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Fatal gas explosion accidents on Chinese coal mines and the characteristics of unsafe behaviors: 2000–2014

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ABSTRACT

Although the total death toll due to various accidents in China's coal mining industry has decreased in recent years, coal mine gas explosion is still occupied the main proportion of major accident and threatening miners' lives. The repeated occurrence of gas explosions, often in a similar manner and triggered by unsafe behavior, indicates that we failed to learn from the past and make inadequate changes in response. In an effort to further reduce these rates, the human factors associated with accident need to be addressed. The exact direct causation and sub-standard performance at operator level have been quantitatively identified and classified within the sample of 201 significant gas explosions in China across 2000–2014. An analysis of the data revealed that unsafe behavior existed in and had precipitated influence to all of gas explosion accidents in sample, and all unsafe behaviors can be analyzed from 3 dimensions: accident site, working craft and equipment and installation. By illuminating the unsafe behaviors and its distribution characteristics in a systematic fashion, this study has provided mine safety professionals the information necessary to reduce gas explosion further.

1. Introduction

Coal mining industry remains one of the most high-risk industries in China and bears the worst safety record in the world. One of the significant goals of mining industries is to operate in a safe manner. Safety policy for fulfilling this goal involves, among others: safety oriented devices design, relevant organization, and compliance with safety laws and regulations. Even with steady safety improvements in recent years, thousands of people yet are killed in coal mining each year, hundreds of times of the corresponding fatalities compare to the United States. The major accident categories for coal mining in China are gas explosion, coal and gas outburst, roof fall, flooding, and fire (SACMS, 2015). Among them, gas explosion constitutes a large part of the fatality list in China's coal mining (Wang et al., 2014).

Major accidents keep occurring that seems preventable and has similar causes according to the accident investigation reports, but we often fail to learn from the past and make inadequate changes in response to probability of gas explosion. Thus, the numbers of events do not eliminate and similar events seem to recur. Their repeated occurrences, often in depressingly similar manner and work site, are a clear indication of the failure of the coal mining industry and the regulatory system to heed the lessons of the past and adopt a robust approach to eliminate these sinister accidents.

There is a moral and an economic argument in support of the viewpoint that the most important property of the coal mine is the miner. It is thus unacceptable to forfeit action to improve safety in the coal mining industry and be content with its current safety track record worldwide. But how to go about devising strategies and executing on them to improve safety in the coal mining industry? Heinrich (1959) estimated that 88% of accidents can be attributed to unsafe acts. Blackmon and Gramopadhye (1995) stated that 98% of all accidents are caused by unsafe behavior. Chen et al. (2012) revealed that 97.67% of coal mine accidents are attributed to unsafe behaviors. Nishigaki et al. (1994) found that most accidents occur because of human-ware failure. Reducing accidents and improving safety performance can only be achieved by systematically focusing on those unsafe behaviors (Choudhry and Fang, 2008; Choudhry, 2012). For example, not wearing safety helmet when entering construction site, not fasten seat belt when driving, etc., are all unsafe behaviors. So, it is important for the miners to have the proper operating manner, behavioral pattern, and understanding of various hazards for dealing with accident causation. While many publications have analyzed general coal mine safety statistics or engineering (Kezhi and Courtney, 2009; Wei, 2011; Xu et al., 2014; Patterson and Shappell, 2010; Lenné

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et al., 2012), a focus on the characteristics of unsafe behaviors of gas explosion is rare (Chen et al., 2012). Engineering approaches have typically focused on designing out the possibility of accident occurrences, which does not match the rapidly changing technologies (Cooper, 1994). In this work, we mainly analyze the gas explosion accidents, acquire the unsafe behavior causations of miners for the accident and its distributions, and attempt to quantitatively identify the various unsafe behaviors affecting gas explosions. Those who know the exact cause of the accident and what to do will conduct themselves in a safe manner and can effectively prevent the accident, so our purpose is to contribute one small step in supporting mining operators improve on the current safety conditions in this industry and sustainably reduce its casualty rate.

2. Overview of coal mining safety statistics

This section provides an overview of the whole safety situation and gas explosion record of the China's coal mining industry for which the statistical data are available from the State Administration of Work Safety (SAWS) and State Administration of Coal Mine Safety (SACMS).

Fatality number tells one part of the safety record of an industry, and another important dimension of the safety record is the number of accidents associated with the industry we are studying on. Fig. 1 shows the evolution of the number of accidents and fatalities in the China's coal mining industry between 2000 and 2014. During this period, a temporary increase in the number of accidents and fatalities emerged in 2000–2002 and peaked at 2002, and then the curves display a substantial concavity. In 2014, the fatality number in coal mine accidents was 931, and the number of accidents was 509, dropped by 86.69% and 88.52% respectively when compared to 2002 which has a peak through 15 years, although it is still a high figure compared to that safety record of U.S. (Saleh and Cummings, 2011) but the figure shows a steady decreasing trend.

Since the coal production and fatalities data in the CHN coal mine exist, an index, death rate per million tons, that the Chinese government often use can be computed and their evolution between 2000 and 2014 displayed for visual assessment. Fig. 2 shows the evolutional relationship between output and death rate per million tons of China's coal mining industry. Along with the increase of the output of coal, a decreasing trend of death rate per million tons is noticeable in the figure, from 5.86 in 2000 to 0.25 in 2014. This tremendous success reflects the effect of safety modes of production and better safety supervision by chinese government to minimize the likelihood of accident occurrence, such as "improve the coal mine admittance standard", "close small-scale coal mines ", and "consolidate unqualified safety condition mines" (SACMS, 2012, 2013).

Although the total fatality involved in China's coal mining industry has decreased in recent years, by collecting the basic information of 492 cases of major accidents which lead to 10 or more people die from year 2000 to 2014, we have attracted to one pervasive and deadly failure mode in coal mines, namely gas explosion. Because there are 231 cases of major gas explosions included in the 492 cases of whole accident types. Currently, coal mine gas explosion is still a horrible monster that threatens mine workers' lives and notorious for its high casualty tolls (e.g. Yongji coal mine major gas explosion which has resulted in 10 fatalities, on Oct. 9, 2015, Jiangxi province, China) (China daily, 2015). Fig. 3 shows the comparison of fatalities of major accidents between gas explosion and other coal mine accident types from 2000 to 2014. It provides a breakdown of the fatalities by sector of accident types sector, a classification of the accident between gas explosion on the one hand, and other types of coal mining industry accident (exclude gas explosion) on the other hand. We can get a meaningful result that gas explosion has always been the main part in major accidents and fatality list in China coal mine industry. Displayed next to the fatalities graph is some of the representative gas explosions each caused more than 100 deaths in the CHN coal mines over the same period (see Table 1).

According to the accident investigation, the collected 231 cases of major gas explosions were all confirmed as "Human element accident", which means all these gas explosions can be prevented as long as the proper safety behavior was taken. Actually, the literature and the real life have proved, in coal mining industry as well as in other hazardous industries (e.g. oil and gas drilling, construction, and petrochemical plants), that the majority of accidents are caused by unsafe behaviors; thus, various safety levers were acted upon to correct and improve the reasons of unsafe behavior involved, and to minimize their likelihood of occurrence. Within the field of hazardous industries, many efforts, including safety training, behavior-based safety, safety awareness campaign, were made to improve unsafe behavior, so as to prevent the various accidents. In order to use these methods effectively, the most important thing is that we should ensure the contents and details in itself are useful, and then those who know what should do will conduct themselves in a safe manner. Nevertheless, this has not always been the case, and these methods always cannot implement efficiently onsite. So, for the purpose of promoting the qualities of contents and details of the said methods and then preventing gas explosion accident onsite effectively, it is crucial to analyze and conclude the causation of the previous gas explosions, especially the unsafe behaviors referring to material causes that directly led to the happening of gas explosion.

3. Materials and methods

We took a case study approach, in order to get an in-depth understanding of which unsafe behavior and how the unsafe behavior were being existed in coal miners who precipitated in the gas explosion and aggravated its consequences.

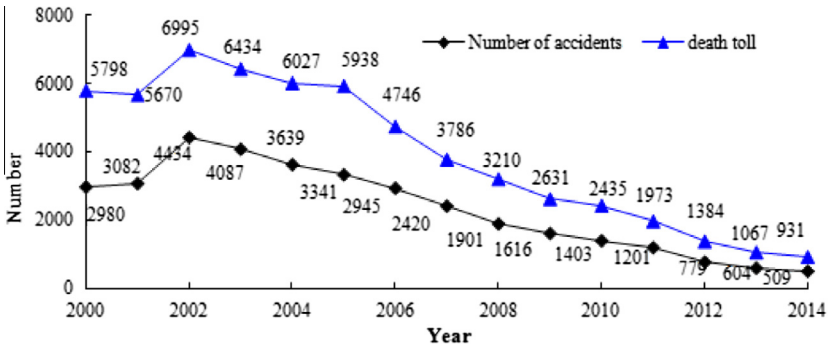

Fig. 1. Annual number of accidents and death toll from coal mining of China.