# Recovery of Coal by Froth Flotation Equipment

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*Abstract*:-- **Coal in India and worldwide, is cleaned predominantly by dense medium separations. But when it comes to cleaning of fine coals such as mine dust, slack coal, washing rejects and slurries, froth flotation method of coal cleaning has better efficiency and handling. In this method of wet cleaning, froth is made in a flotation cell by bubbling air through water in presence of frothing agents, collecting agents on addition pure and light coal adhere to air bubble while the dirtier part sinks to bottom of the cell. Thus clean coal is recovered from the collected froth amount. In this current project froth flotation was being carried in a fixed froth flotation cell used in the laboratory. Runs of froth flotation have been carried out using the same stock of coal but varying the size of coal fines, concentration of coal slurries and different doses of collecting agents, frothing agents and of their mixtures. After the completion of the process the slurry consisting coal is collected and dried in atmospheric conditions. In order to measure the ash content, moisture content, volatile content, and fixed carbon in recovered coal were calculated by proximate analysis. Effect of size of particles in slurry was very much visible while the recovery was enhanced when higher dose of collecting agents and frothing agents were used. Use of advanced frothing agents and collecting agents can be studied further in this direction.**

*Index Terms*— **Coal cleaning, Froth flotation, Frothing agents, Collecting agents, coal analysis**

## I.    INTRODUCTION

The recovery and utilization of these fine coal as a significant energy source will have considerable environmental and economic benefits. The removal of coal could be achieved by physical or chemical processes such as gravitational separation[1],electrostatic separation[2]or froth flotation[3]. Among them, Flotation has been proven to be the most effective method for the recovery of coal[4]. Many researchers have investigated the recovery of coal by flotation.

The components of coal which comprise of Shale, Clay, Sandstone, Silica, Pyrite, Gypsum, Sulphates and Phosphates constitute the mineral impurity in coal. Impurities can be of two types: a) Inherent of Fixed and b) Extraneous or Free. The first category gets associated to coal during its formation period while the second one gets associated during the mining activities, storage and transportation, after the coal is formed. chemical method of cleaning is restricted to laboratory testing. It is also very costly and less efficient. The physical cleaning processes help us cleaning coal on the basis of the differences in the physical properties of pure coal and impurities. Wet and Dry methods[4] can be defined, as predictable, by the type of operation i.e. wet and dry respectively. Majority of dry processes operate on the basis of density, friction, resilience; while most of the wet processes operate on the basis of density, shape, size and wettability.

Froth flotation can be coined as a highly adaptable method for the physical separation of particles based on the differences in the ability of air bubbles to selectively adhere to the specific mineral surfaces in the mineral or coal slurries. When attached to air bubbles the particles are carried to the surface and removed gradually, while the particles which are completely wetted stay in the liquid phase. Froth flotation can be implemented to a wide range of mineral separations as it uses chemical treatment methods to selectively modify mineral surfaces so that they possess the necessary properties for the separation. Currently it is being used as a versatile method in separating sulphide minerals from silica gangue[5] (and from the other sulphide minerals); separating potassium chloride from sodium chloride; separating coal from ash-forming minerals[7]; removing silicate minerals from iron ores; separating phosphate minerals from silicates; and even non-mineral applications such as de-inking recycled newsprint[6]. Whether it is fine-grained ores or coals that are not suitable for gravity concentration, it is particularly useful.

The phenomenon of froth flotation depends on the following three systems being specific [8]. Equipment Components: Cell design, Agitation, Air flow, Cell bank configuration, Cell Bank. Control Operation Components: Feed rate, Mineralogy, Slurry density, Particle size, Temperature. Chemical Components: Frothers, Collectors, Activators, Depressants, pH controller[9].Thus the area of research related to Froth Flotation revolves around the study of the effect of such components on the efficiency of cleaning using froth flotation the aforesaid technique.

The major variables in this process can be listed as [10]: • Slurry flow rate (or retention time) • Slurry

composition (Nature of solid content, concentration) • Chemical reagents (Frothers, collectors, pH controllers) • Electrochemical potential (Eh) and Conductivity • Froth properties (Bubble size, density, froth stability) • Slurry levels and air flow rates If we wish to change all the parameters simultaneously we cannot achieve satisfactory cleaning.

## II . METHODS & EXPERIMENTS

SAMPLE COLLECTION AND PREPARATION: For the experiments coal was collected from Ramagundam open cast project (Seam-2). At first lumpy coal was subjected to jaw crusher. Next the coal is crushed in roll crusher followed by ball mill to fine size. For proximate analysis, coal was then intermixed thoroughly and sampling was done by seiving. This was meant to attain further uniformity in the obtained coal sample. Some amount of coal was kept aside for proximate analysis. Small quantity of coarser coal was found; those were screened, crushed again and mixed in the obtained powdered coal.here we used coal of different mesh size and various trials were done for attaining maximum purity. PROXIMATE ANALYSIS: Determination of moisture, volatile matter, ash and fixed carbon in coal comprises its proximate analysis. It suggests us the overall composition of coal without incorporating elemental analysis. It also gives a picture of uniformity in the coal sample [9].

Determination of Moisture Content: Approximate 1 g fine coal was taken in a weighed porcelain crucible and was placed in a hot air oven at 100 – 110˚C for 1 hour. Then the loss in weight of the coal due to this heating gave us the moisture per cent of coal used. %moisture in coal=loss in weight of coal/weight of coal initially taken×100 Determination of Volatile Matter in Coal: It is the loss in weight of moisture free powdered coal when heated in a crucible fitted with a loosely fitting cover in a muffle furnace at 950˚ C for exactly 7 minutes.
% volatile matter in coal=loss in weight of moisture free coal/weight of moisture in coal×100 Determination of Ash in Coal: It is the weight of residue left in a crucible after complete combustion of a previously weighed quantity of powdered coal in an open crucible (i.e. in the presence of air) at 750 ˚C in a muffle furnace for duration of 90 minutes. % Ash in coal=weight of residue ash formed/weight of coal initially taken×100 Determination of Fixed Carbon: It was mathematically calculated and was determined indirectly by deducting the sum of total of moisture, volatile matter and ash percentage from 100. % Fixed carbon in coal=100-(moisture%+volatile matter%+ash%)

The proximate analysis was carried out for 3 specimens from the same sample to check the correctness and to ensure uniform result throughout. It was reported in tabulated manner and average value of Ash % and Fixed Carbon % were obtained.

Float and Sink Test: The crushed coal sample was sieved and size fraction of -2 mm + 1 mm was obtained. The organic liquids used in this method were Carbon Tetrachloride (sp. Gravity 1.595, Benzene (sp. Gravity 0.878) and Bromoform (sp. Gravity 2.889). By inter-mixing these liquids, liquids of specific gravities 1.3, 1.4, 1.5, 1.6, 1.7, 1.8 were prepared. The component calculation is given in Table 3. Due to limited availability of organic liquids, the test was carried out in small scale in 250 mL beakers. The beakers were arranged in the increasing order of their specific gravity. The specific gravity was measured using Hydrometer; when any deviation was found w.r.t. the desired specific gravity, further organic liquids were added to achieve correct specific gravity. 50 g sample was first placed in the lowest specific gravity fluid i.e. 1.30. The fraction lighter than the liquid did float and the heavier fractions did sink. The sink was then dried and placed in the next heavier liquid and as earlier, the float and sink fractions were separated, and the sink was again put into next higher density liquid, it was carried out up to the 1.80 fraction. In this way the fractions from different densities were collected, dried and weighed. The ash analysis of all coal was done and reported.

Sample Testing: For sample testing, sieved coal of 10 gm is taken. 2 ml of kerosene is added to it as a collector. Pine oil of 2-3 drops is added as frother and stirred thoroughly.In second testing we used eucalyptus oil as frother and same process is repeated.For third testing, we used sodium lauryl sulphate as frother and same process is repeated.

## III. MODELLING OF FLOTATION

A flotation cell consists of two distinct phases**:** A coal phase and a froth phase with various inter and intra-phase processes involved in the transport of material. The proposed framework in this research is based on a multi-scale approach where attachment processes are coupled to equipment scale and inter-phase processes. This was achieved by formulating population balance, hydraulic force balance, mass transfer and kinetic rate equations for attachment and detachment and entrainment/drainage of mineral particles[11].

*Flotation kinetics - Batch flotation*

      Many authors presented their equations that should describe flotation kinetics of various minerals. These equations are also present in different forms in mineral processing modelling and simulation software, such as MODSIM™, USIM™ PAC, etc. Although many different equations have been proposed over the years, only the selected ones describing batch (laboratory) flotation are implemented in this tool.

*Namely there are following four models [11]:*
1. **Classical model**
2. **Klimpel model**
3. **Kelsall model**
4. **Modified Kelsall model**

**1. Classical model**

Classical model uses two parameters to describe flotation kinetics:

$R = R\infty (1- e^{-k\tau})$

Where:

**R** - Recovery of mineral (dependent variable)

$R_{\infty}$- infinite (equilibrium) recovery - maximum possible recovery of mineral

**K** - Flotation rate constant.

$\tau$ - Flotation time [min] (independent variable)

**2. Klimpel model** (Klimpel 1980)

Klimpel model uses two parameters to describe flotation kinetics:

$$R = R_{\infty} \left(1 - \frac{1}{k\tau}(1 - e^{-k\tau})\right)$$

where:

$R$ - recovery of mineral

$R_{\infty}$ - infinite (equilibrium) recovery - maximum possible recovery of mineral

$k$ - modified first-order rate constant .

$\tau$ - flotation time

**3. Kelsall model** (Kelsall 1961)

Kelsall model uses three parameters to describe flotation kinetics:

$R = (1-\varphi)(1-e^{-kf\tau})+\varphi(1-e^{-ks\tau})$

where:

$R$ - recovery of mineral

$\varphi$ - fraction of flotation components with the slow rate constant

$k_f$ - fast flotation rate constant

$ks$ - slow flotation rate constant

$\tau$ - flotation time

**4. Modified Kelsall model** (Jowett 1974)

Modified version of Kelsall model adds influence of infinite recovery to Kelsall model and brings number of parameters to four:

$\infty$

$R = R \quad (1-\varphi)(1-e^{-kf\tau})+\varphi(1-e^{-ks\tau})$

$R$ - recovery of mineral .

$R_{\infty}$ - infinite (equilibrium) recovery - maximum possible recovery of mineral .

$k_f$ - fast flotation rate constant .

$k_s$ - slow flotation rate constant .

$\varphi$ - fraction of flotation components with the slow rate constant .

$\tau$ - flotation time .

$\tau$ - flotation time .



*Image of froth at the onset of the run( t = 0 min)*



*Image of froth at the end of the run( t = 10 min)*

## IV. RESULT & DISCUSSION

*The observations and calculations of proximate analysis are reported below:*

*Table 1: Observations of Proximate Analysis*

| Sample No | Weight of Empty Crucible (g) | Weight of coal content (g) | Weight after moisture removal (g) | Weight after Volatile matter removal (g) | Weight after ash residue formati-on (g) |
|---|---|---|---|---|---|
| 1 | 21.43 | 1.00 | 22.38 | 22.06 | 21.72 |
| 2 | 22.57 | 1.00 | 23.52 | 23.19 | 22.86 |
| 3 | 21.07 | 1.00 | 22.02 | 21.70 | 21.34 |

*Table 2: Results of Proximate Analysis*

| Sample No | Moisture (M)% | Volatile Matter (VM)% | Ash (A)% | Fixed Carbon (FC)% |
|---|---|---|---|---|
| 1 | 5.00 | 33.68 | 29.00 | 32.32 |
| 2 | 5.00 | 34.74 | 29.00 | 31.26 |
| 3 | 5.00 | 33.68 | 27.00 | 34.32 |

The average ash % is 28.33 % and average fixed carbon % is 32.63%. The proximate analysis of the obtained coal sample suggested that it is of uniform composition which will prevail for all the runs using the coal of same stock.
While studying the effect of collecting agents and their doses on coal cleaning, the densities of collecting agents used did not vary much, thus the doses could be equivalently calculated in terms of g per kg of coal feed.

## V. CONCLUSION

Froth flotation has been more widely used in mineral ore beneficiation processes than in coal beneficiation. Since we know that the majority of coal cleaning processes are dense medium separations which clearly give better results than froth flotation processes, the scope of froth flotation processes are limited to mine dust, slack coal and washing rejects, slurries. But it eliminates the inability of cleaning fine coals and slurries as in dense medium separations. The results obtained in the laboratory are very much different to that of washeries that operate on froth flotation principles on industrial scale because all of them operated in a continuous fashion where feeding and froth collections are continuous. Effect of several frothing agents and their addition rates can be studied as the future scope of this project. Moreover, all such experiments are needed to be performed on all grades of coal obtained from different origins or seams, to draw more confident conclusions in this direction.

## REFERENCES

[1]. Annual Report 2010-2011, Ministry of Coal, Government of India, http://coal.nic.in

[2]. Sarkar Samir. Fuels and Combustion, 3e, University Press

[3]. Gupta O. P. Elements of Fuels, Furnaces & Refractories, 5e, Khanna Publishers

[4]. Chakraborty M. Coal technology development activities in India, Energy, Vol. 11 (1986), pp. 1231-1237

[5]. Wills Barry A. and Napier-Munn Tim: Will"s Mineral Processing Technology, 7e, Elsevier Science & Technology Books

[6]. Singh Suman P. N. Coal beneficiation (Chapter 10), Chemical technology division, Oak Ridge National Laboratory, Oak Bridge

[7]. Gagarin S. G., Gyul"maliev A. M., Tolchenkin Yu. A.: Trends in Coal Beneficiation: A Review, Coke and Chemistry, 2008, Vol. 51, No. 2, pp. 31–42. © Allerton Press, Inc. (2008)

[8]. Kawatra S. Komar. Froth Flotation Fundamentals. MichiganTechnicalUniversity. www.chem.mtu.edu/chem_eng/faculty/kawatra/Flotation_Fundamentals.pdf

[9]. Shean B. J., Cilliers J. J.: A review of froth flotation control, International Jounal of Mineral Processing, Vol. 100 (2011), pp. 57-71

[10]. Laurila H, Karesvuori J, Tiili O. Strategies for instrumentation and control of flotation circuits, Mineral processing plant design, practice and control. Vol. 1 (2002), 21742195

[11].http://year7hawkesdale.wikispaces.com/file/view/froth_flotation2.gif/66318086/394x 324/froth_flotation2.gif