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Dry Beneficiation of Coking Coal Fines using an Advanced Air Cyclone

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An attempt is made on coking coal fines dry beneficiation of below 2 mm size, with VSK separator consisting of advanced air cyclone. The results of these investigations reveal that simple size with 250 micron can give a product with 18% ash at 17.4% yield, whereas by using VSK separator the product obtained contains 17.8% ash with 48.1% yield from a feed sample containing 23.3% ash. Since the preliminary investigations has shown encouraging results on reduction of ash, large scale continuous tests can provide better yield for various samples.

Keyword: Air cyclones, Coarse, Coking coal fines, Dry beneficiation, VSK separator

Introduction

Due to scarcity of water and water contamination, Indian mineral industry is planning to replace some of the wet circuits by dry methods using advanced air classifier or air fluidized bed separators. Air cyclone is one similar type from advanced air classifiers. It is very identical to hydro cyclones in terms of construction and operation. Air cyclones are used in mineral and material processing industries for closed circuit dry grinding system where fine and coarse particles are classified and coarse particles are fed back into the system. VSK separator is one of the air classifiers with a combination of static and dynamic separators to satisfy the above requirements. However, such units were mostly found in many fertilizer manufacturing units as well as in cement industries.[1–4] Many research works have been attempted for iron ore and beach sand industries as well as in vermiculite industries.The CSIR-IMMT, Bhubaneswar has carried out large scale continuous investigations on Beach sands, Teri sands, lime stone, iron ores for separation of fines and pre-concentrate the ore and submitted the project reports to different industries for implementation.[5–10] However, so far, no attempt is made on coal samples for size classification, clean coal preparation and dust/slimes separation by using such air cyclones.

In view of this an attempt is made on coking coal fines from one of the operating washeries by using an advanced air cyclone with VSK separator.

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VSK Separator Operation Principle

The feed enters from V-Separator with a controlled rate from Hopper connected with Electromagnetic feeder tube by gravity.[4] As per VSK Separator datasheet, [4] the fine and coarse material are separated at the rotor cage periphery in a vortex predetermined by air deflectors and the cage rotation. The airstream, which is fed horizontally, will drag the fine particles against the centrifugal force to the inside of the cage wheel and from there to the fine material discharge. The coarse grains are pushed away from the separator wheel by the centrifugal force and drop into the coarse material discharge.

Materials and Methods

About 100 Kg of coking coal fines were collected from one of the washeries to carry out dry beneficiation studies. The VSK separator (SKS-VS-10.4 model) from M/s Humboldt Wedag India was used for classification of fines and preparation of clean coal. The detail specifications of this VSK separator are described in Appendix A (in last section). The schematic pilot plant set up of VSK separator is shown in Fig. 1. Continuous large scale VSK experiments were conducted at a constant cage wheel speed of 1800 rpm, screw feeder of rpm 1800, air rate of 49Hz considering the moisture with 0.5 % as optimum conditions achieved earlier.

In the present investigations, the feed sample (100 Kgs) was loaded to first stage VSK separator device to get fine as well as coarse materials. The first stage coarse material was further loaded to second

stage separator device to get fine material and clean coarse material.

Similarly, the first stage fine material was also loaded to second stage separator for getting cleaner coarse material. The schematic flow sheet to recover coarse and fine materials with VSK separator device is shown in Fig. 2.

The coarse and fine materials were calculated by sink float and size analysis test. The samples size analysis was carried out by using Indian standard test sieves. The VSK separator cut size was calculated from d_{50} values, which was obtained from the plotted average size (µm) vs. coarse % responded from feed.

Effective separating size particles from VSK separator was evaluated from the half of the difference between d_{75} and d_{25}. Size analysis of the feed sample VSK product and tailings were carried out using standard sieves. Ash analysis of the feed sample, VSK product and tailings were determined by using Proximate analyzer, model TGA 601, of Leco Corporation, USA. Qualitatively VSK products and tailings were analyzed from X ray diffraction data generated using X-Ray diffractometer X'Pert of M/s PANanalyticalPW 1830.

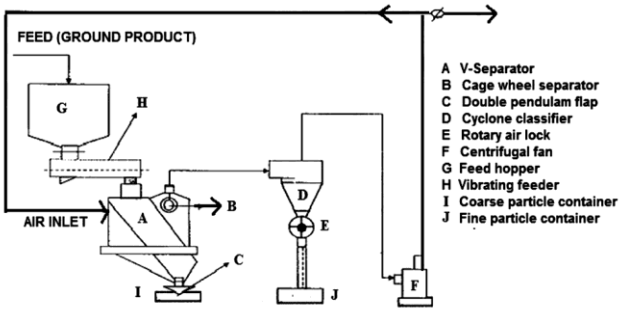

Fig. 1 — Schematic pilot plant set up of VSK Separator

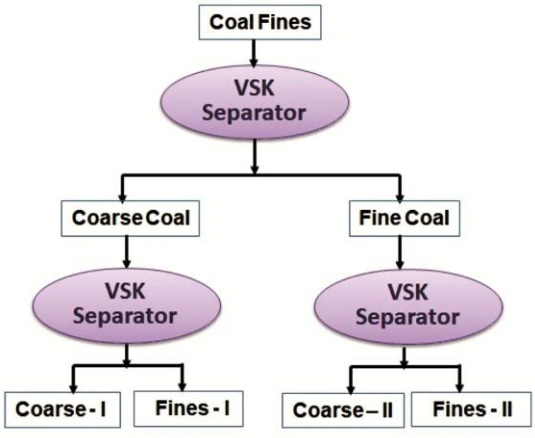

Fig. 2 — Flow sheet to recover coarse and fine materials by using VSK separator

Results and Discussion

The results of size and ash distribution of feed sample are shown in Table 1. It indicates that the sample contains 23.3% ash and the coal is preferentially accumulated in the finer fractions. Further it can be clearly seen from the data that the fraction below 250 microns contains less ash content. On the basis of this observation, simple classification at 250 microns can give a product with 18% ash at 17.4% yield (Table 2).

The results of pilot plant VSK separator tests are shown in Tables 3 to 7 and Figs. 3 to 5. The size analysis of VSK first stage product shown in Table 3 indicates that the VSK coarse product contains d_{80} passing size 900 microns and fines contain 200 microns. The second stage tests results shown in Table 4 indicate that d_{80} passing size of coarse I is 910 microns and fines I is 250 microns. These two products are obtained from the reprocessing of VSK first stage coarse product. Similarly, the d_{80} passing size of coarse II is 240 microns and fines I are 140 microns. These two products are obtained from the reprocessing of VSK first stage fines product.

The performance of VSK separator on first stage classification of feed sample indicates that the coarse fraction and fines fraction contain 61.8% and 38.2% by weight respectively. The performance of VSK separators on second stage classification of VSK coarse obtained from first stage operation shown in Table 4 indicate that the fines fraction and coarse fraction contains 20.2% and 79.8% by weight respectively.

The cut size and separation size calculated from the data are shown in Figs. 3 to 5 and also shown in Table 5. These results indicate that the cut size of

Table 1 — Results of feed sample size and ash distribution

Size, microns	Wt %	Ash %
+2000	0.3	26.9
−2000+1000	22.6	27.1
−1000+500	28.8	26.4
−500+250	30.9	20.7
−250+100	5.9	17.4
−100+50	11.3	18.3
−50	0.2	20.2
Head	100	23.3

Table 2 — Products obtained by size classification using IS sieves

Size, microns	Wt %	Ash %
+250	82.6	24.4
−250	17.4	18.0
Head	100.0	23.3

Table 3 — Performance of VSK separator on first stage classification of feed sample sieves

Size, µm	Avg size, µm	Coarse Wt %	Fines Wt %	Wt. Dist % Coarse	Wt. Dist % Fines	Feed calculated Wt %	% Coarse responded in feed
−1000+850	925	30.0	—	18.5	—	18.5	100.0
−850+710	780	30.0	—	18.5	—	18.5	100.0
−710+600	655	18.8	—	11.6	—	11.6	100.0
−600+420	510	6.0	0.6	3.7	0.2	3.9	94.9
−420+300	360	7.7	8.6	4.8	3.3	8.1	59.3
−300+210	255	2.9	10.9	1.8	4.2	6.0	30.0
−210+150	180	2.3	15.2	1.5	5.8	7.3	20.5
−150+100	125	0.7	8.6	0.4	3.3	3.7	10.8
−100+75	82	0.9	12.3	0.5	4.7	5.2	9.6
−75+45	60	0.4	25.0	0.2	9.7	9.9	2.0
−45	22	0.3	18.8	0.2	7.3	7.5	2.7
Total	—	100.0	100.0	61.8	38.2	100.0	—

Table 4 — Performance of VSK separators on second stage classification of VSK coarse obtained from first stage operation

Size, µm	Avg size, µm	Coarse Wt %	Fines Wt %	Wt. Dist % Coarse	Wt. Dist % Fines	Feed calculated Wt %	% Coarse responded in feed
−1000+850	925	35.0	—	27.9	—	27.9	100.0
−850+710	780	30.0	—	23.9	—	23.9	100.0
−710+600	655	17.0	—	13.6	—	13.6	100.0
−600+420	510	5.6	0.8	4.5	0.2	4.7	95.7
−420+300	360	7.7	11.9	6.2	2.4	8.6	72.1
−300+210	255	2.5	13.0	2.0	2.6	4.6	43.5
−210+150	180	1.5	18.1	1.2	3.6	4.8	25.0
−150+100	125	0.3	15.5	0.2	3.1	3.3	6.1
−100+75	82	0.1	16.7	0.08	3.4	3.5	2.3
−75+45	60	0.3	18.6	0.2	3.8	4.0	5.0
−45	22	0.05	5.4	0.04	1.1	1.1	3.5
Total	—	100.0	100.0	79.8	20.2	100.0	—

Table 5 — Results of performance of VSK separators on first and second stage classification of feed sample and VSK coarse and fines obtained from first stage operation

Size, µm	Performance of VSK separators on feed sample	Performance of VSK separators on VSK coarse obtained from 1st stage operation	Performance of VSK separators on VSK fines obtained from 1st stage operation
Cut size, d_{50}	290	290	70
d_{75}	420	390	120
d_{25}	180	150	30
Separation size, $(d_{75} - d_{25})/2$	120	120	45

Table 6 — Results of VSK separator on yield and ash distribution

(a) First Stage

Details	Wt %	Ash %
Coarse	61.8	26.1
Fine	38.2	18.8
Head	100.0	23.3

(b) Second Stage (Reprocessing of first stage Coarse)

Details	Wt %	Ash %
Coarse	49.3	28.0
Fine	12.5	18.8
Head	61.8	26.1

(c) Second Stage(Reprocessing of first stage Fines)

Details	Wt %	Ash %
Coarse	35.6	17.8
Fine	2.6	36.6
Head	38.2	18.8

Table 7 — Comparison of standard sieve size classification and VSK size separation with mass balance

Details	Classification by sieving	VSK Separator
(a) Fines (Product)		
Yield %	17.4	48.1
Ash %	18.0	17.8
(b) Coarse (Reject)		
Yield %	82.6	51.8
Ash %	26.35	28.5

received feed sample is 290 microns and separation size is 110 microns. Similarly, the cut size of the coarse feed sample (obtained from first stage VSK separator) is 290 microns and separation size is 110 microns, where as the cut size of the fine feed sample

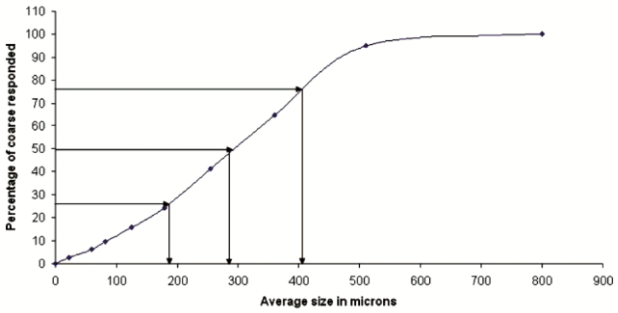

Fig. 3 — Performance of VSK separator on first stage classification of feed sample

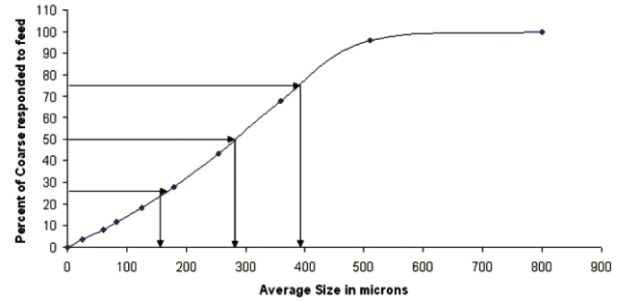

Fig. 4 — Performance of VSK separator on second stage classification of VSK coarses obtained from first stage operation

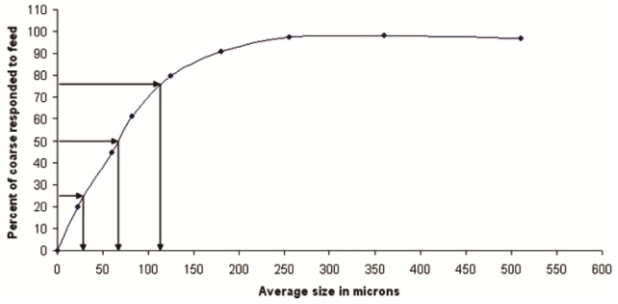

Fig. 5 — Performance of VSK separator on second stage classification of VSK fines obtained from first stage operation

(obtained from first stage VSK separator) is 70 microns and separation size is 45 microns.

The results of ash distribution on two stage VSK separation shown in Table 6 indicate that the first stage fines obtained from as received feed sample contains 18.8% ash. Similarly, the fines obtained by second stage (reprocessing of first stage coarse) also contains 18.8% ash.

X- ray diffraction pattern shown in Fig 6 also indicate that qualitatively the peak intensities of mineral matters in rejects is more compare to product coal. However, these results indicate that even though it may be possible to reduce the ash in clean coal by 5-6 units; rejectable tailings could not be generated. Tailings generated (coarse material) may be treated on

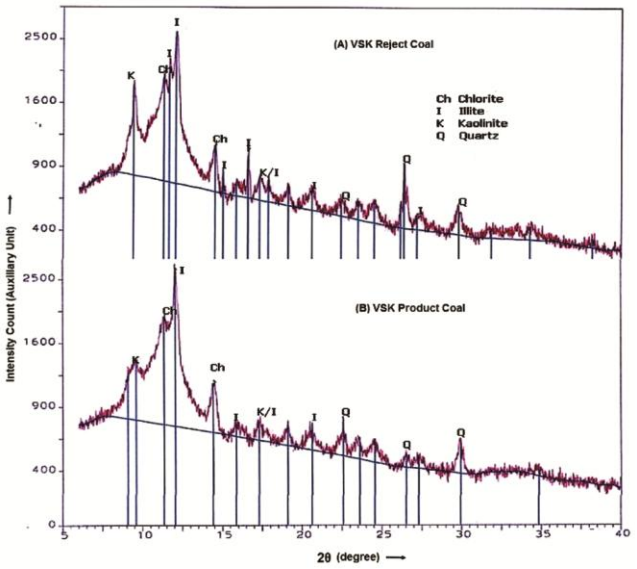

Fig. 6 — XRD pattern of minerals in VSK rejects coal and product coal

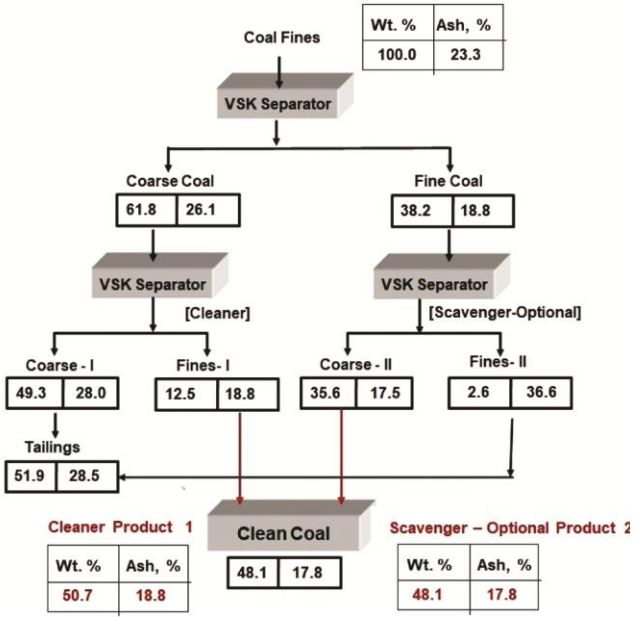

Fig. 7 — Conceptual flowsheet for recovery of clean coal with VSK separator

the spirals to recover additional clean coal. The data shown in Table 7 indicate that the comparison of standard sieve size classification and VSK size separation. It can clearly be seen from the data that by simple size classification a product obtained contain 18% with 17.4% yield; whereas by using VSK separator, the product obtained contain 17.8% ash with 48.1% yield. The observations can clearly be seen from the conceptual flow sheet with material balance shown in Fig 7. Since the preliminary investigations has shown encouragement results on

reduction of ash, large scale continuous tests can be carried out on different types of samples to establish the fact.

Conclusions

The following conclusions were made, based on the experimental results:

- The feed sample contains 24.9% ash and the quality of coal is preferentially accumulated in the finer size fraction below 250 micron.
- Simple classification at 250 micron can give a product with 18% ash at 17.4% yield, whereas by using VSK separator, a product with 17.8% ash at 48.1% yield can be produced.
- Since the scavenger has shown much improvement in reduction of ash, this step can be considered as optional.
- However, these results indicate that even though it may be possible to reduce the ash in clean coal by 5–6 units; rejectable tailings could not be generated. Hence further work is essential.
- Since the preliminary investigations has shown encouragement results on reduction of ash, large scale continuous tests may be carried out on different types of samples to establish the fact.

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Appendix A : Technical specifications of VSK separator

V-Separator		**Specifications**
Capacity (solids)	:	10,000 Kgs/hr
Overall size (L mm × B mm × H mm)	:	1300 × 800 × 1500
Material inlet size (L mm × W mm)	:	280 × 250
Air outlet size (L mm × W mm)	:	340 × 185
Air inlet size (Diameter in mm)	:	280
Discharge opening (Diameter in mm)	:	168
Application	:	For separation of coarse product from ground mineral/ore
Feed material	:	Ground product
Separation size (in microns)	:	150 to 2000