Technical Progress Report
Tenth Quarter
(July 1, 1998 - September 30, 1998)

AN ADVANCED CONTROL SYSTEM FOR FINE COAL FLOTATION

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Contract Number
DE-AC22-95PC95150 -10

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October 25, 1998

“US/DOE patent clearance is not required prior to the publication of this document.”

ABSTRACT

A model-based flotation control scheme is being implemented to achieve optimal performance in the handling and treatment of fine coal. The control scheme monitors flotation performance through on-line analysis of tailings ash content. Then, based on an on-line estimate of incremental ash, the pulp level is adjusted using a model-based control algorithm to compensate for feed variations and other process disturbances. Recent developments in sensor technology are being applied for on-line determination of slurry ash content.

During the tenth quarter of this project, Task 6 (Equipment Procurement and Installation) was completed through the efforts of J.A. Herbst and Associates, Virginia Tech, Pittston Coal Company, and FGR Automation. As a result of this work, a model-based control system is now in place which can predict incremental ash based on tailings ash content and general plant data, and adjust pulp level accordingly to maintain a target incremental ash. Testing of this control system is expected to be carried out during the next quarter, and the results of this testing will be reported in the Eleventh Quarterly report.

In addition, calibration of the video-based ash analyzer was continued and an extensive set of calibration data were obtained showing that the plant is running remarkably well under manual control. This may be a result of increased attention being paid to froth flotation as a result of this project.

TABLE OF CONTENTS

	page
ABSTRACT	ii
TABLE OF CONTENTS	iii
LIST OF ILLUSTRATIONS, TABLES AND FIGURES	iv
EXECUTIVE SUMMARY	v
INTRODUCTION	1
TECHNICAL DISCUSSION	2
Task 1 - Project Planning	2
Task 2 - Sampling and Data Analysis	2
Task 3 - Model Building and Computer Simulation	2
Task 4 - Sensor Testing	2
Subtask 4.1 - Calibration Testing	2
Subtask 4.2 - Design and Fabrication	3
Task 5 - Sample Analysis and Characterization	3
Task 6 - Equipment Procurement and Installation	3
Task 7 - Operation and Testing	5
Task 8 - System Evaluation	5
Task 9 - Decommissioning	5
Task 10 - Final Report	6
SUMMARY STATUS AND FUTURE WORK	6
REFERENCES	6

LIST OF ILLUSTRATIONS, TABLES AND FIGURES

	page
Figure 1. Calibration plot for the video-based ash analyzer showing data points obtained from April through September, 1998.	3
Figure 2. Flow diagram showing control logic for the Moss No. 3 flotation circuit.	4

EXECUTIVE SUMMARY

Over the past thirty years, process control has spread from the chemical industry into the fields of mineral and coal processing. Today, process control computers, combined with improved instrumentation, are capable of effective control in many modern flotation circuits. Unfortunately, the classical methods used in most control strategies have severe limitations when used in froth flotation. For example, the nonlinear nature of the flotation process can cause single-input, single-output lines to battle each other in attempts to achieve a given objective. Other problems experienced in classical control schemes include noisy signals from sensors and the inability to measure certain process variables. Factors related to ore type or water chemistry, such as liberation, froth stability, and floatability, are often difficult or impossible to measure.

The purpose of this project is to demonstrate an advanced control system for fine coal flotation. The demonstration is being carried out at an existing coal preparation plant by a team consisting of Virginia Polytechnic Institute and State University (VPI&SU) as the prime contractor and J.A. Herbst and Associates as a subcontractor. The objectives of this work are: 1) to identify through sampling, analysis, and simulation those variables which can be manipulated to maintain grades, recoveries, and throughput rates at levels set by management; 2) to develop and implement a model-based control strategy that continuously adjusts those variables to maximize revenue subject to various metallurgical, economic, and environmental constraints; and 3) to employ a video-based analyzer for on-line analysis of ash content in fine coal slurries.

Previously, the steady-state and dynamic performance of the flotation bank at the test site (Pittston's Moss No. 3 plant), were characterized as part of Task 2 - Sampling and Data Analysis, and the results of this sampling campaign were reported in the Seventh and Eighth Quarterly Technical Progress Reports. The data collected from Task 2 were then used to

construct a population balance model of the flotation bank at the Moss No. 3 plant (Task 3.1). The details of this work were described in the Eighth Quarterly Technical Progress Report. Finally, the population balance model was coded into a flotation circuit simulator which was then used to evaluate control strategies. A control strategy based on maintaining a constant incremental ash in the last cell was deemed most appropriate as discussed in the Ninth Quarterly Technical Progress Report.

During the past quarter, control system installation was completed at the Moss No. 3 test site. This work included the physical interfacing of the PC-based control computer to the video-based ash analyzer, as well as the interfacing of the control computer to the Modicon plant controller. It also included interfacing of the entire system to the pulp level sensor and dart valve controller.

At the same time, calibration of the video-based ash analyzer continued so that an extensive calibration data base could be obtained. Calibration data collected over the past six months indicate that the flotation tailings ash is consistently in excess of 80%. This is quite remarkable and may indicate that this project is causing plant personnel to take an increased interest in the flotation section. This often presents a problem when control systems are being installed and comparisons with manual control are being made.

At present, it appears that the project is roughly three months behind schedule, but it is expected that some of this lost time can be recovered once control system testing begins during the month of October.

INTRODUCTION

Over the past thirty years, process control has spread from the chemical industry into the fields of mineral and coal processing. Today, process control computers, combined with improved instrumentation for monitoring process parameters and performance, have demonstrated improved control in many modern flotation plants. Unfortunately, the classical methods used in most control strategies have severe limitations when it comes to control of froth flotation. The nonlinear nature of the flotation process, for example, can cause single-input, single-output control lines to battle each other in attempts to achieve a specific control objective. Other problems experienced in classical control schemes include noisy signals from measuring devices and the inability to measure certain process variables. Furthermore, factors related to ore type or process water chemistry, such as liberation characteristics, froth stability, and floatability, cannot be measured by conventional means.

The purpose of this project is to demonstrate an advanced control system for fine coal flotation at an operating coal preparation plant. The objectives of this work are: 1) to identify through sampling, analysis, and simulation those variables which can be manipulated in the plant to maintain grades, recoveries, and throughput rates at levels set by management; 2) to develop and implement a model-based computer control strategy that continuously adjusts those variables to maximize revenue subject to various metallurgical, economic, and environmental constraints; and 3) to employ a video-based optical analyzer for on-line analysis of ash content in fine coal slurries. The following is a summary of work completed during the tenth quarter of this project.

TECHNICAL DISCUSSION

Task 1 - Project Planning

Project planning during the past quarter focused primarily on coordinating the efforts of Virginia Tech, J.A. Herbst and Associates, Pittston Coal Company, and FGR Automation in completing Task 6 (Equipment Procurement and Installation). In addition, direction was provided to the continued work on calibrating the video-based ash analyzer (Task 4).

Task 2 - Sampling and Data Analysis

This task has now been completed.

Task 3 - Model Building and Computer Simulation

This task has now been completed.

Task 4 - Sensor Testing

Subtask 4.1 - Calibration Testing: Calibration of the video-based ash analyzer continued during the past quarter. As a result of this on-going calibration work, nearly 50 calibration points have been obtained over the past six months yielding the calibration curve shown in Figure 1. As shown, a linear trend exists between slurry ash content and mean gray level. Based on the scatter in the data, it appears that tailings ash content can be predicted within $\pm 2.5\%$ ash. This is in-line with previous data collected during the development of the sensor (Dunn et al., 1998). Perhaps of more interest, however, is the fact that only two of data points collected during this period fell below 80% ash. This amounts to less than 5% of all the samples collected. It is a known fact that the installation of a control system and the constant monitoring of a process during this installation period often leads to increased attention to the process by plant personnel. It is possible that the remarkable performance of the Moss No. 3 flotation section during the

past six months may be attributed to increased attention by plant personnel. This factor may create a bias when comparisons are made between manual control and automatic control during the coming quarter.

Figure 1. Calibration plot for the video-based ash analyzer showing data points obtained from April through September, 1998.

Subtask 4.2 - Design and Fabrication: This subtask is essentially complete barring any changes suggested by continued calibration testing at the Moss No. 3 site.

Task 5 - Sample Analysis and Characterization

Sample analysis is continuing as samples are collected under Tasks 4 and 6. All sample analysis and characterization work is on schedule.

Task 6 - Equipment Procurement and Installation

Installation of the model-based flotation control system was completed during the past quarter. This work involved the physical interfacing of the control computer to (i) the ash analyzer, (ii) the Modicon plant controller and (iii) the level sensor and dart valve. In addition,

the flotation model was installed, along with the Kalman filter and expert system rules. The basic control strategy being employed is illustrated in the flow diagram shown in Figure 2.

Figure 2. Flow diagram showing control logic for the Moss No. 3 flotation circuit.

As shown, the expert system first checks the various plant inputs from the Modicon controller to determine if an emergency condition has occurred. An emergency condition could include such things as no flotation feed, flotation machines down, reagent pumps down, and any other circuit or plant malfunction. The system then takes a reading from the ash analyzer and determines if this reading is within specifications based on an estimated incremental ash. If the ash reading is not within specifications, the control system calculates the coal floatability to determine if the floatability has changed. If the floatability has changed, the system then calculates a new pulp level set point and determines if this new set point is in an allowable range. This step is necessary because Pittston has limits on downstream filtration capacity, and a pulp level set point change may not be possible if the filtration circuit is already at capacity. If a pulp level set point change is permitted, a signal is then set to the dart valve controller to make the appropriate change.

The flotation control system is now in place at Moss No. 3; however, the system has not yet been tested due to difficulties that arose in interfacing the flotation control computer to the Modicon plant controller. In September, FGR Automation of Pittsburgh, Pennsylvania, was hired to complete the interfacing to the Modicon. This work has now been completed, and testing of the control logic should begin in October.

Task 7 - Operation and Testing

Due to delays in completing Task 6, this task will likely be delayed until October, 1998.

Task 8 - System Evaluation

Due to delays in completing Task 6, this task will likely be delayed until October, 1998.

Task 9 - Decommissioning

This task is scheduled to begin in January, 1999.

Task 10 - Final Report

This task is scheduled to begin in February, 1999.

SUMMARY STATUS AND FUTURE WORK

Major accomplishments during the past quarter were the completion of Task 6 (Equipment Procurement and Installation) and the continued calibration of the video-based ash analyzer. As a result of this work, the following conclusions can be drawn:

1. A calibration curve for the video-based ash analyzer has been established showing an excellent correlation between mean gray value and percent ash. The sensor appears to be able to predict tailings ash content within approximately $\pm 2.5\%$ ash. The flotation circuit has been operating extremely well over the past six months with less than 5% of the calibration points obtained falling below 80% ash. The excellent manual operation of the flotation circuit may make significant improvements with automatic control difficult to quantify.
2. Installation of the model-based control system has been completed including the interfacing of the flotation control computer to the ash analyzer, the Modicon plant controller, and the level sensor and dart valve. The system is now ready to be tested over the next quarter.

Work is progressing well, and it appears that the delay caused by switching test sites has only set the project back by three months. It now appears that the operation and testing of the control system (Task 7) will be carried out from October through December. This should make it possible to bring the project back on schedule and complete all work within the original time frame.

REFERENCES

Dunn, P.L., Cruz, E.B., Luttrell, G.H., and Adel, G.T., 1998, "Development of a Video-Based Coal Slurry Ash Analyzer", Minerals and Metallurgical Processing, Volume 15, No. 2, pp. 1-10.