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EFFICIENT ULTRASONIC GRINDING: A NEW TECHNOLOGY FOR MICRON-SIZED COAL

QUARTERLY TECHNICAL PROGRESS REPORT NO. 4
June 16, 1980 - September 15, 1980

by W. B. Tarpley, Jr.
P. L. Howard
G. R. Moulder

October 1, 1980

Work performed under Contract No. DE-AC02-79ER10466
For U. S. DEPARTMENT OF ENERGY

ENERGY & MINERALS RESEARCH COMPANY
964 East Swedesford Road, P. O. Box 389
Exton, PA 19341

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ABSTRACT

During the fourth quarter, experimental work was conducted in the following areas:

1. Moist grinding with and without ultrasonics;
2. Tests of pyrite selective liberation; and
3. Fabrication and assembly of the dual-roller apparatus.

Using a water spray as a moistening agent, grinding was performed with the cylinder-segment apparatus. A 13:1 increase in -7 micron fines resulted.

A more accurate iron determination method (ASTM D2492-68) was applied to two samples of well-characterized coals, enabling an expansion of the data on the degree of preferential liberation of inclusions attributable to ultrasonic comminution. A 5:1 reduction in pyritic iron occurred with ultrasonic grinding of the two coals tested.

The dual-roll apparatus was completely assembled and aligned. Preliminary grinding was begun to determine basic parameters and to check out the equipment.

Project Description

The objective of this project is to demonstrate on a laboratory scale the technical feasibility and economic promise of efficiently applying ultrasonic energy to the production of -10 micron coal fines. Such a system could overcome the inherent inefficiency and economic penalty of mechanical grinding, while producing better size uniformity in the product. An additional benefit associated with the mechanism of ultrasonic effect is the possibility of selective liberation of ash and pyrite inclusions.

I. INTRODUCTION

Coal processing has become an increasingly important industry as America continues conversion efforts from petroleum to coal. In order to provide coal with combustion performance approximately equivalent to oil or gas, much finer particle sizes will be needed than the conventional plant grind size (75% -200 mesh).

Conventional grinding techniques cannot economically meet this goal. A new comminution technology, ultrasonic grinding, can offer a solution. Because it operates by methods not common to those of conventional grinding systems, it is expected that ultrasonics can significantly enhance grinding efficiency in the -10 micron range needed for various types of processing and "clean coal" applications.

The mechanisms of ultrasonic grinding appear to be:

- Very rapid (10-60 kHz) vibratory promotion of fatigue fracture;
- Promotion of stress corrosion;
- Preferential energy delivery to discontinuities;
- Prevention of small particle shielding by larger ones;
- Cavitation and preferential shear in damp or paste media.

These mechanisms all appear beneficial in producing the desired particle size range by a process entirely amenable to high volume production and at dramatically decreased energy requirements.

II. EXPERIMENTAL PLAN

The program is following the steps outlined below:

Phase I

A. Conduct preliminary ultrasonic comminution tests using existing laboratory equipment.

B. Design and fabricate laboratory-scale ultrasonic comminution apparatus.

C. Using selected samples of candidate coal, conduct experimental runs with and without ultrasonic activation.

D. Evaluate samples produced for particle size distribution and generate Phase II apparatus design data.

Phase II

A. Optimize laboratory comminution equipment.

B. Conduct sufficient experimental runs and evaluation to:

1. estimate maximum requirements of ultrasonic energy to produce ultrafine coal particles;

2. estimate production equipment requirements;

3. demonstrate repeatability of ultrasonic effect;

4. determine if selective fragmentation of coal inclusions occurs.

III. EXPERIMENTAL WORK

During the fourth quarter, experimental work was conducted in the following areas:

1. Moist grinding with and without ultrasonics;
2. Tests of pyrite selective liberation; and
3. Fabrication and assembly of the dual-roller apparatus.

Using a water spray as a moistening agent, grinding was performed with the cylinder-segment apparatus. A 13:1 increase in -7 micron fines resulted.

A more accurate iron determination method has been selected (ASTM method D2492-68) and was applied to two samples of well-characterized coals (PSOC-688, HGI-97 and PSOC-275, HGI-56), enabling an expansion of the data on the degree of preferential liberation of inclusions attributable to ultrasonic comminution. Ultrasonics resulted in a 5:1 reduction in pyritic iron in the two coals tested.

The dual-roll apparatus has been completely assembled and aligned. Preliminary grinding has begun to determine basic parameters and to check out the equipment.

A. Moist Grinding

The cylinder segment apparatus was used to grind dry and moist coal (PSOC-769, HGI-109) with and without ultrasonics. As shown in Table I, with ultrasonic activation there was a 7:1 increase in -7 micron fines with moist comminution over dry. When non-activated comminution was compared to activated in moist media, ultrasonics gave a 13:1 increase in production of the -7 micron fines.

TABLE I

COMMINUTION OF COAL WITH AND WITHOUT ULTRASONICS
MOIST AND DRY

Size Range	Dry Grind With Ultrasonics (% in Size Range)	Moist Grind With Ultrasonics (% in Size Range)	Moist Grind Without Ultrasonics (% in Size Range)
+200 Mesh	57.70	35.00	73.00
-200+325 Mesh	13.99	17.00	8.00
-325 Mesh +30 Microns	3.23	11.23	14.82
-30 Microns +15 Microns	18.82	12.43	1.84
-15 Microns +7 Microns	4.62	12.24	1.43
-7 Microns	1.64	12.10	0.91

It is possible that more than one mechanism is working to grind moist coal with ultrasonics. In addition to the normal grinding action of the cylinder segment against the moving plate, there is also ultrasonically induced impingement of the cylinder segment on the coal and the plate. Coupling of this energy into moist coal can be expected to be greater than for dry coal. Additionally, cavitation occurs during wet grinding (and was detected audibly); when a cavitation void collapses, considerable energy is released and very high stresses are exerted on adjacent particles, resulting in further grinding enhancement. Considerable turbulence is also evident, resulting in further particle-to-particle impact and increased attrition.

B. Preferential Liberation of Inclusions

In order to improve accuracy and repeatability of iron determination measurements (and thus pyrite content determination) in the size ranges of interest, an alternate test procedure was used involving standard wet chemistry procedures which rely on redox titrations to determine the amount of iron extracted from coal samples, as outlined in ASTM D2492-68. In the analysis, the iron is extracted from the coal under refluxing acid. The leachant is titrated with a standard permanganate solution to a color end-point. The iron content is determined by calculation based on the amount of standard permanganate solution used.

Two coals, PSOC-688 and PSOC-275, were ultrasonically ground and sized in the -200+325 mesh and -325 mesh ranges and within the -325 category to the -10 micron range. The results in Table II indicate that preferential liberation of inclusions is occurring in the pyritic iron in the -200+325 mesh size range. The decrease in pyritic iron percentage in the -10 micron size range suggests that the majority of the inclusions were liberated from the comminuted coal and settled during sedimentation. The 5:1 reduction in pyritic iron indicates significant preferential liberation. The non-pyritic iron is probably due to particles ground from the non-hardened plate of the cylinder segment apparatus.

Table II

IRON ANALYSIS OF ULTRASONICALLY COMMINUTED COAL

Coal Type	Size Range	% Pyritic Iron	% Non-Pyritic Iron	Total Iron
PSOC-688 (HGI-97.5)	+200 mesh	1.30	0.20	1.50
	-200+325 mesh	1.51	0.43	1.94
	-325 mesh	1.25	0.48	1.73
	-10 microns	0.21	0.22	0.43
PSOC-275 (HGI-56.7)	+200 mesh	0.91	0.14	1.05
	-200+325 mesh	1.98	0.31	2.29
	-325 mesh	1.68	0.66	2.34
	-10 microns	0.33	0.59	0.92

C. Dual-Roller Apparatus

Initial check-out has begun on the dual-roller apparatus. PSOC-688 (HGI-97.5) coal is being ground in small quantities at several power levels in order to determine best conditions. After screening of the fines from the dual-roller, a high percentage of -325 mesh fines were found. Even with no ultrasonic power applied, the percentage of -325 mesh fines was above 40%. The cylinder segment apparatus only approached these results when it was used for wet grinding with ultrasonics.

The traveling wave mode is being examined first, at several power levels. Other conditions being varied are:

1. roller gap width
2. roller speed
3. relative roller surface speed between the active and passive rollers
4. condition of coal - moist or dry.

After the traveling wave mode tests are completed, the standing wave mode will be investigated. Then the roller-plate mechanism will be tested, again with respect to the listed parameters. Initial analyses of these test results will be available for the next report.

IV. FUTURE WORK

- Perform coal comminution utilizing the dual-roller apparatus;
- Optimize final apparatus and begin Phase II experimental runs.

ENERGY & MINERALS RESEARCH COMPANY

September 11, 1980

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Operations Division II (2 copies)

Reference: DE-AC02-79ER10466, "Efficient Ultrasonic Grinding: A New Technology For Micron-Sized Coal"
Technical Status Report No. 8
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I. INTRODUCTION

Coal processing has become an increasingly important industry as America continues conversion efforts from petroleum to coal. In order to provide coal with combustion performance approximately equivalent to oil or gas, much finer particle sizes will be needed than the conventional plant grind size (75% -200 mesh).

Conventional grinding techniques cannot economically meet this goal. A new comminution technology, ultrasonic grinding, can offer a solution. Because it operates by methods not common to those of conventional grinding systems, it is expected that ultrasonics can significantly enhance grinding efficiency in the 2-7 micron range needed for various types of processing and "clean coal" applications.

The mechanisms of ultrasonic grinding appear to be:

- Very rapid (10-60 kHz) vibratory promotion of fatigue fracture;
- Promotion of stress corrosion;
- Preferential energy delivery to discontinuities;
- Prevention of small particle shielding by larger ones;
- Cavitation and preferential shear in damp or paste media.

These mechanisms all appear beneficial in producing the desired particle size range by a process entirely amenable to high volume production and at dramatically decreased energy requirements.

II. ACCOMPLISHMENTS

A. Overview

During this report period, effort was concentrated in the following areas:

1) Moist grinding with and without ultrasonics;
2) Tests of pyrite selective liberation;
3) Assembly of the dual-roller apparatus.

Baseline moist comminution tests were run utilizing the cylinder segment tester without ultrasonic excitation. By comparison to the dry comminution baseline (without ultrasonics) non-activated moist comminution was slightly less effective. Comparing activated moist comminution to this baseline indicates a 13:1 ultrasonic increase in -10 micron fines.

Iron determination on two coals, PSOC-688 and PSOC-275, show some preferential liberation of pyrite inclusions attributable to ultrasonic comminution, especially in the -10 micron size range.

All the parts for the dual-roller apparatus have been finished and assembly has begun.

B. Experimental Work

1. Moist Grinding

The cylinder segment apparatus was used to grind moist coal (PSOC-769, HGI-109) with and without ultrasonics. In the last report a comparison between wet and dry grinding with ultrasonics was shown. There was an increase in -7 micron fines content of 7:1 with moist comminution. To complete the comparison, moist comminution was performed without ultrasonic activation on the PSOC-769 coal. As can be seen in Table I, there

Table I

ULTRASONIC MOIST COMMINUTION OF COAL

Size Range	Moist Grind with Ultrasonics (% in Size Range)	Moist Grind without ultrasonics (% in Size Range)
+200 mesh	35.00	73.00
-200+325 mesh	17.00	8.00
-325 mesh +30 microns	11.23	14.82
-30 microns +15 microns	12.43	1.84
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-7 microns	12.10	0.91

is a 13:1 increase in -7 micron fines content when ultrasonic activation is used.

It is possible that more than one mechanism is working to grind moist coal with ultrasonics. In addition to the normal grinding action of the cylinder segment against the moving plate, there is also impingement of the cylinder segment upon the coal and moving plate due to ultrasonic activation. Energy coupling into moist coal can be expected to be greater than for dry coal. Additionally, during wet grinding, cavitation is present (and was detected audibly); when a cavitation void collapses, considerable energy is released and very high stresses are exerted on the particles, an additional source of grinding enhancement Considerable turbulence is also caused, resulting in further particle to particle impact and increased attrition.

2. Selective Liberation

Two coals, PSOC-688 and PSOC-275, were ultrasonically ground and sized in the -200+325 mesh and -325 mesh ranges and within the -325 category to the -10 micron range. The results in Table II indicate that preferential liberation of inclusions is occurring in the pyritic iron in the -200+325 mesh size range. The decrease in pyritic iron percentage in the -10 micron size range suggests that the majority of the inclusions were liberated from the comminuted coal and settled during sedimentation. The 5:1 reduction in pyritic iron indicates significant preferential liberation. The non-pyritic iron is probably due to particles ground from the non-hardened plate of the cylinder segment apparatus.

3. Dual-Roller Apparatus Assembly

All parts have been manufactured, ground, and aligned and final assembly has started. The motors and controllers required for roller rotation and speed control have been electrically wired and checked; the rollers

Table II

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Coal Type	Size Range	% Pyritic Iron	% Non-Pyritic Iron	Total Iron
PSOC-688 (HGI-97.5)	+200 mesh	1.30	0.20	1.50
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	-200+325 mesh	1.98	0.31	2.29
	-325 mesh	1.68	0.66	2.34
	-10 microns	0.33	0.59	0.92

are installed in the frame with the bearings pressed on, the transducers are being assembled onto the apparatus and final alignment is in process.

III. FUTURE WORK

- Complete assembly, alignment and functional testing of the dual-roller apparatus;

- Perform coal comminution utilizing the dual-roller apparatus; and

- Optimize final apparatus and begin Phase II experimental runs.