" Recovery of coal fines using hydrotrope as promoter in soap flotation"

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Abstract

Investigations on the efficiency of hydrotrope as promoter in soap flotation is presented in this paper. Bhowra Coking Coal sample was used in the tests. The aim of the investigation is to achieve higher yield recoveries of cleans with lower ash percent of cleans. Flotation experiments were conducted by varying three prameters i.e hydrotrope dosage, collector dosage and kinetics. Urea was used as hydrotrope and soap light diesel oil emulsion was used as collector in flotation test. Hydrotropes acts as in flotation. Promoters when used along with collectors results in high recoveries.The results of the flotation efficiency in terms of higher yield recoveries and low percent of concentrate were noted. From results it can be inferred that about 78% of the coal cleans were recovered when hydrotrope was used along with soap LDO emulsion with corresponding 13.63 percent of ash. On the other hand only 37.6% of cleans were recovered when diesel oil is used as collector. From Lagergren first order kinetic study the R^2 value was found to be 0.9048 and from pseudo second order kinetics study the R^2 value was found to be 0.9372 which explains satisfactory flotation results.

Key words Hydrotrope, soap light diesel oil emulsion, collector, kinetics, cleans, promoter, flotation efficiency, concentrate, yield, ash percent.

Introduction

About 50% of the world's proven coal deposits are quite made up of low -rank coal such as lignite and sub-bituminous coal. The low-rank coal gained high attention and the urge to use due to the rise of the world's energy demand [1].Low-rank coals are normally treated as waste, posing an excellent threat to the environment . Hence, reducing oxygen-containing functional groups and enhancing hydrophobic functional groups on the coal surface seems to be an appropriate method to enhance the oxidized coal flotation.

The upgrading of low-rank coal to get high-quality coal resource has been conducted by the forth flotation. Froth flotation is an efficient method for the upgrading of fine coals of less than 0.5 mm [2].This is a surface-based

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method supported the differences in surface properties between the target minerals and gangue minerals. within the process of froth flotation, the target minerals are often selectively hydrophobic by adding agents called collectors at the liquid/solid interface. The bubbles are injected into the flotation cell, and therefore the hydrophobic minerals within the upper a part of the flotation cell are recovered under strong stirring conditions [3].
In the process of fine flotation, the hydrophobicity of the coal particle surface is one among the foremost important factors to work out the flotation effect. However, the surface of low-rank coal is abundant with oxygen-containing functional groups (hydroxyl, carboxyl, carbonyl, phenolic hydroxyl), which can form a chemical bond with water molecules and cause the low hydrophobicity of the coal surface.most coals are vulnerable to surface oxidation by weathering, which may occur during storage or transportation of the raw coal. The result's generally the formation of surface oxygen functional groups, most ordinarily carboxyl, hydroxyl and carbonyl groups. These oxygen containing functional groups reduce the hydrophobicity of the coal surface and thereby make the coal difficult to float [4].

Soaps as collectors in flotation rose out thanks to their high performance in inducing hydrophobicity to mineral surface. Soaps are the sodium and potassium salts of the long chain acid mainly having palmitic, steric, oleic, linoleic, linolenic, ricinoleic acids and capric, cpriylic lauric and myristic acids are in minor quantities. Straight chain carboxylic acid s within the soap form compact adsorbed layer of fatty acid molecules on the mineral surface [5].Some plants use soap–light diesel fuel (LDO) [6-7]. Use of soap–LDO emulsion helps in collecting coarse particles whereas light diesel oil(LDO) acts an extender of hydrocarbon chain [8]. It is reported that Jhamarkotra soap–LDO emulsion performed better [9]. Soap .molecules serve dual purpose in the flotation process [10].

Hydrotropes are a type of amphiphilic molecule that can't form well-organized structures in water, such as micelles, but can help organic molecules dissolve in water [11].Hydrotropes are a class of chemicals that improve the solubility of sparingly soluble solutes by several orders of magnitude under normal conditions. Hydrotropy is a molecular phenomenon in which the addition of a second solute (the hydrotrope) causes the aqueous solubility of weakly soluble solutes to increase [12-13]. Hydrotropes such as urea, sodium benzoate, and sodium salicylate were used to improve soap flotation efficiency when analysing Eshidya phosphate ore (Jordan) [14].

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Reagents

Commercial grade reagents used in the plant are used in flotation experiments. Light Diesel oil was supplied by Indian oil . Diesel oil and Urea which are used in experimentation are procured from the plant store, CMIFR, Digwadih, Jharkhand.

Materials and Methods

Laboratory flotation test were performed in Denver type sub-aeration cell of 2 liter capacity. The ore pulp was conditioned at 25% solids in the same cell . The collector(Soap-light diesel oil emulsion @ 2.5 kg per ton of ore) as required for different tests in this study was added into the pulp for 2 min, followed by the conditioning of promoter at a concentration of 2.3 kg/t for another 2 min. Throughout the test, impeller was set at an agitation speed of 1500 r/min in the flotation cell where pulp was fully dispersed but no excessive flow of pulp into the froth was observed. After air was introduced to the cell at a flow-rate of 200ml/min, the froth was scraped for 30sec.The concentrate and tailing were filtered, dried and weighed to calculate the flotation yield. The tap water was used in all the experiments.

Results and Discussions

Bhowra cleans sample was used to study the efficiency of hydrotropes in soap flotation. Table-1 specify the characterization of raw coal which proximate analysis of coal. Table-2 depicts the petrographic analysis of coal, Table-3 give the ultimate analysis of coal particles. In Table-4 the screen analysis of the coal sample were presented.

Table 1-Characterization of raw coal

Moisture%	Ash%	Volatile Matter %	Fixed Carbon %	CSN	LTGK
2.1	26.2	25.6	46.1	2.5	F

Table-1 presents the characterization data of raw coal. The results of the characterization states that the raw coal used for experimention coantins about 26.2% of ash which decreses the quality of coal and grade of the coal. It was found that high percent of ash in coal is due to coals are susceptible to surface oxidation by weathering, which can occur during storage or transportation of the raw coal. The result is generally the formation of surface oxygen functional groups, most commonly carboxyl, hydroxyl and carbonyl groups. These oxygen containing functional groups reduce the hydrophobicity of the coal surface and thereby make the coal difficult to float [4]. And the volatile matter percent is 25.6%,Moisture 2.1% with fixed carbon percent of 46.1% which is a sign that these amounts are high than normal standard as a result along with ash percent they too contribute in decreasing the grade of coal. As a result froth flotation process with suitable minerals have been used to upgrade the grade of coal.

Table-2 Petrographic analysis of coal

Maceral Analysis & Reflectance				Mean	V type distribution (%)		
Volume (%)				Reflectance	V8	V9	V10
Vitrinite	Liptnite	Inertinite	Mineral Matter	(Ro)	31	47	22
56.9	2.0	28.5	12.6	0.94			

Table-2 gives the results of the petrographic analysis carried out for raw coal. Coal petrography refers to a method for characterizing the organic constituents (macerals) and inorganic constituents (mineral matter) of coal which helps us to fit the best method to upgrade the coal for industrial use [15].Based on petrographic analysis coal are classified as bright or dull coal in which is based on Vitrinite percent in coal. Here 56.9% of vitrinite which names coal as bright coal [16].

Table 3-Ultimate analysis of coal

C %	H%	N%	S%
59.59	4.07	1.59	0.57

Table-3 shows the results of the ultimate analysis of the coal. The sulfur content in coals varies considerably but most common within the range of 0.5% to 5% total sulfur. The coal with less than 1% is classified as low-sulphur coal. Coal usually contains between 0.5 and 3 % nitrogen on a dry weight basis. The nitrogen found in coal typically takes the form of aromatic structure such as pyridines and pyrroles. With increasing the percent of the carbon the purity of the coal increases[17].

Table 4 Screen Analysis

Size(micron)	Wt%	Ash%
500	0.0	0.0
-500+250	9.8	17.0
-250+125	16.4	15.6
-125+63	20.5	16.5
-63	53.3	32.0
	100.0	24.7

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Table 4 gives the screen analysis data of Bhowra coal. It is inferred from the data that coal contains 53.3% of fines which are difficult float. Hence froth flotation is fit to recover fines.

A) Effect of hydrotrope (urea) dosage to recover cleans

The hydrotrope employed in this experiment was urea . Urea was chosen for flotation of Bhowra cleans and Bhowra cleans because it proved to be the best recover for tiny particles. The urea dosage was varied between 0.17 and 0.57 ml per 250 grams of coal sample.

Table 5 The effect of hydrotrope (urea) dosage on cleans and ash percent recovery

Sl.no	Conditioning		Cleans		Rejects		Feed	combustible	Non–combustible	Efficiency
	Promoter	Promoterdosageml	Wt%	Ash%	Wt%	Ash%	Ash%	Recovery	Recovery	Index
01	Urea(hydrotrope)	0.17	70	13.26	30.0	46.0	23.1	78.9	40.2	38.7
02		0.27	71.6	13.83	28.4	52.1	24.7	81.9	40.1	41.8
03		0.37	76	14.03	24.0	63.6	25.9	88.2	41.1	47.1
04		0.47	82	15.03	18.0	52.3	21.7	89.0	56.7	32.3
05		0.57	83	15.26	17.0	63.3	23.4	91.9	54.1	37.8

Cleans wt percent and ash percent are plotted against the urea(hydrotrope) dosage(ml) in fig 1. The recovery of clean coal rose as the dosage of urea increased, as shown in the graph below. About 76 percent of cleans were recovered with an ash percent of 14.03 using an optimum dosage of urea of 0.37ml for 250 gm of coal (collection time of 30sec,RPM-1500,Conditioning of pulp 5min,pH-7) and an optimum dosage of urea of 0.37ml for 250 gm of coal (collection time of 30sec,RPM-1500,Conditioning of pulp 5min,pH-7).However, the recovery of coal in Cleans increased from 37.6% when diesel oil was used to 76 percent (urea=0.37ml for 250 grammes of sample, frother dosage(MIBC)=0 lit/ton of ore,collection time= 30 seconds, RPM-1500,Pulp density-250grams for one litre of water) with corresponding 14.03 percent of ash (diesel oil-0.33ml,MIBC-30 ml,RPM-1500, However, raising the dosage further only resulted in a minor change in cleans recovery. As the collector dose was increased, the amount of ash % grew linearly. The technical cause could be related to urea's capacity to alter the structure of water near the phosphate mineral surface, enhancing bubble particle attachment [18] .Other authors [19] have made similar observations.

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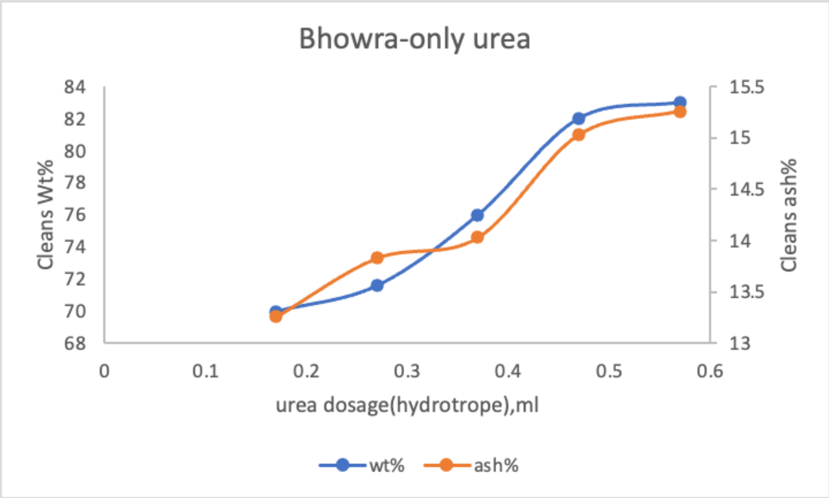

Fig. 1 Effect of urea (hydrotrope) dosage to recover clean coal(Bhowra)

B) Effect of collector dosage (urea+ soap light diesel oil emulsion) to recover clean Bhowra coal and ash percent

The current experiment uses urea (hydrotrope) as a collector, combined with a soap-light diesel oil emulsion. Because urea, when combined with soap-light diesel oil, proved to be the most effective method for recovering fine particles. The soap-light diesel oil dosage was varied in the range of 1 to 20ml per 250 grams of coal sample using a set optimum urea dosage (0.37 ml).

Cleans wt percent and ash percent are plotted versus the collector dosage(ml) in fig 2. As the collector dosage increases, the clean coal recovery increases, as shown in the graph below. About 82 percent of cleans were recovered with an ash percent of 14.25 at an optimum dosage of collector(urea 0.37ml +soap light diesel oil emulsion-20ml) for 250 gm of coal(collection time of 30sec,RPM-1500,Conditioning of pulp 5min,pH-7) for 250 gm of coal(collection time of 30sec,RPM-1500,Conditioning of pulp 5min,pH-7). However, the recovery of coal in Cleans increased from 76 percent when urea alone was used to

Table 6 Effect of collector(hydrotrope + soap LDO) dosage to recover BCC cleans and ash percent

Sl.no	Conditioning		Cleans		Rejects		Feed	combustible	Non–combustible	Efficiency
	Urea (hydrotope) dosage ml	Collector+urea(hydrotrope) ml	Wt%	Ash%	Wt%	Ash%	Ash%	Recovery	Recovery	Index
01		10	70	13.06	30.0	46.0	22.9	79.0	39.8	39.1
02		20	76	13.2	24.0	52.1	22.5	85.2	44.5	40.6

03	**0.37 ml**	**30**	**78**	**13.63**	**22.0**	**63.6**	**24.6**	**89.4**	**43.2**	**46.2**
04		**40**	**82**	**14.25**	**18.0**	**52.3**	**21.1**	**89.1**	**55.4**	**33.7**
05		**50**	**84**	**15.5**	**16.0**	**63.3**	**23.1**	**92.4**	**56.2**	**36.1**

(urea-0.37ml,MIBC-30 ml,RPM-1500, collection time-30 sec,Pulp density-250grams for one litre of water) 82 percent when urea was combined with soap-light diesel oil emulsion(urea=0.37ml+soap-light diesel oil-20ml, frother dosage(MIBC)=0 lit However, raising the dosage further only resulted in a minor change in cleans recovery. As the collector dose was increased, the amount of ash % grew linearly. The technical rationale could be due to Light diesel oil's ability to lengthen the hydrocarbon chain, whilst urea works as a water structure breaker, increasing selectivity[20].

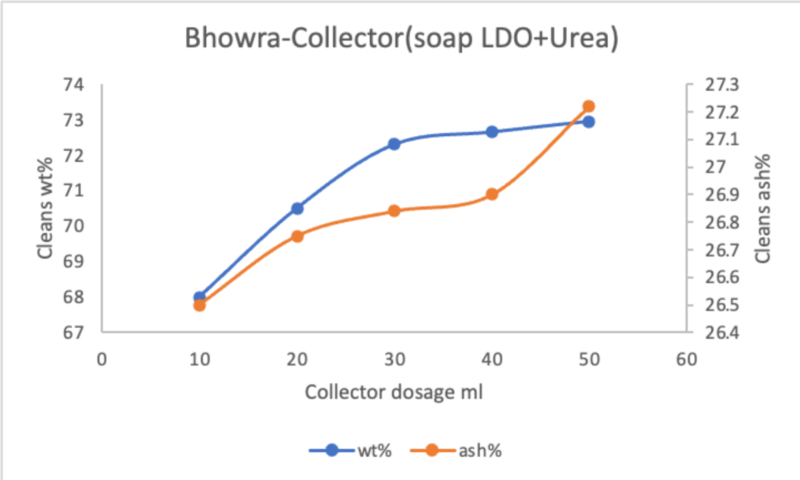

Fig 2Effect of collector dosage (urea+ soap light diesel oil emulsion) to recover clean Bhowra coal and ash percent

C) Flotation kinetics studies Bhowra coal

The below tables gives the flotation kinetics dat

Table 7 Kinetics data

Sl.no	Conditioning			cleans		Rejects		Feed	combustible	Non–combustible	Efficiency
	Urea (hydrotrope) ml	Collector (Soap LDO) ml	Timesec	Wt %	Ash %	Wt %	Ash %	Ash %	Recovery	Recovery	Index
01		20	5	18	13.65	82.0	46.0	40.2	26.0	6.1	19.9

02	0.37		10	21.2	14.44	78.8	52.1	44.1	32.5	6.9	25.5
03			15	32	14.98	68.0	63.6	48.0	52.4	10.0	42.4
04			20	2	18.34	98.0	52.3	51.6	3.4	0.7	2.7
05			25	1.6	34.55	98.4	63.3	62.8	2.8	0.9	1.9
06			30	0.8	42.06	99.2	78.6	78.3	2.1	0.4	1.7

(i) Lagergren first order

Figures 4.3.1.3(a) and 4.3.1.3(b) depict a Lagergren plot and a pseudo second order kinetics plot for the flotation of Bhowra cleans (b). The rate constant values for first and second order rate equations [22-23] are summarised in Table-5.2. The first order rate equation does not satisfactorily explain flotation, but second order rate equations satisfactorily explain flotation interactions.

Wt%= -0.9989t + 30.08,R^2 = 0.5123

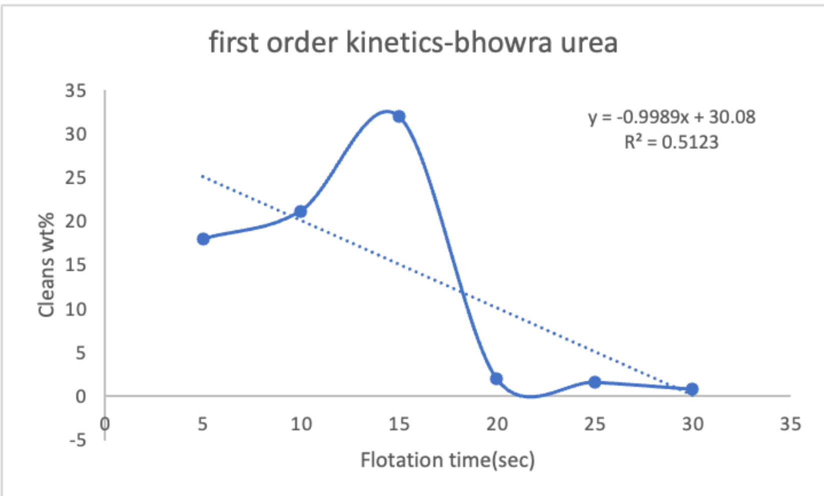

Fig 3(a) Lagergren first order for flotation of Bhowra coal

(ii) pseudo second order

Second order rate equations explain the flotation interactions satisfactorily [21-22]. The rate constant values for second order rate equations

Ash % = 1.1757t + 2.4293,R^2 = 0.8134

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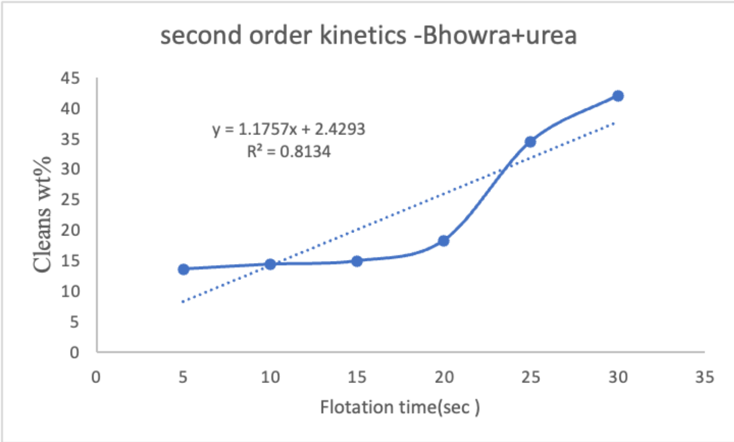

Fig 3 (b) pseudo second order for flotation of Bhowra coal

Table 8 Equation and rate constants

Order	equation	R^2
Lagergren first order	Wt%= -0.9989t + 30.08	$R^2 = 0.5123$
pseudo second order	Ash % = 1.1757t + 2.4293	$R^2 = 0.8134$

Conclusions

It can be concluded that hydrotropes are best reagents to gain higher recovery of fines and also hydrotropes when used along with collector clearly shows best results.From results it can be inferred that about 78% of the coal cleans were recovered when hydrotrope was used along with soap LDO emulsion with corresponding 13.63 percent of ash. On the other hand only 37.6% of cleans were recovered when diesel oil is used as collector. From Lagergren first order kinetic study the R^2 value was found to be 0.9048 and from pseudo second order kinetics study the R^2 value was found to be 0.9372 which explains satisfactory flotation results.

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