

SELECTION OF SYNTHETIC FLOCCULANTS FOR MUD SETTLING AT KORBA ALUMINA REFINERY

N. K. KSHATRIYA, G. R. CHANDEL, AND DR. P. K. N. RAGHAVAN
QUALITY ASSURANCE AND R. & D.
BHARAT ALUMINIUM CO. LTD., KORBA (C.G.)

ABSTRACT

Efficient solid /liquid separation plays a major role in the overall economics of a Bayer plant operation. It is essential in terms of process efficiency that maximum aluminate liquor is recovered from the red mud and this is achieved mainly by liquor decantation from digested slurry. Enhancing the settling operation is one of the principal tasks of technological development in the alumina refinery. At Korba Alumina Refinery, synthetic flocculants in combination with starch is in regular application for red mud separation in the settlers. The settling characteristics of red mud vary from one refinery to another, and involve the mineralogical composition of bauxite and the digestion parameters. This paper covers a series of experiments conducted with Polyacrylamide base polymers, Hydroximated Polyacrylamide (HxPAM) and combination of both synthetic flocculants with process optimization for the Korba Alumina Refinery.

INTRODUCTION

Flocculant plays an important role in the red mud separation. During the olden days starch or flour was used as flocculants for red mud. In more recent years, synthetic flocculants have progressively displaced the former.

The major advantage is that the synthetic flocculants can be "tailor made" in terms of molecular weight and composition and are, therefore, efficient at very low dose levels when compared to starch. In addition, synthetic flocculants are easily dissolved and do not require cooking. Since the early 1970's, synthetic polyacrylamide based polymers have largely replaced starch in the industry in all but a few Alumina Plants, the major exception being plants employing sand filters for secondary clarification. In most cases, if starch is employed, it is used in combination with a polyacrylamide flocculant. The lower flocculant dosage, the higher mud settling rates, better liquor clarity with lower overflow solids and improved mud compactions achieved with synthetic polymers has allowed in increase in plant flow rate without extensive and costly equipment installations.

A number of new synthetic flocculant chemistries have been introduced to the industry over last 10 years, viz.

- Acrylic Acid based polymers, containing carboxylic acid and acrylamine group,
- Hydroxamate containing polymers, containing Hydroxamate functional groups except the above ones (HxPAM),

Polyacrylamide based polymers have been used for the flocculation of red mud slurries in settlers and washer circuit of Bayer plants since late 1960's. The use of polyacrylamide based hydroxamic acid containing flocculants has increased significantly over the past eight years. These polymers provide tight settling interfaces and hence give excellent supernatant clarity on a variety of bauxite slurries without the need for co-dosing starch. However, when adopted as single flocculant they

tend to cost significantly more than traditional polyacrylamide. In recent years, many plants have adopted their use in combination with a traditional polyacrylamide flocculant.

Synthetic flocculants have historically been supplied to the Industry in two basic forms: Dry (Powders) and Oil - based emulsions (Liquid). Depending upon the variation in molecular weights, there could be ranges of products both in polyacrylamides and HxPAM Flocculants. Having available varieties of products in the market the suitable grade and dosages of flocculants suiting to their respective need through laboratory and plant scale trials and cost benefit analysis. Dry powder contains approximately 90% polymer solids while emulsion will contain approximately 33% polymer solids.

LABORATORY EVALUATION OF RED MUD FLOCCULANTS

Laboratory prediction of flocculant efficiency is important as extensive plant trials are time consuming and expensive.

A series of laboratory tests were conducted with powder and emulsion flocculants from different suppliers to evaluate relative effectiveness of these flocculants with respect to the mud getting in the Alumina Refinery at Korba.

Flocculants from different suppliers were tested for their suitability. All the flocculants were tested under identical conditions so that their performance can be compared. Tests were conducted in a number of 1 litre measuring cylinders so that the screening of flocculants could be carried out simultaneously. Diluted slurry sample of 1 litre was poured in each cylinder. The temperature of water bath was maintained between 95 - 97 °C. Fixed dosages of flocculants were added to the slurry. The sample was agitated with the help of plunger to ensure proper dispersion of the flocculants. Visual observation of the flocs formed as well as the settling rate and the mud compaction of the same were recorded to aid in the selection of the suitable flocculant from each other. Subsequent to the screening tests, detailed settling tests were carried out with the selected flocculant which gave the best results with respect to good quality flocs, good settling rates and good clarity. Settling tests were conducted according to the standard procedure.

From the trials, it can be seen that for the same dosage of flocculant, the settling characteristics are different from the slurry collected on different days even though there is only a small variation in caustic concentration and the feed solid. Therefore, trial was repeated for samples collected on different days for observing the variations.

RED MUD SETTLING BY FLOCCULANT ALONG WITH RHEOLOGY MODIFIER

A flocculant is added to solids bearing liquors as it enters the center of one of several successive vats called settlers. The liquors moves slowly to an overflow launder around the outer edge of the settler. The flocculated mud particles collect and settle slowly to the bottom of the settler. A rake then moves the mud to the out let at the center of the vessel, where it is removed by pumping. A major limiting factor in operating a settler at higher throughputs (tonnages) is the torque required to drive the raking mechanism. If the mud tonnage is too high, then rake will bag and the settler will be left inoperable. To overcome this limitation, a viscosity modifier was added to reduce the rheology of the underflow of the settled mud. The advantage of viscosity modifiers is reducing the viscosity of red mud, rake torque and increasing the speed of consolidation of flocculated solids of slurry. Flocculation and settling experiments were carried out in the laboratory constant temperature bath. Flocculants and rheology modifiers were added together and settling rate, mud compaction; liquor clarity and viscosity of underflow mud were determined. Viscosity of underflow mud was determined by Brookfield viscometer meter (model LVT) spindle no 3, rpm 60 at 85 °C.

Table - I: Comparative Performance Of Flocculants

Na₂OC of Slurry - 147.3 gpl
Feed Solid - 66 gpl

Flocculant(s)	Flocculants Dosage (g / T Mud)	Settling Rate (mt / hr.)	Mud Compaction (ml)	Suspended Solid (mg / litre)
A Powder	45.4	1.29	410	93
	49.2	1.65	340	107
	53.0	2.05	320	120
	56.8	2.52	270	126
B Powder	52.3	1.17	390	69
	61.1	1.55	330	74
	68.2	1.83	330	86
C Emulsion + Powder	166.6 + 18.9	1.42	300	75
	172.7 + 20.4	1.98	290	80
	181.8 + 22.7	3.32	250	102
	212.2 + 26.5	5.59	250	128
D Emulsion	140.9	2.04	310	102
	145.4	2.16	300	110
	150.0	2.22	300	123
	159.0	2.31	300	133
E Emulsion	155.0	1.34	400	96
	159.0	1.55	370	102
	170.4	1.73	375	112
	181.8	1.81	360	122

Table - II: Comparative Study Of Powder Flocculants

Na₂OC of Slurry - 142.6 gpl
Feed Solid - 72 gpl

Flocculant(s)	Flocculant's Dosage (g / T Mud)	Settling Rate (mt / hr.)	Mud Compaction (ml)	Suspended Solid (mg / litre)
A	27.7	1.02	370	82
	31.2	2.85	330	94
	34.7	4.33	260	127
B	27.7	0.17	410	55
	41.6	3.10	310	81
	56.5	4.16	280	118
C	27.7	0.76	440	87
	31.2	2.55	330	105
	34.7	3.95	260	132

MODIFIER

at successive
edge of the
ettler. A rake
pumping. A
ue required to
settler will be
: the rheology
; the viscosity
lids of slurry
perature bath.
action; liquor
ow mud was
C.

Table - III : Effect Of Split Dosage & Addition Of Starch On Powder Flocculants

Na₂OC of Slurry - 142.6 gpl
Feed Solid - 75 gpl

Flocculant(s)	Flocculant's Dosage (g / T Mud)	Settling Rate (mt / hr.)	Mud Compaction (ml)	Suspended Solid (mg / litre)
A	23.3	2.42	305	84
	26.6	3.79	290	102
	20.0 (split 50:50)	2.83	300	86
	23.3 + 0.5 kg (starch)	2.5	300	66
B	23.3	1.47	340	62
	30.0	2.47	280	70
	26.6 (split 50:50)	2.66	290	68
	26.6 + 0.53 kg (starch)	2.74	280	53
C	23.3	2.31	300	105
	20.0 (split 50:50)	2.65	290	109
	23.3 + 0.54 kg (starch)	2.40	290	92

Table-IV : Comparative Study Of Emulsion Flocculants

Na₂OC of Slurry - 151.9 gpl
Feed Solid - 60 gpl

Flocculant(s)	Flocculant's Dosage (g / T Mud)	Settling Rate (mt / hr.)	Mud Compaction (ml)	Suspended Solid (mg / litre)	REMARKS
D	100.0	2.12	350	90	SPLIT DOSE 50:50
	125.0	2.62	210	95	
	87.4	2.59	230	92	
E	100.0	2.52	240	86	SPLIT DOSE 50:50
	125.0	2.73	220	93	
	75.0	2.87	230	84	
F	100.0	2.06	355	84	SPLIT DOSE 50:50
	125.0	2.32	230	96	
	87.4	2.59	210	80	

Table - V : Comparison Of Polyacrylamide & Hydroxamated Polyacrylamide Flocculant (Hxpam)

Na₂O_c of Slurry - 151.1 gpl
Feed Solid - 95 gpl

Type of Flocculant(s)	Flocculant's Dosage (g / T Mud)	Settling Rate (mt / hr.)	Mud Compaction (ml)	Suspended Solid (mg / litre)
Polyacrylamide 'A'	35.5	3.92	210	126
	29.7	2.35	280	79
Polyacrylamide 'B'	54.3	3.62	320	114
	49.0	2.94	290	68
Polyacrylamide 'C'	132.5	1.24	380	70
	137.8	1.92	350	80
Hydroxamated Flocculants (HxPAM)	345.6	1.73	350	51
	365.0	2.44	330	55
Polyacrylamide 'B' and Hydroxamated Flocculants.	43.0 + 182.7	1.93	320	67
	43.0 + 193.5	2.47	310	57
	43.0 + 204.3	3.26	300	44
	53.0 + 107.5	Very Slow	-	-
	21.0 + 189.4	0.81	470	64
	31.5 + 189.4	1.69	410	62
	52.6 + 189.4	2.05	360	55
	63.1 + 189.4	2.17	350	51

Table - VI : Settling Of Diluted Slurry Alongwith Rheology Modifier

Na₂O_c of Slurry - 133.3 gpl
Feed Solids - 39 gpl

SN	Dosage gm/T mud		Settling rate (mt/hr)	Mud Compaction (After 1 hr) ml	Suspended Solid mg /lit.	Viscosity of underflow mud, (Cps)
	Flocculant	Rheology Modifier				
1	26	Nil	3.8	250	86	290
2	26	13	3.6	255	80	250
3	26	13	3.9	240	78	260
4	26	13	3.6	250	75	260

ended Solid
g / litre)

84
102
86
66

62
70
68
53

105
109
92

REMARKS

SPLIT DOSE
50:50

SPLIT DOSE
50:50

SPLIT DOSE
50:50

Table - VII : Settling Of Diluted Slurry Alongwith Rheology Modifier

Na₂O_c of Slurry - 151 gpl
Feed Solids - 81gpl

SN	Dosage gm/T mud		Settling rate (mt/hr)	Mud Compaction (After 1 hr) ml	Suspended Solid mg /lit	Viscosity of underflow mud, (Cps)
	Flocculant	Rheology Modifier				
1	30.9	Nil	1.96	245	128	400
2	30.9	12.4	1.90	240	120	310
3	30.9	16.1	2.16	240	82	320
4	30.9	18.5	2.25	230	90	320

The results of performance of powder and emulsion flocculants are shown in Table - I, II and IV. The dosage of powder flocculant was lower than the emulsion flocculant for the same settling rate. Comparative study of powder flocculants is shown in Table - II. Emulsion flocculants were tested separately and the results are given in Table IV. It was observed that irrespective of the type of flocculants, the mud was highly sensitive to variation in flocculant dosage. Higher dosage gave higher settling rate but with deteriorated overflow clarity suggesting therefore a plant design that would optimize a dosage with respect to both settling rate and clarity. Hence plant scale trials were embarked upon with an aim to get 2.5 meter / hour settling rate and an acceptable overflow clarity. The performance of polyacrylamide and hydroximated and combination of both are shown in Table - V. Laboratory results of rheology modifier are given in Table VI and Table VII.

FIG 1 - EFFECT OF FLOCCULANT (POWDER) DOSAGE ON SETTLING RATE & SUSPENDED SOLID

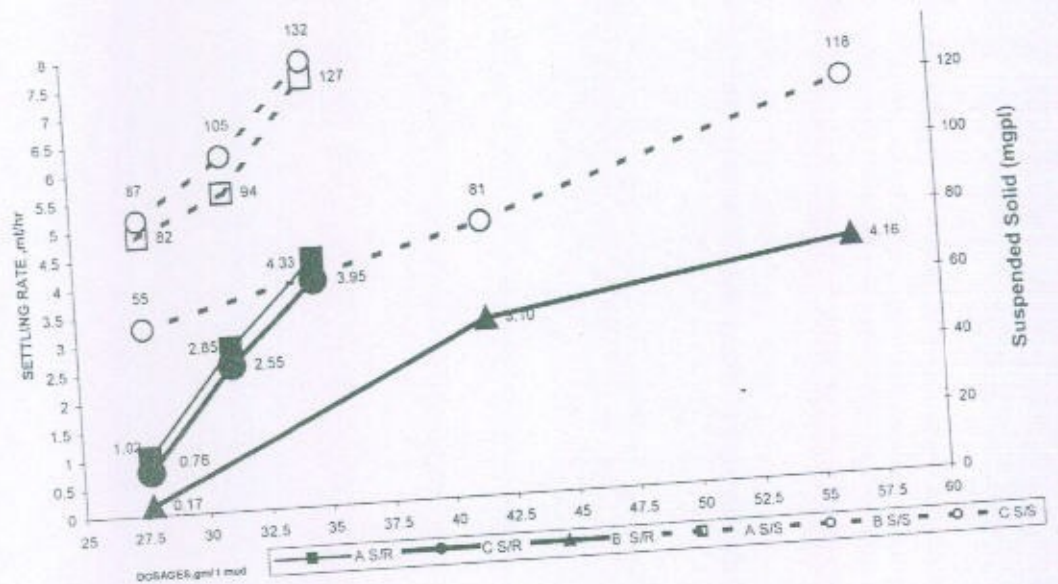


FIG 2 - EFFECT OF FLOCCULANT (EMULSION) DOSAGE ON SETTLING RATE & SUSPENDED SOLID

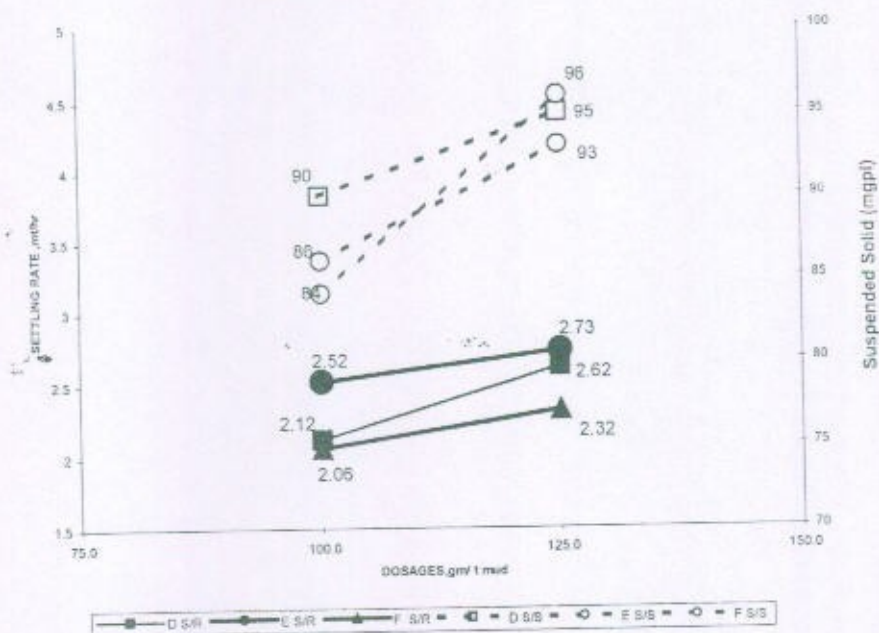
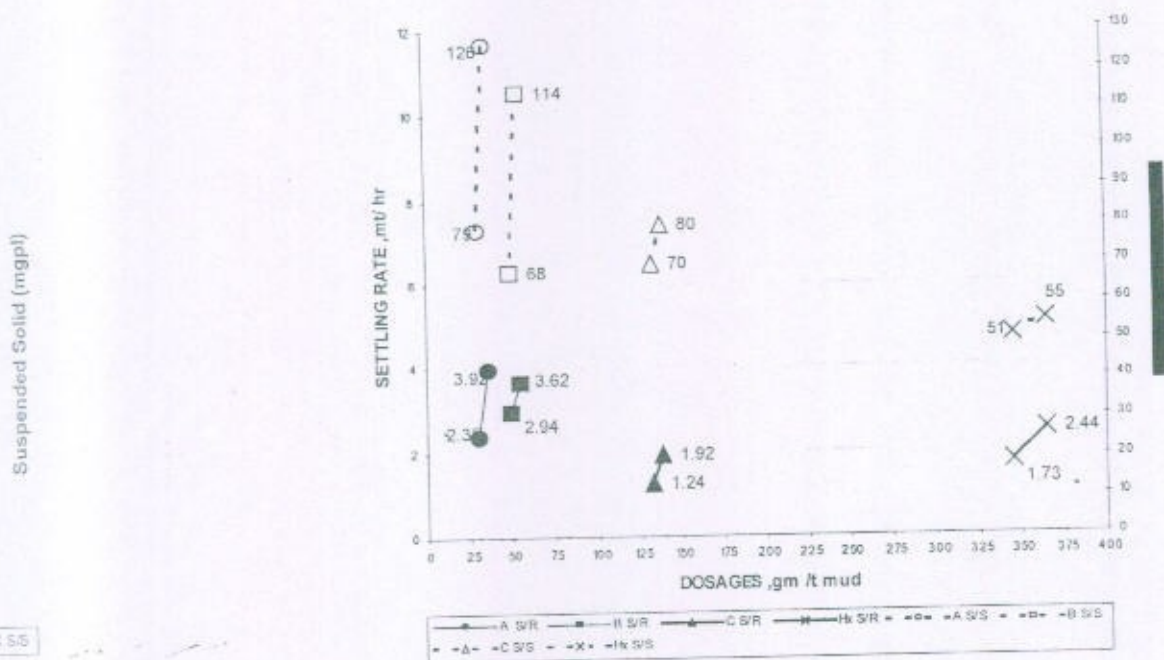


FIG 3-COMPARISON OF SETTLING RATE AND SUSPENDED SOLID (POLYACRYLAMIDE & HxPAM)



osity of
rflow
(Cps)

00
0
0
30

U and IV:
tling rate.
ere tested
ic type of
age gave
design that
trials were
clarity.

n in Table

Suspended Solid (mg/l)

C S/S

RESULTS AND DISCUSSIONS

Based on the laboratory tests, following can be summarized as-

- (1) The dosage of powder flocculant was lower than emulsion flocculant for the same settling rate.
- (2) It can be seen from the Table-I, Table-II and Fig.-1 that the dosage of powder flocculant were in the range of 30-70 gm/T mud and suspended solid were in the range of 75-100 mg/liter for 2.5 m/hr settling rate.
- (3) In case of emulsion flocculant the dosage were in the range of 100-145 gm/T mud and suspended solids were 90-105 mg/litre for settling rate of 2.5 m/hr (Table-IV and Fig.-2).
- (4) As seen from the Table-III that the dual addition gives lower dosage flocculant and somewhat higher settling rate, but clarities do not improve.
- (5) Polyacrylamide could induce high settling rate and mud compaction even at nominal dosages, but the inherent drawbacks is that it alone can not produce desired liquor clarity, making it mandatory using the same along with starch. It can be seen from Table -III that liquor clarity improves on addition of starch with polyacrylamide flocculants.
- (6) It was observed that the settling is very uneven in early stages, with no clear mud interface for polyacrylamide series. Hydroxamated Flocculants are more dependants on the addition and mixing conditions. In contrast to the poorly defined initial settling with polyacrylamides, the hydroxamated flocculants give no induction time and a very sharp mud interface essentially from the beginning of settling with very clear liquor above the interface.
- (7) From the Table-V and Fig.-3, it can be seen that the dosage of hydroxamated Flocculant was too high, but the floc formation, overflow clarity and the mud interface was very good, compare to polyacrylamide flocculants.
- (8) In order to reduce the dosage of hydroxamated flocculants, the combination of polyacrylamide and hydroxamated were tested and found good performance at the dosage level of 40-45 gm/T mud for polyacrylamides and 195-200 gm/T mud for hydroxamated (Table-V and Fig-3).
- (9) Table VI and Table VII shows the reduction in viscosity of settled mud on use of rheology modifier.

CONCLUSIONS

Comparative study of each flocculant for the settlers are shown in Table I to Table -VII and Fig. 1 to 3. From the Tables and Figures following can be concluded.

The powder Flocculant A is the best for the settler for low dosages of flocculant with desired settling rate though the overflow clarity is poor. In order to improve the overflow clarity, it is suggested to add a minimum quantity of (0.5-1 Kg/T mud) starch along with the flocculants. The powder flocculants C can be taken as alternative to A. In case of emulsion flocculant E may be used. The rheology modifier can used along with flocculant. The techno-economical feasibility of use of combination of hydroxamated and polyacrylamide shall be established after the plant trial are conducted.

ACKNOWLEDGEMENT

The authors are thankful to the Management of Bharat Aluminium Co. Ltd., Korba for granting permission for presenting the paper. The authors would like to thank Mr. T.L. Palani Kumar, Managing Director, Aluminium Business, and Mr. C.P.Baid, Director, Balco-Korba for their encouragement during the course of this work.