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Study of the mechanism of fine coal beneficiation in air table

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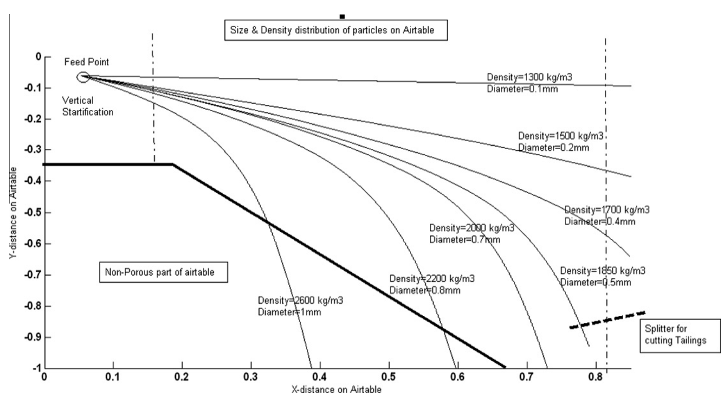
HIGHLIGHTS

- Around 10% (absolute) reduction in ash was achieved in a single stage operation.
- Mechanism is adequately explained by vertical stratification and horizontal segregation.
- Model equations developed to describe separation features of the air table.
- Particle trajectories and process performances estimated from model equations.

GRAPHICAL ABSTRACT



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ABSTRACT

Beneficiation of fine (−1.0 mm) coal in air table was studied both from theoretical and experimental angles. Experiments were performed according to Response Surface Method with high ash (43%) coal fines using air table. The features of separation were established and favorable operating regimes identified for the targeted product. About 10% (absolute) reduction in the ash level was achieved in single stage operation with a reasonably high product yield. Separation in air table was described by a set of mathematical equations. It was established that the vertical stratification and horizontal segregation are the two phenomena responsible for separation. Both these phenomena are described mathematically from a fundamental standpoint using force balance approach. Simulation performed using the model equations led to the identification of the trajectories of various particles with different size and density over the deck surface. Following the trajectories and using the size and density distribution of the coal particles the mass yield and the ash level of the product are computed. The computed data and the experimental observations were found to be in good agreement.

1. Introduction

Beneficiation of coal fines containing high ash has become essential due to the depletion of reserves and deterioration of quality. Besides, coal is well liberated in the fines range which increases the prospects of recovering purer material. However, the cost of cleaning fine particles is approximately 3 times higher than that for coarse particles. Wet beneficiation is predominantly used for cleaning fines and high level of moisture is retained as the fine particles have larger surface area. Lot of work has been done in the last couple of decades in developing process for cleaning fine coal but much less in the area of dewatering of

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coal fines. Thermal drying was tried as an option in dewatering the fine product although it has economic and pollution issues [1–3]. When the particle size is below 0.5 mm the cost of dewatering by mechanical and thermal drying methods sharply increases [1].

To avoid the difficult task of dewatering coal fines, dry beneficiation of coal fines is envisaged to be the most prospective route. It exploits the differences in physical properties between the coal and the waste rock (or ash) [4]. Pneumatic methods use combination of differences in several of these properties for dry fine coal beneficiation. Pneumatic methods of coal cleaning can be broadly divided into settling devices (Air table, FGX, etc.) and dense medium devices. Air dense medium uses density, size and shape difference between coal and ash particles. For fine coal beneficiation, magnetic field was introduced to create a magnetically stabilized fluidized bed [5–8]. The Ep of separation was 0.066 with a magnetic field intensity of 30 Oe and a gas velocity of 12.3 mm/s. Luo et al. [9] introduced vibration energy into a conventional fluidized bed separator. Feed coal ash of 17.5% was reduced to 8.5% with an Ep of 0.07 in this vibrating fluidized bed.

Settling devices such as air table take the advantage of many physical properties i.e., density, size, shape and frictional properties of fine dry coal. Earlier work on air table for cleaning coals with various ash contents offered a generalized strategy for fine coal beneficiation [10]. In another work, progress of separation as particles move along the air table deck is explained for a high ash coal [11]. In the present work the efforts toward understanding the process from a fundamental angle are presented. The particle trajectory over the deck surface is computed from the basic forces acting on the particles. On the air table deck fine coal beneficiation takes place in two steps. First, due to air drag, buoyancy, and the gravity forces on the particles vertical density stratification of fine coal particles takes place. As the feed material is introduced from the hopper the particles fall against the air stream rising upward through the porous deck surface. The air stream partially fluidizes the incoming feed particles. The velocity of the air stream is adjusted carefully such that the light particles in the feed are lifted to the top while the heavy particles remain in contact with the deck surface. All other particles occupy intermediate positions along the thickness of bed [12]. The particles are thus stratified vertically with increasing density from the top of the particle bed to the bottom.

Thereafter, due to vibrating force and frictional force and a component of gravity force, horizontal segregation takes place and the high density (ash) particles are separated from the light (coal) particles along the plane of the deck. After the particles are properly stratified into vertical layers according to their density and size, these layers are made to move apart and separate so that they discharge into different collector bins as heavy and light fractions. A combination of deck slopes (in both longitudinal and transverse directions) and deck vibration was used to separate these layers to the desired extent with the assistance of vibrating and gravitational force.

The study of vertical stratification and horizontal segregation of fine coal (−1.0 mm) adopting the fundamental force balance approach on the particles on air table was taken up in this work. Separation features in terms of density and size segregation on the deck surface were studied. Modeling and simulations of separation in an air table were carried out and the computed data were validated against the experimental results on high ash coal. In the subsequent sections, first the generation of experimental data is described followed by presentation of detailed mathematical formulations. Conclusions are then drawn from the computation results and validations with experimental data.

2. Experimental

2.1. Raw material

Thermal coal from Dakra mines, Central Coalfields Limited, India was used which has over 43% ash. The proximate analysis of the ROM coal is given in Table 1. The washability data of the ROM coal crushed to a top size of 1.0 mm is shown in Fig. 1. The data gives the theoretical limit of clean coal yield obtainable at any target ash level using gravity methods of washing. It may be seen from the figure that the coal has reasonably good washability characteristics in spite of the high ash content. A maximum of 71% yield at 30% clean coal ash level and around 54% yield at 25% target ash level is achievable under ideal conditions. Earlier work on air table indicates that significant ash rejection is possible from the ROM coal at a relatively fine size using this technique [10]. Hence, fine coal of size −1.0 mm was used in the present study. The size analysis of the coal fed to the air table is given in Table 2. Nearly half of the material was observed to be larger than 0.5 mm while about 17% of the material was finer that 0.15 mm. The coarsest fraction had about 40% ash which increased steadily with lowering of size and the finest fraction had nearly 51% ash.

2.2. Experimental set up

The air table used for the experiments is shown in Fig. 2. It consists of a base and frame, centrifugal fan, air chest, a porous deck, feed hopper, eccentric drive system and product collectors. The base section is bolted to a solid foundation to keep the machine from shaking so that all deck motions will be created by the eccentric drive mechanism. The frame provides structural support for all other parts of the machine and serves as part of the walls of the air

Table 1
Proximate analysis of the feed coal.

Moisture (%)	Volatile matter (%)	Ash (%)	Fixed carbon (%)
5.5	21.6	43.0	29.9

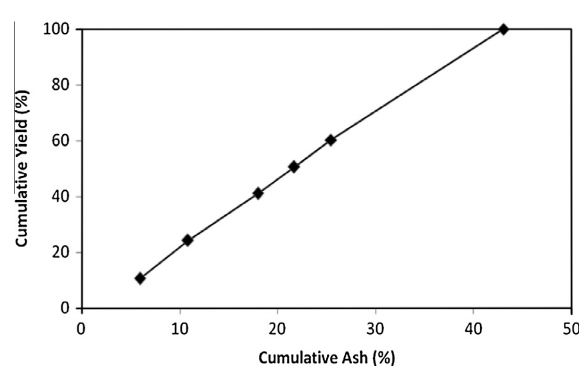

Fig. 1. Washability characteristics of the feed coal at 1.0 mm top size.

Table 2
Size and size wise ash distribution of the feed coal crushed to 1.0 mm.

Size range (mm)	Wt%	Ash%
−1 + 0.5	48.12	40.55
−0.5 + 0.15	34.95	43.30
−0.15	16.94	50.99