Electromagnetic interference (EMI) in underground coal mines: A literature review and practical considerations

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Special Extended Abstract

This paper is aimed at helping the mining industry to better understand the challenges posed by electromagnetic interference (EMI) and to promote electromagnetic compatibility (EMC) in underground coal mines. The paper begins with a review of EMI standards in other industries, then presents some representative examples of EMI instances that have occurred in the mining industry, followed by a literature review of published EMI research in mining and, finally, a discussion on mitigation strategies and practical considerations related to EMI in mining.

Introduction

Modern smart mining increasingly depends on the use of sophisticated electrical and electronic systems for improved safety and better productivity. With more electronic systems being introduced underground, the mining industry is facing electromagnetic compatibility (EMC) issues caused by electromagnetic energy emitted by one device adversely impacting the normal function of another.

As shown in the EMI triangle model in Fig. 1, an EMI instance is usually associated with three key components: a source, a victim, and coupling/propagation paths from the source to the victim. All three elements in underground mining environments are unique as compared to those elements in other environments, and thus, the EMI in underground mining deserves a special consideration.

EMI instances, scope and standards

Historically, there have been a variety of EMI instances reported in underground coal mines. One of the most recent notable EMI instances is that the magnetic fields emitted from a personal dust monitor interfere with the normal operation of a proximity detection system. More examples can be found in the full paper.

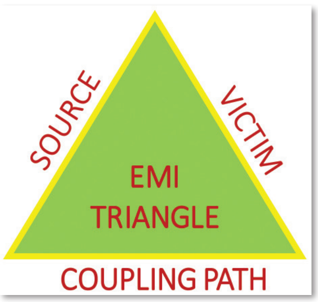

Fig. 1 An EMI triangle model to illustrate the three key elements for an EMI instance to occur.

EMI standards have been formulated to ensure that electronic devices and systems are able to tolerate a specified degree of interference and not generate more than a specified amount of interference. As a result, the scope of EMI typically includes two broad categories: susceptibility and emissions. The susceptibility category includes characterizing a victim's susceptibility to conducted emissions, radiated emissions, lightning and electrostatic discharge (ESD), and comparing them to the corresponding given regulatory limits. The emissions category then covers characterizing and regulating conducted and radiated emissions from a device across the spectrum.

Currently, a standard or set of requirements for dealing with EMI specifically in mining does not exist. However, numerous organizations have attempted to resolve EMI issues by developing standards for emissions and susceptibility testing in other industries. For example, in the United States, the U.S. military created the standard MIL-STD-461 to control the EMI issues in subsystems and equipment used in military environments. A review of EMI standards developed in other industries that may be applicable to mining can be found in Girman et al. [1].

Published research, mitigation strategies and practical considerations

Although it has been extensively investigated in many other industries, EMI in the mining industry has received much less attention, and the corresponding published research pertaining to EMI in mining is relatively scarce. Some major research efforts conducted by different institutions in the world are reviewed in the full paper.

Generally, EMI effects can be mitigated by attacking one or more of the three elements shown in Fig. 1. Particularly, EMI mitigation can be achieved by (1) suppressing the emission at its source, (2) making the coupling path less efficient, and (3) making the victim more robust to the emission. Typical EMI mitigation strategies include shielding, grounding, filtering and distancing, which are discussed in detail in the full paper.

Mineworkers should consider the EMI triangle — that is, source, victim and path — when examining a suspected EMI incident and stay alert when operating electronic devices in the vicinity of EMI sources. Some practical examples of potential EMI sources in an underground coal mine are wireless communication and tracking systems, such as handheld radios; electronic systems, such as personal dust monitors, called PDMs; power centers; variable-frequency-drive systems; electric motors; and lightning, whose effects can penetrate the earth overburden and reach areas inside a mine.

In addition to the mitigation strategies discussed above, EMI effects and associated safety concerns can be ultimately reduced by developing and applying EMI standards across the mining industry. The formulations of EMI standards often are related to the equipment and operational environments in a specific industry. As such, different EMI standards are formulated for different industries. Compared to other industries, the mining industry has some unique characteristics in terms of its geological and EM environments that one must consider when developing a mining-specific EMI standard.

Conclusions

An overview of EMI in underground coal mines is presented, and the impacts and practical solutions of EMI that can affect the health and safety of mineworkers are investigated. Some key issues and practical considerations pertaining to EMI in mining are highlighted. It is concluded that similar to EMI standards that were developed in many other industries decades ago, ultimately mining-specific EMI standards may need to be promoted to overcome the increasing EMI issues in underground mining. ■

Selected reference

1. Girman M, Reyes M, Zhou C (2022) An overview of existing EMI standards applicable to mining. Mining Metall Explor 39(1):77–88

Trace-element content and partition in apatite-group minerals in phosphate ore from Catalão, Brazil

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Special Extended Abstract

Three types of apatite were identified by means of cathodoluminescence (CL) images in flotation concentrate and tailing samples from the Catalão Mine in Brazil. They are predominantly blue apatite, followed by green apatite and, less frequently, yellow apatite. The chemical compositions of these types of apatite were determined by electron microprobe analysis and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Blue and green apatite responded well to the process, thus remaining in the concentrate, while yellow apatite remained in the tailings. Yellow apatite has the lowest phosphorus pentoxide (P_2O_5) content and largest anionic and cationic sites substitution, followed by green apatite, whereas blue apatite is the most homogeneous, with highest phosphorus (P) and calcium (Ca) grades and lowest substitution level. A negative correlation of the amount of phosphorus with fluorine was observed. Furthermore, impregnation of iron oxide-hydroxides in the yellow apatite was also observed. Therefore, the low flotation behavior is due to low crystallinity coupled with impregnation onto its surface.

Background

Phosphorus is obtained from the mining of phosphate rocks — mainly, the mining of minerals belonging to the apatite group. These ores represent a limited and nonrenewable resource [1]. Apatite supergroup is a term referring to a series of hexagonal and monoclinic phosphates having the general chemical formula $^{IX}M1_4{}^{VII}M2_6(^{IV}TO_4)_6X_2$ [2]. The most common minerals of this group are the calcium phosphates, and the occupation of the X site defines terms as fluorapatite, chlorapatite or hydroxylapatite, while Ca occupies both the M1 and M2 sites. Although the predominance in the occupation of the sites defines the mineral name, its composition may be more complex.

The flotation efficiency of phosphate ores of igneous origin is influenced by the mineralogical composition of the ore that feeds the concentration process. Several studies tried to link the chemical composition of apatite to process efficiency, but usually no significant differences could be detected in the bulk sample.

In this study, based on CL analyses, we attempt to establish a correlation between the CL color and the chemi-

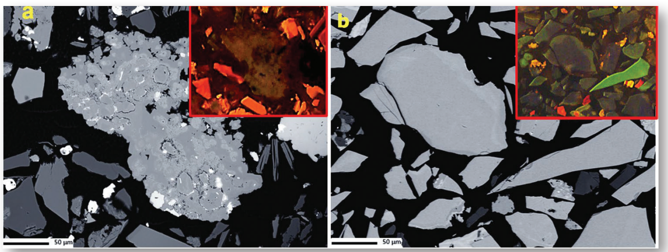

Fig. 1 BSE images of apatite from siliceous carbonate ore by electron microprobe analysis, and their respective CL images (inserts) of the different colors of the apatite: (a) extensively altered texture, typical of yellow apatite, and (b) green apatite as a rim of blue apatite and liberated green apatite. Carbonates are colored yellow/orange (calcite) and red/pink (dolomite).