Effective Conveyor Belt Inspection for Improved Mining Productivity

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Abstract

This document details progress on the project entitled “Effective Conveyor Belt Inspection for Improved Mining Productivity” during the period from May 15, 2004 to November 14, 2004. Highlights include installation of belt imaging equipment in coal mines, testing of alternate lighting technologies, and fabrication of above-ground test equipment.

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1 Introduction

This report presents technical progress on the Effective Conveyor Belt Inspection for Improved Mining Productivity project, funded under U.S. Department of Energy award number DE-FC26-04NT42086.

The project proposal describes the first-year objective as follows:

Phase I (Year 1) Objective

Expand the capability of the belt inspection system to detect vulcanized splices. The Phase I objective will be to identify and test sensors capable of surviving the mining environment and the detection hardware to precisely locate the sensor. In addition, we will develop a prototype version of the image capture and lighting hardware that will form the heart of the low cost automated belt inspection system.

The following sections describe progress toward this objective.

2 Executive Summary

This 6-month period includes several noteworthy achievements, which are summarized here. More detailed discussion of these accomplishments is presented in sections 3, 4, 5, and 6.

First patent application review completed The US Patent and Trademark Office has completed its first review of Belt Inspection System patent. Most claims have been approved, and the review is mostly positive.

Belt imaging equipment installed Prototype BeltVision systems have been installed in several CONSOL mines, and are available for image acquisition and testing.

Full-resolution belt image recording completed A full resolution belt recording has been acquired at CONSOL's Blacksville mine and brought to the surface for detailed analysis.

Additional full-resolution belt image recordings underway Full-resolution belt recordings are being acquired at several other CONSOL mines in order to provide a rich dataset for testing and further development. These recordings will allow us to assess the extent of belt-to-belt variation, and the impact of this variation on our detection algorithms.

Fabrication of test conveyor in process A test conveyor is being constructed to allow above-ground testing of belt-inspection hardware and algorithms.

Testing of alternate fluorescent light technologies completed Testing has been conducted to assess the viability of alternate fluorescent light technologies, including fluorescent aperture lights and fixtures of multiple 96 Watt compact fluorescent lights. The ultimate goal is to maximize lighting of the belt and improve image quality in preparation for vulcanized splice detection efforts.

Initiated software development for belt viewer (VCR) A GUI application is being developed to allow belt foremen and other users to interact with the BeltVision system. The completed application will include present detected splices via a computer screen and allow VCR-like playback so that the user can move from splice to splice and evaluate splice condition.

First version of low cost belt inspection system fabricated and tested A reduced cost BeltVision assembly has been fabricated and tested, with good results.

Sale and installation of one belt inspection system to BHP San Juan. The first commercial sale of the system has been completed, and a working prototype has been installed at the customer mine.

3 Experimental Apparatus

The majority of proposed effort towards experimental effort falls under Task 4 of the proposal document. We describe the relevant portions of Task 4 here, along with statements of technical progress, which are **bolded** and inset for easy reference.

Task 4.1 Upgrade NREC Prototype System Computing Capability The current imaging system prototype at the NREC will be upgraded to support the objectives described in this document. The NREC will make the needed upgrades and repairs.

In order to reduce costs and allow preliminary marketing, a low-cost prototype of the BeltVision system has been designed, and prototype fabrication is underway. The low-cost prototype uses inexpensive off-the-shelf computing hardware and a redesigned fluorescent lightbar. Figure 1 shows these components, along with the protective enclosure for the computing subsystem. As with the current BeltVision system, a touchscreen user interface is provided for convenient user interaction.

Task 4.3 Design and Fabricate Bench top Mechanical Splice Simulator

The Beitzel Corporation will design and fabricate a bench top mechanical splice simulator for use in developing the low cost vision system.

To facilitate development and testing of BeltVision hardware, an above-ground test rig is under construction at Beitzel Corporation, as shown in figure 2. This test rig includes drives and rollers to operate a short (16 m) length of conveyor belt, as well as fixtures for attaching cameras, lighting units, and other test hardware.

Task 4.4 Assemble lab prototype of Low Cost Belt Vision System Cameras, lenses, and digitizers, as needed, will be assembled for the development and testing of imaging for low cost vision system. The NREC and CONSOL Energy will be responsible for this task

(a)

(b)

Figure 1: A reduced cost BeltVision prototype has been designed in order to facilitate testing, marketing, and deployment. The new design is highly modular, permitting easy replacement of parts. Subfigure (a) shows inexpensive, off-the-shelf computing hardware in a protective enclosure, and subfigure (b) shows the fluorescent lightbar assembly.

Figure 2: Fabrication of an above-ground test rig is underway at Beitzel Corp.

NREC and CONSOL Energy performed careful evaluation of several fluorescent lighting technologies in an attempt to improve image quality and system reliability while reducing maintenance costs. Fluorescent aperture lights have been tested, as have fixtures holding multiple high-power (96 W) compact fluorescent bulbs. Testing of additional lighting options will continue in the coming months.

4 Experimental and Operating Data

Feasibility studies and experimental data are addressed in Tasks 1 and 2 of the proposal document. We describe the relevant portions of Tasks 1 and 2 here, along with statements of technical progress, which are **bolded** and inset for easy reference.

Task 1.1 Determine Defect Detection Requirements at Hard rock Mines A number of the major hard rock mining companies will be contacted and then the corporate engineering offices will be visited to determine defect and rip detection requirements and to arrange site visits for data collection. The Beitzel Corporation will be responsible for this task.

A number of visits to hard rock mines have been made by Beitzel. Rip detection has been identified as one of the major defects that causes belt downtime and very expensive maintenance.

Task 1.3 Evaluate the feasibility of using Structured Light for Rip Detection in Coal Mines Visits will be made to coal mines to survey belt coordinators and view slope belt structure to determine the feasibility of using structured light for rip detection. CONSOL and the Beitzel Corporation will be responsible for this task.

Two mines have been examined. To use structured light for rip detection imposes some challenging, perhaps insurmountable problems. At the slope belt tail the cameras would have to look up, which poses technical challenges due to rock-dust accumulation and lens fouling. Furthermore, two cameras would be required because of lack of clearance (nominally 2 feet).

Task 2.1 Fabricate Mechanical Splice Inspection Systems and Install In this task CONSOL Energy will fabricate several of the existing belt inspection systems and install the systems on problematic belts. In addition to providing coverage of mechanical splice defects, these systems will be made available to NREC personnel for full resolution image data collection and future testing of enhanced functionality. CONSOL Energy will have main responsibility for this task.

Two data collection units have been fabricated and installed at CONSOL mines, and full resolution images have been collected from the Blacksville mine. The data has been transferred to NREC for use in software algorithm development and verification. Figure 3 is a photo of the Blacksville mine installation in operation.

Figure 3: A photo of the Blacksville BeltVision unit in operation.

Task 2.2 Design and Fabricate a Portable Belt Inspection System Beitzel will design and fabricate a lightweight and portable Belt Inspection System based on the existing belt Inspection System design. The Portable Belt Inspection System will be made available to NREC personnel for data collection on various processing plant and hard rock mining conveyor belts. Beitzel will lead this task.

This effort corresponds to the redesigned system described under Task 4.1 in section 3. The highly modular nature of the redesigned system, along with the reduced weight of the computing components, makes the system easily portable. The primary limiting factor to portability is the length of the lightbars, which will be more easily transported in a minivan than in a sedan.

5 Data Reduction

Data reduction and image processing are addressed in Task 3 of the proposal document. We describe the relevant portions of Task 3 here, along with statements of technical progress, which are **bolded** and inset for easy reference.

Task 3.1 Develop Software for Full Resolution Recording of Belt CONSOL Energy will develop PC based software for full resolution recording of the belt for the purpose of collecting data to be used in the development of defect/vulcanized splice detection software.

CONSOL Energy has developed and deployed full resolution recording capability on the data collection units. A full resolution recording has been gathered at CONSOL’s Blacksville coal mine and transferred to NREC for use in algorithm development and testing.

Task 3.2 Develop Software to Filter the Full Resolution Image NREC and CONSOL personnel will use the data collected at the CONSOL Energy mines and at hard rock mines to develop software to identify “interesting features” located on the belt surface. The algorithm will reduce the size of the data set that will be processed by future algorithms to eliminate false positives and classify the features. CONSOL Energy will have primary responsibility for this task.

A simple algorithm for filtering full resolution images into a subset containing “interesting features” has been developed. The algorithm is based on size of the stored image and can significantly reduce the data set for future defect detection algorithms.

Task 3.3 Enhance the Data Player Capabilities to Provide a VCR like Interface. CONSOL personnel will modify the data player software and create a user interface that acts like a VCR (i.e. play, stop, pause, fast-forward and rewind). The enhanced data player will provide useful capabilities for an operator who can either review the reduced belt image sets or the full-length belt image. Both are useful features for managers responsible for maintaining mine belts. CONSOL will have main responsibility for this task.

CONSOL has developed VCR-like software to permit display and review of the acquired belt images. This software was developed with input from potential users, and is slated for deployment at CONSOL mines in conjunction with future installations of the BeltVision system.

6 Hypothesis and Conclusions

At this early stage in the work, we have only preliminary conclusions. Both below-ground performance of the installed unit and above-ground processing of the full-resolution belt images indicate excellent performance on mechanical splice detection. Visual inspection of recovered full-resolution images suggests that vulcanized splice detection will be challenging, however no concrete conclusions have been drawn.