COMBINED AIR JIG AND DRY MAGNETIC SEPARATOR FOR CLEANING COAL

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ABSTRACT

We present results of dry magnetic separation (patent pending) of ¼ inch topsize fines removed through the dust hood of an Allair®-Jig processing a 2 inch topsize North Dakota lignite. A split of the fine material blown through the air jig and collected in a bag-house used for dust suppression was processed with a rare earth belt magnetic separator without any pre-treatment such as crushing, screening, or drying. Use of the magnetic method improved the Btu recovery of the air jig from 78% to 91% without impacting the product ash level or pounds SO_2 per million Btu. The performance of the dry magnetic separator is enhanced because the air jig reduces surface moisture for the fine particles. Use of the combined technologies improves the overall performance.

INTRODUCTION

Use of dry methods for separation of mineral contaminants from coal began in the 1800's and peaked around 1965 when wet methods, generally more effective in mineral separation, were developed for coal cleaning. However, the growth of concern for the massive volumes of wet refuse to be managed has piqued new interest in development of dry methods for ore dressing. Dry methods have always been of interest in arid regions of the world where water is not available for wet processing.

Air jigs are one technology now being reconsidered for dry cleaning of raw coal.[1] However, they are largely ineffective in cleaning coal particles larger than 50 mm and smaller than 0.6 mm diameter.[2] All together, the ineffectiveness of the air cleaning devices in treating fine coal has limited the application of this technology. Further, air jigs are generally limited to "black-and-white" separations at 1.6 specific gravity or higher. Separations at specific gravities much below 1.6 are not normally economic. Like all dry methods, the air jig has a practical upper surface moisture limit of about 6% and dust control is a necessity.

COMBINED MAGNETIC AND AIR SEPARATION TECHNOLOGY

The dust collected in air jig operation can be processed efficiently by dry magnetic methods with the potential to make a significant improvement in overall Btu recovery. The high air velocities employed by the air jig remove surface moisture from the coal thus making dry magnetic separation viable. The dry magnetic separators are limited by surface moisture as are the air jigs. The combination is significantly more efficient than either alone.

Stand-alone dry magnetic separators, however, have not previously found acceptance in the coal mining industry because of problems of treating large quantities of coal of differing particle size. There is a limit to the top size which can be treated by a belt magnetic separator because of the weak magnetism of minerals in coal and because of the short range of the gradient magnetic fields required to make the separations. Particle top size is generally in the ¼ inch range. Coal dependent, 15 to 25 tons per hour is a practical upper limit of throughput for a single magnet belt separator. Using the belt magnetic separators to treat the fines fraction of dry coal cleaning equipment such as air tables and air jigs (patent pending) is practical.

A schematic of an air jig employing dry magnetic separation of the dust fraction is shown in Figure 1.

Raw coal is fed to the airflow jig through a feed bin. Both steady and pulsating air are fed through a plenum chamber underneath the separator and mechanical action vibrates the porous surface of the inclined air table (jig). A stratified layer is formed as the stream of coal works its way down the inclined table. The Allair® airflow jig (table) produces clean, refuse and fine coal fractions. The fine material is recovered by a dust collection system which in this case is a bag house. The solids discharge from the dust collection system is then sent to a dry magnetic separator suitable for processing nominally ¼ inch topsize particles where a separation of clean coal and refuse was effected. The clean coal from the airflow jig and the dry magnetic separator are combined as product and the refuse fractions are discarded.

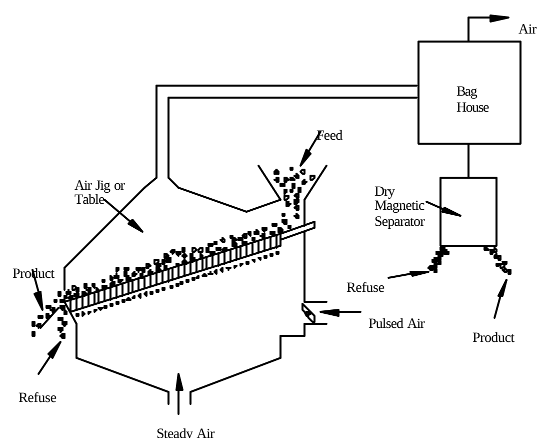

Fig. 1. Combined air jig and magnetic separator.

EXPERIMENTAL

A 24 ton batch of 2 inch topsize North Dakota lignite from the Falkirk Mining Company was processed in a single pass through the Allair® airflow Jig. The fines fraction was collected in a bag house. A split of the fine material was then processed through ETCi's belt magnetic separator. The overall result of the testing is shown as a mathematical recombination of the fractions from each device.

Figure 2a is a schematic illustration of the laboratory scale permanent magnet belt separator which was used to process the minus ¼ inch dust fraction from the air flow jig. Figure 2b is a photo of a nominal 1 TPH separator.

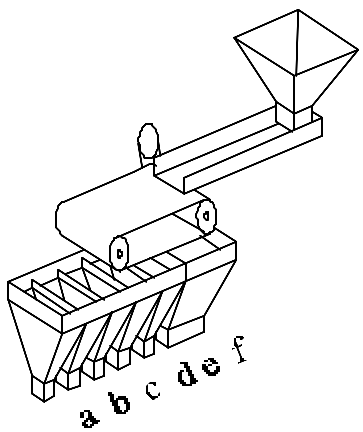

Fig. 2a. Schematic drawing of belt magnetic separator.

Fig. 2b. ElectriMag™ Separator

The separator of Figure 2a has flow dividers and receiving bins located at the magnet end and underneath the belt. Coal is transferred from the dust collector of the air jig into the hopper. The fine coal is fed from of the hopper onto the surface of a vibratory tray which prepares a flowing stream of particles of uniform thickness and controls the rate at which particles are fed onto the surface of the moving belt at the idler pulley end of the belt. The belt speed is controlled by a drive motor which changes the rate of rotation of the magnet pulley and hence the thickness of the coal layer moving with the belt.

The material being carried by the belt will be separated into particles of differing levels of magnetism at the magnet end of the belt. The least magnetic particles will be collected in receiver ***a*** located at the greatest distance from the leading edge of the magnetic roller and upon separating from the magnet, as for all particles, will follow a trajectory dictated by their momentum, gravity, and aerodynamic drag. Particles of strong magnetism will be carried around the perimeter of the magnet and deposited in receivers ***d***, ***e***, and ***f*** underneath the belt. Particles of intermediate magnetism will land in receivers ***b*** and ***c*** between the two extremes.

A vertical section along the length and through the center of the permanent magnet used to produce the magnetic force of attraction is shown in Figure 3. The magnet consists of a cylindrical arrangement of alternating segments of permanent magnets separated by thin cylindrical carbon steel spacers. The permanent magnets are magnetized parallel to the axis of the cylinder and are arranged so that nearest faces are magnetized in opposite directions. In this arrangement, the lines of magnetic flux emerge and return radially over the outside surfaces of the carbon steel spacers. These surfaces are the regions of high magnetic force corresponding to high values of the magnetic energy gradient, $B\nabla B$. Any permanent magnet with sufficient demagnetizing force can be employed. Permanent magnets made from mixtures of neodymium, iron, and boron are preferred to produce large forces. The thickness of the permanent magnets and the spacers can be adjusted to produce maximum force on the surface of the magnet. Figure 3 shows the lines of magnetic flux in the permanent magnet separator.

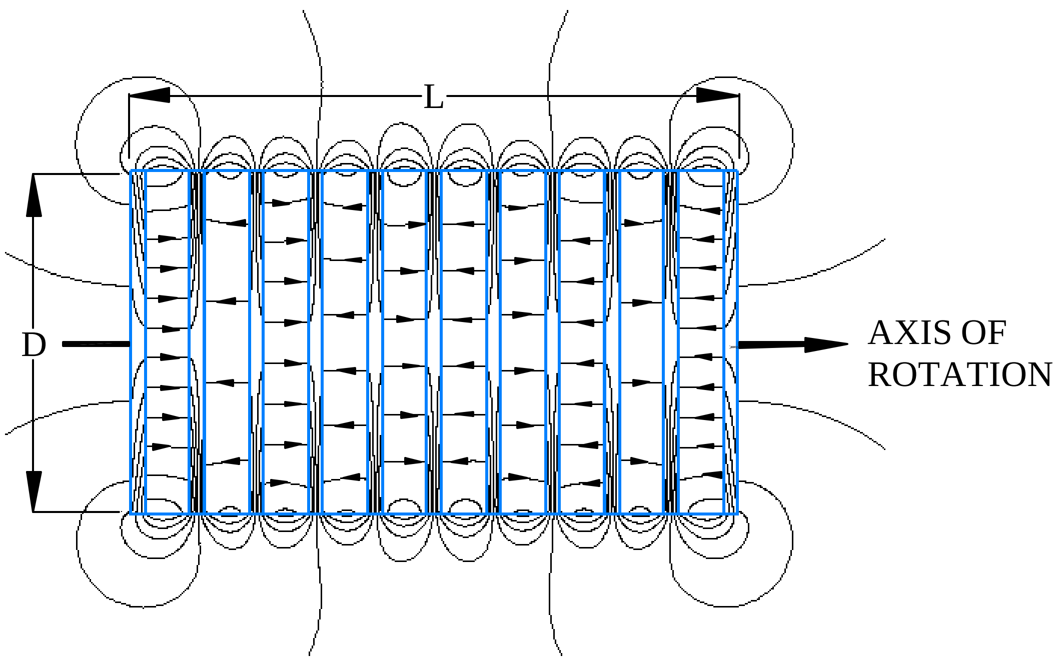

Fig. 3. Lines of magnetic flux in the permanent magnet separator

TEST RESULTS

EXPORTech Company, Inc. (ETCi), Falkirk Mining Company and Allmineral, LLC, have tested the concept of combining a modern air jig and a dry magnetic separator to achieve improved recovery and greater ash and sulfur reductions when cleaning nominal 50 mm topsize coal. Twenty-four tons of North Dakota lignite were shipped to Ohio for processing at the rate of 50 tons feed per hour through the commercial Allair® Jig shown in Figure 4. Since only 24 tons of coal were shipped, it was decided to run the Falkirk lignite in a single batch with no size separation. Typically this unit would operate on either a stream of coarse or fine coal. The system was purged and the Falkirk coal was run through as a batch with samples being taken of the feed, coarse product, baghouse fines, and reject material throughout the test. The test took approximately 20 minutes. The results of the testing are shown in Table I.

Fig. 4. Allair® Jig

Table I. Results of Processing Lignite with an Air Jig

			Dry Basis			
Sample	**Recovery wt.%**	**Moisture wt.%**	**Ash wt.%**	**Energy Btu/Lb**	**Sulfur wt.%**	**SO_2/MBtu**
Feed	100	30.65	28.84	8588	1.33	3.10
Av. Prod.	69	32.40	18.83	9857	1.30	2.64
Av. Fine	22	26.27	36.74	7514	1.18	3.14
Rejects	9	19.75	73.93	2445	2.12	17.36

Twenty-two percent of the feed to the air jig was collected in the baghouse. As shown in Table I above, this ¼ inch topsize material had 26.27 % moisture, and 36.74% ash, 1.18 % sulfur, and 7,514 Btu/lb on a dry basis. A representative sample of the baghouse fines reject from the Allair® Jig was shipped to EXPORTech Company in New Kensington, PA where it was processed at the rate of 86 lb/hr through a bench scale model of the ElectriMag™ Belt Separator (US patent 6,540,088 April 1, 2003) similar to that shown in Figure 2b. The laboratory scale magnetic separator split the air jig dust into six different fractions for detailed analysis. The results are shown in Table II.

Table II. Results of Magnetic Separation of Air Jig Dust Component

	Dry Basis			
Canister No.	**Weight Recovery wt.%**	**Ash wt.%**	**Sulfur wt.%**	**Magnetic Susceptibility Micro cc/g**
a	7.58	12.23	1.31	1.58
b	44.28	20.26	1.41	2.17
c	26.87	41.89	1.38	2.70
d	6.05	55.34	1.22	4.69
e	3.03	69.94	1.13	24.18
f	12.18	73.79	1.05	68.59
Composite	99.99	35.63	1.33	11.06

Strongly paramagnetic minerals are separated from the airflow jig fines fraction. The result of the magnetic separation is a coal with reduced ash and similar sulfur but which is still paramagnetic. Additional sulfur bearing minerals may be removed from the airflow jig fines if they were ground finer to achieve better mineral liberation.[3]

The composite products which can be made by combining the air jig products with the products of the dry magnetic separation are shown on a dry basis in Table III.

Table III. Composite Products, Dry Basis

Sample		**Recovery wt.%**	**Ash wt.%**	**Sulfur wt.%**	**Energy (Btu/Lb)**	**$LbSO_2$/MBtu**	**Btu Recovery %**
Air Jig Product		69.00	18.83	1.33	9,857	2.70	78.05
Magnetic Separator Product	***a***	70.67	18.67	1.33	9,903	2.69	80.31
	b	**80.41**	**18.87**	**1.34**	**9,877**	**2.71**	**91.14**
	c	86.32	20.44	1.34	9,665	2.78	95.73
	d	87.65	20.97	1.34	9,593	2.79	96.49
	e	88.32	21.34	1.34	9,543	2.81	96.72
	f	91.00	22.89	1.33	9,335	2.85	97.47
Air Jig Reject		100.00	27.49	1.4	8,715	3.22	100.00

Using the dry magnetic separator to process the air jig fines can recover additional material that would have been lost. By doing this the Btu recovery of the air jig product for this lignite can be increased from 78.05% to 91.14% without substantially hurting the $LbSO_2$/MBtu.

CONCLUSIONS

Dry magnetic separation and pneumatic methods (patent pending) are a viable combination of technologies for dry cleaning of coal. The belt separator is a suitable choice of magnetic methods for processing coals where the magnetic susceptibility of the refuse fraction is generally greater than 5×10^{-6} emu/g-Oe as is the case in this example.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge Russell Jamison who carried out the magnetic separation test work reported here.

REFERENCES

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