56.00	64.10
Rzanovo	2.0% FeS	49.50	47.20	52.30
	3.5% FeS	61.50	56.35	63.50
	2.0% BaS	50.25	48.10	53.10
	3.5% BaS	60.10	56.00	64.10
	2.0% $BaSO_4$	49.80	48.00	51.40
	3.5% $BaSO_4$	60.50	56.10	64.00
Rudinci II	2.0% FeS	79.60	76.30	81.85
	3.5% FeS	80.50	79.10	83.10
	2.0 % BaS	82.40	78.25	85.00
	3.5% BaS	76.50	73.45	80.00
	2.0% $BaSO_4$	70.30	65.30	74.00
	3.5% $BaSO_4$	76.50	73.45	78.00

5. Conclusion

The combined processes **segregation-flotation-magnetic separation ammonia leaching** by the synthetic mixures and appropriate ore samples (various nickel content) have achieved satisfactory results related on the metal recoveries. The existing environmental problems will lead to increased interest in combined processes or hydrometallurgical processes. These include combined processes: **segregation-flotation-ammonia leaching** or some other process as an oxidation and biooxidation.

6. References

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