Release Analysis of Coal

Harish Singh*[1], Shobhana Dey[2] and S. Bhattacharya[1]

[1]Indian School of Mines Dhanbad,
[2]National Metallurgical Laboratory Jamshedpur, India

Keywords: Coal Flotation; Release Analysis.

Abstract

Washing of fines is more problematic than the washing of coarse coal. One of the perceived barriers in large scale application of flotation in the cleaning of Indian coking coal is the absence of benchmarking. Release analysis is the counterpart in froth flotation to float and sink analysis in the gravity concentration of coal. Thus it provides a benchmark for the coal flotation actually carried out in plants. The present work has been carried out with a LVC coal following the BS 7530 procedure of release analysis. Reagents used include MIBC as the common frother and n-dodecane and a synthetic collector, as the two collecting agents. Current published research indicates that with LVC coal only about 20- 30% yield at 18-19% ash content could be obtained. However, in the present work yields, up to 62% at about the same ash content could be obtained.

* Corresponding author: Harish Singh, E-Mail: singhharish012@gmail.com , Ph. No. +91-8102072595.

1. Introduction

Coal is the prime source of energy and perhaps the largest contributor to the industrial growth of India. India is the world's third largest coal producer after China and the United States. Coal meets approximately 63 % of the country’s total energy requirements. The mineral matter present in Indian coal is of inherent nature and therefore, is intimately mixed with coal mass right from the time of formation resulting in difficult to very difficult cleaning characteristics. Although coarse and small coal can be washed by gravity and centrifugal separation, flotation is more commonly employed to process the coal fines.

Virtually the entire run-of-mine coking coal produced in India is washed in 16 odd wash plants. Since the percentage of fines in the crushed coal was small and ash content was low, the plants set up in nineteen fifties and sixties, did not include any fines circuit. Fines generated were directly mixed with the washed coal to deliver a final ash of 17±0.5% at around 60% yield level. Flotation circuits have become an integral part of coking coal wash plants in India only over the last three decades. Flotation is difficult if NGM in feed is >10, which is the case in all coal flotation circuits in India. Same is true for the low volatile coking coals (LVC), which constitute more than half of the existing coking coal reserves. This is one of the reasons why in terms of installed capacity only about 11 % of the wash plant feed [1] is designed to be washed by flotation (Table 1). In actual plant practice, this figure would be only about 6-7%. This is low, if the quantum of total coal production and the corresponding quantum and ash content of coal fines produced are taken into account.

The existing wash plants, except for those owned by Tata Steel, currently operate at a yield level of 25–45%. Average ash of clean coal is anywhere between 18% and 23%. Quite frequently washed coking coal ash jumps the negotiated limit by 2–3%, inviting a penalty @ 0.5% of the base price for every 0.1% increase over the cut-off point. That approximately works out to be Rs9.00 per 0.1% ash increase per ton. The demand – supply gap for indigenous coking coal of acceptable quality in India has reached such a level that coal blends in SAIL plants usually have a ratio of 70:30 between the imported and domestic. At times it increases to 80:20. It is important therefore to maximize the clean coking coal yield from the wash plants within India.

Table 1: Percentage distribution of installed capacity for different coal cleaning processes across the world

Country	Froth flotation, %	WOC cyclones, %	Dense medium, %	Jigs, %	Others, %
United states	20.3	20.1	45.9	5.6	8.1
China	14.0	1.8	23.0	59.0	2.2
UK	12.1	5.2	45.5	15.1	22.0
India	11.1	3.3	44.6	40.1	0.9
Canada	9.5	22.4	65.5	2.6	0.0
Australia	9.4	9.6	67.1	13.9	0.0
South Africa	1.8	17.4	80.8	0.5	0.0
Indonesia	0.0	14.1	39.8	46.1	0.0
World Population	13.6	13.1	49.3	19.5	4.5

2. Why this work?

One of the perceived barriers in large scale application of flotation in the cleaning of Indian coking coal is the absence of benchmarking. This is besides the fact that the flotation of in situ coal is easier because the grain size of the ash forming minerals is larger and easily liberated. Compared to that drift origin coal in which the ash forming minerals are more and even their sizes are very small and quite frequently not really liberated make flotation of Indian coal very difficult. Published flotation research indicates that with LVC coal only about 20- 30% yield at 18-19% ash content could be obtained [2]. Washability analysis done through float and sink analysis provides a good benchmark to assess the actual performance of gravity and centrifugal separators in coal preparation. The release analysis is the counterpart in froth flotation to float and sink analysis. Its object is to make a perfect separation of a sample into a number of fractions, so that a washability curve for the sample can be constructed. As a result it is possible to estimate what could be the maximum possible yield at a specified ash. No published literature seems to be available on release analysis of Indian coking coal and in particular of LVC coal.

3. Literature Review

The object of the release analysis procedure initially developed by Dell [3] was to separate a perfectly ground ore into a number of fractions by flotation so that the degree of liberation or 'state of release' of the ore could be seen. Subsequently he developed another method of release analysis [4] more refined and more convenient. The basic requirement for the new method, which has been followed in this work, is a standard laboratory flotation cell whose impeller speed can be reduced to the point where flotation ceases, and whose air can be turned off completely. Four concentrate basins and four buckets for tailings are required for each analysis. Experimental procedure followed was laid down by the BS 7530 (part 2) [5].

Tree analysis [6] involves repeated branching of the flotation steps. The coal feed is initially floated at some arbitrary reagent dosage and the resultant concentrate and tailings are subjected to a number of successive scavenger and cleaner flotation in a laboratory batch cell. This procedure is more complicated than the release analysis in that 10-30 separate fractions may be generated. According to Mohanty et al. [7] in the release analysis middling particles are more effectively treated. Middlings are typical for drift origin coal. Tree analysis is difficult to perform and is time consuming. Refined release analysis [4] is relatively convenient to perform and provides easily reproducible results.

4. Materials

The coal sample used in this work belongs to combined V, VI and VII seam LVC coal from eastern flank of Jharia coalfield. Reagents used included two collectors: MIBC as frother and n-dodecane as collector as prescribed by BS 7530 (part 2) and a synthetic collector. Justification for the feed sizes used in this study are as follows; conventional flotation feed of -0.5 mm, typical split feed flotation sizes of -0.5+0.1 mm and -0.1 mm, usual "adequate liberation" size of -0.075 mm and typical ultra fine size of -0.05 mm. Results presented are the average of duplicate tests. Proximate analysis (Table 2) indicates the coal used is a low moisture and low volatile high rank coal. Bulk of the feed is +0.1mm in size with little variation in ash content between the sizes.

Table 2: Proximate analysis (%) of flotation feed

Size Fraction (Mm)	Weight %	Moisture,%	Volatile Matter, %	Ash,%	Fixed Carbon , %
-0.5	100	1.026	19.34	28.89	50.74
-0.5+0.1	76.7	1.045	19.230	29.20	50.525
-0.1	23.3	0.96	19.705	27.890	51.445

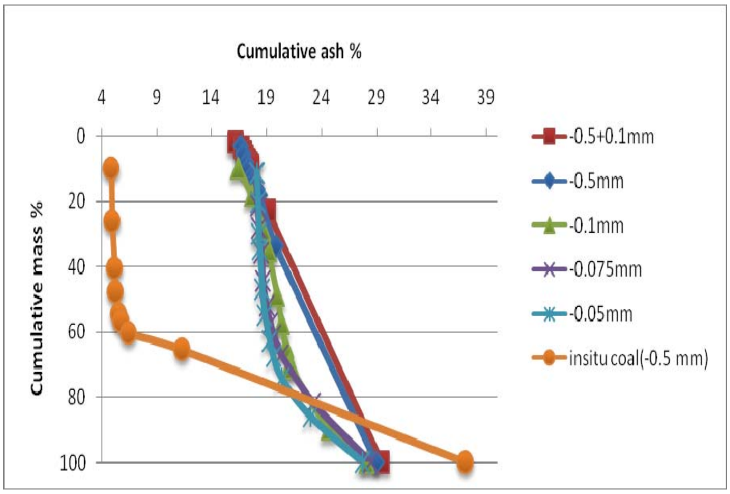

Fig 1: Cumulative mass as a function of cumulative ash (collector; n-dodecane)

5. Results and Discussions

Release and tree analysis procedures were developed for -0.5mm coal, because all in situ coal and most of the drift origin coal (as in India) are virtually liberated at that size. The curves plotted for in situ coal (Fig. 1-2) illustrate the point; more than 75% yield can be obtained at say 19% ash. In contrast, the LVC coal curves obtained for -0.5mm and -0.5+0.1mm with n-dodecane are monotonous, at times overlapping with only about 20% yield at the same ash. That indicates an incomplete liberation even at a size of +0.1mm. Liberation improves for the particles less than 0.1mm and in particular less than 0.05mm.

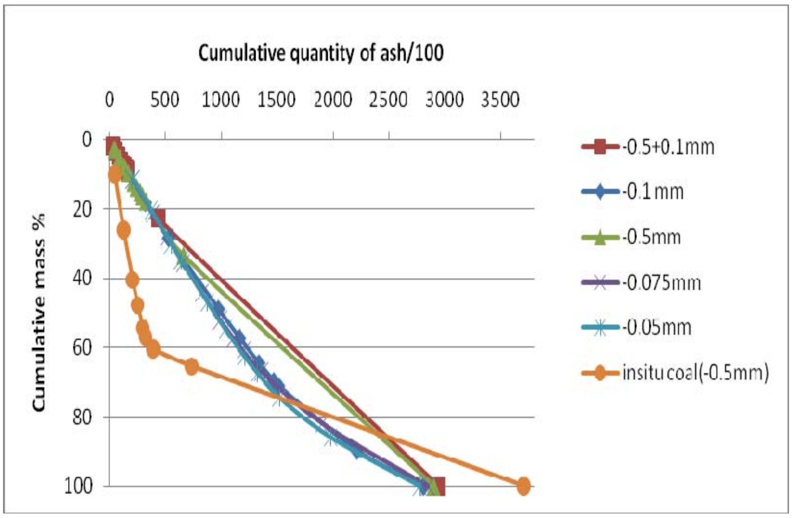

Fig 2: Mayer’s curve (collector; n-dodecane)

Yet, falls far short of what could be achieved for -0.5mm in situ coal. Initial tailings recorded an ash content of about 60%, typical for wash plant reject. However, no yield could practically be obtained at lower ash contents. Use of n-dodecane at the prescribed dosages [4] could also be a reason for poor performance.

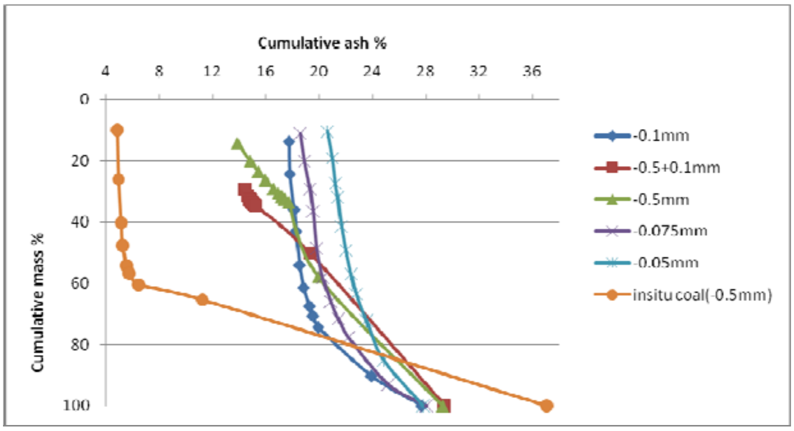

Fig 3: Cumulative mass as a function of cumulative ash (synthetic collector)

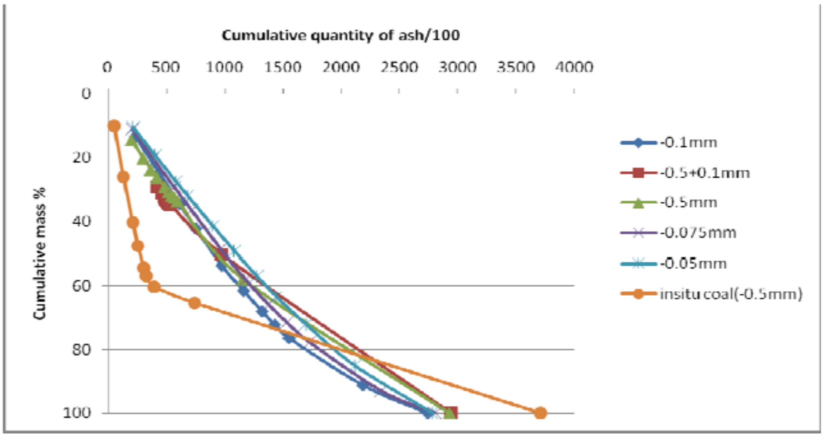

Fig 4: Mayer's curve (Synthetic collector)

The results obtained for the -0.5 mm feed with the synthetic collector (Fig 3-4) indicate fairly high yield at the stipulated ash levels. Tailing ash however remained low. Both the curves, in particular the yield-ash curve (Fig 3) indicates difference in flotation pattern in the ash ranges of <18%, 18-20% and >20%. This kind of distinct break in trends is not evident in release analysis with n-dodecane and is hardly evident with other feeds. These breaks possibly indicate changes in the level of liberation of "coal matter" from "associated mineral matter", which could be exploited by the synthetic collector, because of its stronger collecting power than n-dodecane and because of appropriate dosages. As a result, for the finer feeds the same collector appears to exploit the increased liberation more effectively (Fig. 1 and 3). Yields are quite high at the stipulated ash and release analysis curves moved closer to the one for in situ coal. Selectivity of the synthetic collector also appears to play its role. Yield reduction factor however is quite high, in the range of 7-25%, indicating difficulties associated with the flotation of LVC coal fines even when those are fairly liberated.

Let it be noted that release analysis data are not available in published literature for finer feeds. Therefore, direct comparison can be made only for the -0.5mm feed. The differences with the in-situ coal are most pronounced for the same collector used, i.e. n-dodecane. At 13% ash content, e.g., clean coal yield would be about 70% for the in situ coal. For the drift origin LVC coal, only about 10% yield at the same ash could be obtained with the synthetic collector and that through extrapolation; and no yield at all with n-dodecane.

6. Summary and Conclusions

The present work seems to be the first reported release analysis of coal in India.

For the size fraction of - 0.5+0.1 mm, n-dodecane reduces the ash to a minimum of 16% with only 2% yield, whereas with the synthetic collector the clean coal ash reduces to 14.5% with 29% yield. Except for the size fractions of less than 0.075mm, the clean coal yield increases (48-62%) and the ash content reduces for all other sizes by the use of the synthetic collector. Yield reduction factor however is quite high, in the range of 7-25%. This is in contrast to the LVC coal yield of 20-30% at 18-19% ash through flotation, as previously reported by CIMFR and ISM.

For the ultrafine size fractions, -0.075 mm and -0.05 mm 48-71% yields could be obtained with n-dodecane at 19-20% ash with practically no flotation at lower target ash. That indicates the requirement of improved selectivity and/ or dosage adjustment of the collector used. As the size of the coal decreases liberated fine clay in feed possibly gives rise to clean coal with high ash. Since release analysis involves number of flotation stages, it is also possible that locked coal particles and clay particles get more entrained in the froth.

Choice of reagent and of dosage is an important consideration, particularly with respect to feed size and coal type, in situ and drift origin. n-dodecane might not be the ideal collector for the release analysis of coarser fractions of LVC coal and even of drift origin coal, but could be for the ultra-fines of the same coal.

Release analysis proved to be a very useful tool in benchmarking the flotation performance of an Indian LVC coal of drift origin because of its difficult liberation and flotation characteristics.

7. Acknowledgement

The authors are grateful to the Director National Metallurgical Laboratory Jamshedpur for his permission to carry out the work.

8. References

[1] Kempnich 2000, Coal Floatation: Laskowski J.S., Lu ttrell G.H., Arnold B.J..

[2] Bhattacharya S., Processing of coal fines – The challenges we face in India, IV Asian Particle Technology Symposium, Rai B., Runkana V., and Pradip (Ed.), New Delhi, APT 2009/ 5, 2009.

[3] Dell C. C., Bunyard M. J., Rickelton W. A. and Young P.A.: ‘Release analysis, a comparison of techniques’, Trans. IMM, 1972, 81, C89–C96.

[4] DELL C. C.: ‘An improved release analysis procedure for determining coal washability’, J. Inst. Fuel, 1964, 37, 149–150.

[5] BS 7530: Methods for Froth flotation testing of hard coal, Part 2.

[6] Pratten S.J., Bensely C. N. and Nicol S. K.: “An evalution of the flotation response of coals”. Int.J.Miner.Process. No.27, 1989, pp.243-262.

[7] Mohanty M.K., Honaker R.Q. and Ho K., Coal flotation washability: an evalution of the traditional procedures. Coal Preparation, 19 (1998) 33.

*Currently with allmineral Asia