



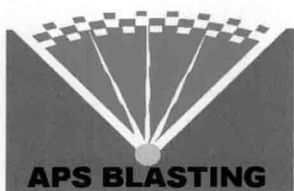
APS Blasting 3

NEW DEVELOPMENT ON ENGINEERING

BLASTING

**Editor in Chief
Prof. WANG Xuguang**

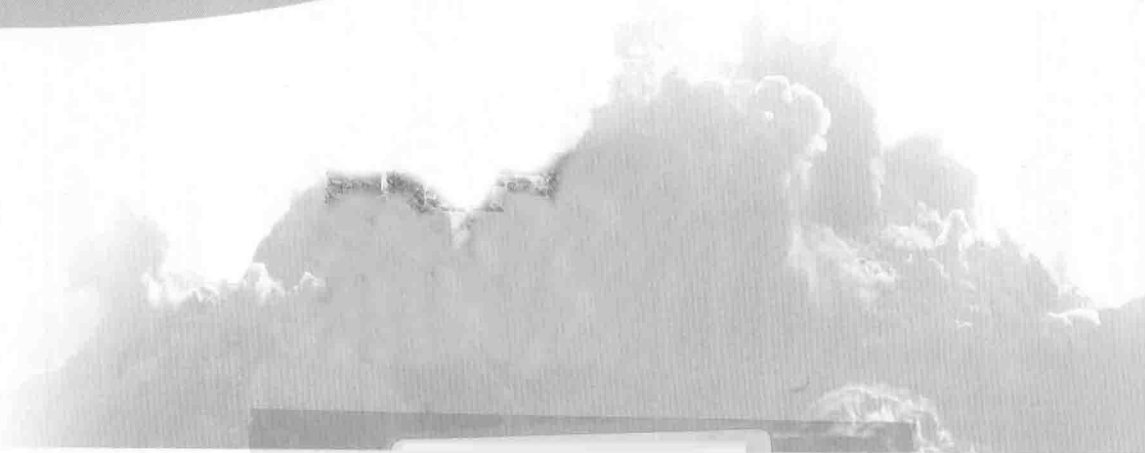
METALLURGICAL INDUSTRY PRESS



APS Blasting 3

NEW DEVELOPMENT ON ENGINEERING BLASTING

**Editor in Chief
Prof.WANG Xuguang**



METALLURGICAL INDUSTRY PRESS

Copyright © 2011 by Metallurgical Industry Press, China

Published and distributed by
Metallurgical Industry Press
39 Songzhuyuan North Alley, Beiheyuan St
Beijing 100009, P. R. China

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the copyright owner.

图书在版编目 (CIP) 数据

工程爆破新进展. 3: 英文/汪旭光主编. —北京:
冶金工业出版社, 2011. 7
ISBN 978-7-5024-5682-5

I. ①工… II. ①汪… III. ①爆破技术—文集—英文
IV. ①TB41-53

中国版本图书馆 CIP 数据核字 (2011) 第 136591 号

出版人 曹胜利
地 址 北京北河沿大街嵩祝院北巷 39 号, 邮编 100009
电 话 (010)64027926 电子信箱 yjcb@cnmip.com.cn
责任编辑 程志宏 戈 兰 美术编辑 李 新 版式设计 孙跃红
责任校对 王永欣 李文彦 责任印制 牛晓波
ISBN 978-7-5024-5682-5
北京兴华印刷厂印刷; 冶金工业出版社发行; 各地新华书店经销
2011 年 7 月第 1 版, 2011 年 7 月第 1 次印刷
210mm×297mm; 29.5 印张; 1601 千字; 459 页

冶金工业出版社发行部 电话:(010)64044283 传真:(010)64027893
冶金书店 地址:北京东四西大街 46 号(100010) 电话:(010)65289081(兼传真)
(本书如有印装质量问题, 本社发行部负责退换)

Asia-Pacific Symposium on Blasting Techniques (2011)

ORGANIZED BY:

China Society of Engineering Blasting

CO-ORGANIZED BY:

Engineering Blasting Society of Fujian Province, China

Xiamen Blasting Engineering Co., Ltd., China

CHAIRMAN:

Prof. WANG Xuguang

Academician of Chinese Academy of Engineering, China

VICE-CHAIRMAN:

Prof. CHEN Shaopan (Senior engineer)

Director of Engineering Blasting Society of Fujian Province, China

ORGANIZING COMMITTEE MEMBERS (in alphabetical order):

BHANDARI Sushil	(India)	KANEKO Katsahiko	(Japan)
CARLOS P. Orlandi	(Chile)	KUNIHISA Katsuyama	(Japan)
Chang-Ha Ryu	(Republic of Korea)	LI Xiaojie	(China)
CHEN Shaopan	(China)	LI Zhanjun	(China)
CHIAPETTA Frank	(America)	LIU Dianshu	(China)
Francisco Mardones B	(Chile)	LIU Honggang	(China)
GAO Wenxue	(China)	LIU Qian	(Canada)
GU Yicheng	(China)	Mckenzie Keith Cameron	(Australia)
GUAN Zhiqiang	(China)	MOHANTY Bibhu	(Canada)
HUSTRULID William	(America)	Qon Hoe Sing	(Malaysia)



QU Guangjian	(China)	XIONG Daiyu	(China)
RICHARDS Alan B	(Australia)	XU Tianrui	(China)
Sergei D. Victorov	(Russia)	XUE Peixing	(China)
SHI Fuqiang	(China)	YANG Chaoyang	(China)
SPATHIS Alex	(Australia)	YANG Jun	(China)
SUMIYAA Ganjargal	(Mongolia)	YANG Ruilin	(America)
Terushige Ogawa	(Japan)	YANG Xusheng	(China)
WANG Minglin	(China)	YU Yalun	(China)
WANG Xuguang	(China)	ZHANG Yongzhe	(China)
WANG Yaohua	(China)	ZHANG Zhengyu	(China)
WANG Zhongqian	(China)	ZHANG Zhengzhong	(China)
WU Chengqing	(Singapore)	ZHENG Bingxu	(China)
XIAO Shaoqing	(China)	ZHOU Jiahan	(China)
XIE Xianqi	(China)		

EDITORIAL BOARD

CHIEF EDITOR :

WANG Xuguang

EDITORIAL BOARD MEMBERS (in alphabetical order) :

GAO Yintong	(China)	XIE Xianqi	(China)
GAO Wenxue	(China)	XU Tianrui	(China)
GU Yicheng	(China)	XUE Peixing	(China)
GUAN Zhiqiang	(China)	YANG Jun	(China)
LI Zhanjun	(China)	YU Yalun	(China)
LIU Dianshu	(China)	ZHANG Jingjing	(China)
LIU Honggang	(China)	ZHANG Yongzhe	(China)
SONG Jinquan	(China)	ZHANG Zhengzhong	(China)
WANG Hao	(China)	ZHANG Zhengyu	(China)
WANG Ke	(China)	ZHENG Bingxu	(China)
WANG Xuguang	(China)	ZHOU Jiahan	(China)
WANG Zhongqian	(China)		

SECRETARIAT:

CUI Mingying ZHU Mingxiu

PREFACE

The Asia-Pacific region and Russia are the most active regions globally in the field of engineering. There is no exaggeration to say that the development of blasting technology in the Asia-Pacific region and Russia is of far-reaching influence around the world.

In order to further promote the development of blasting industry in the Asia-Pacific region, China Society of Engineering Blasting has successfully held two sessions of Asia-Pacific Symposium on Blasting Technology in the year of 2007 and 2009 in China. According to the general consensus of the organizing committee, 3rd Asia-Pacific Symposium on Engineering Blasting will still be held in China. The International Conference on Physical Problems of Rock Destruction has been successfully held five times in Russia. Other Chinese experts and I were warmly invited to attend the Conference many times. To expand conference dimensions and share conference resources, the organizing committees of two conferences are decided to combine Asia-Pacific Symposium on Engineering Blasting with Conference on Physical Problems of Rock Destruction starting from 6th International Conference on Physical Problems of Rock Destruction in 2009. This year will hold 7th International Conference on Physical Problems of Rock Destruction also hosted by China Society of Engineering Blasting.

The Asia-Pacific Symposium on Engineering Blasting and the International Conference on Physical Problems of Rock Destruction are intended to strengthen the academic exchange and technological cooperation among various countries in Asia-Pacific region and Russia to enhance inter-disciplinary penetration, to explore the opportunities, challenges and counter-measures faced by blasting technology and physical problems of rock destruction in the new century and to forecast the application prospects of blasting technology in various fields to jointly promote the development of rock blasting technology and physical problems of Rock Destruction in the world.

The two conferences will offer valuable opportunities for experts, professors and engineers engaged in industrial explosives, engineering blasting, rock destruction and other relevant fields to enhance understanding and cooperation in the Asia-Pacific region and Russia. I hope and believe these two series international conferences will go ahead smoothly and successfully.

The two conferences have attracted intensive and extensive attention and support from various countries among the Asia-Pacific region and Russia as well as from Chinese engineering blasting industry. The organizing committee has received more than 110 papers and finally accepted 91 of which 39 papers



are from Russia, America, Canada, Japan, Korea, Sweden, India, Mongolia, Australia and Kazakhstan. The Symposium proceedings have been published, covering a wide range of subjects and presenting the leading technological innovations and achievements in industrial explosives, detonating facilities, rock fragmentation theory, physical problems of rock destruction, blasting vibration effect, blasting numerical simulation, blasting excavation, blasting demolition and others. At present, the deep spread of international financial crisis has an increasingly evident impact on the global real economy. It has become a severe challenge for the international community to promote global economy in the face of global financial crisis. But we believe these two conferences will further the development of industrial explosives and blasting technology not only in the Asia-Pacific region and Russia but also in the whole world and finally make new contributions towards a brighter future for human beings.

The two conferences have been well prepared thanks to the great effort and contribution from the organizing committee composed of experts of various countries. They have done a lot of work in publicizing the conference theme and calling for more papers. Here I'd like to express my truly gratitude to those experts both at home and abroad for their active support and assistance to our conference.

Prof. Wang Xuguang

President of China Society of Engineering Blasting

Academician, China Academy of Engineering

June 28, 2011

Contents

1 Blasting Theory

Phenomenon of the Emission of Microparticles under Quasi-Static Loading of Rocks

S. D. Victorov, V. N. Odintcev, A. N. Kochanov, A. A. Osokin (Russia) 3

Influence Analysis of Structural Dynamic Response to Damage and Strain-Rate Effect

CHEN Shihai, ZHANG Ankang, DU Rongqiang, YAN Yongfeng (China) 6

Development of Blasting in Russia

K. N. Trubetskoy, S. D. Victorov, V. M. Zakalinsky (Russia) 11

Numerical Simulation and Stress Testing Research on Elliptical Bipolar Linear Shaped Charge

LI Bihong, QIN Jianfei, CUI Weifeng, LI Shiliang, ZHENG Yi (China) 16

Investigation of Electrostatics in Mineral Particles of Ferruginous Quartzite when Ruptured by Blasting

Stepan A. Goncharov (Russia) 22

Study on Influence of Air Decouple Charge Impact on Blasting Stress Field in Rock

ZONG Qi, LI Deisheng, WANG Xueli (China) 29

About One Mechanism of Formation of Zone Decomposition of the File of Rocks Round Excavations

A. I. Chanyshv, O. E. Belousova (Russia) 33

Numerical Simulation of Shaped Charge Jet Perforating Rock by SPH-FEM Coupling Method

LI Lei, SHEN Zhaowu, MA Honghao (China) 39

Dynamic Tension Tests of Pre-stressed Rocks

R. Chen, K. Xia (Canada) 43

Research on Blasting Fragmentation and Charge Weight in Simulating Deep Water

ZHANG Li, ZHANG Mingxiao, SUN Yueguang, ZHONG Shuai, GAO Yugang (China) 47

The Theory of Post Limit Deformation of Rocks in Geomechanics Problems

A. I. Chanyshv (Russia) 55

A Neural Network Model of Blasting Parameter Design for Controlling Blasting Flying Rock

YAO Jinjie, WANG Guizhu, DONG Chuanpin, JIN Zhihui (China) 59

On the Role of Stress Waves on Process of Explosive Destruction of Rocks

A. N. Kochanov (Russia) 62

Basic Characteristics of the Stages of Rock Massif Destruction by Explosive Crushing

B. Rakishev, Z. B. Rakisheva (Kazakhstan) 65

A Model Based on Uncertain Measure for Comprehensive Evaluations of the Quality of Blasting

TAO Tiejun, SONG Jinquan (China) 70

Pulsed Power Technologies for Processing of Mineral Complexes: Theory and Applications

V. A. Chanturiya, I. Zh. Bunin (Russia) 74

2 Explosives and Initiation Techniques

Condensed Phase Explosions, Safety Distances, and Blast Resistance

B. Mohanty (Canada) 87

Energy Release Characteristics of Explosives and Their Impact on Blast Results

P. K. Singh, M. P. Roy, A. Sinha (India) 95

A New Principal Formula for the Determination of Explosive Strength in Combination



with the Rock Mass Strength	
<i>Agne Rustan (Sweden)</i>	104
Experimental Study on Energy Output Characteristics of Underwater Explosion for Emulsion Explosive	
<i>WANG Quan, SHEN Zhaowu, GUO Ziru, ZHANG Xianpei (China)</i>	114
Blasting Performance Evaluation vis-à-vis Energy Factor Based Selection of Explosives in Surface Mines	
<i>G. K. Pradhan, N. R. Thote (India)</i>	118
Effect of Moisture Content on MANFO Performance	
<i>LIU Liansheng, HU Yonghui (China)</i>	126
Improvement of Domestic Technology of Explosives Production in Kazakhstan	
<i>Cand. Tech. Sci. Tambiev P. G. (Kazakhstan)</i>	133
Powder Cooperated with Explosives	
<i>XIE Xinghua, DI Yunxin, YAN Xianrong, ZHOU Huisheng, ZHU Jing, YAN Shilong (China)</i>	136
Features of Excitation and Distribution of a Detonation of Charges of Emulsion bm in Boreholes	
<i>A. S. Derzhavets, N. L. Vyatkin, A. V. Sosnin (Russia)</i>	140
Experimental Study on the Initiated Reliability of Nonel Tube by Industrial Detonator	
<i>WANG Quan, SHEN Zhaowu, LI Zhimin, GUO Ziru (China)</i>	145
Investigation of Explosive Characteristics of ANFO Mixtures Based on the Fine-grained Porous AN as a Result of Pneumatic Loading	
<i>S. A. Kozyrev, A. V. Sokolov, E. A. Vlasova, V. Y. Fadeyev (Russia)</i>	150
New Method to Verify the Safety Distance of Commercial Electric Detonators	
<i>DU Bin, YAN Shilong, YAO Hongzhi, FENG Qingmei, LI Jinrong (China)</i>	154
Experimental Research on Underwater Explosion Energy in the Simulated Plateau Condition	
<i>HUANG Lin, ZHANG Li, GAO Yugang, XIONG Su, LI Xuejiao (China)</i>	159
Channel Effect of the Modified Powdery Mixture of Ammonium Nitrate and Fuel Oil	
<i>WU Chunping, LIU Liansheng, WANG Xuguang (China)</i>	163
Research on Induction Current of Bridge Wire of Industrial Electric Detonator using Non-Orthogonal FDTD Arithmetic	
<i>DU Bin, YAN Shilong, YAO Hongzhi, FENG Qingmei, LI Jinrong (China)</i>	169

3 Rock Blasting

Explosive Testing by Single Hole Blasting in Model SHB-MS and Full-Scale SHB-FS	
<i>Agne Rustan (Sweden)</i>	177
Theory and Practice of the Fragmentation Control of Rock Blasting	
<i>ZHENG Bingxu, LI Zhanjun, LIU Yi (China)</i>	188
Improvement of Blasting in Underground Development of Iron Ore Deposits of Siberia	
<i>S. D. Victorov, A. A. Eremenko, V. M. Zakalinsky (Russia)</i>	195
Experimental Investigation on Propagation Rule of Shock Wave Generated by Underwater Blasting	
<i>ZHAO Gen (China)</i>	199
Consideration for Shield TBM and NATM Method of Design VE in Korea-China-Japan Sea Botton Tunnel	
<i>Myung-seog Ahn, Sung-jin Kim (Korea)</i>	203
Research on Multi-functional Engineering Equipment for Blasting Excavation	
<i>ZHAO Baomin, LI Fulong, YANG Xusheng (China)</i>	209
Methodic for Determination of Blast Design Parameters, Taking into Consideration Rock Mass Joints and Blast Ability	
<i>Laikhansuren B., Nyamdorj D., Munhkdelder S., Jamsranjav L., Tsendjav Sh. (Mongolia)</i>	213
Research on the Key Technique for Explosive Mining of the Building Stone of Different Specifications	
<i>ZHENG Bingxu, CAI Jiande, LI Zhanjun, SONG Jinquan (China)</i>	217
Systems of Mineral Objects Gornotekhnologichesky Destruction and Prirodno-Technogenic	



Infringements of Their Structure	
<i>G. V. Sekisov, S. D. Victorov (Russia)</i>	222
Study of Tunnel Perimeter Blasting on Fracture Zones	
<i>GAO Fuqiang, HOU Aijun, YANG Xiaolin, LU Yaobang (China)</i>	229
Efficiency of Destruction of Rocky and Semirocky Rocks Under Transformed Gas-Permeable Shelter	
<i>E. B. Shevkun, A. V. Leschinsky, G. V. Sekisov, V. M. Zakalinsky (Russia)</i>	233
The Application of Artificial Neural Networks to Blasting Engineering	
<i>YAN Guojian, ZHOU Ming'an, LI Bihong, LI Shiliang (China)</i>	236
Rock Pre-Fracturing Effect on Performance of Blast Crushing	
<i>G. N. Volchenko, V. M. Seryakov, V. N. Fryanov (Russia)</i>	241
Rapid Blasting Excavation	
<i>XIE Xinghua, YAN Xianrong (China)</i>	247
Estimation of the Brittle Fracture Zone Generated by Concentrated Charge Blasting Near a Free Surface	
<i>Sher E. N., Mikhailov A. M. (Russia)</i>	250
Study of Blasting Seismic Effect on Fracture Zones	
<i>GAO Fuqiang, HOU Aijun, YANG Xiaolin, YANG Jun, ZHANG Zijian (China)</i>	255
Application Gas Generating Structure of Structures for Branch the Block Stone on Opencast Building Materials	
<i>Paramonov G. P., Kirsanov O. N., Kovalevskij V. N. (Russia)</i>	259
Research on Loosen Blasting Technology for Fully-Mechanized Mining Face Crossing Fault	
<i>CHEN Qiuyu, HUANG Wenyao (China)</i>	262
Application of Elongated Cumulative Charge Directed to Fracture of Rocks	
<i>Kovalevskii Vladimir Nikolaevich (Russia)</i>	265
Study of Chaotic Characteristics of Rock Breaking	
<i>DU Bin, YAO Hongzhi (China)</i>	268
Use of Weakened Charge in A Compensatory Chink, As A Way of Increase of Operating Ratio of A Borehole at Roadway Driving by Long Stopes in Soft and Viscous Breeds	
<i>Kovtun J. V. (Russia)</i>	270
Research on Calculation Method of Specific Charge in Bench Blasting	
<i>ZHOU Guisong (China)</i>	272
The Practice and Application of the Air-deck Charging Techniques for the On-site Mixed Emulsion Explosive Truck	
<i>RONG Guangfu, WANG Xingguo, YANG Shuguang, HUANG Tiefei, ZHAN Daozhen (China)</i>	276
The Technique Measure of Control Dynamite for the Blast Area of Careful Homework in the JDC	
<i>YIN Yanjun (China)</i>	281

4 Special Blasting and Demolition Blasting

Study on the Application of Blasting Technology to Against the Ice Jam of Yellow River	
<i>YANG Xusheng, TONG Zheng, SONG Changqing, LIANG Qiuxiang, XUE Peixing, YAN Junwei (China)</i>	287
Study of Cold Shock-Wave Extinguishing Engulfment and Its Phenomenon	
<i>JIANG Yaogang, SHEN Zhaowu, GONG Zhigang (China)</i>	292
Removals of a Top Part of Cast-in-situ Concrete Piles Utilizing Simplicity Charge Holder Blast System	
<i>Hak-Man Kim, Sang-Ho Cho, Jeung-Ryang Ahn, Yuich Nakamura, Kato Masatoshi, Katsuhiro Kaneko, Fukuda Daisuke, Moriya Kazuma, Seung-Kon Kim, Chul-Gi Suk (Korea)</i>	297
Demolition Blasting Technique for Directional Collapse in Segments of Building with Frame Construction	
<i>XIE Xianqi, JIA Yongsheng, LIU Changbang (China)</i>	301
Numerical Simulation on the Collapse Process of Port Silo under Demolition Blasting	
<i>YANG Jun, LI Shunbo, CHEN Dayong, HAN Di (China)</i>	305



Experimental Approach for Explosive Welding Interfacial Wave	
<i>HOU Fachen, ZHANG Chao, LIU Fuguo (China)</i>	310
Process Optimization of TA2/Q345B Explosive Composite Plate	
<i>X. W. Yin, J. R. Zhou, G. N. Rao (China)</i>	315
Experimental Investigation on Explosive Welding Titanium/Steel Clad Plate	
<i>ZHANG Yuejue, YANG Xusheng, LI Xiaojie, WANG Yong, XIAO Hui, ZHAO Enjun (China)</i>	320
Research on Firing Methods of Full Bore Perforation	
<i>LI Senmao, LIANG Rui (China)</i>	325
The Simulation of Interface Wave in Steel Explosive Welding	
<i>LI Xiaojie, MO Fei (China)</i>	329
Study and Practice on Rock Mass Cofferdam Blasting Demolition of Pumped Storage Power Station	
<i>ZHAO Gen, WU Xinxia (China)</i>	333
Disjoint Bidirectional Folding Blasting Demolition of Harbin Longhai Building	
<i>XU Liren (China)</i>	337
Old Nan'an Bridge Controlled Blasting Demolition Design and Construction	
<i>LI Mingren (China)</i>	342
Detonation Synthesis of Carbon-encapsulated Alloy Nanocomposite Materials	
<i>LUO Ning, FEI Honglu, LI Xiaojie (China)</i>	348
<hr/>	
5 Blasting Vibration and Safety	
Information Management for Improved Blasting Operations and Environmental Control	
<i>Sushil Bhandari (India)</i>	355
Impact of Elevation on Blasting Vibration Frequency in an Open Pit	
<i>FEI Honglu, XIA Yingjie, WANG Suning (China)</i>	361
Assessment of the Structural Effects of Blasting by the Analysis of Motion Measurements	
<i>Adrian J. Moore, Alan B. Richards (Australia)</i>	365
Blasting Vibration Frequency Control Technology Research and Application	
<i>SHI Fuqiang, ZHOU Bin (China)</i>	373
On the Database of Accidents by Blasting	
<i>Kunihisa Katsuyama (Japan)</i>	376
Study on Shallow Tunnel Blasting Excavation and Vibration Controlling	
<i>GAO Wenxue, YAN Pengcheng, LI Zhixing, WEI Pengwei, HOU Binghui (China)</i>	379
Model to Estimate the Damage of Reinforced Concrete Dams Subjected to Underwater Explosions	
<i>Yumin Li, Ettore Contestabile, Bert von Rosen, Abass Braimah (Canada)</i>	383
Study on Blast-induced Cumulative Damage of Tunnel Surrounding Rock and Its Application	
in Determining Allowed Safety Distance	
<i>MA Haipeng, ZHOU Ming'an, LI Lifeng (China)</i>	388
Study on Blasting Effect with Pre-Assessment Borehole Status by Inserting Real-time Bore Hole	
Endoscope Verification	
<i>D. W. Kang, W. H. Hur (Korea)</i>	392
Numerical Simulation on Vibration Response Characteristics of Masonry Structures under	
Blasting Seismic Wave	
<i>WANG Haibo, LUAN Ruixuan, XU Ying (China)</i>	398
Characteristics of Impact-induced Ground Vibration and Predictive Method	
<i>Chang-Ha Ryu, Byung-Hee Choi, Ju-Hwan Jeong, Hyo-Jin Kim (Korea)</i>	403
Monitoring and Analyses on Blasting Vibration of a Thousand-ton Charge Level Long-hole	
Casting Blasting Project	
<i>YANG Nianhua, WANG Pingliang, ZHANG Le (China)</i>	408



Study on the Blast Vibration Produced by Mining Activity and Safety Criteria	
<i>Byung-Hee Choi, Chang-Ha Ryu, Ju-Hwan Jeong (Korea)</i>	413
Characteristics of Blasting Vibration Response Spectrum Analysis and Its Application	
<i>CHEN Chao, YAN Guobin, ZHANG Yabin, WANG Xiaolei, LI Zhanjin (China)</i>	417
An Instance on a Vibration Reduction in a Tunnel Blasting by Controlling the Burden and Charge	
<i>Choo-Won Kang, Ha-Rim Song, Yeon-Ho Won, E-Hwan Oh (Korea)</i>	424
Wavelet Packet Analysis of Blasting Vibration Caused by Small Interval Tunnel of Large Span	
<i>JIANG Lili, LIN Congmou (China)</i>	432
Change of the Maximum Mass Speed in a Wave of Pressure	
<i>N. N. Kazakov, A. V. Shlyapin (Russia)</i>	438
Exploration and Practice of the Popularization of Professional Blast Service Modes in Beijing	
<i>TAN Quan, ZHANG Xinning (China)</i>	440
Increase of Reliability of the Estimation of Seismic Safety of Ground Constructions of the Mountain Enterprises, Leaders Explosive Works	
<i>Kholodilov A. N. (Russia)</i>	445
Precise Analysis of Full-band Time-frequency Characteristic of Blasting Vibration Based on Wavelet Packet Transform	
<i>YAN Junwei, LIANG Qiuxiang, DU Fugui, YANG Xusheng (China)</i>	448
About One Approach to Calculation of Pipelines on Seismic Loads	
<i>A. P. Gospodarikov (Russia)</i>	453
Blasting Demolition of Brick & Concrete Office Building under Complex Environment	
<i>LIANG Rui, LIU Guojun, LI Senmao (China)</i>	455

Blasting Theory



Phenomenon of the Emission of Microparticles under Quasi-Static Loading of Rocks

S. D. Victorov, V. N. Odintcev, A. N. Kochanov, A. A. Osokin

(Institute of Comprehensive Exploitation of Mineral Resources, Russian Academy of Sciences, Russia)

ABSTRACT: The article presents the results of experimental studies on the phenomenon of microparticle emission from the free surface of rock samples with a through-hole under uniaxial compression as a stress concentrator. The technique of experimental studies with the use of laser spectroscopy of particle sizes in the air has been developed. As a result of experimental studies the formation of microparticles and their detachment from the free surface at a certain level of stresses were documented. The phenomenon of microparticle emission is observed in samples of rocks with different physical and mechanical properties (dolomite, granite, limestone, and samples of concrete). Quantitative estimates were made of the emission of sub-micron particles in the range of 0.3 ~ 5.0 microns, depending on the operating voltage. Disperse composition of the particles, the dynamics of their formation depend on the petrographic characteristics of rocks, their degree of tension, and loading parameters. The quantity of particles generated during the testing of samples representing one type of rock in some cases differs significantly. This is explained by varying degrees of microfracturing of the samples, which presence predetermines the course of deformation and disintegration of the samples. In the emission of particles there is a mode of exacerbation—a dramatic increase of emission intensity, which precedes the disintegration of the sample. In rock disintegration control the dramatic enhancement of particle emission can serve an indicator of the forthcoming macrodisintegration. The research results suggest a conclusion that one of the mechanisms of sub-micron particle formation in the course of disintegration can be explained by the surface detachment of microscopic fragments. The established patterns and dependences have served a basis for the development of a radically new instrumental method for predicting man-induced phenomena resulting from the uncontrolled disintegration of the rock mass. A method has been developed for the registration of fine particles with a laser aerosol spectrometer during the deformation and disintegration of rocks.

KEYWORDS: rocks; stress-strain state; emission of microparticles; laser spectrometry

Today, the aspects of sub-micron disintegration of rocks acquire particular importance, and it dictate the necessity of the assessment of conditions for the formation of sub-micron mineral particles in the processes of mineral mining^[1,2]. On the one hand, rock disintegration facilitates its decomposition and separation of components in the course of mineral processing. On the other hand, the intensive man-induced disintegration of rocks results in the formation of ultra-fine particles that produces negative environmental effect. Besides, with the deformation and disintegration of rocks the formation of ultrafine particles characterizes the conditions of these processes that is a basis for the development of radically new methods of rock mass state control. The earlier studies^[3-5] experimentally proved the existence of such a phenomenon as sub-micron particle emission in conditions of uniaxial compression of samples. The objective of this study is the research into objective laws governing the emission of sub-micron particle from the surface of rocks under uniaxial compression.

The following rock samples were investigated: dolomite, granite, limestone, urtite. The samples were of cubic (with an edge of 40 ~ 50mm) or cylinder (38mm diameter and 45 ~

50mm height) shape. The rock samples were exposed to uniaxial loading in a hydraulic press with a certain load setting and concurrent registration of sub-micron mineral particle emission.

Based on the results of experiments Fig. 1 shows the distribution of sub-micron particle emission from different rock samples within a 0.3 to 5.0 micron range.

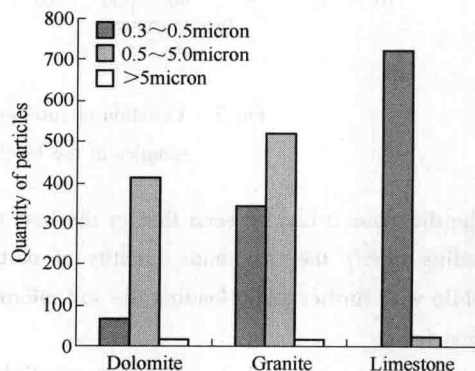


Fig. 1 Distribution of the emission of sub-micron particles for different rock samples at the stress level of 0.5 ~ 0.8 σ_{comp}^*



The results of experiments show a significant increase of particle emission on reaching a certain level of stresses. Fig. 2 reflects the distribution of the quantity of particles for dolomite (a) and urtite (b) samples depending on the relative level of loading.

From these diagrams it can be seen that at the relative level of loading $\sigma_{\text{comp}}/\sigma_{\text{comp}}^* < 0.6$ either no particle is observed or their quantity is negligible. The palpable in-

crease of emission for these samples appears at a relative level of $0.8 \sigma_{\text{comp}}^*$, where σ_{comp}^* is the ultimate compression strength, MPa.

It has been proved experimentally that the maximum quantity of particles is formed at the moment of loading, i. e., with the change of the stress-strain state. Fig. 3 shows the variation of sub-micron particle emission with time for granite (a) and urtite (b) samples.

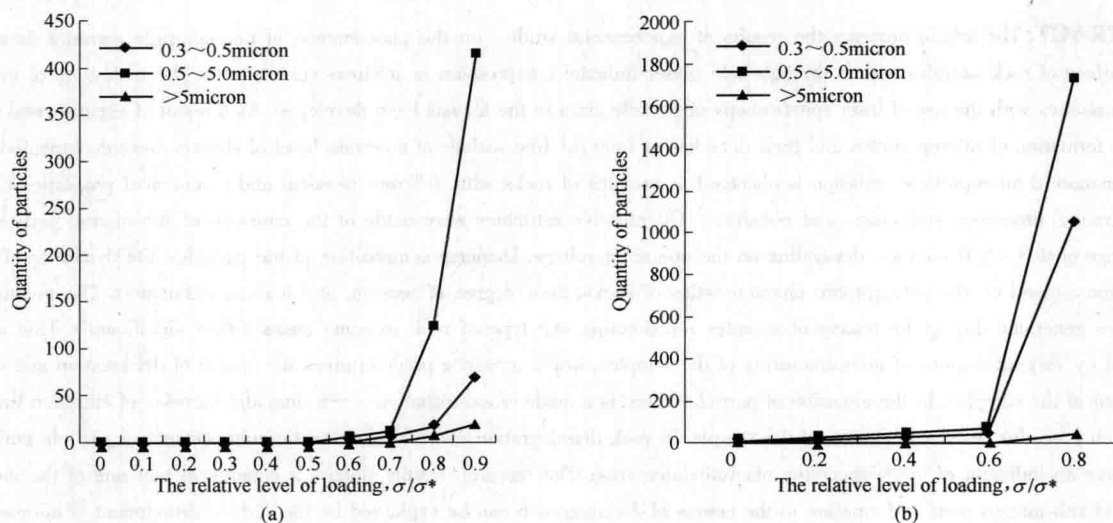


Fig. 2 Distribution of sub-micron particles with the loading of dolomite (a) and urtite (b) samples depending on the relative level of loading

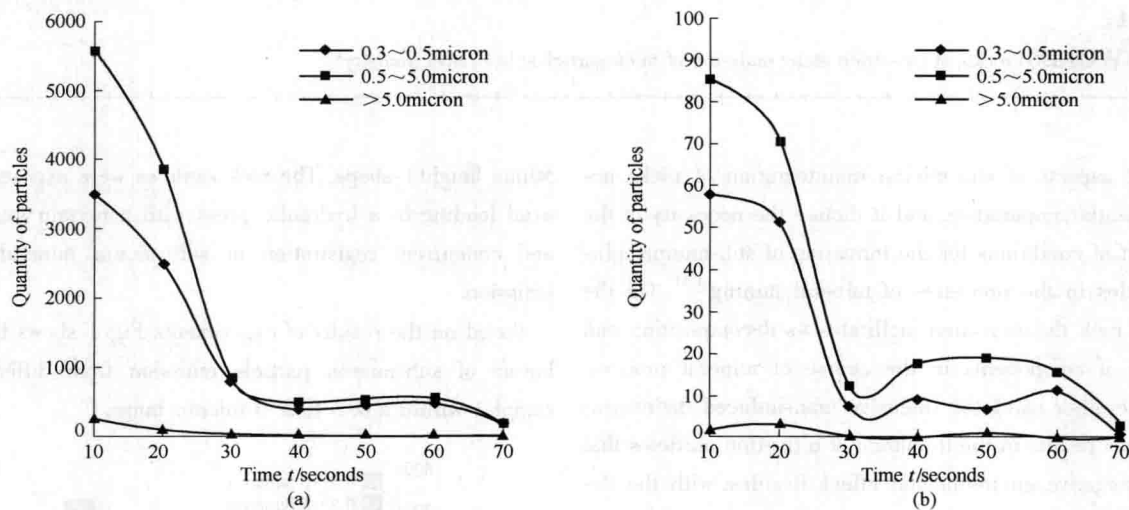


Fig. 3 Variation of sub-micron particle emission in granite and urtite (b) samples at the level of compression stress $\sigma_{\text{comp}} = 0.6\sigma_{\text{comp}}^*$

From the diagrams it can be seen that in the first ten seconds (loading time) the maximum quantity of particles is formed, while with further static loading the sub-micron particle emission fades.

It is important to note that sub-micron particle emission may significantly vary for one and the same rock type. This can be explained by a varying degree of sample microfracturing, which presence predetermines the course

of deformation and disintegration processes. Fig. 4 reflects the distribution of particles for two red granite samples. From Fig. 4 it can be seen that at a relative level of loading $\sigma_{\text{comp}}/\sigma_{\text{comp}}^* = 0.6$ the quantity of particles is rather small. With further increase of load the dramatic growth is observed of sub-micron particle emission, which proves the formation of new and growth of the existing microfractures.