PROCESSING OF LOW- GRADE NICKEL BEARING LATERITES

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Abstract:A combination of current trends and developments may undermine the sulphides supremacy and might tip the balance in favour of laterites for new investigations or projects. A list of current laterite operations or laterites processing today is following: Ferronickel smelting, Matte smelting, Reduction roasting-ammonia leaching and High pressure sulphuric acid leaching.Apart from the above mentioned process routes, there have been many attempts to develop processes know as alternative processes, which have included: Nitric acid leaching, Chlorine leaching, Acid pugging and sulphation roast, esspecialy Segregation Process etc
Key worrds: Segregation, flotation, leaching

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 tretment 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. 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.

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

$$\mathbf{CaCl_2 + H_2O = CaO + 2HCl}$$
$$\mathbf{CaCl_2 + H_2O + SiO_2 = CaO.SiO_2 + 2HCl}$$
$$\mathbf{CaCl_2 + \tfrac{1}{2}\,Al_2O_3.2SiO_2.2H_2O = CaO.Al_2O_3.2SiO_2 + 2HCl}$$
$$\mathbf{CaCl_2 + H_2O + MgO.SiO_2 = CaO.MgO.SiO_2 + 2HCl}$$
$$\mathbf{CaCl_2 + H_2O + Fe_2O_3 = CaO.Fe_2O_3 + 2HCl}$$

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

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

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

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:

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

$$NiO.2SiO_2 \Rightarrow 2NiO.SiO_2 \Rightarrow NiO.SiO_2$$
$$\Downarrow \qquad\qquad \Downarrow$$

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. Result obtained from segregation - flotation - magnetic separation -NH_4OH leaching

Mixture	T (^0C)	t (min)	Flotation R_{Ni} (%)	Magnetic separat. R_{Ni} (%)	Leaching 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.

Table 2. Results obtained from segregation - flotation of the ore samples (100% -0.150mm)

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

Table 3. Results obtained from segregation - flotation - magnetic separation - NH_4OH leaching

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 a oxidation and biooxidation.

6. References

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