Effect of Crusher Type and Crusher Discharge Setting On Washability Characteristics of Coal

Ahila P, S. Battacharya
Department of Fuel and Mineral Engineering, Indian school of mines, Dhanbad-826004, Jharkhand, India

Abstract. Natural resources have been serving the life of many civilizations, among these coals are of prime importance. Coal is the most important and abundant fossil fuel in India. It accounts for 55% of the country's energy need. Coal will continue as the mainstay fuel for power generation. Previous researches has been made about the coal feed size and coal type had great influence on the crushing performance of the same jaw crusher and amount of fines generated from a particular coal depends not only upon coal friability but also on crusher type. Therefore, it necessitates crushing and grinding the coal for downstream process. In this paper the effect of crusher type and crusher discharge setting on washability characteristics of same crushed non-coking coal has been studied. Thus four different crushers were investigated at variable parameters like discharge settings, different capacities and feed openings. The experimental work conducted for all crushers with same feed size and HGI (Hardgrove Grindability Index). Based on the investigation the results indicate that the four crushers which has been involved for the experimental work shows that the variation in not only the product size distribution and also reduction ratio. Maximum breakage has been occurred at coarsest size fraction of irrespective of crusher type and discharge setting.

Keywords: Coal, discharge setting, breakage efficiency, washability characteristics, crusher

1. Introduction
Coal is a sedimentary, combustible rock derived from vegetable debris which has undergone many physical and chemical changes during the very long course of millions of years. It consists primarily of elemental carbon [1]. About 67% of electricity produced in India is by combustion of coal. The total estimated reserves of coal in world are estimated to be 909.064 BT and for India the same is estimated to be 301.24 BT [2]. And such Coal is a heterogeneous substance, which is consisted of combustible (organic matter) and non-combustible (moisture and mineral matter) materials. Comminution behavior or grindability of coal, which is a measure of its resistance to crushing and grinding, is related to its physical properties as well as its rank, chemical, and petrographical compositions. Examining the grinding behavior of coal is significant, because the comminution of coal is essential for any kind of its utilization such as combustion, carbonization, gasification, and beneficiation [3-4].

Coal requires a certain treatment before it is marketed as an end product. The treatment may be simple size preparation involving crushing and screening or elaborate beneficiation involving physical cleaning of the coal and/or chemical processing. Coal is crushed in many stages. There are many crusher manufactures and there are many varieties of machines made for crushing of minerals and coals such as jaw crusher, roll crushers, impact crusher and hammer mill [5].

According to Deniz [6] coal feed size and coal type had great influence on the crushing performance of the same jaw crusher used by him in a laboratory investigation and indicated significant variation in crushed coal size distribution. An investigation of this nature could assist plant manager in the selection of appropriate coal crushing equipment. Mikhal et al [7] have shown that the amount of fines generated from a particular coal depends not only upon coal friability but also on crusher type. Similar dependency was observed for crusher product size distribution also. Four crushers, jaw crusher, hammer mill, coalpactor and Bradford breaker, were used to reduce...
the top size of five coals from different operating mines. The Bradford breaker generated the least fines and the jaw crusher generated the greatest amount of fines. Similarly the Bradford breaker produced the largest average particle size while the hammer mill and the coalpactor produced the smallest. This article presents a study effect of crusher and crusher discharge setting on washability characteristics on coal.

2. Materials and methods

Coal samples with top size of 63.5x3mm were collected from Calcutta Electric Supply Corporation power used for experimental studies. Proximate analysis [8] of the sample which is showed in Table 1 has high ash content, low volatile matter and low fixed carbon. Therefore it is non-coking coal. Hargrove Grindability Index (HGI) test were made for coal sample and it was found that average HGI of the coal 61[9]. Crushers used in the experimental work listed in Table 2. These crushers with varied capacities, feed openings and discharge settings were used. Coal was crushed by all the four crushers in parallel followed by size by size float – sink [10] test. Plots of the size distribution curve of feed material were given in Fig 1.

Table 1. Proximate Analysis of Coal Sample Using in Experiments

| Parameter      | Ash (Wt. %) | Volatile matter (Wt. %) | Moisture content (Wt. %) | Fixed carbon (Wt. %) |
|----------------|-------------|-------------------------|--------------------------|----------------------|
|                | 46.86       | 19.75                   | 3.82                     | 29.57                |

Table 2. Crushers used in the experimental work

| Reduction Ratio | Crusher I | Crusher II | Crusher III | Crusher IV |
|-----------------|-----------|------------|-------------|------------|
| d 100           | 1.27      | 1.22       | 1.27        | 1.27       |
| d 90            | 1.66      | 1.09       | 2.04        | 2.14       |
| d 80            | 1.63      | 1.12       | 1.8         | 2.11       |
| d 50            | 1.26      | 1.05       | 1.35        | 1.9        |
| d 100/Discharge setting | 2.63 | 1.59 | 2.94 | 3.85 |

* Calculated as a ratio of feed opening and discharge setting

![Fig 1 Feed size distribution curve](image)
3. Result and discussion

3.1 Feed and all four crusher product size distribution curves

Comparing feed PSD curve with products of different crushers shown in Figure 2. Tables 3 and 4 indicate that d100 product sizes are not showing significant difference as compared to the feed size, which means notable crushing, occurs at d100. But when it comes to d90 and d80 product size improved crushing is observed. D50 values of both the jaw crusher are quite close, 19mm and 15mm. So, in case with the roll crusher 14mm and 10mm. Such closeness in value however does not get translated into a similarity in reduction ratios. Fig 3 shows how crusher having different capacities and different discharge settings contribute to different average particle sizes for the same coal. Coal has same HGI and which produce different average particle size for the crushed coal.

![Fig 2 Feed and all crusher product size distribution](image)

Table 3. Feed size and all crusher product size for the same feed size coal

| Feed size, mm | Crusher I product, size mm | Crusher II product, size mm | Crusher III product size, mm | Crusher IV Product size, mm |
|---------------|---------------------------|-----------------------------|-----------------------------|-----------------------------|
| d100          | 63.5                      | 50                          | 52                          | 50                          |
| d 90          | 45                        | 27                          | 41                          | 22                          |
| d 80          | 36                        | 22                          | 32                          | 20                          |
| d 50          | 19                        | 15                          | 18                          | 14                          |

Table 4. Reduction ratio of all crushers for the same feed size coal

| Reduction Ratio | Crusher I | Crusher II | Crusher III | Crusher IV |
|-----------------|-----------|------------|-------------|------------|
| d 100           | 1.27      | 1.22       | 1.27        | 1.27       |
| d 90            | 1.66      | 1.09       | 2.04        | 2.14       |
| d 80            | 1.63      | 1.12       | 1.8         | 2.11       |
| d 50            | 1.26      | 1.05       | 1.35        | 1.9        |
| d 100/Discharge setting | 2.63 | 1.59 | 2.94 | 3.85 |
Table 5 shows that irrespective of crusher type and discharge setting, maximum breakage occurs for the coarsest size fraction. Table 3 shows that the ratio between d100 i.e. Maximum product size and discharge setting is highest for roll crusher.

| Size Fraction, mm | Breakage Efficiency (%) | Crusher I | Crusher II | Crusher III | Crusher IV |
|-------------------|--------------------------|-----------|------------|-------------|------------|
| -63.5+50          |                          | 96.18     | 72.48      | 100         | 100        |
| -50+25            |                          | 60.46     | 4.18       | 79.09       | 94.56      |
| -25+12.7          |                          | -         | -          | -           | -          |
| -12.7+6           |                          | -         | 4.82       | -           | -          |
| -6+3              |                          | 5.94      | -          | 2.04        | -          |
| -3                |                          | -         | -          | -           | -          |

3.2 Comparison of washability curves for all crushed products

Fig 4 shows significant differences between the float curves of the coarsest size fraction obtained in the crusher products, same is the case with yield gravity curves. Only the float curves obtained for the roll crusher products have certain similarly. These differences however decrease as the product size becomes smaller (Fig. 5-8). The differences however increase somewhat for the finest size fraction (Fig.9) due to discharge setting of the crusher and size of the particles.
Fig 4. Float and yield curves for all crusher product at -50+25mm

Fig 5. Float and yield curves for all crusher product at -25+12.7mm
Fig 6 Float and yield curves of all crusher products at -25+12.7mm

Fig 7 Float and yield curves for all crusher product at -12.7+6mm
Fig 8 Float and yield curves for all crusher product at -6+3mm

Fig 9 Float and yield curves for all crusher product at -3mm

Table 6 shows typical cleaning parameters as obtained from the washability curves. For every size fraction clean coal yield differ between the crusher products. Since it is a high ash non coking coal target ash for the clean coal has been set at 30%. Cut density however varies only for the two coarsest size fractions because these are having bigger size ranges. Yield variations is however nominal for the finest size fraction indicating similar level
of liberation irrespective of the crusher discharge setting and crusher type. Reject ash variation is however similar between the size fractions except the coarsest one. NGM variation is rather significant for a given size fraction between the crusher type and discharge setting. Table 6 illustrates how far a given feed, crusher type and discharge setting can affect the washability results and thereby actual performance of the wash plant designed and built by using the set of data generated through this work.

Table 6 Typical washability parameters for the different crusher products

| Size mm       | Crusher I | Ycc | CD | NGM | At | Yr |
|---------------|-----------|-----|----|-----|----|----|
| At-50+25mm    |           |     |    |     |    |    |
| Crusher I     | 57        | 1.80| 14 | 72.7| 43 |
| Crusher II    | 74.5      | 1.86| 13 | 74.7| 25.5|
| Crusher III   | 49        | 1.78| 17 | 67.5| 50.5|
| Crusher IV    | 36        | 1.70| 23.5| 64.0| 64 |
| At-25+12.7 mm |           |     |    |     |    |    |
| Crusher I     | 74        | 1.89| 23 | 73.3| 26 |
| Crusher II    | 78        | 1.88| 14 | 77.4| 22 |
| Crusher III   | 76        | 1.94| 12 | 76.8| 24 |
| Crusher IV    | 72        | 1.87| 13 | 72.0| 28 |
| At-12.7+6 mm  |           |     |    |     |    |    |
| Crusher I     | 85        | 1.90| 10 | 80.6| 15 |
| Crusher II    | 85        | 1.90| 11.5| 80.4| 15 |
| Crusher III   | 88        | 1.90| 8  | 84.2| 12 |
| Crusher IV    | 96        | 1.90| 13.5| 81.5| 4  |
| At-6+3 mm     |           |     |    |     |    |    |
| Crusher I     | 87        | 1.90| 11 | 80.0| 11 |
| Crusher II    | 94        | 1.90| 10 | 84.2| 6  |
| Crusher III   | 89        | 1.90| 16 | 82.1| 11 |
| Crusher IV    | 90        | 1.90| 13 | 80.7| 10 |
| At-3 mm       |           |     |    |     |    |    |
| Crusher I     | 93        | 1.90| 13 | 84.8| 7  |
| Crusher II    | 100       | NA**| NA | NA  | NA |
| Crusher III   | 93        | 1.90| 18 | 88.5| 7  |
| Crusher IV    | 92        | 1.90| 13 | 80.7| 8  |

**Not applicable

4. Conclusion

The following conclusion can be made from this work.

The results indicate that the four crushers which have been used in the experimental work shows variation not only in the product size distribution but also in reduction ratios. Maximum breakage has occurred for the coarsest size fractions irrespective of crusher type and discharge setting. Each crusher though crushing the same coal produced a different average size for the crushed coal.

It has been shown that there is significant difference between the float curves and yield curves of the same coarsest size fractions in the four crusher products. The difference however decreases with the smaller size fractions though it again increases for the finest size fractions. Washability analysis of all the crusher products have shown that for every size fraction clean coal yield varies between the crushers and cut density variation occurred at coarser size fractions, but not in finer size fractions. For a given feed coal, crusher type and discharge setting can therefore affect the crushing efficiency and breakage product size distribution and washability results and thereby the actual performance of the wash plant designed on the basis of this set of laboratory data.
5. References

[1] Joseph W. (Editor) Leonard (1979), Coal Preparation Technology, 4th edition AIME , New York p:1-11
[2] www.wikipeadia.coal reserves.com and www.coal.nic.in ,last accessed 27-04-2016.
[3] Vuthaluru, H. B et al. 2003. Effects of Moisture and Coal Blending on Hardgrove Grindability Index of Western Australian Coal. Fuel Processing Technology 81: 67–76.
[4] Chelgani, S. C et al 2008. Prediction of Coal Grindability Based on Petrography, Proximate and Ultimate Analysis using Multiple Regression and Artificial Neural Network Models. Fuel Processing Technology 89: 13–20.
[5] Deniz, V., and Y. Umucu. Forthcoming Interrelationships between the Bond Grindability with Physicomechanical and Chemical Properties of Coals. Energy Sources (Part A), doi: 10.1080=15567036.2010.504942.
[6] Vedat Deniz (2014), A study on the effects of coal feed size and coal type on the performance of a laboratory jaw crusher Energy source, Part A, 36:1249-1255
[7] Mikhal M.W et al. The effect of different crusher of fines generation from western Canadian friable coals, XVI International Mineral Processing Congress, Stockholm pp:1573-1583.
[8] Indian Standard: 1350 Part 1, 1984, Methods of Test for Coal and Coke: Proximate analysis (Second Revision), Bureau of Indian Standards, New Delhi.
[9] Indian Standard: 4433, 1979, Determination of Hargrove Grindability Index of Coal, Bureau of Indian Standards, New Delhi.
[10] Indian Standard: 13810, 1993, Code of Practice for Float and Sink analysis of Coal, Bureau of Indian Standards; New Delhi.