Final Report

Development of an Advanced Fine Coal Suspension Dewatering Process

Submitted to

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From

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DISCLAIMER

EXECUTIVE SUMMARY

With the advancement in fine coal cleaning technology, recovery of fine coal (minus 28 mesh) has become an attractive route for the U.S. coal industry. The clean coal recovered using the advanced flotation technology i.e. column flotation, contains on average 20% solids and 80% water, with an average particle size of 35 microns. Fine coal slurry is usually dewatered using a vacuum dewatering technique, providing a material with about 25 to 30 percent moisture. The process developed in this project will improve dewatering of fine (0.6mm) coal slurry to less than 20 percent moisture. Thus, thermal drying of dewatered wet coal will be eliminated. This will provide significant energy savings for the coal industry along with some environmental benefits. A 1% increase in recovery of coal and producing a filter cake material of less than 20 % moisture will amount to energy savings of 1900 trillion Btu/yr/unit. In terms of the amount of coal it will be about 0.8% of the total coal being used in the USA for electric power generation. It is difficult to dewater the fine clean coal slurry to about 20% moisture level using the conventional dewatering techniques. The finer the particle, the larger the surface area and thus, it retains large amounts of moisture on the surface. The coal industry has shown some reluctance in using the advanced coal recovery techniques, because of unavailability of an economical dewatering technique which can provide a product containing less than 20% moisture. The U.S.DOE and Industry has identified the dewatering of coal fines as a high priority problem.

The goal of the proposed program is to develop and evaluate a novel two stage dewatering process developed at the University of Kentucky, which involves utilization of two forces, namely, vacuum and pressure for dewatering of fine coal slurries. It has been observed that a fine coal filter cake formed under vacuum has a porous structure with water trapped in the capillaries. When this porous cake is subjected to pressure for a short time, the free water present is released from the filter cake. Laboratory studies have shown that depending on the coal type a filter cake containing about 15% moisture could be obtained using the two-stage filtration technique. It was also noted that applying intermittent breaks in vacuum force during cake formation, which disturbed the cake structure, helped in removing moisture from the filter cakes.

In this project a novel approach of cleaning coal using column flotation was also developed. With this approach the feed capacity of the column is increased significantly, and the column was also able to recover coarser size coal which usually gets lost in the process. The outcome of the research benefits the coal industry, utility industry, and indirectly the general public. The benefits can be counted in terms of clean energy, cleaner environment, and lower cost power.

ACTUAL ACCOMPLISHMENTS WITH THE GOALS AND OBJECTIVES OF THE PROJECT

The main goals of the projects were:

- Develop an effective, efficient, and economic dewatering technique for ultra-fine clean coal slurry to provide a dewatered product containing less than 20 percent moisture.

- Develop a conceptual design for a continuously operating machine and conduct a preliminary technical and economical assessment of the process

- Develop an efficient way to improve recovery of coarse particles in column flotation

Accomplishments:

- A two stage dewatering process was developed, where in the first stage vacuum force is applied to form a cake and as soon as free water disappears high pressure 30 psi (~2 bar) is applied. The final moisture in the filter cake obtained was about 17% compared to about 30% obtained with vacuum alone.
- Coal slurry treated with carbon dioxide gas and then dewatered using the carbon dioxide (CO_2) gas was effective in significant reduction of moisture. The use of CO_2 during pressure filtration decreased the cake moisture from 28.76% to 23.05%
- A conceptual design of the process was developed. Contacts have been made with a couple of equipment manufacturer to evaluate possibility of manufacturing a proto-type machine for testing in coal field.
- A novel way of operating a flotation column provided higher product yield at similar ash levels compared to the conventional column operation.
- A novel way of operating a flotation column gave a higher product yield of 79.4% compared to conventional column flotation yield of 73.4% at 9% product ash.
- The optimized experimental data show that a novel way of operating a flotation column was able to handle a higher feed rate of 317 ml/min as compared to 200 ml/min feed rate of a conventional flotation column, an increase of about 60 percent feed rate, while still providing similar product ash. The air requirement was reduced by about 12%.
- A novel way of operating a flotation column also improved recovery of coarse (+ 18 mesh) coal particles from 0.9 weight percent to 2.2 weight percent compared to the conventional way of operating the column. Similarly, recovery of 18x30 mesh particles improved from 4.6 weight percent to 8.3 weight percent at the same ash level.

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PROJECT ACTIVITIES

Water present in coal slurries can be classified as free or chemically bound moisture. The mechanical dewatering processes are effective in removing the bulk of the free water. However, it can not remove free moisture present in the capillaries of the filter cake. Thus, the conventional dewatering methods are not effective in providing low moisture filter cakes. The novel hybrid dewatering concept tested in this project utilizes a combination of two forces namely vacuum and pressure in two different stages. It is well recognized that a filter cake formed using the vacuum force has a porous structure, thus, when a high pressure (~ 2 to3 bar) is applied to the cake formed in vacuum, the free water trapped in the filter cake capillaries will be released.

The project consisted of the following tasks:

- Sample Collection and Characterization
- Laboratory Studies
- Conceptual Design of the process
- Develop an advanced column flotation process

Samples of coal slurries were obtained from the project participating cal companies. The samples were basically flotation products with an average particle size of 50 microns. The laboratory set-up is shown in Figure 1.

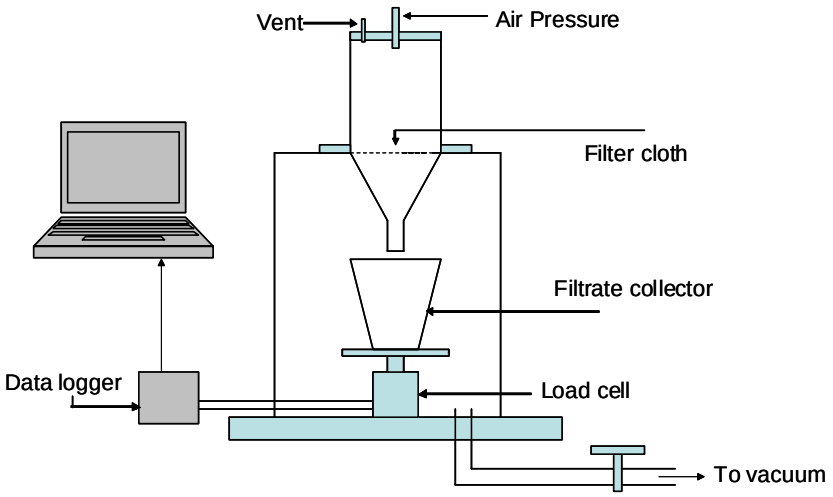

Figure 1. Laboratory dewatering equipment set-up

For the laboratory studies a known amount of slurry was introduced into the dewatering chamber containing a nylon filter cloth. Filtrate collected in a vessel placed on a load cell, which records weight with respect to time. Figure 2 shows the dewatering data utilizing the coal slurry supplied by James River Coal. By cleaning the supplied coal slurry from 12.5% to 4.9% ash, the moisture content could be reduced to below 17% using the hybrid dewatering system.

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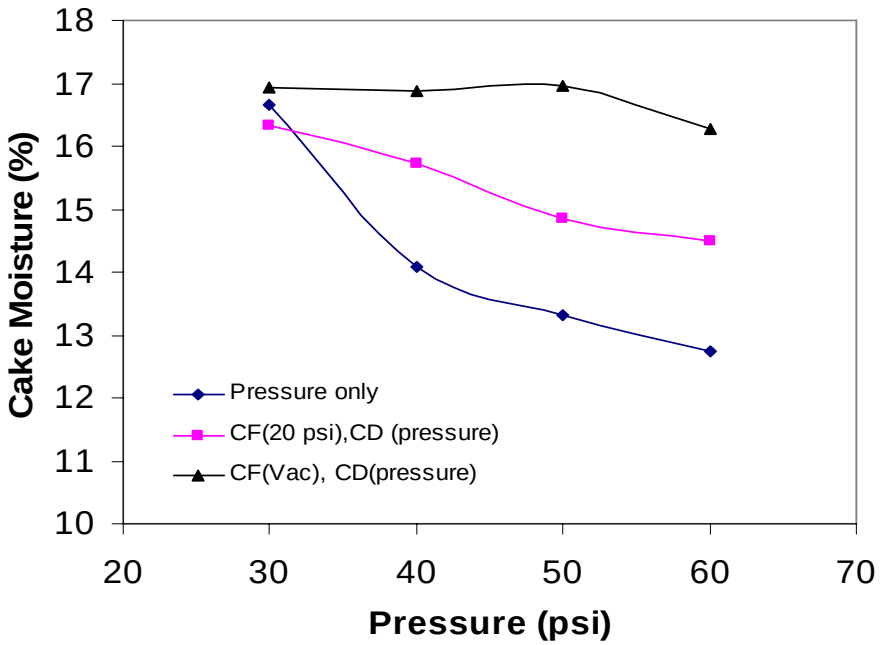

Figure 2. Dewatering data obtained with the hybrid filtration system (CF: cake formation; CD; Cake drying)

For the Consol Energy supplied coal slurry the hybrid filtration system marginally performed better at lower cake drying pressures compared to other systems (Figure 3).

Table I list the dewatering data for the James River and Peabody Energy coal slurry using the hybrid filtration system, where vacuum and pressure break technique was applied. During cake drying time vacuum or pressure breaks were applied to increase cake porosity. The breaks were achieved using a solenoid valve and a timer controller. As can be seen that both coal sample showed reduction in filter cake moisture by about 2% absolute points.

Table I. Dewatering Data Using Vacuum break/hybrid filtration system

Sample	Vacuum		Pressure (50 psi)	
	Baseline	Break	Baseline	Break
Peabody	24.23	22.63	19.36	17.81
James River	32.98	30.80	21.46	20.26

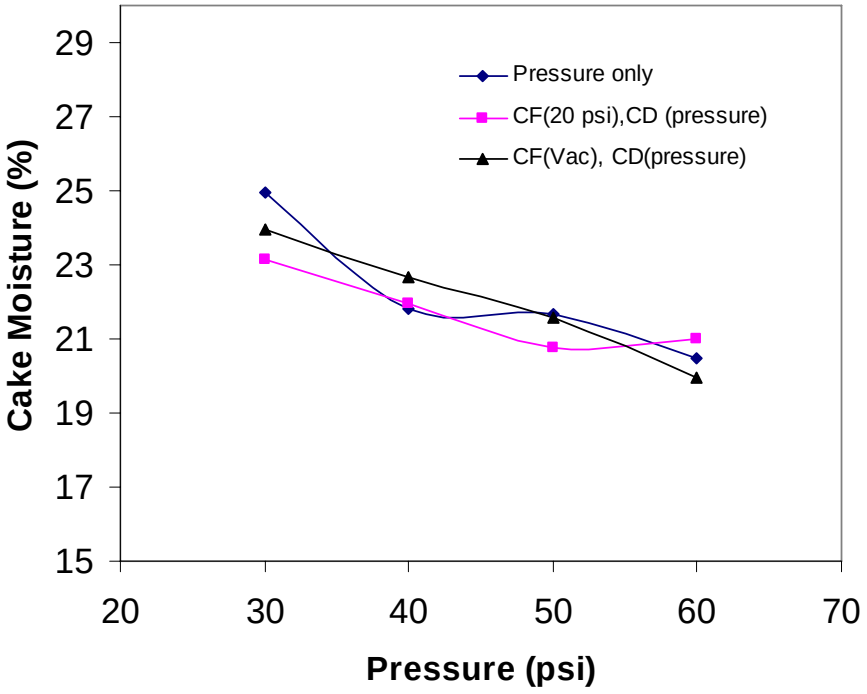

Figure 3. Hybrid filtration data for the Consol Energy supplied slurry

Effect of CO_2 gas on Vacuum or Pressure Filtration - Peabody coal slurry:

Hypothesis: CO_2 readily adsorbs to coal in very large amounts as indicated by carbon sequestration studies and also makes coal more hydrophobic. Hence, it was hypothesized that the adsorbed CO2 will replace the moisture from the coal surface.

- Vacuum filtration tests were conducted by treating the slurry with CO_2 at various conditioning times.
- Pressure filtration Tests were conducted, with conditioning of the slurry with CO_2 prior to normal air pressure filtration. Filtration tests were also conducted by replacing air with CO_2 without prior conditioning of the slurry with CO_2

The filtration data are shown in Figure 4 which shows that use of CO_2 during pressure filtration increased the cake moisture from about 15% to 18.4%.

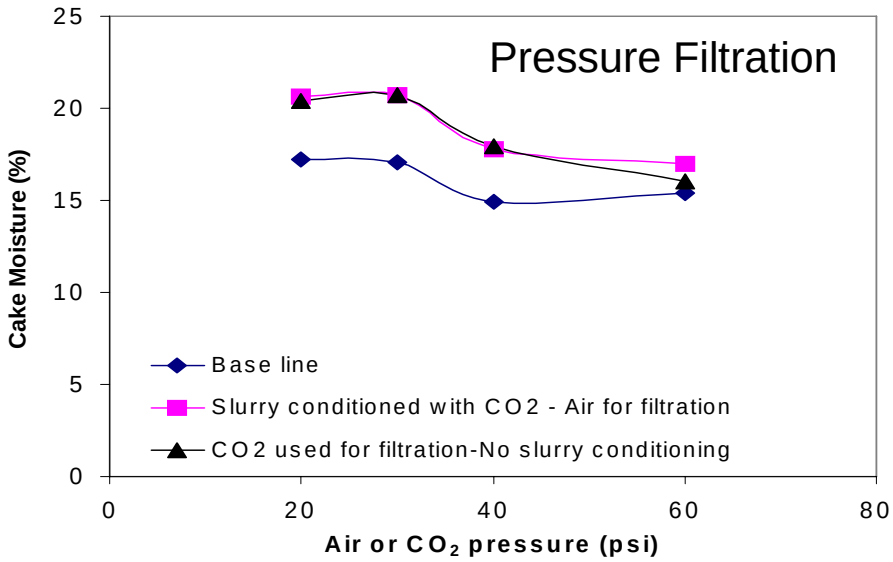

Figure 4. Effect of CO_2 conditioning and usage on dewatering of fine coal slurry.

A schematic diagram for a continuous hybrid dewatering unit is shown in Figure 5. The coal slurry will enter from one side of the filter and vacuum force will be applied for a short time and immediately high pressure will be applied.

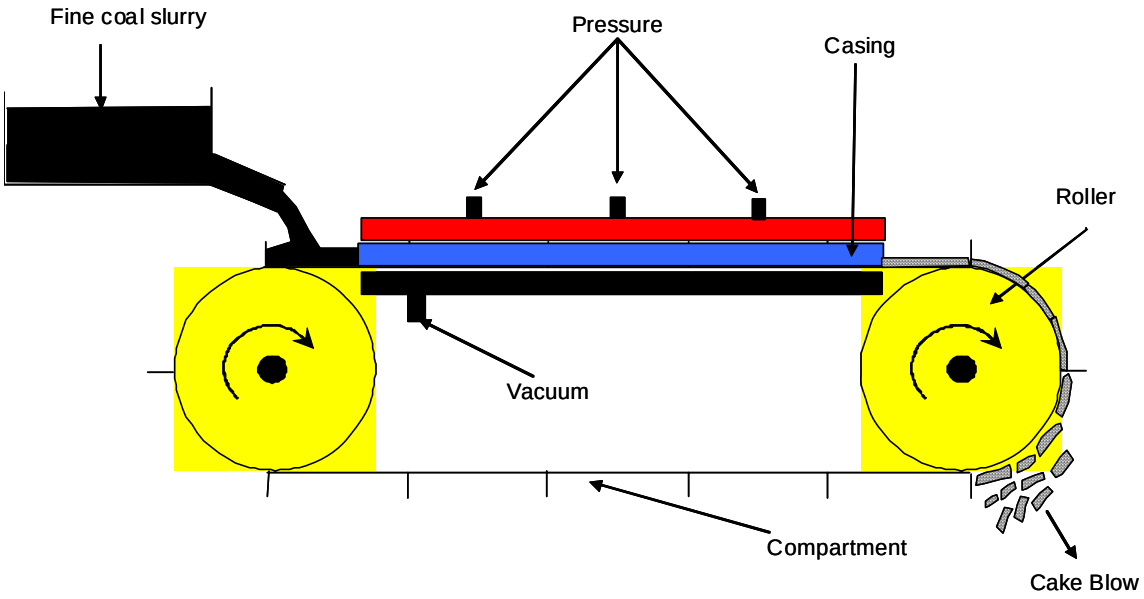

Figure 5. Conceptual design of a continuous hybrid dewatering unit.

Novel Modified Column Flotation System:

A novel way of operating a flotation column was implemented and the results compared to those from operating the same column in the conventional fashion. The graph in Figure 6 clearly shows that the novel column flotation system provides higher yield at similar product ash content.

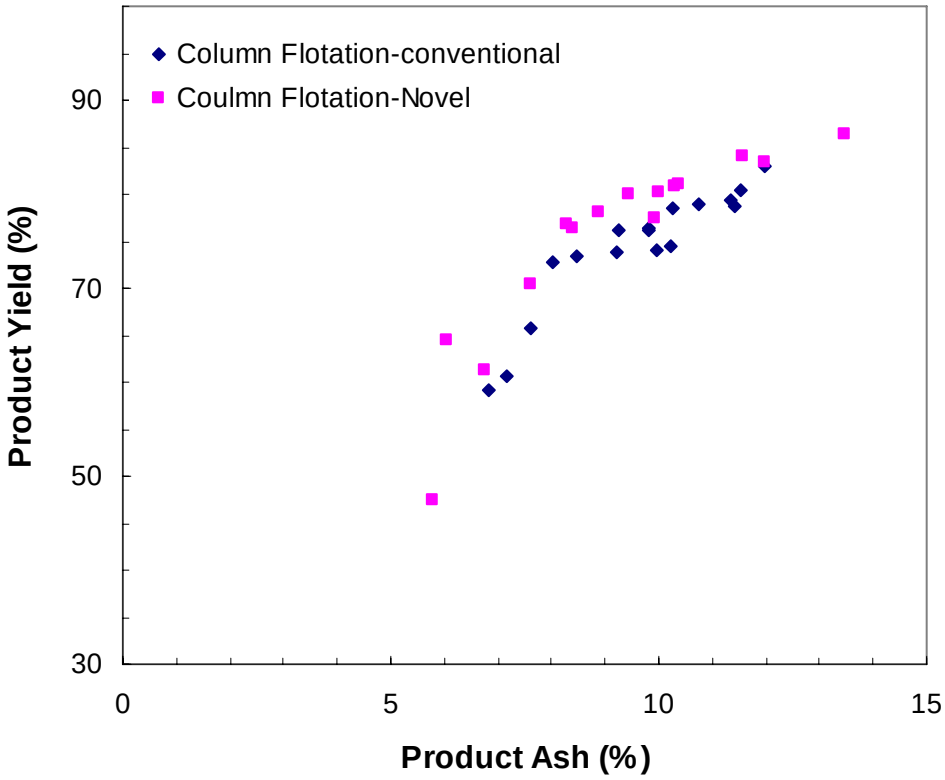

Figure 6. Comparison of novel operation to conventional operation

The novel concept is potentially patentable material, and so the results are presented as a function of certain parameter values. Figure 7 shows the effect of changing parameter X.

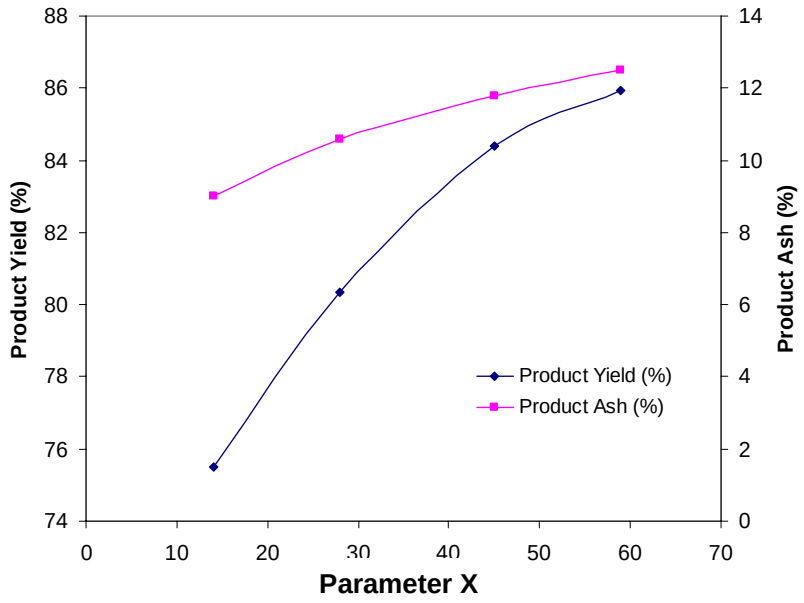

Figure 7. Effect of parameter x on yield and ash (Feed rate: 400ml/min; wash water 250 ml/min and air flow 2 scfh)

A detailed comparison between conventional and the modified approach were conducted using a statistical design of experiments. Table II shows the experimental data for the novel flotation system. Figure 8 shows the effect of airflow and feed rates on product ash and yield.

Table II Factorial Design Test Data for the Novel Flotation System

Run No.	Feed Rate ml/min	Air flow rate (SCFH)	Wash water ml/min	Float Ash %	Product Yield %
1	600	1.5	400	8.3	73.4
2	400	1.5	250	11.2	82.5
3	600	1.5	100	13.5	86.4
4	200	2	250	8.3	76.9
5	200	1.5	400	6.1	64.4
6	400	1	100	7.6	70.5
7	600	1	250	9.9	77.4
8	400	1.5	250	10.0	80.3
9	400	1.5	250	9.5	80.0
10	600	2	250	12.0	83.4
11	400	2	100	11.6	84.1
12	400	2	400	10.4	81.0
13	400	1.5	250	8.9	78.1
14	200	1.5	100	8.4	76.3
15	400	1	400	6.8	61.2
16	400	1.5	250	10.3	80.8
17	200	1	250	5.8	47.4

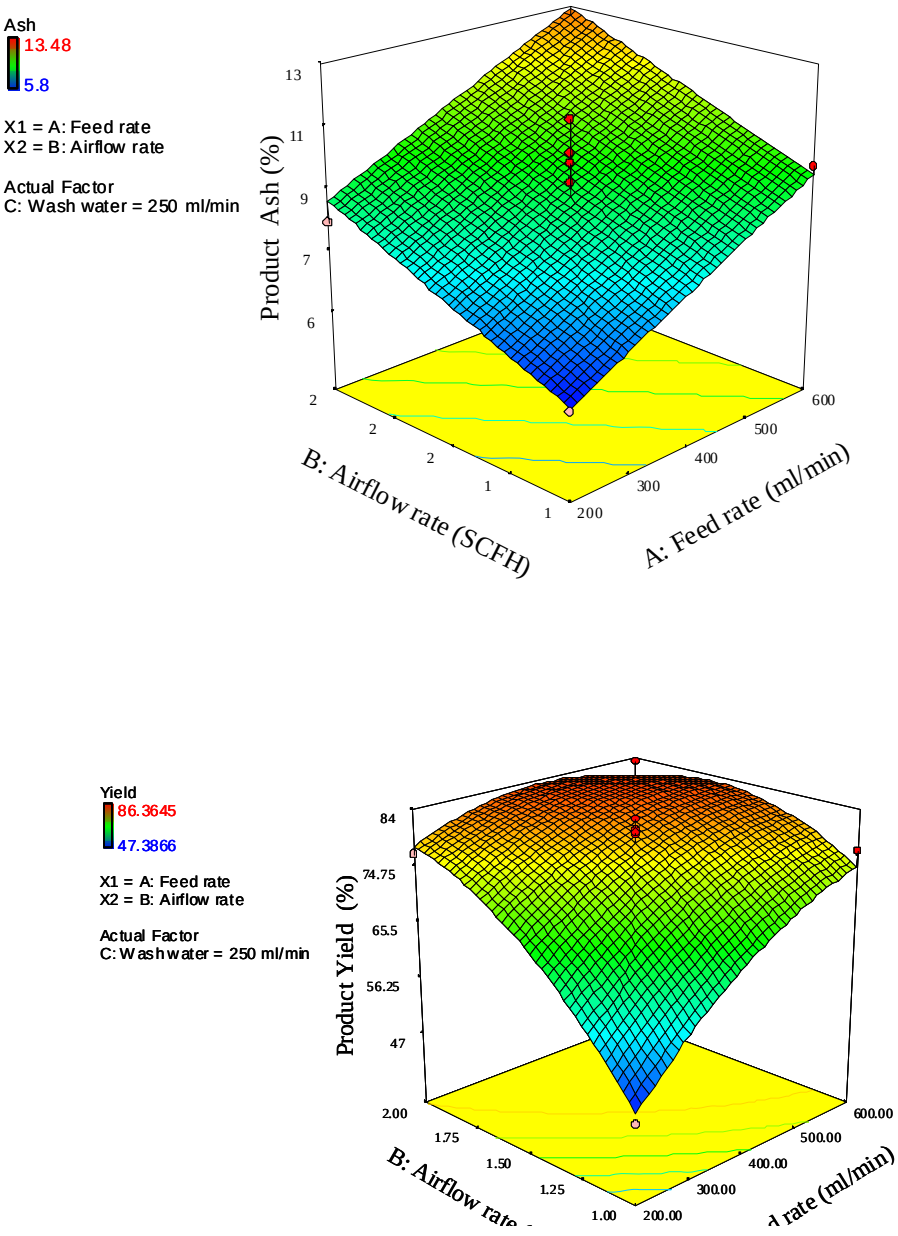

Figure 8. Effect of Airflow and Feed rates on Product Ash and Yield

The factorial design study showed that:

- The novel column behaves similarly to that of conventional column with respect to changes in operating parameters.
- The novel column operation provided clean coal ash as low as 5.8% ash with 47.4% yield compared to the lowest product ash of 7.2% ash with 60.7% yield obtained with conventional column flotation. This shows the improved selectivity with the novel column operation.

A comparison between the conventional and the novel column are summarized in Table III. The data shows that using the novel approach at the same ash content of 9.0%, the feed rate increased from 200 ml/min to 317 ml/min an increase of more than 50%., The use of air usage was about 12% and the yield increased by about 6%.

TABLE III. Comparison of Optimized Data of the Conventional and Novel Column

Type	**Feed rate (ml/min)**	**Airflow rate (SCFH)**	**Wash water (ml/min)**	**Ash (%)**	**Yield (%)**
Conventional Column flotation	**200**	2.0	283.43	9.0	**73.7**
Novel Column flotation	**317**	1.75	287.98	9.0	**79.4**

The effect of particle size using the novel column can be summarized as follows:

The conventional column floated only 0.9 wt% of +18 mesh particles with 5.2% ash. Whereas the novel approach produced 2.2 wt% of +18 mesh particles having 6.9% ash. Similarly, for 18x30 mesh particles conventional and novel column flotation produced product yield of 4.6% with 6% ash and 8.3% yield with 6.6% ash, respectively. Similarly for other size fractions (30x100 and -100 mesh) the novel approach provides higher product yield.

Test of Further Modification

Another set of tests investigated the impact of parameter Y. Figure 10 shows the experimental data. Results of the study showed that changing parameter Y can reduce the product ash but at the cost of decreased product yield.

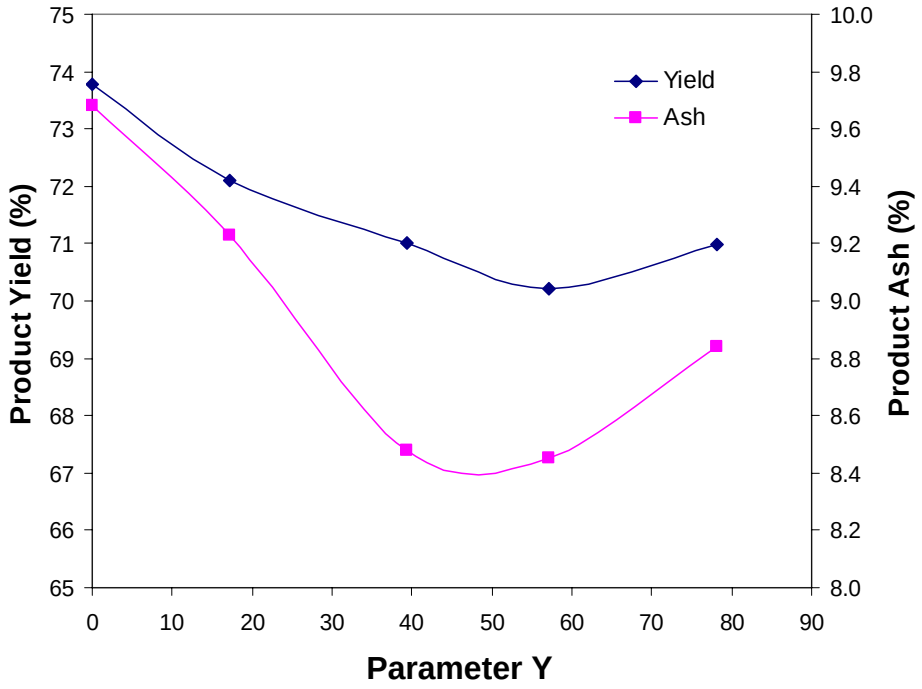

Figure 10. Effect of Parameter Y on clean coal product yield and ash.

Conclusions

- The hybrid dewatering system, consist of using vacuum and pressure in two stages, showed a marginal improvement (~2%)in dewatering of fine coal slurries tested in this project.

- The hybrid filtration system provided filter cake moisture below 17%.

- Carbon dioxide gas conditioning of coal slurry improved dewatering by reducing filter cake moisture from 28.7% to 23.0% using vacuum technology.

- The novel column provided a higher product yield of 79.4% compared to conventional column flotation yield of 73.4% at about 9% product ash.

- The optimized experimental data show that the novel approach was able to handle a higher feed rate of 317 ml/min as compared to 200 ml/min feed rate of conventional flotation column, an increase of about 60 percent feed rate, while still providing similar product ash.

- It was observed that the novel approach also improved recovery of coarse (+ 18 mesh) coal particles from 0.9 weight percent to 2.2 weight percent compared to the conventional way of operating the column. Similarly, recovery of 18x 30 mesh particles improved from 4.6 weight percent to 8.3 weight percent at the same ash level.

- Another variation of the novel approach slightly reduced the product ash, and product yield. At one condition, the product yield was about 71% with 8.48% ash as compared to 74% yield with 9.68% ash obtained conventionally.

Acknowledgment

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