

of the process. It is concluded that the overall flow field in this particular kiln is not significantly affected by the heat release and gas volume expansion due to the flame. The flow field, however, affects the combustion process by controlling the mixing rates of fuel and air and governing the flame propagation. The pellet quality depends strongly on the temperature and gas profile. A sound knowledge of the kiln aerodynamics and the resulting flow field is therefore necessary in order to optimize the combustion process to maxi-

mize the quality of the iron ore pellets produced. To better model the real process, more advanced submodels for both the combustion and especially the flow field are needed. The choice of turbulence model is of utmost importance to accurately describe the complex flow field in this type of iron ore pelletizing rotary kiln. ■

References

A list of all references is available in the full paper.

Assessing longwall gateroad ground response and support alternatives

Gabriel S. Esterhuizen^{1,*}, Ted Klemetti¹, Morgan M. Sears¹, Peter Zhang¹, Mark van Dyke¹, Heather Dougherty¹ and I. Berk Tulu²

¹National Institute for Occupational Safety and Health, Pittsburgh, PA, USA

²West Virginia University, Morgantown, WV, USA

*Corresponding author email: eee5@cdc.gov

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Keywords: Longwall, Ground control, Gateroad, Support design, Monitoring, Numerical modeling

To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Ground falls in longwall gateroad entries remain a concern in modern longwall operations. The gateroads are subject to changing horizontal and vertical ground stress induced by longwall extraction. These stress changes can result in failure of the strata around an entry leading to large deformations of the entry roof, floor and ribs. The gateroad support systems are required to control the failed strata while maintaining safe access to the longwall face and unimpeded ventilation. This paper presents research conducted to better understand the stability issues in gateroad excavations and to develop procedures for evaluating support and layout alternatives for longwall gateroads. Using the results of a field-monitoring program and numerical model analysis of case histories, a conceptual model of gateroad support needs was developed. The conceptual model formed the basis for developing a set of equations that can be used to estimate likely roof sag and support loading for given roof geology and longwall-induced loading conditions. The developed equations were used to compare predicted gateroad stability to field study results, showing satisfactory agreement. The calculation procedures are used to demonstrate their application in assessing support alternatives at a case study mine. It is concluded that the developed analysis procedures provide realistic assessments of likely ground stability and can be used to evaluate alternative gateroad support systems at operating longwall mines.

Background

Ground falls in underground coal mines in the United States accounted for 12.9 percent of reported lost-time injuries and 29.7 percent of fatalities during the five-year pe-

riod of 2015 to 2019. Achieving adequate ground control in longwall gateroad entries is especially challenging because these excavations are subject to changing loads induced by longwall extraction that can result in large deformation of the roof, ribs and floor strata. In addition, the geologic composition of the roof can vary considerably along the length of a gateroad, resulting in variable ground response and support requirements. Designing appropriate support for the variable geologic conditions and loading conditions typically encountered in a longwall gateroad is challenging because of the large number of parameters that affect the stability of the excavation. This paper describes the development of gateroad support design procedures that allow designers to simultaneously assess many of the important parameters that affect gateroad stability.

Methods

The research in this study was conducted through a combined program of data collection on current gateroad support practices, full-scale testing of gateroad support systems at the National Institute for Occupational Safety and Health (NIOSH) Mine Roof Simulator; monitoring of longwall-induced ground deformation, stress changes and support response at longwall operations in the United States; analysis of the results; and development of numerical modeling procedures that allow expected support performance and ground response to be evaluated. The developed numerical models were used to conduct parametric studies in which the important factors affecting entry stability under changing stress were evaluated. The understanding of gateroad stabil-

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ity derived from the results formed the basis of a conceptual model of support requirements in longwall gateroads. Using the conceptual model as a basis, the relationships between important input parameters for gateroad stability were derived through regression analysis of the results of the parametric studies. The derived relationships can be used by support designers to assess support alternatives for local geologic conditions and longwall-induced loads.

Results

Field monitoring. The field monitoring program was initiated in 2015 in which data were collected at operating longwall mines in Pennsylvania, West Virginia, Virginia, Wyoming and Utah. The mines were operating in the Pittsburgh, Lower Kittanning, Sunnyside, Pocahontas No. 3, and D41 coal beds. Monitoring was initiated during the development stage and recorded the effects of longwall extraction on both sides of the gateroad. The monitoring studies demonstrated that the roof of gateroad entries is essentially stationary after development and before the impact of the approaching longwall face becomes evident. As the first longwall panel approaches and passes by the monitoring in-

struments, roof deformations are typically less than 35 mm. The roof sag increases up to about 100 mm at the tailgate corner as the second longwall mines up to the instruments. These deformations are small relative to the yield capacity of standing supports but may approach or exceed the yield limit of cable bolts. Data from monitoring in poor ground conditions were obtained in which roof deformations in excess of 150 mm were recorded in a headgate entry. Cable bolt monitoring demonstrated that the load in 3.6-m-long cable bolts increased to the yield capacity after about 75 to 100 mm of roof deformation and shed load as the roof sag exceeded 100 mm. Standing support loading at one site successfully demonstrated how the load on timber cribs rapidly increased as the cable bolts started shedding load (Fig. 1).

Numerical models. The numerical modeling studies demonstrated that realistic estimates of expected ground deformation and support response in gateroads subject to longwall-induced loads can be achieved when the models include sufficient detail of the local roof geology, bedding planes, and bolting and standing support characteristics. The FLAC3D finite difference software was used in the analyses using strain softening strata response and the built-in structural elements to model the support systems. Figure 2 presents an entry-scale model showing various types of strata failure and associated roof deformation around an entry that is subject to longwall-induced loading. Insights from the field monitoring studies and numerical models were used to develop a conceptual model of gateroad roof stability.

Parametric studies were conducted using numerical models to identify factors that had the greatest impact on roof stability under changing stress. Using the modeling results, regression equations were developed for estimating the roof sag and the height of potentially detached roof strata for gateroad entries under various combinations of geology, loading, and support systems. The roof sag and height of potentially detached roof form the basis for assessing the effectiveness of support systems when gateroads are subject to longwall-induced loading.

Case study. A case study is presented in which changes in the local geology resulted in unstable headgate conditions at a longwall operation in the Pittsburgh coal bed. Information on the geologic parameters, support systems and longwall loading conditions were gathered and evaluated using the procedures developed during this research. The results demonstrated that the standard headgate support system would be inadequate to control the roof in the unfavorable local geology, while the remedial support would adequately control the roof, as experienced in practice.

Conclusion

It is concluded that the developed analysis procedures provide realistic assessments of likely ground stability in longwall gateroads and can be used to assist in the evaluation of alternative support systems. ■

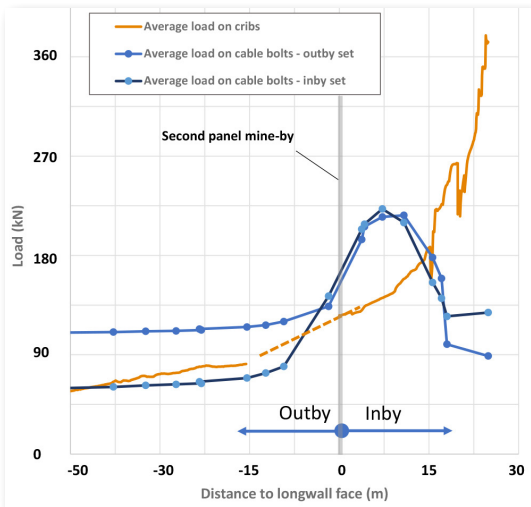


Fig. 1 Average response of crib standing supports and two sets of cable bolts against the distance of the monitoring site to the advancing longwall face.

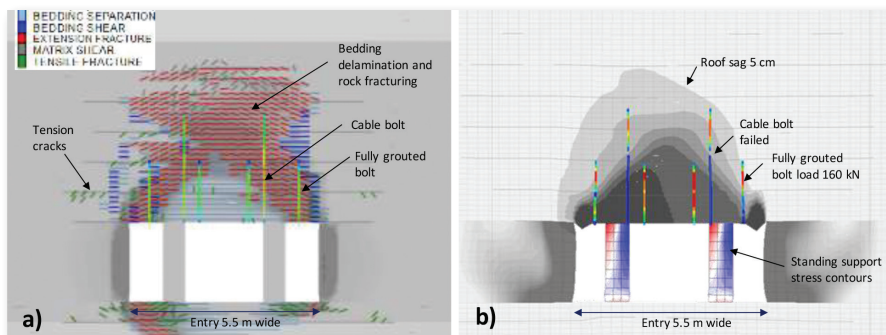


Fig. 2 Example of FLAC3D numerical model results of entry and support response to longwall-induced loading, showing: (a) rock failure modes and (b) roof deformation and support response.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Men-

tion of any company or product does not constitute endorsement by NIOSH.

References

A list of all references is available in the full paper.

Characterization and evaluation of recycling potential for discarded laptops

Shaila Mir and Nikhil Dhawan*

Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Roorkee, Uttarakhand, India

*Corresponding author email: nikhil.dhawan@mt.iitr.ac.in

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Consumer preference for ever-higher laptop performance coupled with laptops' declining lifespans make them a significant contributor to electronic waste. An in-depth evaluation of elemental composition and distribution is important for determining metal recovery potential and sustainable recovery processes. In this work, the characterization of individual components of laptops is studied for the systematic identification of important elements and for streamlined and structured recycling, to reduce processing steps and improve economics. A process flowsheet highlighting various recycling routes by targeting metals and various components is also proposed.

Background

Electronic waste is a rapidly growing waste stream that poses an alarming concern due to its volume and potential for exposure to hazardous contaminants. Laptops contain a spectrum of metals considered scarce due to economic, social, geochemical and geopolitical constraints [1], and they are becoming smaller and more compact due to miniaturization, which results in a concentration of valuable resources.

Characterization of the constituents of laptops is essential for determining the disassembly process to facilitate the separation of materials. The appropriate peeling, separation and sorting of integrated circuit chips, capacitors, connectors and processor units from printed circuit boards (PCBs) can offer an intermediate step in recycling. The current study determines the potential of recycling and the economic importance of different metals recoverable from a discarded laptop through market-value calculation.

Materials and methods

Twenty discarded laptops procured from the institute's computational facility were manually dismantled and broadly classified into casing, display unit, PCB, hard disk drive

(HDD) and lithium-ion battery (LIB). The electronic components mounted on the PCBs were separated by desoldering, classification and crushing. The bare PCBs were reduced using a band saw cutter and an impact hammer mill. The HDDs were dismantled manually into their components, and the HDD magnets were demagnetized at 350 °C for 1 hour and pulverized to particle size smaller than 100 µm. The LIBs, each comprising six cells, were dismantled, discharged, grounded using an attritor mill, and sieved to separate the active material (particle size smaller than 53 µm) from the current collectors, plastic and steel casings (particle size larger than 53 µm).

Table 1 – Metallic contents in the electronic components of a PCB, analyzed by ICP-MS.

	Component (ppm)					
	Ag	Au	Fe	Ta	Cu	Al
Capacitor						
Aluminum	–	–	–	–	5,700	350,000
Tantalum	180	–	10	420,000	220	1,320
Ceramic	90	50	50	–	410,000	2,250
Resistor						
Metallic	54	12	–	–	2,400	1,740
Ceramic	3.6	3,600	–	–	58,000	240
Integrated circuits						
Large	5,400	2,520	1,890	–	120,000	20
Small	2,450	75	–	–	325,000	920
Processor	55	517	–	–	500,000	–
Connectors	16	700	–	–	770,000	8,800

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