Introduction to the Special Issue “Rock Mechanics Advances in China Coal Mining”

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1 Introduction

Coal has been an important conventional natural resource in the economy development worldwide. China, USA, India, and Australia stand out as the top four largest producers in recent years. The total coal reserve is 1566.31 billion ton in China, where more than 90% coal reserves are mined at depth. Since 2010, the annual production of raw coal in China has been more than 3.4 billion ton, as shown in Fig. 1, even though some decline is taking place in recent years due to the end of a 10-year coalmine boom (National Bureau of Statics of China 2018). During such a large-scale coal extraction process, efficient and safe mining has been a prerequisite and it is, today, even more so. In addition, modern coalmines face more strict public scrutiny in environment protection.

Except for the concern on the efficiency of coal breaking, “ground control” is vitally important during coal production. The target-mining strata have been going deeper, 10–20 m annually, and to date, around 40 coalmines with mining depth greater than 1000 m are active in China. These mines are mainly distributed in the East, North, and Northeast. This increasing growth of mining depth brings great challenges in “ground control”, especially in coal mining under thick hard roof strata or thick weak strata.

The thick hard strata usually result in high mining-induced stresses, causing large deformations in coal mine

structures and in cases even rock bursts. In thick weak strata, large deformations do often occur and lead to costly expenses in roadway maintenance, including delay of coal production. Water overflowing into coalmines is another issue when dealing with safe mining. In addition, the flow of surface water into the underground can cause environmental problems due to fracture development in the overlying roof strata.

When mining gassy coal seams or coal seams with high spontaneous combustion tendency, the understanding of permeability evolution is of key importance, with reference to gas mitigation in coal seams and leakage of airflow into mined-out gob. In addition, attention is to be paid to ground subsidence problems because of coal extraction.

The experience, which may be gained in dealing with case studies and properly addressing the problems arising from them, is of great importance. Fundamental studies on novel topics are equally important if they provide new tools from both the theoretical and practical points of view that allow dealing with the complex mechanisms mentioned above.

So far, “China Coal Mining” has addressed and solved many challenging problems, which may be well located in Rock Mechanics and Rock Engineering. The purpose of this Special Issue “Rock Mechanics Advances in China Coal Mining”, which follows the May Issue on “Deep Mining”, is to illustrate selected contributions from both the academic–practitioner research collaboration to share light on some of the relevant topics mentioned above.

Eleven contributions (ten “Original Papers” and one “Technical Note”) were finally accepted for publication in the Special Issue after a complete review process carried out according to the rules of the Rock Mechanics and Rock Engineering Journal under the supervision of the guest editors. It is worth noting that all the reviewers for both the selected and unselected papers are international peer reviewers from countries other than China. Special thanks go to all of them for their outstanding contribution and help.

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Fig. 1 Annual production of raw coal in China

2 The Special Issue

The Special Issue “Rock Mechanics Advances in China Coal Mining” covers ground control, coal breaking, strata mechanics, coal seam gas seepage, coal spontaneous combustion in gob, water inundation/overflow, and fundamentals in the development of a new rock bolting system research apparatus and numerical modeling.

Three papers focus on ground control in underground coal mining. The key roof strata significantly influence the movement of the overlying strata and its sudden failure may lead to violent impact on mine space.

Lu et al. (2019) report the use of a surface hydraulic fracturing technique to crack the far-field hard roof strata when mining extra-thick coal seams of 20 m average thickness. The target stratum for fracturing is estimated by comparing the cracking energy release of the different roof strata based on numerical simulations. Field experiments confirm that the support pressure and roadway deformation are reduced after the fracturing operation.

Feng et al. (2019) study the stability of an irregularly shaped pillar when mining two coal seams separated by a 1.2 m-thick mudstone layer. The irregularly shaped pillar is formed by setting the headgate in the upper coal seam and the tailgate in the lower coal seam for reduction of fragmentation size of interlayered mudstone and mitigation of pillar burst risk. The optimum pillar size is inferred with numerical modeling and verified by using field monitoring.

Han et al. (2019) propose a short-staged gob-side entry retaining strategy to alleviate the multiple and long-term disturbance due to grouped roof collapse. According to physical modeling, the collapse of roof strata, especially

key strata, and the movement of the main roof are identified as the main factors causing the excessive deformations of the gob-side entry. The relevant parameters for implementing this technology are determined by calculating the timing and strength of key strata disturbance.

The longwall top-coal caving technique is a favorable method when extracting thick coal seams. Top-coal cavability and coal recovery rate are the mine design parameters to define. They are influenced by the specific geological and engineering conditions at the site.

Zhang et al. (2019a) study the movement and structure of the overlying roof strata of a longwall top-coal caving working face when passing an abandoned roadway. Theoretical analysis, numerical, and analogue simulations are carried out. With the advance of the mining face towards the abandoned roadway, roof fractures are shown to develop ahead of the mining face and the support stresses to increase drastically.

Guo et al. (2019) present a theoretical study to predict the height of the fractured water-conducting zone in overlying roof strata during longwall mining. The overburden strata failure process is divided into transmission development and termination stages. Rock failure criteria are used to determine the maximum suspension length and maximum overhanging length. A new theoretical method is proposed to determine the height of the fractured water-conducting zone. The theoretical work is verified with numerical simulations.

With interest in air leakage and flow in the gob zone, Chao et al. (2019) investigate the permeability evolution of a broken coal particle assembly under the coupling of multiple factors, such as axial loading, temperature, and moisture. The experimental results obtained show that the permeability of the broken coal particle assembly is negatively correlated with temperature, water content, and pore pressure while maintaining the same loading condition. Furthermore, the relationship of permeability versus temperature, water content, and pore pressure is empirically defined.

In the background of coal seam gas drainage, Liu et al. (2019a) report a laboratory study on the permeability of coal under true triaxial conditions. It is shown that the coal permeability tends to be heterogeneous for different stratification orientations, and decreases exponentially with increase of stress, irrespective of the major principal stress, intermediate principal stress, minor principal stress, or effective stress values.

Yang et al. (2019) report a field study of ground subsidence when mining multiple close-distance coal seams at the average depth of 100 m in the Bulianta Colliery. It is shown that multi-seam mining can activate the previously mined-out gob area and cause instability of previously formed key strata structure, leading to larger ground deformations. Field observations show that cracks appear ahead of the mining

face and tend to appear periodically. The mining advance rate influences the phenomenon.

The induced ground deformations can trigger landslides as is the case in Southwestern China. In relation to this, Tang et al. (2019) present a theoretical model to predict fracture development in a bedded rock slope following underground coal mining. The results of a physical model in the laboratory are presented to validate the theoretical model. It is found that tensile fractures appear when the bedding separation reaches a critical value, and appear periodically with the advance of the mining face.

Two papers contribute to the fundamentals of mining-related rock mechanics with interest in the characteristics of the gassy coal outbursts and study the gas flow process. Zhang et al. (2019b) develop a large-scale multifunctional apparatus. In illustrating the details of the equipment, the design principles, units and key technologies are reported.

Based on equivalent continuum methods, Zhou et al. (2019) develop a new 3D numerical model to simulate the hydraulic fracturing in coalmines. A hybrid combination of the embedded element method and the finite volume method is adopted to calculate the displacement and pressure distribution along the discontinuities. The cubic law is used to calculate the water flow along fractures, while consideration is given to aperture variation, shear slippage and shear dilation, with a constitutive model based on a pseudo-continuum concept.

Finally, it is worth mentioning here that two papers, handled during the preparation of this Special Issue were previously published in the RMRE Journal. Bai et al. (2019) studied the influence of hard rock band on top-coal breaking in longwall mining by physical modeling. Liu et al. (2019b) presented the shear characteristics of rock bolting with a cuneiform reaming anchorage. It is shown that this type of rock bolting can provide high shear resistance against shear slip along joint planes when the cuneiform grout is located near to the weak plane.

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