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THE INFLUENCE OF ADDING EMULSION FLOCCULANTS ON THE EFFECTS OF RED-MUD SEDIMENTATION

VPLIV DODATKA EMULZIJSKIH FLOKULANTOV NA POJAVE PRI SEDIMENTACIJI RDEČEGA BLATA

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The main objective of this investigation was to define, based on an industrial probe, the influence of emulsion flocculants on the effects of red-mud precipitation. The precipitation velocity of the red mud as well as the transparency of the liquid phase create the basis for the comparison of the efficiency between the conventional flocculants and the emulsion flocculants. The investigation was also focused on the characteristics of the precipitated mud presented as the content of dry particles as well as the granulation of red mud. The influence of the suspension viscosity on the loading of the mixer inside the decantation vessels was also investigated. All of the precipitation experiments were carried out within the automatic Cytec unit for the preparation and dosage of the liquid flocculants. The parallel investigation of the efficiency of two different flocculants was performed in separate decantation vessels.

The results show that the red-mud precipitation velocity during the experiment with the emulsion flocculants is several time higher than the precipitation velocity obtained with synthetic flocculants. The emulsion flocculants also enable a better solution transparency with a clear and distinct boundary between the two phases (liquid and solid). Besides that, the consequence of the emulsion flocculants' dosage is a higher content of dry particles in the suspension as well as an increased granulation and a lower viscosity. Using emulsion flocculants increased the decantation vessels' productivity, improved the quality of the aluminate's solution and improved the effects of red-mud rinsing.

Key words: flocculants, red mud, precipitation velocity, solution transparency, aluminate's solution, decantation vessel

Glavni cilj te raziskave je bil določitev vpliva emulzijskih flokulantov na pojave obarjanja rdečega blata na podlagi industrijskih preizkusov. Hitrost obarjanja rdečega blata in transparenca tekoče faze sta osnovi za primerjavo učinkovitosti med konvencionalnimi in emulzijskimi flokulanti. Cilj raziskave so bile tudi značilnosti izločenega blata pa tudi vsebnost suhih delcev in granulacija rdečega blata. Vpliv viskoznosti suspenzije na obremenitev mešalnika v posodi za dekantacijo je bil tudi določen. Vse preizkuse smo izvršili v avtomatski napravi Cytec za pripravo in doziranje tekočih flokulantov. Vzporedne preiskave učinkovitosti različnih flokulantov so bile izvršene v ločenih posodah za dekantacijo. Rezultati kažejo, da je hitrost obarjanja rdečega blata med preizkusom z emulzijskim flokulatom večkrat večja od hitrosti pri uporabi sintetičnih flokulantov. Ti flokulanti zagotavljajo tudi boljšo transparenco emulzije z jasno in razločno mejo med obema fazama (tekoča in trdna). Posledica doziranja emulzijskih floukantov so tudi večja vsebnost suhih delcev v suspenziji, povečana granulacija in nižja viskoznost. Uporaba emulzijskih flokulantov poveča produktivnost posod za dekantacijo, poveča kakovost aluminatne raztopine in izboljša izpiranje vplivov rdečega blata.

Ključne besede: flokulanti, rdeče blato, hitrost obarjanja, transparenca raztopine, aluminatna raztopina, posoda za dekantacijo

1 INTRODUCTION

One of the most important operations in the Bayer process of alumina production is the separation of red mud from the aluminate's solution in decantation vessels using flocculants of different types. The separation operation is not based on the chemical reactions, but on the hydrodynamic conditions and the system's characteristics, the separation conditions, the type of flocculants used and the construction of the decantation vessel[1,2]. The mineralogical content of bauxite, the dissolution conditions as well as the red-mud granulation all have an influence on the red-mud precipitation [3].

The main demand from the industrial Bayer process is the final result in the form of relatively clean alumina. The main precursor for the process is the aluminate's solution without any traces of impurities. The precipitation of solid particles is often defined by Stocks' equation, approved by Richardson and Zaki (1954).

According to this equation, the velocity of a particle's precipitation is directly proportional to the square exponent of the aggregate's size and so a small increase in the particle size has a significant influence on the precipitation velocity. This is particularly visible for small particles ($\leq$ 50 μm) with the very long precipitation time. The process of particle aggregation is of great importance for the separation of red mud from the aluminate's solution. The dosage of the flocculants facilitates the creation of red-mud aggregates and the improved possibility of gravitation decantation [5].

The preliminary use of common organic compounds as the precipitation facilitators was replaced with synthetic poly-acrylates because of the improved values of the decantation velocities. On the other hand, the

transparency of the final liquid phase was lower in comparison to the effects of the organic flocculants. Nowadays, a new class of synthetic hydroxamathic poly-acryl-amides flocculants has been developed. The aim was to obtain improved red-mud precipitation velocities and improved transparency of the liquid phase.

The objective of this investigation was to compare the two types of flocculants' efficiency by using the hydroxamatic poly-acryl-amides and the conventional synthetic flocculants used in the alumina factory, Aluminum Plant, Podgorica, Montenegro.

2 METHODS OF WORK

An investigation of the emulsion flocculants' efficiency as well as the influence on the effects of red-mud precipitation started with the industrial low-concentration suspension that has the following content $\rho(Na_2O_k)$ = 160.72 g/L; α_k = 1.56, as well as the following content of red mud:

w (Al_2O_3) = 15.3 %
w (F_2O_3) = 41.8 %
w (Na_2O_r) = 0.341 %
w (Na_2O_{uk}) = 5.42 %
w (SiO_2) = 13.17 %
w (Zn) = 0.0307 %
w (TiO_2) = 5.13 %
w (CaO) = 2.67 %
α_k = 4.495

The experimental conditions were as follows: T = 95–100 °C; ρ = 1320–1340 g/L.

The preparation and dosage of the emulsion flocculants in industrial conditions was carried out in the Cytec automatic unit. The emulsion flocculants were introduced into the separate decantation vessels in two focal points. The gravitation dosage into the decantation vessels was used through the separation box filled with the low-concentration solution after the leaching of the bauxite. The first focal point was on the dosage ring of the decantation vessel and the second one was on the dosage tube through which the suspension is pumped into the dosage ring of the decantation vessel. The preparation and the dosage of the synthetic flocculants in the second decantation vessel were carried out in the existing equipment for the preparation and dosage of the same flocculant. The synthetic flocculants were also introduced through the two points at the same positions as the emulsion one. In some of the experimental parts we even introduced the third flocculant, i.e., starch.

The same conditions for the investigation of the precipitation velocity were used for all three different flocculants (the velocity was measured in the 1L vessel in all of the cases). The used flocculants were as follows: the natural one (starch) (Ipokol Eg 720), the synthetic flocculants (anion type A-185 HMW) as well as the hydroxamatic poly-acryl-amides (HXPAM) HX 300 as the representative of the emulsion flocculants. All of the flocculants were prepared in the same conditions as the water solution with a low content of ρ (Na_2O_k) ≥ 50 mg/L and under a temperature of 50 °C.

The concentration of starch (Ipokol EG 720) was 1 %, with a dosage level of 1.5 kg/t red mud; the concentration of synthetic flocculants (A-185 HMW) was 0.05 %, with a dosage level of 0.08 kg/t red mud; and the concentration of the emulsion flocculants HX 300 was 0.25 % with a dosage level of 0.45 kg/t red mud.

The transparency of the liquid phase was determined by its content of dry particles. The content of dry particles in the red mud was also determined through probes from the drain valve.

The loading of the mixer within the decantation vessel in the case of using the emulsion flocculants and the synthetic flocculants was followed up continuously with dynamometers on both of the decantation vessels.

3 RESULTS AND DISCUSSION

The red-mud precipitation velocity as a function of the time during the dosage of different flocculant types is shown in **Figure 1**. The results show that the highest value of the precipitation velocity is obtained after a period of 1 min, using the HX300 flocculants and it is

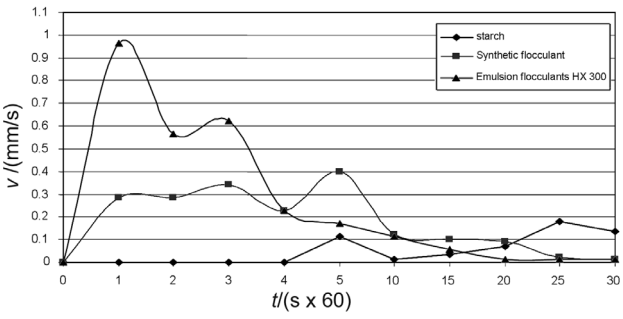

Figure 1: Variation of the red-mud precipitation velocity as the function of the flocculants type

Slika 1: Sprememba hitrosti obarjanja rdečega blata v odvisnosti od vrste flokulanta

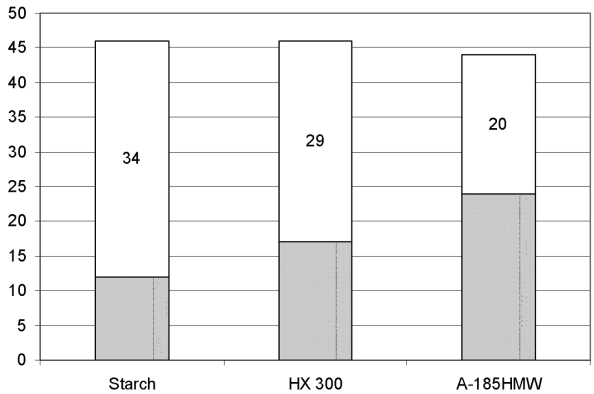

Figure 2: Solution transparency as a function of flocculants type used in the process

Slika 2: Transparenca raztopine v odvisnosti od vrste flokulanta uporabljenega v procesu

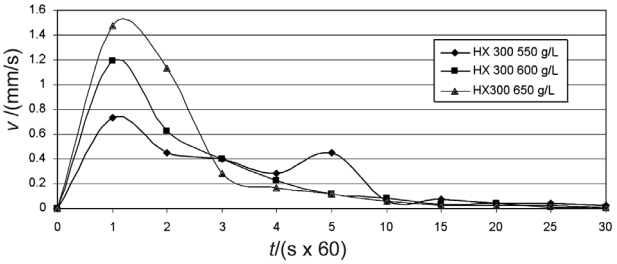

Figure 3: Variation of the red-mud velocity as a function of time during the application of three different concentrations of flocculants HX 300

Slika 3: Sprememba hitrosti rdečega blata v odvisnosti od časa pri uporabi treh različnih koncentracij flokulanta HX 300

0.96 mm/s. Using A-185 HMW flocculants the highest level of velocity is reached after 300 s in the range of 0.4 mm/s. In terms of velocity, starch shows the lower level of velocity (0.2 mm/s) after a period of 300 s.

The dosage of HX 300 flocculants enables the formation of clearly divided zones: the liquid zone (aluminate's solution) and the solid zone (red mud). A kind of transitional zone is present in the application of the A-185 HMW flocculants.

The transparency of the liquid phase in all three cases was measured with an optical prism "Ciba flocculants". The highest level of transparency on the prism's scale is 54, which is equivalent to the transparency of water. In our cases, the best transparency (42) was obtained in the case of the starch application, and it was lower for the HX 300 flocculants application (35). The lowest value of the transparency (20) was obtained with the application of A-185 HMW flocculants (**Figure 2**).

The precipitation velocity as a function of time for different quantities of emulsion flocculants HX 300 is shown in **Figure 3**. The results show an increasing trend for the precipitation velocity with an increased quantity of the flocculants HX 300. The lowest velocity level was 0.8 mm/s, obtained with a dosage of 500 g/t red mud. This increases to 1.2 mm/s with a dosage of 600 g/t red mud. The highest level of velocity (1.5 mm/s) was obtained with a dosage of 650 g/t red mud.

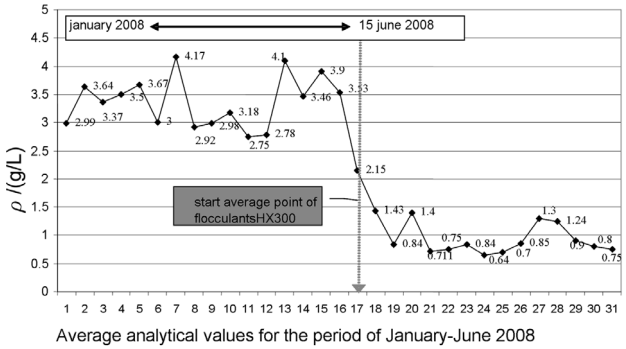

Figure 4: Content of solid particles in overflow settlers before and after the application of HX 300 flocculants

Slika 4: Vsebnost trdnih delcev in pretok uporabo in po njej flokulantov HX 300

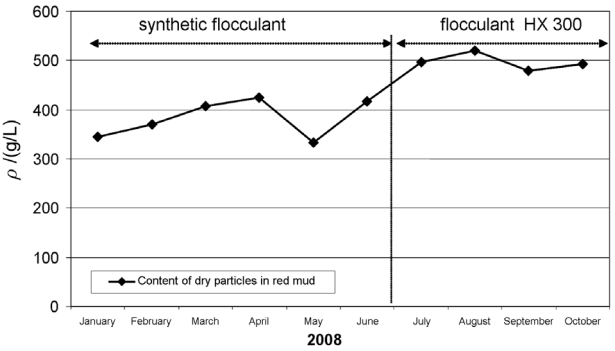

Figure 5: Dry particles' content in the red mud before and after the application of HX 300 flocculants

Slika 5: Vsebnost suhih delcev v rdečem blatu pred uporabo in po njej flokulantov HX 300

The liquid-phase transparency was followed using the content of dry particles in the remaining residue for a period of 4 months. This is the period when the industrial probe of the emulsion flocculants is compared with the effects on the content of dry particles in the aluminate's solution in the case of the application of the flocculants' A-185 HMW. The content of dry particles in the liquid phase using A-185 HMw as well as HX 300 is shown in **Figure 4**. The results show that the content of dry particles in the liquid phase, after a dosage of HX 300, is reduced to an average value of 3g/L. The dosage of A-185 HMW reduced that content to an average value lower than 1 g/L.

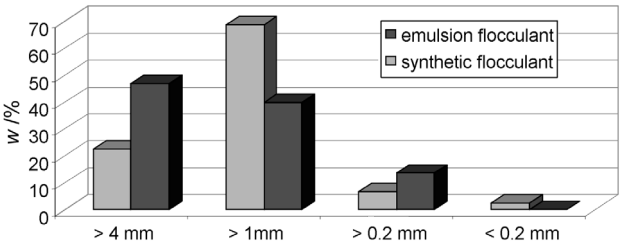

Figure 6: Portion of the individual fractions (percentage) in red mud settled as a function of different flocculants type application

Slika 6: Delež posameznih sestavin (odstotki) v usedlini rdečega blata v odvisnosti od uporabe različnih vrst flokulatov

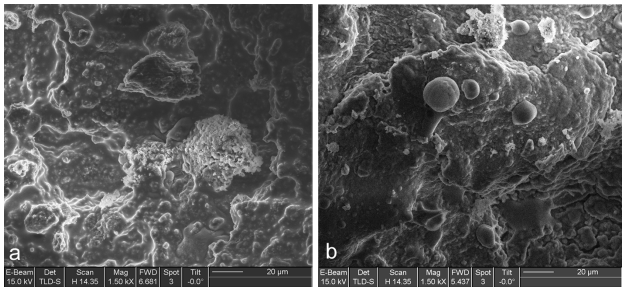

Figure 7: SEM images of the red-mud samples obtained with the application of A-185HMW flocculants (**a**) and HX 300 flocculants (**b**)

Slika 7: SEM-posnetek vzorca rdečega blata, nastalega pri uporabi flokulantov A-185 HMW (a) in HX 300 (b)

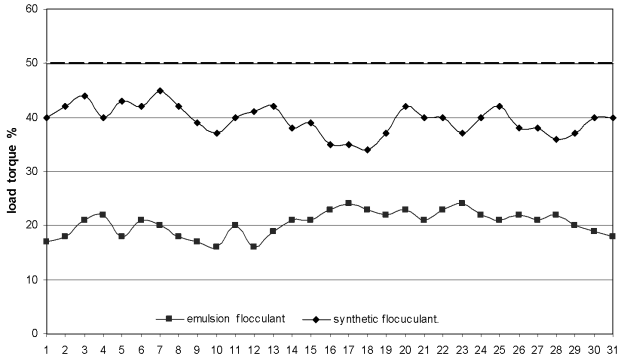

Figure 8: Comparison of the mixer branches' load torque in settlers during the application of synthetic flocculants (A-185 HMW) and emulsion flocculants (HX 300)

Slika 8: Primerjava obremenitev propelerjev mešalnika v usedalnikih pri uporabi sintetičnih flokulantov (A-185H MW) in emulzijskih flokulatov (HX 300)

During the industrial probe with the HX 300 flocculants, the content of solid particles in the red mud was also investigated. The results obtained before and after the dosage of the HX 300 are shown in **Figure 5**. The results show that the content of solid particles in the red mud increases from an average value of 400 g/L (A-185 HMW) to 500 g/L after the HX 300 application. The conclusion is that the red-mud rinsing, as well as the alkali content in it, is more effective after the HX 300 application. A granulometric analysis of the red-mud particles obtained during the A-185 HMW and HX 300 application is shown in **Figure 6**.

The results show that using the HX 300 increases the content of huge fractions in red mud. The SEM analysis indicates the formation of bigger, spherical aggregates (the "closed type") (**Figure 7**).

The red-mud suspension's viscosity was followed indirectly through the mixer branches' load torque in the decantation vessel, with a dosage of A-185 HMW and HX 300 flocculants respectively. The results of thr comparison are shown in **Figure 8**. The dosage of HX 300 decreases the mixer branches' load torque. This can be explained by the lower viscosity of the red mud obtained by using the HX 300 flocculants.

4 CONCLUSIONS

The dosage of HX 300 enables higher sedimentation velocities of red mud in comparison with the dosage of the A-185 flocculants. The consequence is an increased productivity of the decantation vessel and the decreased number of vessels in action.

The dosage of HX 300 flocculants (in comparison with the A-185 dosage) enables a distinct boundary between the solid and the liquid phases. The liquid phase has a lower content of solid particles; a fact that improves the filtration conditions on Kelly filters as well as the transparency of the aluminate's solution.

Precipitated red mud obtained with the HX 300 dosage (in comparison with A-185 HMW) has an increased content of solid particles, which improves its rinsing and alkali loss. The red mud obtained under these conditions has a bigger granulation caused by the chemical composition of the flocculants.

In the case of the HX 300 dosage, the red-mud suspension has a lower viscosity, which improves the condition of extracting it from the decantation vessel, prevents the formation of mud deposits on the walls and the arms of the mixer, and thus lowers the mixer branches' load torque and increases the decantation vessel's life time.

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