PRESSURE HYDROMETALLURGY – – A NEW CHANCE TO NON-POLLUTING PROCESSES

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Abstract:

A wide spectrum of hydrometallurgical processes offers many promising approaches for industrial application in order to improve the environmental impact of conventional metals productions, or for replacing pyrometallurgical processes whose gas emissions and a high content of formed metals (As, Cr, Pb) are becoming increasingly unacceptable. The main advantages of pressure hydrometallurgy are fast kinetics, enhanced selectivity over iron and other dissolved species.The pioneer work on hydrometallurgical operation (dissolution, precipitation, metal winning) was performed in Russia at the beginning of the previous century, mainly by Ipatieff and Bayer, each working independently in Saint Petersburg. Gradually, industrial application took place firstly in aluminium and later in nickel production. Today, in addition to nickel and aluminium, the pressure hydrometallurgy is well established in a wide spectrum of industrial applications for production of different metals (gold, zinc, molybdenium, titanium, germanium) from ore deposits and secondary materials. High pressure leaching in combination with other metallurgical operations (cementation, precipitation, solvent extraction, and electrowinning) provides an adequate technology to reintroduce lost metals into the industrial cycle, thereby saving resources and energy, while keeping the environment cleaner. It seems that pressure hydrometallurgy might be a very important key to better and nonpolluting processes in production of metals.

Key words: High Pressure, hydrometallurgy, metal, environmental protection.

Introduction

Hydrometallurgical extraction of metals represents an important, widely applied technology in the metallurgical industry for treating both primary and secondary resources of valuable metals [1, 2]. Suc-

cessful hydrometallurgical approaches to metal extraction require a full understanding of a wide spectrum of scientific and engineering principles in many disciplines. These include solution chemistry, electrochemistry, thermodynamics, kinetics, and transport processes. In this study, present relationships among various disciplines influencing hydrometallurgical extraction are reviewed and analyzed with different examples from literature [1–3]. The contribution of pressure hydrometallurgy to technological advancement of metal extraction is undeniable [1].

The first information regarding a reaction under high pressure is reported by Vladimir Nikolayevich Ipatieff (1900). The precipitation processes, however, were performed by Nikolai Beketoff in 1859 and metal dissolution by Karl Bayer in 1892. Although initially autoclaves were used for leaching bauxites for more than 100 years, pressure hydrometallurgy has progressed extensively since the middle of 1980's when it was applied for zinc sulfide concentrates and refractory sulfide gold bearing ores. The application of pressure and high temperature leaching in autoclaves is definitely one way of overcoming the slow kinetics of hydrometallurgical processes. In the early seventies Habashi [3] reported that pressure hydrometallurgy is the best option for better and non-polluting leaching processes. In his paper [4] Habashi thoroughly discussed how pressure hydrometallurgy is applied for the leaching of nickel oxide, sulphide and arsenide, highlighting the importance of the pressures reactors, i.e., autoclaves. Nowadays, laboratory autoclaves for hydrometallurgical investigations are available in different sizes, models and materials [4]. The maximum pressure and temperature at which the autoclaves can be used depend upon the design of the vessel and the materials used in its construction (rotary autoclave, horizontal and column autoclave system). Titanium is an excellent material for use with oxidizing agents, such as nitric acid, aqua medium and other mixed salts. Prospective users must remember that titanium will burn vigorously in the presence of oxygen at elevated temperatures and pressures. While there have been many successful applications where oxygen and sulphuric acid are handled in titanium equipment, the danger of ignition is always present and must be prevented.

The high pressure acid leaching HPAL is the current widely accepted process for greenfields nickel laterite projects. The extension of the process from tropical limonites to Western Australian laterites is a new approach, and as such the behaviour of the different minerals in tropical and arid laterites during leaching is widely examined.

Tindall and Muir [5] conducted fundamental investigation of the HPAL technique using synthetic goethite as a model ore. It was found that goethite transforms to hematite by dissolution and the re-precipitation mechanism. The leaching rate depended on the acid concentration,

the slurry oxidation potential, and the type of cations in the solution. It was also confirmed that the nontronite (the silicate ore) reacted more promptly than iron oxides.

Rubisov and Papangelakis [6] have developed a comprehensive model including the kinetics of Co, Fe, Al, Mn and Ni dissolution in the temperature range from $230^{\circ}C$ to $270^{\circ}C$. The resulting model is capable of predicting the Ni extraction and the concentration of major impurities during autoclave operation for a variety of process conditions and feed compositions. The model was validated with data from a continuous mini plant provided by the INCO Technical Services during its process development campaigns.

Canterford [7] reported sulphatisation studies for oxidized nickel ore under high pressure conditions. He mentioned that the sulphation studies for nickel oxidized ore have been restricted to only one or two samples. Since each process is not uniformly applicable to each ore, the optimization studies and models from the literature will not allow ready determination of the appropriate processing conditions for other untested ores.

Arroyo et al. [8] proposed an improved method to predict leaching of the nickel from the high-magnesium fraction by processing the limonite fraction of the ore. The pressure leach slurry, or solution, is then contacted with the magnesium fraction of the ore to dissolve most of the nickel contained in the high-magnesium ore fraction while dissolving only a small portion of iron.

In hydrometallurgical processes the design of the reactor is of critical importance for an improved metal extraction [9]. After determining a chemical hydrometallurgical reaction with certain kinetics and reaction mechanisms, the best choice of a reactor design determines operating costs, environmental and operating problems, as well as the product quality. The kinetics of hydrometallurgical processes is made more complex by the existence of a very complex system since all three phases: gas, liquid and solid, are often present at the same time in a closed system.

The maximum pressure and reaction temperature at which any pressure vessel can be used depend upon the design of the vessel and the materials used in its construction. Since all materials lose strength at elevated temperatures, any pressure rating must be stated in terms of the temperature at which it is applied. The choice of material of construction of an autoclave (titanium, stainless steel) depends on the operating medium whether or alkaline, the temperature range, and the presence or absence of oxidizing atmosphere. A rupture disc is installed in a safety head. To prevent the action of corroding vapour, the discs can be coated on one or both sides with teflon. Such coating and lining increase the minimum rupture ratings available in a given disc.

As a result of the permanent increase of nickel production costs associated with traditional pyrometallurgical techniques (flash smelting) and the depletion of high-grade sulfide ores, a renewed interest has developed concerning the production of nickel and cobalt by high pressure sulphuric acid leaching of nickel laterite (oxidic ore) [10]. The residence time is limited to some economical maximum volume controlled by the cost of an autoclave in relationship to the project cost. As a consequence of the need to minimize operating costs in the Chemical industry, EKATO Ruhr und Mischtechnik GmbH developed an impeller system to increase the mass transfer rate and optimise gas utilisation in autoclaves [11].

Because of high production costs the usage of equilibrium software is a new, easy way to solve reaction problems on personal computers. The HSC Chemistry, developed by Outokumpu, Finland, has a wide range of application possibilities in metallurgical industry, research and education [12]. The HSC Chemistry helps to avoid trial-and-error chemistry, allowing chemists or engineers to set up optimum reaction conditions for their experimental investigation.

FactSage™, was developed during 20 years of collaborative efforts between the Thermfact/CRCT (Montreal, Canada) and the GTT-Technologies (Aachen, Germany) showing the largest fully integrated database computing systems in chemical thermodynamics in the world. It was introduced in 2001 and is the fusion of the FACT-Win/F*A*C*T and ChemSage/SOLGASMIX thermochemical packages [13]. The usage of Factsage is of big importance for calculating the stabilities of ionic and non ionic-species in water solutions. The information regarding corrosion, dissolution, leaching and selective precipitation is presented in the constructed diagrams: E (potential) – pH (the negative decimal logarithm of the hydrogen ion). In chemistry, pH is a measure of the acidity of an aqueous solution. In order to perform selective leaching of based metals from complex ores with different reagents (sulphuric acid, sodium hydroxide) the construction of E-pH (Pourbaix diagrams) is required. As shown in Fig. 1, a selective leaching of zinc might be performed in an acidic medium (pH=2, E=0.4) in order to remove present iron in the form of Fe_2O_3. A further increase of the pH- value from 2 to 4 leads to the formation Fe_2ZnO_4, which is not desirable.

Generally, the main advantages of pressure hydrometallurgy are fast kinetics, enhanced selectivity over iron and other dissolved species, enhanced solubilities of reagent gases, and more stable residues as compared to atmospheric processes. The drop in the dielectric constant of water with temperature and the associated enhancement in metal-anion bonding offer new possibilities to explore in terms of metal extraction selectivity.
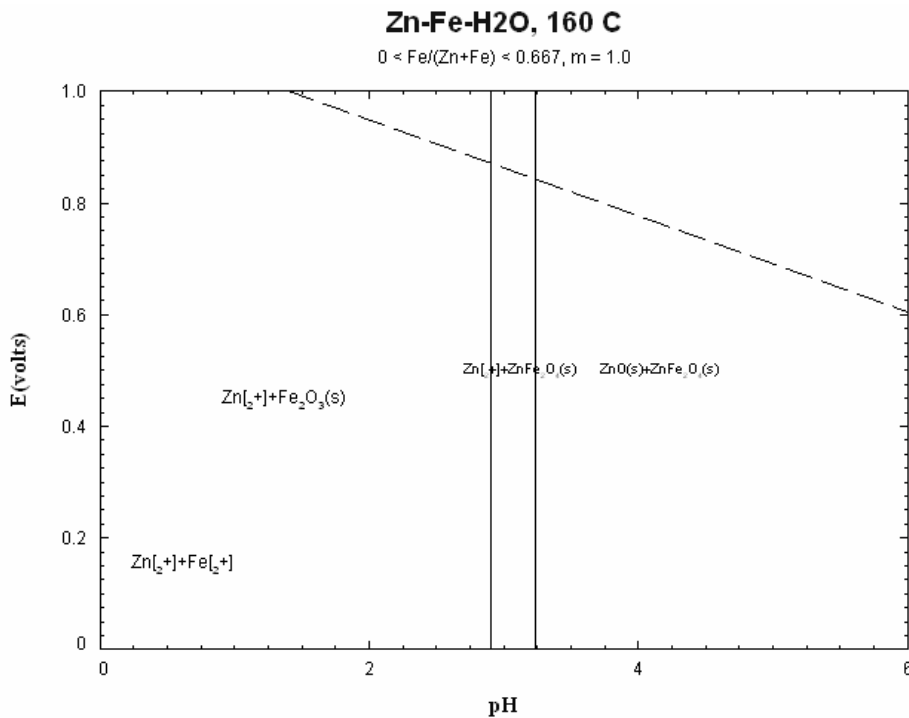
Zn-Fe-H2O, 160 C

0 < Fe/(Zn+Fe) < 0.667, m = 1.0

Figure 1 – E-pH diagram in the Zn-Fe-H_2O system at 160°C (approx. P = 0.5 MPa)
Slika 1 – E-dijagram u sistemu Zn-Fe-H_2O na 160°C (približno P = 0,5 MPa)

General principles of pressure hydrometallurgy

Pressure hydrometallurgy is based on the following:
1. classical hydrometallurgy principles (theory, structure of technolo-gical schemes, apparatus implementation)
2. mechanism of heat-mass exchange in the systems liquid-solid, li-quid-gas-solid, liquid-gas
3. the theory for hydrothermal processes of mineral generation

High attention and quick commercial development of autoclave pro-cesses (Fig. 2) are stipulated by a series of its benefits:
- essential intensity of a process due to the application of high tem-peratures and pressures for reaction gases
- ecologically consistent production
- capability of operating mechanization and automation
- complete extraction of valuable components
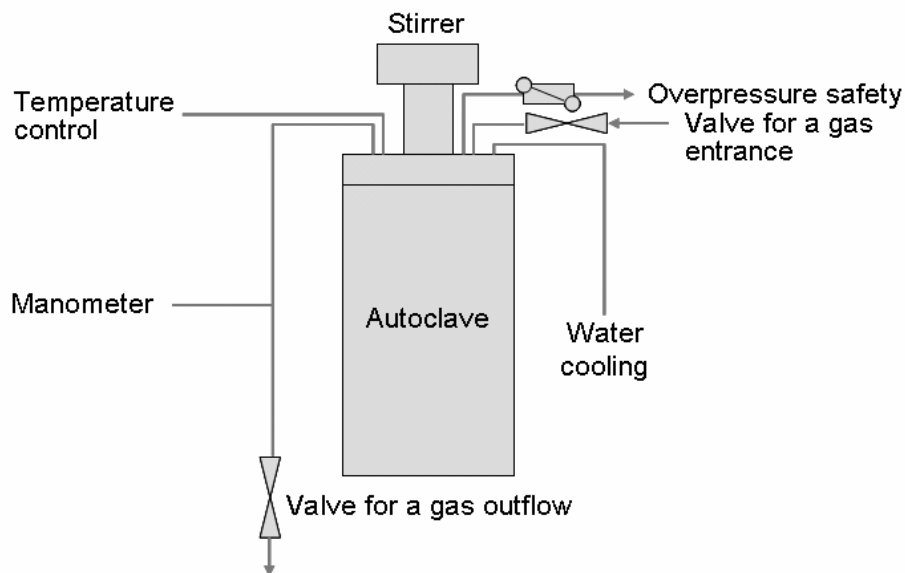- synthesis of new materials with unique features

Figure 2 – Scheme of an autoclave
Slika 2 – Šematski prikaz autoklava

The material base for dynamical development of autoclave processes will be the following:

- effectiveness of chemical engineering, which created efficient devices made of corrosion-resistant materials
- development of perfect sensors and safety systems for sampling and sulphuric acid injection under high pressure
- synthesis of new reagents and creation of productive technologies for reaction gases generation (oxygen, hydrogen, hydrogen sulphide)
- good power equipment of the branch, satisfying enterprise's needs in electric power, high parameters, and the utilization of mechanisms for wastewater treatment

As a typical hydrometallurgy scheme of polymetallic raw materials, processing includes three main parts of the technological process:

- lixiviation of the extracted metal
- purification of the received solution from dirt
- precipitation of the extracted metal in the elemental form or as a compound as an end-product

Different smelters in metallurgical industry have been operating for hundreds of years emitting millions of tons of SO_2 in the environment. As a result of the ever increasing costs of metal production associated with traditional smelting techniques, the decrease of high-grade sulfide ores, and especially higher metal prices, a renewed interest has developed concerning the production of nickel and cobalt from lateritic deposits using pressure hydrometallurgy [14, 15]. Laterites are oxide ores, rich in iron and aluminum hydrous oxides containing extractable nickel and cobalt values [16]. Laterite deposits are numerous throughout the world and can be estimated at 22 billion tons. Oxide ore deposits worldwide are in New Caledonia, Indonesia, Philippines, Australia, Russia, Brazil, Guatemala, Columbia, USA and in South-East Europe (Greece – Larymna with 120 million tons, Serbia with four regions: a) West Morava: 35 million tons, b) Zlatibor: 150 million tons, c) Sumadija: 11 million tons and d) Kosovo: 10 million tons; Macedonia Rzanovo: 100 million tons and Albania: 10 million tons).

Lateritic deposits constitute from 70 to 80 percent of the world-known nickel resources [17–20]. The two well-known types of nickel deposits are: limonitic type, as a nickel-ferrous iron ore, and silicate type. The silicate of nickel deposit, often called a serpentine ore, represents a more complete separation of nickel from iron and nickel is present as a constituent of silicate minerals formed during the laterization process. In more basic, especially dunitic differentiation minerals, nickel may partly replace magnesium in their lattice, and especially in olivine. The olivine decomposes magnesium, iron and nickel go into solution, and silicon tends to form a colloidal suspension of submicroscopic particles of silica. Then under laterite weathering conditions this low nickel content is available to form nickel-magnesium silicates and could finally concentrate resulting in economically interesting deposits.

Because of the large presence of Nickel Oxide Ores in South-East Europe and a small number of plants for nickel production there is a high request for studies of pressure hydrometallurgy. Treating oxidized nickel ores with sulfuric acid at elevated temperatures between 250 and 280°C and pressures of 4.5 and 6.0 MPa results in selective dissolution of nickel and cobalt as sulfates since ferric sulfate is unstable under the leaching conditions [21]. The ferric sulfate hydrolyzes to hematite and sulfuric acid. Thus the acid consumption is reduced while iron free pregnant liquor is produced. The HPAL offers at present the most promising prospect because it requires the smallest amount of energy input from fossil fuels, and because it is capable of high nickel and cobalt extraction from a wide variety of types of oxides [22–25].

The HPAL is the preferred process to recover nickel and cobalt from limonitic laterites, due to their low magnesia content and consequently low acid consumption [26]. One of the operating problems that must be addressed in design of pressure leaching systems is scaling of reactor surfaces [27]. The economic feasibility of the HPAL route for the extraction of nickel and cobalt values from silicate ores is highly dependent upon the behavior of aqueous aluminum. This is primarily due to its precipitation as hydronium alunite $((H_3O)Al_3(SO_4)_2(OH)_6)$, which is one of the major scale-forming compounds found in autoclaves used for pressure leaching [28]. Less recognized is the potential for formation of $MgSO_4 \cdot X\ H_2O$ and silica scale.

The leach residues encountered in the hydrometallurgical processing of the nickel oxidic ore are often in the colloidal or near-colloidal particle size range [29]. The direct dewatering of such finely divided leach suspension by conventional sedimentation is difficult and physical-chemical characteristics of the slurries must be changed in order to achieve higher settling velocities. In practice, this needed modification of the leach residues involves the addition of destabilizing agents, i. e. and organic polymer, to flocculate the particle and to produce settleable aggregates [30, 31].

Slurry rheology plays a vital role in pipeline transport, classification, heating and processing of laterite ores [32–34]. This is especially true in sulfuric acid leaching processes as slurry with no thermal treatment. The complex rheology of laterite slurries can be generally attributed to the presence of goethite (needle-shaped crystals) and various clays (plate structure). It is expected, regardless of the mechanisms involved in flow behavior, that the measurements of bulk properties of slurries will provide the necessary parameters for the design of processing facilities. The most effective method for modifying the flow properties of suspension is to change the surface chemistry of the suspended particles using tenside, i. e., the surface charge density and ionic strength, which is accomplished by changing the pH and the electrolyte concentration of the suspension [34].

Optimizing gas mass transfer in autoclave

In pressure hydrometallurgy, pure gases like oxygen and hydrogen are used for oxidation and reduction. The gases are expensive and therefore should be used efficiently. The EKATO Gassing Impeller offers a new technology for hydrometallurgical processes to increase gas mass transfer rates (as shown in Fig. 3). Better gas utilization can be achieved by the replacement of impeller systems or by upgrading impeller systems to use the installed power better [11].
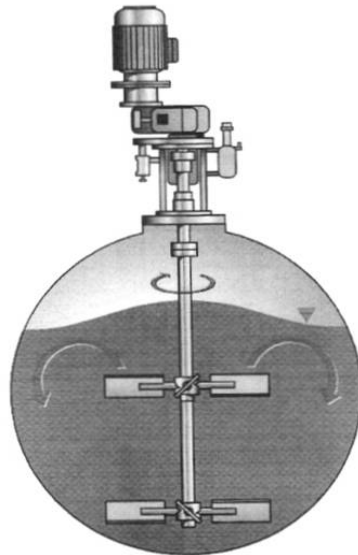
Figure 3 – Surface gassing impeller [11]
Slika 3 – Pokretač uvođenja gasa

The most efficient means of gas mass transfer into liquid iscalled "Surface gassing". Gas enters the headspace of the autoclave. The elemental gas partial pressure or concentration is low due to dilution with water vapor or other by-product gases. The interfacial area is a multiple of the surface area of the liquid-gas interface. An impeller pumping liquid upwards to the pulp-gas interface creates a multiple of the surface area. A head differential is created continuously replenishing the liquid at the interface with unsaturated liquid to create the greatest concentration gradient of the element in the gas and in solution. The consequence is a mass transfer coefficient greater than the one created by vortex gassing. The EKATO gassing impeller not only adds to the overall mass transfer, but also it can contribute to a prolonged period of time between maintenance activities.

The oxygen mass transfer rate in various aqueous applications was measured by the EKATO with a relatively high degree of accuracy typically by oxidizing a sodium sulphite solution under similar or simulated conditions as to real operations [11]. Besides the extent of mixing, the oxygen mass transfer coefficient depends on temperature and reaction kinetics. The normal trend is when temperature rises over 100°C under higher pressure or when reactions involving dissolved oxygen accelerate the value of the oxygen mass coefficient.

Tube reactor

In most cases the bauxite used as main raw material for metallurgical grade alumina is diaspore bauxite. Its difficult extraction behavior and its high silica content cause pyrogenic processes coexisting with the Bayer process. Many efforts were made to shorten the extraction time with intensification of leaching in the autoclave caused Bayer process to be developed more efficiently. Tube digestors have the potential use for decomposition of bauxites.

Based on data in references, a laboratory tube reactor for bauxite leaching was constructed and operated by Rajko Vracar and Slobodanka Markovic (now Vukcevic) [35, 36]. The characteristics of this reactor were:
- temperature leaching up to 300°C,
- pulp flow rate from 0.35 to 1.21 m s^{-1},
- residence time of suspension in working space from 56.3 to 194.8 s, residence time in direct heating zone from 18.6 to 64.5 s and
- flow rate of pulp of 76.3 to 260.4 dm^3 h^{-1}.

The results of leaching of bauxite with the following composition (%): 51.22 Al_2O_3; 22.80 Fe_2O_3; 2.01 SiO_2; 2.90 TiO_2; 0.57 CaO and 20.5 loss after calcination, using a solution of 120 g Na_2O/l depending on the pulp flow rate and the temperature in the zone of direct heating are showed in Table 1 and Table 2. The obtained results confirmed:

1. Under a specific moving regime of pulp in the tube digestor a leaching process is very fast ensuring the high degree of dissolution (85 to 94%) e.g. maximum degree of dissolution at the temperature of 245°C for 72 s. Under similar conditions for a battery of autoclaves a necessary time is 2 to 400 s. At the same time the leaching time represents the time for heating up to the working temperature. Under laboratory conditions (a rate pulp flow from 0.35 to 0,96 m·s^{-1} and the flow rate from 76 to 205 m^3·h^{-1}) the above mentioned time amounts from 72 to 195 s. In other words, the necessary residence time for bauxite leaching can be reduced by using a tube digestor approx. to 1/10 of the value typical for processing in autoclaves.

2. The desirable degree of leaching can be realized using a solution of low NaOH concentration (120 g Na2O per dm^3).

Table 1 – Dissolution of Al_2O_3 depending on the pulp flow rate at 228°C in the zone of direct heating

Tabela 1 – Rastvaranje aluminijum oksida u zavisnosti od protoka pulpe na 228°C u zoni direktnog zagrevanja

Pulp flow rate (m s^{-1})	Heating time (s)	Degree of dissolution of Al_2O_3 (%)
0.35	194.8	85.65
0.64	106.0	86.00
0.79	85.8	83.85
0.96	71.8	84.21

Table 2 – Dissolution of Al₂O₃ depending on the temperature in the zone of direct heating at a pulp flow rate of 0.79·m s⁻¹ and a heating time of 85.8 s

Tabela 2 – Rastvaranje Al₂O₃ u zavisnosti od temperature u zoni direktnog zagrevanja pulpe za protok 0,79·m s⁻¹ I vreme zagrevanja 85,8 s

Temperature (°C)	Degree of dissolution of Al₂O₃ (%)
160	85.65
200	86.00
230	83.85
250	84.21
270	85.65

Bagaev [37] confirmed that the use of the tube digestor rather than autoclaves in alumina production would make it possible to increase alumina extraction and reduce equipment costs. As the particle diameter is reduced, it becomes necessary to reduce the diameter of the subsequent reactor stages to maintain the specific rate of processes involving diffusion or mixed kinetics. For the same constant value of suspension flow rate in the tube digestor – $dV/dt = 0.0011$ m³ s⁻¹. the reactor diameter was changed in experiments ($D = 0.4$; 0.277 and 0.071 m). and the degree of conversion was increased from $X = 0.34$ to 0.73 in the temperature range from 240 to 270°C. The residence time was decreased from 40 to 10 min at the above mentioned conditions.

Table 3 – Conditions and results of bauxite dissolution in the tube digestor [38]
(flow rate $dV/dt = 0.0011$ m³ s⁻¹)

Tabela 3 – Uslovi i rezultati rastvaranja boksita u cevnom reaktoru [38]
(protok $dV/dt = 0,0011$ m³ s⁻¹)

Composition of bauxite (%)				$d \cdot 10^6$ (m)	t (min)	T (°C)	X
Al₂O₃	SiO₂	Fe₂O₃	loss of calc.				
52.15	4.66	22.28	14.9	93	40.0	271	34.0
53.97	3.97	22.00	2.2	49	15.0	273	55.0
51.87	4.75	13.5	13.2	4.5	10.0	261	73.0

Longitudinal mass diffusion in the free granule volume was analyzed by Abramov and Terekhin in relation to the problem related to leaching of finely dispersed aluminate sinter [38]. Experimental data on counter leaching of –1.0 + 0.5 mm white electrocorundum with 5% NaOH at 20°C in 1 000 mm high and 60 mm diameter tube reactor indicate a significant deviation from the ideal displacement regime. Experimental values of the longitudinal mixing coefficient were higher than expected.

Slurry bubble column reactor

Gas-liquid bubble columns and three-phase fluidization systems are widely used in industry, particularly chemical and petrochemical industries. Three-phase fluidization describes a gas-liquid-solid flow system in which particles are in motion induced by gas and/or liquid phases. High pressure operations are common in industrial applications of slurry bubble columns for reactions, such as residue hydrotreating, Fischer- Tropsch synthesis and methanol synthesis. The design and scale-up of slurry bubble column reactors require knowledge of the hydrodynamics and heat transfer characteristics. Studies reported in the literature for such characteristics have been limited to ambient conditions. Some details have been reported for high-pressure conditions. The studies conducted under this program by the "Air Products and Chemicals, Inc.", USA examine the effects of pressures and temperatures on some areas pertaining to fundamental hydrodynamics in slurry bubble columns [39]. These area include single bubble formation in liquid-solid suspensions, gas holdup and maximum bubble size, pressure effect on the flow fields and Reynolds stresses, axial liquid mixing, and heat transfer behavior. Bubble formation from a single nozzle is investigated analytically and experimentally in non-aqueous liquid and liquid-solid suspensions at pressures up to 17.3 MPa.

Pressure hydrometallurgy in environmental protection

Environmental hydrometallurgy refers to both hydrometallurgical waste treatments and hydrometallurgical processes that can replace existing with attendant environmental benefits [40]. In contrast to pyrometallurgical processes the comparatively low temperatures were sometimes equated to low energy demands and lower pollution. The development of TiO_2 or ZrO_2 – supported noble metal nanoparticle catalysts receives considerable attention since many high pressure aqueous-phase catalytic reactions (>150°C, up to 15 MPa) are performed in the presence of such catalysts. The hydrothermal processing was used to treat wastewaters by oxidizing the organic contaminants or ammonia to harmless gases or to convert biomass-derivatives to value-added products [41, 42]. Identified catalysts are based on refractory oxide supports (TiO_2, ZrO_2) on which the active metallic phase is deposited (e.g. Pd, Pt, Ru, Pd-Re).

Regarding leaching under atmospheric and high pressure, the IME Process Metallurgy and Metal Recycling of the RWTH Aachen University has focused research activities on the treatment of nickel laterite, manganese sulfidic ore in order to obtain nonferrous metals [43–45].

Conclusion

The main advantages of pressure hydrometallurgy are fast kinetics, enhanced selectivity over iron and other dissolved species, enhanced solubilities of reagent gases, and more stable residues as compared to atmospheric processes. New special alloys must be developed to reduce maintenance time of high pressure reactors (autoclave, tube reactor). High pressure leaching as an important part of environmental hydrometallurgy offers a more flexible route in order to recover lost metals from secondary materials, saving resources and energy and especially keeping the environment cleaner. Optimizing gas mass transfer in autoclaves using EKATO Gassing Impeller increases gas mass transfer rates and makes gas utilization better. The use of the tube digestor increases alumina extraction and reduces the equipment costs. Although slurry bubble columns are applied in different industrial processing (methanol synthesis) the design and scale-up of slurry bubble column reactors require knowledge of the hydrodynamics and heat transfer characteristics. Because of high production costs the using of equilibrium software (HSC; FactSage) is a new promising way to solve reaction problem on personal computers regarding the hydrometallurgical process. In the future, the planned using of the Artificial Neural Network (ANN) approach in pressure metallurgy will be investigated in order to reduce operational costs, give better modeling accuracy and provide a more successful process optimization

Acknowledgment

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HIDROMETALURGIJA PRI VISOKIM PRITISCIMA, NOVA ŠANSA ZA PROCESE KOJI NE ZAGAĐUJU ŽIVOTNU SREDINU

OBLAST: Hemijske tehnologije

Sažetak:

Širok spektar hidrometalurških procesa obećava različite mogućnosti industrijske primene u nameri da poboljša zaštitu životne sredine u tradicionalnoj proizvodnji metala ili da zameni pirometalurške procese, kod kojih su emisije gasova i visok sadržaj formiranih metala (As, Cr, Pb) postale nedopustive. Glavna prednost hidrometalurgije pri visokim pritiscima je kinetika procesa, brzo rastvaranje metala i povećana selektivnost prevođenja osnovnih metala u rastvor u odnosu na železo i druge prateće metale. Početkom prošlog veka, nezavisno jedan od drugog, Ipatieff i Bayer u Sankt Peterburgu izvodili su početne aktivnosti vezane za hidrometalurške operacije (rastvaranje, precipitacija, dobijanje metala). Postepeno industrijska primena započela je vezano za metalurgiju aluminijuma i nikla. Dodatno za nikal i aluminijum, luženje pri visokim pritiscima iz ruda i sekundarnih sirovina je uspostavljeno za širok spektar drugih metala (zlato, cink, molibden, germanijum). Luženje pri visokim pritiscima u kombinaciji sa drugim metalurškim operacijama (cementacija, precipitacija, solvent ekstrakcija i dobijanje metala elektrolizom) obezbeđuje odgovarajuću tehnologiju vraćanja metala u industrijski proces, čuvajući energiju i resurse, i čineći životnu sredinu još čistijom. Čini se da bi u budućnosti hidrometalurgija pri visokim pritiscima mogla biti veoma važan kljuc za bolje i čistije procese u proizvodnji metala.

Ključne reči: *visok pritisak, hidrometalurgija, metal, zaštita životne sredine*