A New Fly Ash Separator Combining Magnetic Forces with Air Drag

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ABSTRACT

This paper presents results obtained in separating fly ash into value-added fractions using EXPORTech's VacuMag™ separator (Patent Pending). Fine particles (such as fly ash which has mean particle sizes below 60 microns) present unique problems in physical separations because of their high surface area which makes them subject to air drag, electrostatic, and hydrophilic agglomeration forces which are often difficult to control. EXPORTech's VacuMag™ separator overcomes problems of separating small dry particles by employing a combination of magnetic and aerodynamic forces. Thirteen different fly ashes were separated into meaningful quantities of fly-ash-derived-magnetite, particles with less than 4% Loss-On-Ignition (LOI), and particles with specific gravity less than 2.2 g/cm^3. The prototype separator has been operated at feed rates up to 3300 lb/h.

INTRODUCTION

Particles of less than 60 micron mean particle diameter are difficult to separate using dry processing technology. Because of their high surface areas , they are strongly affected by aerodynamic drag, frictional or electrostatic forces, and hydrophilic agglomeration. These forces are difficult to control. EXPORTech Company, Inc. (ETCi) has invented a new separator that uses two very strong forces to separate small dry particles and has applied it to separation of fly ash. These forces — aerodynamic and magnetic — dominate other surface and mass forces allowing for efficient separation of fly ash into value added products including magnetite, particles of low LOI, and a mixture of particles exhibiting a composite density less than 2.2 g/cm^3.

THE VacuMag™ SEPARATOR (Patent Pending)

ETCi's VacuMag™ separator feeds a stream of fly ash particles onto a belt magnetic separator. The belt conveys the particles toward a magnetic roll that attracts ferromagnetic and strongly paramagnetic particles holding them on the belt. Aerodynamic forces are applied in various configurations to augment the magnetic force of separation.

FLY ASH SAMPLES

Thirteen fly ash samples from 8 different coal-fired power plant units were tested. The samples are identified by a letter indicating the source power plant and a number to differentiate various samples from the same plant. Additional information about each fly ash is provided in Table I. Low LOI (less than 2%) and highly magnetic fractions were removed from each fly ash sample during bench top testing.

Table I
Fly Ash Samples, LOI, and Source Information

Fly Ash	LOI (wt%)	Low NOx Burners (Yes/No)	Source Coal	Comment
A 1	12.98	Yes	Kittanning and Freeport seams (2% S, 8% A)	Unit 1
A 2	11.15	Yes		Unit 2
A 3	12.80	Yes		Blend of Units 1&2
B 1	6.46	No	Illinois Basin (3% S, 8% A)	Scrubber
B 2	5.31	No		Scrubber
B 3	7.32	No		Scrubber
C 1	6.81	Yes	Colorado & Eastern Bituminous, W. Kentucky, PRB	
C 2	8.52	Yes		
D 1	5.89	Yes	E. Kentucky (1% S, 9% A)	SCR-ammonia
D 2	6.19	Yes		SCR-ammonia
E	5.76	Unknown	Unknown	
F	1.98	No	Pittsburgh seam (2% S, 8% A)	
G	1.73	No	Pittsburgh seam (4% S, 12% A)	Scrubber

EXPERIMENTAL PROCEDURE

A broad range of separator parameters was studied. Each separated fraction was examined by measuring its LOI in order to determine the quality of the separations and to evaluate the fractions as value-added products,. Note that the LOI of magnetite is –3% because, when heated in air, magnetite converts to hematite and gains mass. Apparent magnetic susceptibility, specific gravity, and size distribution were analyzed on many fractions. LOI was measured according to

ASTM method C 311-98b. A *Johnson Matthey* Gouy balance was used to measure apparent magnetic susceptibility. Because of the high susceptibilities of most of the fly ash samples, they were diluted with a low susceptibility material [natural calcium carbonate at 3.8 μ emu/(g•Oe)]. The weight percents of the sample and dilutant were then used to calculate the susceptibility of each sample. Specific gravity was measured in a la Chatelier flask according to ASTM procedure C 311-98b. Wet screening at 325 mesh was performed in accordance with ASTM procedure C311-98b. This included a calibration of the screen and a resulting correction factor (add 2.8 % to the weight percent retained on the 325 mesh screen).

PERFORMANCE OF VARIOUS SEPARATOR CONFIGURATIONS

Table II compares the low LOI fraction separated from the A 3 fly ash for various separator configurations. Recoveries and feed rates are compared for the fractions near but below 4% LOI and for the lowest LOI fractions removed using different configurations.

Table II
Comparison of Low LOI Fraction Separated from Fly Ash A 3
Using Various Separator Configurations

Configuration	**Recovery (wt%)**	**LOI (wt%)**	**Feed Rate (lb/hr)**
1A	6.11	3.5	1500
1B	11.73	2.8	200
2A	13.17	2.6	46
2B	13.89	2.5	140
1C	2.99	-0.5	350
2C	8.3	0.1	49

Configurations 2A, 2B,& 2C recovered more material "near" 4% LOI; the lowest LOI recovered for this configuration was 0.1 wt%. Configurations 1A, 1B, & 1C removed fractions with LOI as low as –0.5 wt%, and could be operated at much higher feed rates than configurations 2A, 2B and 2C.

Figures 1 and 2 plot the recoveries and LOI values as a function of magnetic susceptibility and feed rate for fly ash B2 (feed LOI: 5.2 wt%).

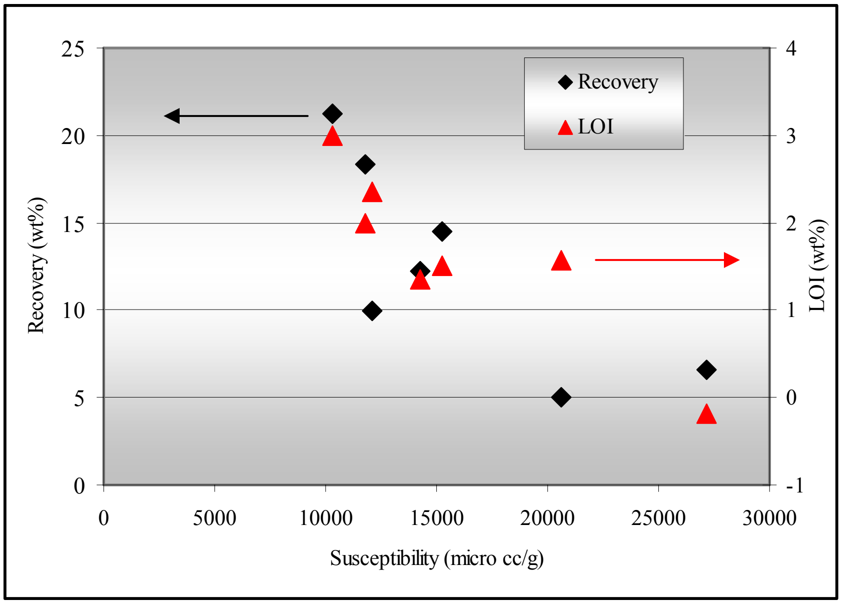

Figure 1. Recovery and LOI for Fly Ash B 2 as a Function of Magnetic Susceptibility

The highest susceptibility fractions are recovered in small quantities with very low (even negative) LOI's. The susceptibility of a sample of magnetite used in coal cleaning circuits was measured to be 25,000 μ emu/(g•Oe). Only a few percent of the original feed was recovered with a susceptibility that is comparable to commercial magnetite for this fly ash.

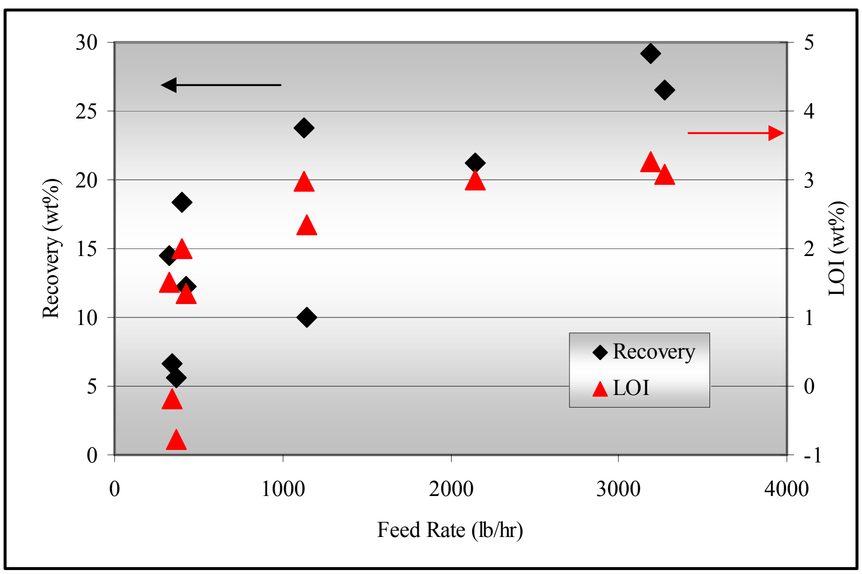

Figure 2. Recovery and LOI for Fly Ash B 2 as a Function of Feed Rate

In order to recover the lowest LOI fractions, low feed rates are required. However, for the B 2 fly ash, less than 4% LOI fractions were removed at feed rates up to 3300 lb/hr with the beta prototype VacuMag™ separator.

FLY-ASH-DERIVED MAGNETITE

Table III lists the characteristics of the fly-ash-derived magnetite samples removed from three different fly ash samples using the beta-prototype separator. The 325 mesh correction factor was applied.

Table III
Fly-Ash-Derived Magnetite Fractions
Separated Using the Beta-Prototype Separator

Fly Ash	**Low LOI Fraction**				
	Recovery (wt%)	**LOI (wt%)**	**Specific Gravity**	**Feed Rate (lb/hr)**	**Percent -325 mesh (wt%)**
H	11.78	-0.85	4.30	520	55.88
D 2	2.62	-0.53	4.09	680	50.29
C 2	5.92	-0.52	3.97	460	50.09

These fly ash derived magnetite samples all have negative LOI values, specific gravities greater than 3.9, and more than 50% passing 325 mesh. Commercial grades of magnetite used for coal cleaning are generally characterized by an iron content of 59%, a specific gravity of 4.8, and 84% or more passing 325 mesh.[1] The susceptibility of these low LOI fractions compared favorably with that of commercial magnetite suggesting that magnetically they would be good substitutes for commercial magnetite. However, the low specific gravities would require that more fly-ash-derived magnetite be added to coal cleaning circuits in order to achieve the same slurry densities being used with commercial magnetite. The percent passing 325 mesh is also low. If material coarser than 325 mesh is unacceptable to a particular cleaning plant, it would have to be removed; a cyclone could perform this size classification.

LOW LOI RECOVERY

Less than 4% LOI samples were removed with the beta-prototype separator as shown in Table IV.

Table IV
Less than 4% LOI Fractions

Fly Ash	Less than 4% LOI Fraction		
	Recovery (wt%)	LOI (wt%)	Feed Rate (lb/hr)
B 2	29.14	3.3	3190
C 1	12.82	3.3	860
D 1	12.55	3.3	1550
A 3	6.11	3.5	1500

The weight recoveries in the less than 4% LOI fraction range from 6 to over 29%. The feed rates varied from less than 1000 to over 3000. Various modifications to the separation parameters can increase the recovery at the expense of a higher LOI or decrease the LOI at the expense of lower recovery.

LOW SPECIFIC GRAVITY

Low specific gravity fractions were removed with the beta-prototype separator from various fly ash samples (Table V). These fly ashes were processed between 800 and 1200 lb/hr.

Table V
Densities of Fly Ashes and Separated Products

		Specific Gravity		Recovery
Fly Ash	Feed Rate (lb/hr)	Feed (g/cc)	Product (g/cc)	Product (wt%)
B 3	1200	2.45	2.20	35 (additional material lost)
C 1	860	2.27	2.16	69 (additional material lost)

The feed samples had specific gravities in excess of 2.20, but the separated products achieved specific gravities of 2.20 or less. The most magnetic fractions of fly ash contain some of the densest material (i.e., magnetite at greater than 3.9 g/cc). When it is removed, the specific gravity of the remainder of the fly ash is significantly reduced. The specific gravities of the B 3 and C 1 fly ashes were reduced enough to make the recovered (nonmagnetic) product fraction acceptable for use in low density aggregate. The product weight percent recovery does not include lost material that blew through the bag house. In a commercial application, this would be captured and, depending on its specific gravity, could be included with the product resulting in a higher yield.

CONCLUSIONS

EXPORTech Company, Inc., has developed a dry fine-particle separator and tested it using fly ash. The separator is capable of producing fly-ash-derived magnetite for use in heavy media coal cleaning circuits, low LOI fractions for use in Portland cement, and low density fractions for use in the production of low density aggregate and blocks. These products were generated from a variety of different fly ashes originating from several different power plants burning a broad range of coals.

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