第二届采矿、安全与环境保护国际会议论文集

常心坦 等主编

天津大学出版社

Proceedings of the 2nd International Conference on Mine Safety and Environment Protection

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天津大学出版社
TIANJIN UNIVERSITY PRESS

图书在版编目（CIP）数据

第二届采矿、安全与环境保护国际会议论文集 = Proceedings of the 2nd International Conference on Mine Safety and Environment Protection：英文 / 常心坦等主编. —天津：天津大学出版社，2011.9

ISBN 978-7-5618-4176-1

Ⅰ.①第… Ⅱ.①常… Ⅲ.①矿山通风—国际会议—文集—英文②矿山安全—国际会议—文集—英文 Ⅳ.①TD7-53

中国版本图书馆 CIP 数据核字（2011）第 195605 号

出版发行 天津大学出版社
出 版 人 杨欢
地　　址 天津市卫津路 92 号天津大学内（邮编：300072）
电　　话 发行部：022-27403647　邮购部：022-27402742
网　　址 www.tjup.com
印　　刷 廊坊市长虹印刷有限公司
经　　销 全国各地新华书店
开　　本 210mm × 297mm
印　　张 24.75
字　　数 908 千
版　　次 2011 年 9 月第 1 版
印　　次 2011 年 9 月第 1 次
定　　价 150.00 元

Preface

Ever since the early days of civilization, mining has been regarded as an important industrial branch characterized by its indispensability and high safety risks. As almost all large-scale mine catastrophes or their afterwards handling is led, controlled or affected by ventilation-related factors, mine ventilation is commonly regarded as the foundation of mine safety. The 2nd International Conference on Mine Safety and Environment Protection — Mine Ventilation and Safety co-chaired by XUST in China and MST in the U. S. A. is certainly a big event of technical exchange in China. The conference certainly provides a good platform to promote mutual understanding among Chinese experts and their foreign colleagues on wide-range issues of mine safety.

Following a fast technical and social progress in the past decades, mining has not only gained a substantial development worldwide, but also gradually become a relative safe practice due to better planning, better equipment, better training, and better safety practice. In a sense, mining activities are effectively conducted within fully-controllable environment in developed countries and have experienced a significant improvement in their safety records. But in many other countries, though the progress is obvious, mining fatalities are still unacceptably high as mining activities are possibly performed under marginal environment between controllable and uncontrollable conditions. Thus it is understandable that the research angles and emphases of mine safety are different in different countries. China is certainly one of the countries in which the research angles are further diversified, more unique, and researches are performed by numerous teams due to tremendous needs by the industry. The experience in gaining high standard of mine safety in developed countries and the global achievements in mine safety research thus attract various mining personnel to share their thoughts and gains.

In the past decades, the needs for timely and comprehensive information in depth have been on top priority in almost all imaginable fields, among which mine safety is surely the one that raises great demands in building a solid foundation for the application of information science and technologies. Tremendous efforts have been put into the research for better understanding of the nature of mine disasters, the possible situation under abnormal cases, the rational countermoves of emergency handling, the response regularities of the mine system towards safety control measures, the optimal and feasible ways to predict, prevent, deal with and control potential dangers or real emergencies. The relevant researches of mine safety always focus on a sustainable improvement of safe production, so as to evoke special emphasis on the practical needs raised in day-by-day production and safety management. As the consistent efforts continue, the development of safety technologies in recent years shows a strong trend of broader and faster application of the newest achievements in all research fields, which has dramatically promoted the progress of safety technologies in the mining industry.

The Conference evoked widespread repercussions in mine safety circles. 89 papers are selected out of 165 papers submitted from 6 countries, covering the categories of Mine Ventilation and Safety, Ventilation Simulation and Software Application, Coal Spontaneous Combustion and Mine Fire, Coalmine Methane Control and Utilization, Mine Emergency Rescue Techniques and Facilities, Mine Occupational Health, and so forth.

It is really my honor and pleasure to write down a few words in the front of the proceeding to express my sincere thanks to all engaged individuals, without whom there is no chance for the conference to succeed. I must express my heartfelt thanks and gratitude to the professors, staff, and graduate students of XUST for the time and efforts they contributed for a fruitful conference. Special thanks also go to the MST colleagues for their fundamental and constructive contribution.

Finally our sense of gratitude to all the sponsors is deeply recorded for their generous support in organizing ICMSE 2011.

Xinfan Chang

2011. 9. 28

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Airflow Adjustment and Minimization of the Air Power of a Ventilation Network

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Abstract The ventilation network analysis calculates the airflow rates in the ventilation network from the data of the roadway resistances and the fan pressure etc. In this case, the resistances and the pressure are given conditions, and the airflow rates are the solutions to be calculated. However, in the practice of mine ventilation, it is often required to know which is roadways (adjustment roadways) resistances and how much values of the resistances should be changed to make the airflow rates in the roadways (target roadways) to certain required values. In this case, the airflow rates of the target roadways and the resistances of the roadways other than the adjustment roadways are the given conditions and the resistances of the adjustment roadways are the solutions to be found. No straightforward method to solve the latter case has been found up to now. Therefore, trial and error method using the ventilation network analysis program which is designed to solve the former case is utilized to solve the latter case so far. That is, the ventilation network analysis is repeated with gradually change of the resistances of the adjustment roadways. If the calculated airflow rates satisfy the required conditions, the adjustment roadway resistances used at the time are the solutions for the case. The method takes long calculation time and the best answer is not necessarily obtained.

The authors newly defined "airflow element" as an element of the ventilation network analysis. The resistances that satisfy the airflow requirements can be calculated straight forwardly by putting the function of the airflow element into the ventilation network analysis. The air power required for the ventilation can be minimized while meeting the airflow requirements by the advanced application of the method. The authors designed the computer program fulfill the method. The program was applied to actual ventilation networks and it was found that the method is very practical and the time required for the analysis is short.

Keywords mine ventilation, airflow adjustment, airflow resistance, optimization

Ventilation and Climate Simulation with the MULTIFLUX Code*

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Abstract It is important to study mine ventilation systems in order to design and control the working environment in deep underground mines better. With increasing depth, heat, and humidity, worker performance may be reduced and the safety of the workers must be given special attention.

MULTIFLUX, (MULTIFLUX Danko 2008) a new thermal, hydrologic, and airflow model and software is being employed to solve the flow of heat, moisture, and air in and around an underground opening. MULTIFLUX models two distinct domains: the rockmass and the airway, each is solved separately first and later re-coupled as an iterative task. The airway domain is solved with an integrated-parameter Computational Fluid Dynamic (CFD) module, which is an embedded part of the MULTIFLUX code. The CFD model includes convection, conduction, and radiation for heat, as well as convection and diffusion for moisture transport in an air-filled opening. The CFD model also solves for the airflow field. The surrounding rockmass model may be from any analytical solution, or from a complex thermal-hydrologic numerical model such as NUFT or TOUGH2. The rockmass model is interfaced to MULTIFLUX using a novel technique called Numerical Transport Code Functionalization (NTCF).

The purpose of this paper is to briefly describe the MULTIFLUX model and show four example applications. The first example reports the results of MULTIFLUX simulations for a mine drift, comparing calculations with CLIMSIM, a well-known mine climate software, and with measured data. The second and third examples involve development ends in two coal mines. Another development-end ventilation model in MULTIFLUX is also shown as the fourth example compared with field measurements from the Lucky Friday Mine in Idaho, USA for comparison.

The results of the study show very good agreement between the MULTIFLUX model and the available measured field results.

Keywords mine ventilation, health and safety, modeling, climate simulation

* The research fund from NIOSH, USA, under grant number 200—2009—30157 is gratefully acknowledged. The permission of using NUFT from the Lawrence Livermore National Laboratory is thankfully appreciated.

Sensitivity Analysis on Parameter Changes in Underground Mine Ventilation Systems

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Abstract A more efficient mine ventilation system, the ventilation-on-demand (VOD) system, has been proposed and tested in Canadian mines recently. In order to supply the required air volumes to the production areas of a mine, operators need to know the cause and effect of any changes requested from the VOD system. The sensitivity analysis is developed through generating a cause and effect matrix of sensitivity factors on given parameter changes in a ventilation system. This new utility, which was incorporated in the 3D-CANVENT mine ventilation simulator, is able to predict the airflow distributions in a ventilation network when underground conditions and ventilation controls are changed. For a primary ventilation system, the software can determine the optimal operating speed of the main fans to satisfy the airflow requirements in underground workings without necessarily using booster fans and regulators locally. An optimized fan operating speed timetable would assure variable demand-based fresh air delivery to the production areas effectively, while generating significant savings in energy consumption and operating cost.

Keywords sensitivity factors, ventilation system, airflow, branch resistance, fixed quantity, fan speed

Numerical Simulation Study of Gob Air Leakage Field and Gas Migration Regularity in Downlink Ventilation

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Abstract Aiming at the issue that mass of gas emission from mining gob and the gas exceeded in working face, this paper studied gob air leakage field and gas migration regularity in downlink ventilation. In consideration of the influence of natural wind pressure, it analyzed the stope face differential pressure, gob air leakage field distribution and gas migration regularity theoretically. Established a two-dimensional physical model with one source and one doab, and applied computational fluid dynamics analysis software Fluent to do numerical simulation, analyzed and contrasted to the areas of gob air leakage on size and gas emission from gob to working face on strength when using the downlink ventilation and uplink ventilation. When applied downward ventilation in stope face, the air leakage intensity was smaller than uplink, and this can effectively reduce the gas emission from gob to working face; when used downlink ventilation, the air leakage airflow carried the lower amount of gas to doab than uplink ventilation, reduced the possibility of gas accumulation in upper corner and the stratified flows.

Keywords downlink ventilation, natural wind pressure, air leakage field, gas migration, numerical simulation

Computer Simulation of the Air Flow Distribution in Goaf Regarding the Use of Inert Gases and Chemical Agents*

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Abstract This paper presents the use of a computer method of the ventilation process simulation for the analysis of the flow distribution of air and gases in the area of wall mining work and the adjacent goaf. In workings and goaf, the complex issue of the formation of a gaseous atmosphere under variable ventilation conditions and an existing fire hazard level, with the possibility of feeding goaf with an additional carbon dioxide flux as the inertizing agent is considered. Some examples of the simulation of feeding goaf with carbon dioxide illustrating the different patterns of the distribution of the goaf atmosphere gases concentration, said distribution patterns being gas supply place dependent, have been presented. In addition, the impact of the additional sealing of goaf on the distribution level of the concentration of gases, the said sealing made from the wall side with chemical agents has also been considered. The capabilities of the *VentGoaf* computer simulation program, being the basis for our calculations, enable consideration of the use of the inert gases supplied to the goaf depending on: the location of the gas feeding the pipe outlet, tightness of the fire field, fire centre location, and spatial situation of the mined wall. It has been found that fire prevention elements, such as chemical sealing agents, are of great impact on the effectiveness of fire prevention.

Keywords mine ventilation, computer simulation, inflow of methane and inert gases

1 Introduction

Production of coal in coal mine is related to occurrence of several natural hazards, particularly fire and methane related hazards. Despite continuous development of production methods and new safety rigours being introduced, we still face numerous unpredictable events, including disastrous ones. Long-term experience, gained from production of useful minerals, has led to gathering of reach record set of events, especially useful for utilisation of testing ventilation process in presence of disturbances. Modernisation of means increasing work safety of mining crews has taken place during recent decade, including also further development of computer simulation methods of monitoring the headings ventilation process (Skotniczny P., 2008). Introduction of atmosphere condition monitoring system in ventilation departments and at coal mine dispatcher post, as well as computer software system for ventilation engineer may be listed among them. Coal mine monitoring system provides dispatcher with huge number of measurement data, gathered from sensors located in vital places of the coal mine. They inform on current basis about methane and carbon monoxide concentration levels, as well as on airflow rate. The computer software system for ventilation engineer enables, by means of computations, control of ventilation condition, for example by determination of air distribution in headings and goaf, or by determination of gas concentration distributions for known inflow sources, including fire gases.

The aim of this paper is to show possibilities of ventilation process forecasting in aspect of fire prevention application in a form of inert gas injection (Nawrat St. 1999) with simultaneous sealing of a longwall heading goaf with chemical agents on its whole lengths, immediately behind covers of longwall heading props from side of the goaf. Method of computer simulation of the air, methane and carbon dioxide mixture flow distribution forecasting within area of goaf and longwall headings, taking into account injection of carbon dioxide to goaf, have been assumed as the research tool. (Dziurzyński W. 1998, Dziurzyński W. 2002)

* This study was performed as a part of research projects (NN524 368237), financed by the Ministry of Science.

2 Application of Ventilation Process Simulation for Analysis of Longwalls and Goaf Region

The *VentGoaf* module of *VentGraph* computer software package is being systematically developed in the Strata Mechanics Research Institute of the Polish Academy of Sciences. The *VentGraph* computer software is used for simulation of air and methane flow within a grid of headings, while *VentGoaf* module enables simulation of flow phenomena in goaf and headings adjoining the goaf. Mathematic model adopted in the computer program has been presented in detail in several papers (Dziurzyński W. 1998, Nawrat St. 1999, Dziurzyński W, et al, 2001). The research completed within recent years has been focused on extension of the *VentGoaf* module capabilities, and also validation of solutions being obtained (Dziurzyński W., et al., Dziurzyński W., et al., 2008). To this end experimental works are carried out in regions of longwall headings production, and they consist in observation of methane and fire hazard development by means of the system of sensors of coal mine monitoring, with simultaneous supplementary ventilation measurements (Dziurzyński W., Wasilewski S., 2009, Dziurzyński W., et al., 2010).

The mathematic model adopted in the *VentGoaf* module of the *VentGraph* computer software, takes into account flow of air and gases mixture both in goaf and in coal mine headings in presence of existing fire and methane hazard, and also considers injection of inert gas, for example carbon dioxide, to the analysed region. Injection of carbon dioxide to goaf results in mixing the gas constituents filling the goaf, which causes a change in distribution of the concentrations of individual constituents of gaseous mixture flowing in the goaf.

The aim of the research is to present the influence of carbon dioxide injection on fire hazard shaping in goaf of D-31 longwall, producing from 510/D bed in "B" coal mine. Determination of carbon dioxide, nitrogen, oxygen and methane concentration distributions in goaf constitutes a basis for evaluation of current fire hazard level for this region.

The *VentGoaf* module of computer software enables execution of computations for each ventilation network, for which data have been prepared in conformity with the adopted mathematical model. In order to prepare initial data for model research, measurement data and additional descriptive information regarding simulation region should be acquired, i. e.: results of ventilation measurements, computer parameterised description of ventilation network for current status of its structure and ventilation controlling system, design data of operation region, profiles of longwall galleries, bed maps, geological sections, data recorded by coal mine monitoring system and measurement results of the composition of goaf gases sampled for purposes of fire-methane hazard evaluation. Considering that direct measurements in goaf are not possible, theoretical model of permeability and height of goaf shaping is used (Dziurzyński W., 1998), as well as information provided by bed map, geological section of the regions, design of longwall headings production (geometry, height spots, thickness of producing bed, type of the roof rocks).

3 Injection of Carbon Dioxide to Goaf — Various Injection Places, Sealing

In order to establish proper technology of carbon dioxide injection, it is essential to find optimum place of carbon dioxide injection to goaf, which results in reduction of fire hazard. In order to present area of goaf filled with carbon dioxide, forecasts of gas distribution in D-31 longwall goaf will be carried out for various locations of gas injection places. In mining situation under question, it is possible to feed carbon dioxide both with use of D-31 gallery (Fig. 1), and D-31a gallery (Fig. 6). As a result of subsequent computer simulations (example 4), a solution will be shown that visualises area of goaf filled with carbon dioxide, for the case of longwall sealed with chemical agent from side of goaf. This agent is used in fire prevention and its purpose is reduction of air flow to and from goaf.

3.1 D-31a gallery — air outlet from the longwall

Results of numerical simulation computations of air mixture flow distribution in the area are showing that 1,120 m^3/min of air flows through the longwall. It should be noted that air flow of such volume causes deep ventilation of goaf and outflow of gases from D-31 longwall to D-31a gallery. Analysis of obtained results of the solution demonstrates high similarity to situation, which has taken place in real conditions of D-31 longwall venti-