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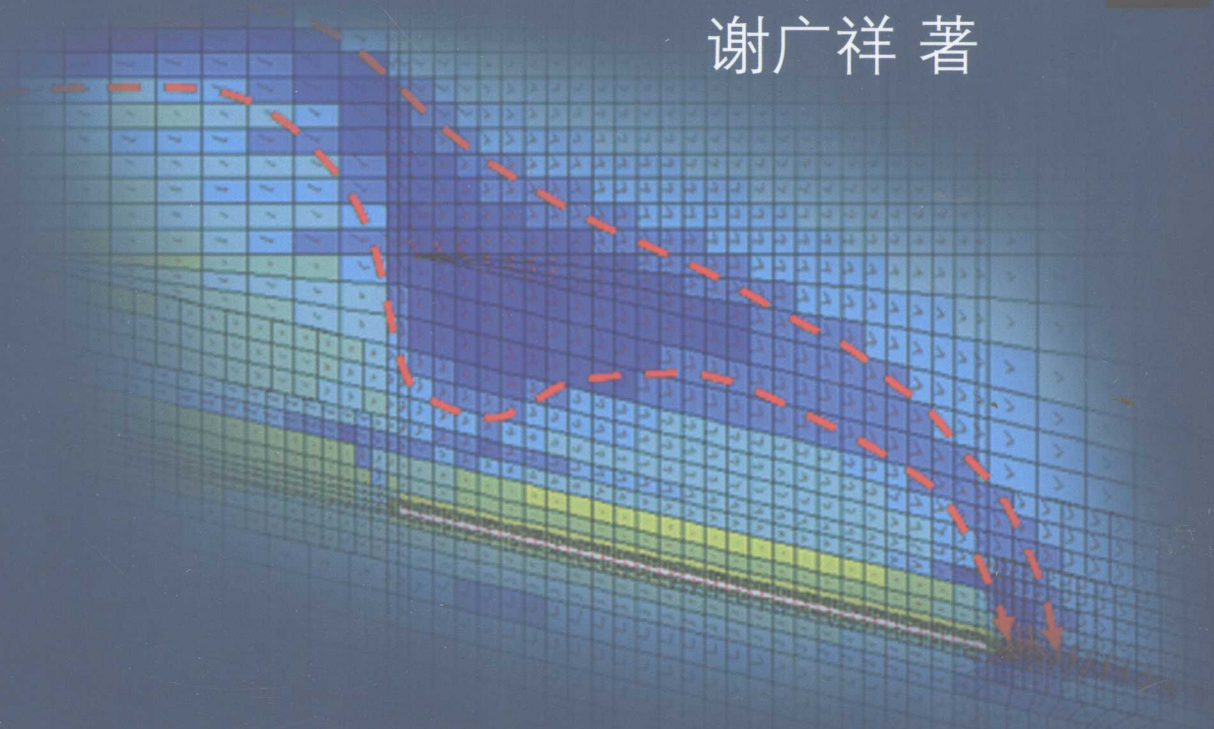
综放采场围岩三维力学特征

谢广祥 著



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综放采场围岩三维力学特征

Three-dimensional Mechanical Characteristics of Rocks Surrounding the Fully Mechanized Top-coal Caving Mining Faces

谢广祥 著

煤 炭 工 业 出 版 社
·北 京·

内 容 提 要

本书是一部系统研究综放采场围岩三维力学特征的著作，全书共6章。通过对综放采场围岩宏观应力壳的发现及其力学特征的分析，阐述了综放采场围岩三维力学特征以及采厚、护巷煤柱宽度和推进速率的变化对其影响的采厚效应、柱宽机制和推进速率的响应，揭示了综放采场围岩三维力学特征、综放面矿压显现趋于缓和及有利于减缓动力灾害的力学本质。

本书内容丰富，资料翔实，图文并茂，供从事煤矿开采领域的科研、教学人员和研究生及本科生学习参考。

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序

综采放顶煤技术是我国煤矿厚煤层开采实现高产高效和集约化生产的主要途径之一，近年来在全国许多矿区得到推广和应用，取得了良好的技术经济效益。厚煤层综放开采与中厚煤层其他开采方法的区别，不仅在于工作面开采煤层厚度的增加，更主要是受开采扰动的范围扩大，采场围岩的矿压显现特征涉及到更大范围空间的岩体力学行为，并处于三维力学状态。特别是在煤与瓦斯突出威胁的厚煤层中，能否使用放顶煤方法开采一直存在着争议，综放面矿压趋于缓和但巷道围岩变形却加剧的力学本质也有不同的解释等，这些都迫切需要在综放开采矿山压力规律的理论研究上取得新的认识和突破，不断完善和发展综放开采矿压新理论。

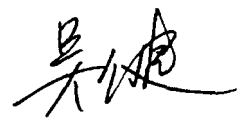
本书作者谢广祥教授在其博士论文研究中，发现了“宏观应力壳”的力学存在和空间分布形态，在此基础上又创见性地提出综放开采有利于缓和煤与瓦斯突出等动力灾害的新观点。后经深入系统的研究，初步形成了综放采场围岩三维力学特征研究的学术思想和理论框架。

《综放采场围岩三维力学特征》详细地阐述了以“宏观应力壳”为代表的综放采场围岩三维力学特征研究成果，提出了在长壁采煤工作面围岩中存在着由“高应力束”组成的“应力壳”理论。认为大部分长壁采煤工作面前方、后方、周边和邻近巷道的矿压显现是受控于“应力壳”的存在和由其变化带来的影响，应力壳失衡会造成剧烈的矿山压力现象，合理调整开采厚度等采场结构参数可改善采场围岩应力壳的动态平衡，对保护工作面、减小矿山压力影响和显现有积极作用。本书所提出的矿压观点和基本理论在现场测试中进一步得到证实，是我国近年在综放开采矿山压力理论方面取得的具有原始创新和突破性的研究成果。

在综放采场围岩三维力学特征研究的基础上，谢广祥教授从理论上深刻揭示并科学论证了厚煤层放顶煤工作面开采时，能缓和回采工作面前方或采空区侧煤巷掘进时出现煤与瓦斯突出危险的威胁。在后续的教学、科研实践中，谢广祥教授对此理论又进行了大量深入研究和实践，学术观点更加鲜明，研究成果得到进一步深化和完善。该项成果获得煤矿开采界同行的高度评价和普遍认同，并在煤矿生产实践中得到证实，为放顶煤开采技术成功推广奠定了重要的理论基础。

综放采场围岩三维力学特征研究的另一个重要成果，是获得了综放开采三维矿压场的柱宽机制。提出了护巷煤柱宽度的变化，不仅使煤柱本身力学状态发生变化，而且对相邻工作面煤体内力学特征有明显影响。其力学分布特征随煤柱宽度改变而相互作用和转化，从而主导了巷道围岩受力和变形特征，也决定了巷道的维护状态。这项创新成果对综放回采巷道煤柱的合理留设及维护有重要的指导意义。

此外，本书对综放开采围岩力学特征的推进速率响应也进行了深入研究，认为随着工作面推进速度增加，工作面低应力区和周围煤岩体破坏区的范围以及位移都相应减少，而前方支承压力峰值位置向工作面煤壁靠近，峰值应力增大。研究成果为现场矿压控制提供了理论指导，颇有新意。



2007 年 7 月 16 日于北京

Foreword

Because of the high output and high efficiency compared with the slicing mining method, the fully mechanized top-coal caving (FMTC) method is, at present, popular for thick coal seams in China, and great technical and economic benefits have been obtained. FMTC for thick coal seams differs from other mining methods for medium-thick seams not merely in that mining thicknesses are increased, but more importantly in that the mining affects larger areas and rock surrounding the face is characteristic of rock mechanic behavior of a larger space, thus exhibiting three-dimensional characteristics. However, there has been a dispute on whether or not to adopt FMTC for thick coal seams being threatened by coal and gas outbursts. And mechanically, there have been different explanations to strata behaviors tending to be eased whereas the deformation of roadway surrounding rock is intensified. All of this demands new understanding and breakthrough in theoretical research on rock pressure patterns of FMTC faces, and hence a new rock pressure theory.

The author of this literature, Prof. Xie Guangxiang, offers his discovery of the mechanical existence of the macro stress shell (MSS) and its spatial distributional configuration. Upon this basis, the author raises an original viewpoint that the FMTC helps reduce the danger of dynamic disasters such as coal and gas outbursts. As a result of deep-going, systematic investigations, the book presents the author's academic concept and theoretical framework of the three-dimensional mechanical characteristics of FMTC surrounding rock.

The literature elaborates on research fruits of three-dimensional mechanical characteristics of FMTC surrounding rock, with the MSS in detail. A theory is put forward that an MSS composed of high stress bundles exists in the surrounding rock of a longwall mining face. The strata behavior of the face and its neighboring roadways is subject to the stress shell and its changes, and off-balance of the shell can result in violent stress behaviors. Rationally adjusting structure parameters of the working face, such as mining thickness, can improve dynamic balance of the surrounding rock stress shell. It plays a positive role in protecting the working face and reducing rock pressure influence. The author's rock pressure viewpoints and fundamental theory are subsequently verified by in-situ observations. They are original and creative, hence a breakthrough in the field of FMTC rock pressure theory.

Based on his researches into the three-dimensional mechanical characteristics of FMTC surrounding rock, Prof. Xie has demonstrated scientifically his viewpoint that top-coal caving method for thick coal seams can mitigate the danger of coal and gas outburst in front of the face and when a coal entry is being driven beside the goaf. Abundant researches and practices have later been carried out by Prof. Xie, and the research fruit has been further deepened and consummated. The colleagues in coal mining have a good opinion of the theory. The theory has been proved in practice, thus establishing an important theoretical basis for a successful popularization of the top-coal caving technology.

Another important result, the mechanism of coal pillar width of the three-dimensional rock pressure fields on FMTC faces, is obtained in the literature. As the width of the coal pillar for protecting an entry varies, the mechanical characteristics changes, not only in the coal pillar but also in the coal mass of adjacent faces, resulting in re-distribution, transformation and interaction, which in turn governs the mechanical behavior of entry surrounding rock and hence entry maintenance. This research fruit is of an important guidance for rational design of coal pillar width and entry maintenance.

In addition, the response to mining speed by the mechanical characteristics of FMTC surrounding rock is deeply investigated. The results show that, with the increase of mining speed, the extent of low stress district, that range of failure and displacement on FMTC faces decrease and, as the abutment pressure peak approaches the face, the peak stress increases. The research fruit provides a theoretical guidance for rock pressure control. It is novel.

Wu Jian

July 16, 2007, in Beijing

前　言

众所周知，我国是以煤炭为主要能源的国家。厚煤层储量在我国煤炭储量中约占44%，其产量比重约占原煤产量的45%。综合机械化放顶煤（综放）开采具有高产高效、生产集中、成本低等特点，已成为我国开采厚煤层的主要方法。

多年来，众多专家、学者与工程技术人员围绕放顶煤技术与理论开展了许多研究，特别在矿山压力及其控制领域开展了大量卓有成效的工作，取得了一系列成果，对推动放顶煤技术发展起到了积极重要作用。工程实践表明，综采技术快速发展迫切需要有完善的采场围岩力学特征基础理论的支持。采场围岩力学特征客观上是一个三维分布问题，矿压显现规律根本上由采场围岩三维力学特征所决定，掌握采场围岩三维力学特征是综放开采技术的重要基础。为此，本书从大范围宏观上研究综放采场围岩三维力学特征。研究发现：在采场围岩空间存在高应力束组成的应力壳。基于应力壳的新发现以及对其力学特征的分析，揭示了综放采场围岩三维力学特征的采厚效应、柱宽机制、推进速率响应，综放矿压显现趋于缓和的力学本质及有利于减缓动力灾害的作用机理，丰富和完善了综放矿山压力及其控制理论。

本书是在导师吴健教授指导下完成的博士论文《综放面及其巷道围岩三维力学特征研究》基础上，由国家自然科学基金项目《综放开采煤与瓦斯突出的采厚效应研究》（项目编号：50674003）、国家重点基础研究发展计划（973计划）子课题《采场围岩宏观应力壳与煤岩体裂隙场动态效应》（课题编号：2005cb221503）和“十一五”国家科技支撑计划重点项目子课题《深部采场结构对煤岩动力灾害影响预测技术研究》（课题编号：2006BAK03B06）资助获得的部分研究成果。该成果获得了2006年安徽省科学技术一等奖。本书的完成，首先归功于导师吴健教授的悉心指导，藉此谨向恩师致以诚挚的感谢和崇高的敬意！此外，特别感谢徐秉业教授、王金安教授、姜耀东教授、王家臣教授等的热情帮助与有益启发！十分感谢中国矿业大学（北京）放顶煤实验室、安徽理工大学采矿实验室和两淮矿区工程技术人员及课题组成员的辛勤劳动和大力支持！真诚感谢本文所引用参考文献的作者以及启迪本人思想的其他国内外学者！

尽管我在撰写过程中，认真细致地整理科研资料，用心地选取内容，设计结构层次，但难免还有不妥和错误，恳请有关专家和广大读者批评指正！

谢广祥

2007年6月6日于淮南

Preface

As is well known, coal is the prevailing energy source in China. The reserves of thick coal seams compose approximately 44% of the total coal reserves and the coal thereof produced accounts for approximately 45% of the total raw coal output. Characteristic of high productivity, high efficiency, centralized production, and low cost of production, etc., the fully mechanized top-coal caving (FMTC) has make this mining method become the chief mining method for thick coal seams.

Over the years, experts, scholars and engineers have conducted a huge amount of research on FMTC faces technology and theory. Particularly, they have done massive fruitful work in the domain of underground pressure as well as its control and achievements have been obtained which play a positive role in the development of the FMTC technology. The engineering practice urgently demands support from powerful basic theories of improved rock mechanics for the rapid development, popularization and application of the technology. The mechanical characteristics of surrounding rock, constitutionally a matter of three dimensions, largely determine strata behaviors. Therefore, it is of great significance to have a good mastery of the three-dimensional mechanical characteristics of FMTC surrounding rock. This very book , on a large scale and from a macro point of view, researches on the three-dimensional mechanical characteristics of the surrounding rock. And my studies show that there is a micro stress shell (MSS) composed of high-stress bundles in the space of the face surrounding rock. Based on the new findings and on the mechanical analysis of the MSS, the three-dimensional mechanical characteristics of FMTC surrounding rock are revealed, including the effects of mining thickness, the mechanism of pillar width, and the response to mining speed. Also discovered is the mechanical nature that accounts for the tendency of the strata behaviors of FMTC faces growing less violent and hence the working mechanism of the technology favoring the reduction of dynamic hazards. The aim of the study is aiming at enriching and improving the theory of underground pressure and its control.

Based on my doctoral dissertation "Study on the three dimensional mechanical characteristics of a fully mechanized coal caving mining face and its gateways", which is supervised by Prof. Wu Jian, this book includes some results of my researches: "Study on the effect of mining thickness and coal and gas burst of FMTC faces " (No. 50674003)

sponsored by the National Natural Science Foundation Project, "Dynamic effect on the macro stress shell and mining induced fracture of surrounding rock of FMTC faces "), a sub-project of National Basic Research Program (973 Program, No. 2005cb221503) and "Study on the dynamic hazard of rock and coal and the prediction technology influenced by deep mining parameters", a sub-project of National Key Technology R&D Program (No. 15th: 2006BAK03B06), which was awarded 1st Prize of Anhui Science and Technology in 2006.

My heartfelt gratitude first goes to my respected supervisor, Prof. Wu Jian. Special thanks are given to Prof. Xu Bingye, Prof. Wang Jin' an, Prof. Jiang Yaodong, Prof. Wang Jiachen etc. for their zealous help and instructive inspiration. Great thanks are extended to the Coal Mining Laboratory of China University of Mining & Technology (Beijing), the Mining Laboratory of Anhui University of Science & Technology, the engineers of Huainan-Huaibei coal mines and the members of my research group for their industrious work and vigorous support. Finally, I sincerely thank the authors as listed in the Bibliography and all domestic and foreign scholars related. Although I have collected research materials conscientiously, selected the contents carefully, and designed the hierarchy and structure elaborately during the writing of the literature, errors and mistakes are unavoidable. The author earnestly welcomes criticism and correction from readers as well as experts.

Xie Guangxiang

June 6, 2007, in Huainan

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