SINGLE REAGENT FOR COAL FLOTATION

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Abstract

Froth flotation is widely used for the beneficiation of fine coal and collectors are important for the effective separation in flotation. Conventionally, diesel in combination with a commercial frother is used in most of the coal washeries. With the escalating costs of petroleum products and their negative impact on environment, attempts were made to formulate an eco-friendly single reagent to replace diesel-frother system without hindering the flotation process performance. NML-Madras Centre in collaboration with M/s Somu Organo Chem Pvt Ltd, has been working on the formulation and evaluation of flotation reagents. Laboratory flotation tests were carried out using series of single reagents on a coking coal sample from Jharia region in the eastern part of India with an ash content of 24.9%. The best among the single reagents, Sokem 590C, yielded a float of 56.57% at 13.97% ash in the bench scale laboratory test. Based on encouraging results of flotation tests and kinetics studies, plant trials were conducted at a coal preparation plant in eastern India. The results of plant trials using this single reagent, Sokem 590C, are highly encouraging and economical as compared to diesel-frother system and this single reagent is non-petroleum based and biodegradable.

Keywords: Coal flotation, diesel, frother, single reagent, Sokem 590C.

Introduction

Coal is a mixture of degradation products of vegetable and mineral matters[1], fossilized through oxidation. The appearance and properties of coal is determined by the nature of its origin and the physical and chemical changes occurred after deposition, leading to wide variation in their genesis and composition. Coal is susceptible to weathering and oxidation resulting in the increase in formation of oxygenated functional groups on the coal surface, thereby, altering the degree of natural hydrophobicity of the coal surface. This influences the coal preparation processes that depend on surface properties of coal. The presence of mineral matter in coal which on combustion transforms to ash is a major drawback in coal when compared to other forms of fuels[2] and also in the coal cleaning process.

Flotation is a solid-solid separation process in aqueous solution based on the hydrophobicity differences between the substances to be separated[3]. This froth flotation technique has been widely deployed in processing of minerals and cleaning of coal especially for fines less than 0.5 mm size, generated due to extensive use of highly mechanized mining techniques. In flotation, fine particles show lower flotation rate, resulting in low flotation recovery[4]. Flotation being a surface based separation, utilizes the differences in the surface properties mainly the hydrophobicity of coal which is one of the main factor in determining the separation efficiency by flotation[5]. However, because of the heterogeneity on surface composition, the hydrophobicity or contact angle of coal surface can vary in a wide range[6-8]. The separation efficiency depends on the wettability difference between the coal-rich and mineral-rich particles of the coal slurry in the flotation circuit. The high percentage of ash presence in the Indian coal is one of the setbacks for coal cleaning.

In froth flotation, coal particles are often subjected to a suitable hydrocarbon oil treatment to alter their hydrophobicity, enhance recovery, and /or improve selectivity[9]. Conventionally, the collector used in most of the Indian coal washeries is diesel oil in combination with different frothers. The dosage of collector and frother has significant effect on flotation performance[10]. The usage of diesel oil, a non-polar oil, as collector comes along with the problem of not so friendly with environment. So a replacement for this diesel-frother system has been taken up in this work aiming to develop an eco-friendly single reagent for fine coal flotation. This also eases the industrial usage of dual reagent system of diesel and frother.

Experimental work

Material preparation

The coking coal fines which were the feed to flotation circuit of an operating coal preparation plant were obtained from Jharia region. The size and ash analysis of the coal samples are presented in Table 1 below.

Table 1 Size & Ash Analysis of coal

S.No.	Size, µm	Coal		
		Wt. %	Ash, %	Ash Dist. %
1	+500	16.61	32.16	20.26
2	-500+355	13.58	26.95	13.88
3	-355+212	18.46	25.67	17.97
4	-212+100	22.11	23.71	19.88
5	-100	29.24	25.27	28.01

The d_{80} of coal was found to be 421 µm and 24.90% head ash content. The +500 µm size fractions constitutes of high ash content of 32.16% as compared to other size fractions. The ash distribution is relatively lower in the middle size fractions in comparison to that in coarser and finer fractions.

Methodology

The experiments in the laboratory were conducted in Denver laboratory flotation machine, D-12 with a cell volume of about 3000 ml. Flotation experiments were conducted at natural pH and at impeller speed of 1200 rpm. The coal slurry was conditioned with diesel and frother for 3 minutes each and the froth (float) was collected till froth formation ceased. The collected float and tailings were dewatered, dried, weighed and subjected to ash analysis as per IS1350 (part I, 1984, reaffirmed 2000).

The diesel oil used as collector was purchased from the local petrol station and the commercial frother used is a proprietary chemical. The series of single reagents (Sokem 580C series & Sokem 590C) used for evaluation studies are proprietary chemicals provided by M/s Somu Organo Chem. Pvt. Ltd., (SOCPL) Bengaluru. Their response was evaluated by the yield and ash content of the float obtained and the results were compared with those obtained for diesel-frother reagent system.

Plant trials were conducted in flotation circuit of 35 tons/hr capacity in an operating coal preparation plant for evaluation of single reagent.

Results and discussion

A suit of single reagents (Sokem 580C series & Sokem 590C) were used in carrying out coal flotation at different dosages of each reagent. The reagent dosage corresponding to the maximum yield of the float with ash ranging from 14% to 16% in it was considered and the results are given in Table 2.

Table 2 Results using various single reagents of Sokem 580C series & Sokem 590C

S.No.	Sokem, Single reagent	Dosage, kg/t	Yield, %	Ash, %
1	583C	0.3356	62.94	14.95
2	584C	0.3524	64.47	16.00
3	586C	0.1742	64.14	15.89
4	587C	0.2693	62.50	15.76
5	589C	0.0762	54.82	14.38
6	590C	0.0775	56.57	13.97

From the above results, it is observed that Sokem 590C yielded 56.57% float with 13.97% ash. Also the consumption of the reagent was also found to be relatively less, proving to be more economical. Hence, flotation tests were carried out in detail using Sokem 590C and with diesel-frother for comparison and the results are given in Table 3.

Table 3 Flotation test with single reagent (Sokem 590C) & diesel-frother systems

S.No.	Sokem 590C reagent, kg/t	Yield, %	Ash, %	Diesel / frother, kg/t	Yield, %	Ash, %
1	0.0581	51.27	12.65	0.363/0.033	47.45	12.66
2	0.0775	56.57	13.97	0.454/0.049	52.36	14.00
3	0.0969	67.35	16.25	0.545/0.065	67.86	16.60
4	0.1163	73.98	17.47	0.726/0.065	81.37	18.84
5	0.1551	77.16	18.06	0.726/0.098	84.92	18.94

In the above table, the float with a minimum ash content of 12.65% at 51.27% yield could be obtained using single reagent Sokem 590C whereas with diesel/frother, the float assayed 12.66% ash at 47.45% yield. The yield Vs ash curve is plotted as Fig. 1 below. Further increase in dosages of both Sokem 590C and diesel/frother resulted in higher yield and also higher ash content in the float.

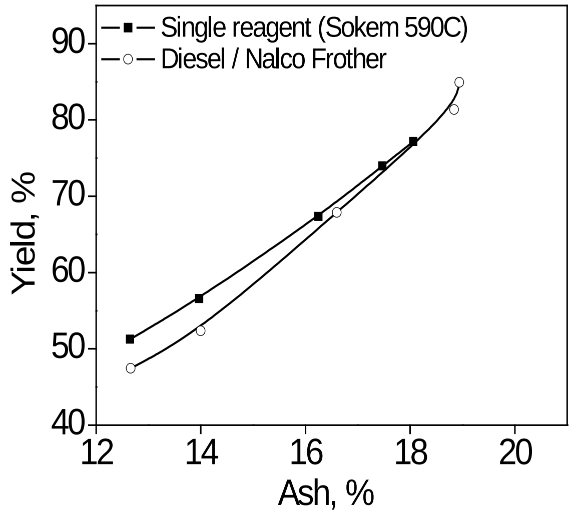

Fig.1 Yield Vs Ash plot for two different reagent systems

Flotation kinetics studies were also carried out on both the reagent systems. The float samples were collected at various time intervals and analyzed for its ash content. The results of the same are presented in the table below**.**

Table 4: Flotation kinetics of coal for two different reagent systems

S.No.	Time, sec	Sokem 590C (0.0775 kg/t)		Diesel & Frother (0.363kg/t & 0.033kg/t)	
		Cum. Yield, %	Cum. Ash, %	Cum. Yield, %	Cum. Ash, %
1	15	16.41	11.95	11.11	10.73
2	30	31.8	12.21	17.17	10.78
3	45	36.93	12.39	21.20	10.80
4	60	39.49	12.43	24.23	10.88

All operational variables are kept constant, the algebraic relationship between the above mentioned parameters is a flotation rate equation expressed as

$dC/dt = - kC^n$, where, C is the concentration of solids, t is the flotation time, n is the order of the process and k is the rate constant.

If n=1, the above equation becomes

$dC/C = -kdt$, which on integration gives

$\ln(C_0/C) = kt$, where, C_0 is the initial concentration of coal in the flotation cell, C is the concentration of coal remaining in the cell at the given time t and k is the flotation rate constant.

If the values for $\ln(C_0/C)$ are plotted against flotation time t, the slope of the straight line obtained is the flotation rate constant 'k'. The data obtained for the calculation of k is shown in Fig.2 for coal for both single reagent (Sokem 590C) and conventional diesel & frother system.

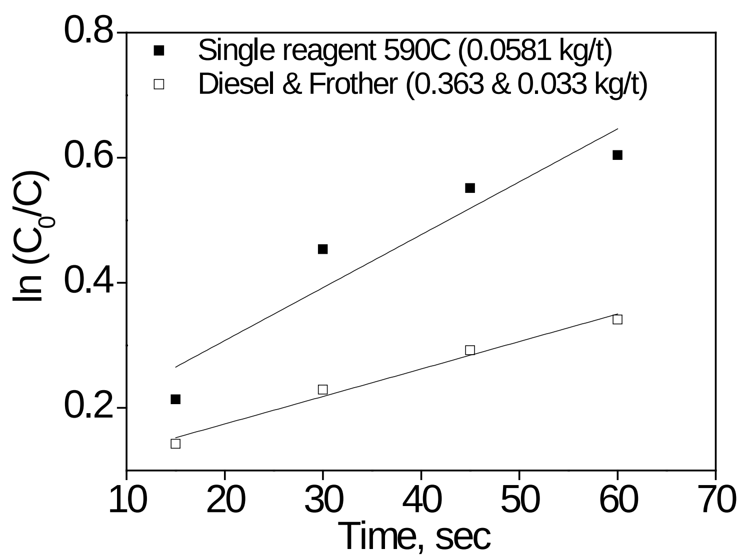

Fig.2 Flotation rate constant plot for two different reagent systems

The rate of flotation of solid particles determines the percentage recovery of the particles which can be obtained during flotation. From Fig.2, it is clear that Sokem 590C (0.0581 kg/t) provides faster flotation kinetics of coal ($k=0.00846\ s^{-1}$) as compared to that of diesel & frother (0.363 kg/t & 0.033 kg/t respectively) regime ($k=0.00436 s^{-1}$).

Plant trials were conducted with Sokem 590C to observe its performance in a flotation circuit of 35 tons/hr capacity of a coal preparation plant. The results of the same are given in table below in Table 6. Also, the results of conventional plant practice with diesel and frother system are given in Table 5.

Table 5: Results of plant trials conducted using diesel & frother

Trial period	Shift	Diesel/frother dosage, cc/min	Feed Ash, %	Froth Ash, %	Tailing Ash, %	Yield, % (fine coal recovery
Day 1	A	450/50	24.97	14.11	40.03	53.37
	B	500/50	28.43	18.73	38.88	
	C	500/50	27.97	18.81	37.18	
Day 2	A	500/50	28.71	18.22	35.62	50.87
	B	500/50	28.17	19.15	35.69	
	C	500/50	28.30	21.25	42.90	

Table 6: Results of plant trials conducted using single reagent Sokem 590C

Trial Period	Shift	Sokem 590C dosage, cc/min.	Feed Ash, %	Froth Ash, %	Tailing Ash, %	Yield, % (fine coal recovery)
Day 1	A	120	25.94	13.94	38.37	53.99
		120	26.14	13.98	48.18	
		120	33.38	18.56	46.34	
	B	120	22.93	13.73	37.44	60.88
		120	23.10	13.63	37.20	
		120	23.87	13.81	40.02	
	C	120	25.91	14.86	38.98	58.66
		120	23.34	13.98	33.01	
		120	20.24	13.82	39.36	
		120	24.51	14.18	37.03	

The above results of the plant trials indicate that single reagent Sokem 590C is very effective in resulting greater yield and lower ash content in the float. It is observed that the reagent is more effective in collecting fine and ultrafine coal particles, rather than the coarser particles. The consumption of Sokem 590C is much less compared to that of diesel being used in the plant. This single reagent doesn’t have adverse effect on the downstream operations in the plant such as thickener water quality. Overall, the single reagent addition at a single point also makes the operation easier.

Conclusion

The new single reagent Sokem 590C was evaluated for its efficiency on coal flotation both in laboratory bench scale studies and in an operating coal preparation plant. It was found that single reagent was superior to the conventional diesel-frother system, in terms of recovery and ash content. Flotation results also indicate that the new reagent Sokem 590C was effective in improving the flotation performance of fines in the flotation circuit. Adopting single reagent Sokem 590C proves to be efficient in coal flotation as found from the flotation kinetics studies. Considering the plant operation point of view, handling single reagent system is much easier than compared to two reagent system. Economically also, this single reagent Sokem 590C proves to be much low in cost as compared to diesel-frother system.

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