



Sustainable Low Impact Mining solution for exploitation of small mineral deposits based on advanced rock blasting and environmental technologies

SLIM DELIVERABLE D8.5

SCIENTIFIC PUBLICATIONS AND PAPERS (1)

Version 3.0

Summary:

This document lists all already issued and planned scientific publications and papers and shows their relation to the project's topic.

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SLIM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 730294.

| | | | |
|-----------------------------|--------|---|-------------------------------|
| Lead beneficiary: | | MINPOL | |
| Other beneficiaries: | | | |
| Due date: | | 2019-05-31 (M30) | |
| Nature: | | (R) - Report (See project Annex 1 - part A) | |
| Diffusion | | (PU) – Public | |
| Revision history | Author | Delivery date | Summary of changes |
| Version 1.0 | MINPOL | 2019-05-17 | First draft |
| Version 2.0 | MINPOL | 2019-05-31 | Completed and amended version |
| Version 3.0 | MINPOL | 2019-06-06 | Amended after rejection |

| Approval status | | | |
|--------------------------------|-------------|-------------|------------------|
| Function | Name | Date | Signature |
| Deliverable responsible | MINPOL | | |
| WP leader | MINPOL | | |
| Project leader | UPM | | |

| Diffusion List | |
|---------------------------|---------------|
| Name, partner name | e-mail |
| PUBLIC | N/A |

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1. PURPOSE

In the context of dissemination and communication activities about the SLIM project and its results, it makes sense to provide an overview about the already issued scientific publications and papers about project topics. This should also include the planned ones at the time of this deliverable (project month 31).

At the end of the project, a similar report (project deliverable D8.6) will be issued containing a complete list of all scientific publications and papers that the project has produced.

2. SCIENTIFIC PUBLICATIONS AND PAPERS

The following list comprises the scientific publications and papers that have been issued already by project partners in the course of the project as of April 2019 (project month 30). It also includes those publications and papers that are already issued and will be published in the near future.

It has to be mentioned that all publications and papers are "Open Access".

Each publication or paper is associated with at least one particular project topic. This association is indicated so that the relation to a project topic becomes more obvious. Further to this, the Annex to this document contains abstracts of the publications as far as available. This should assist the reader to get a quick overview of the content.

| No | Title | Author(s) | Title of journal/proc./book | Number, date or freq. of journal/p roc./book | DOI | Repository link | Relation to project topic |
|----|--|--|--|--|---------------------------------|---|-------------------------------------|
| 1 | Prioritized multi-view stereo depth map generation using confidence prediction | Christian Mostegel, Friedrich Fraundorfer, Horst Bischof | ISPRS Journal of Photogrammetry and Remote Sensing | 1/2018 | 10.1016/j.isprsjprs.2018.03.022 | http://arxiv.org/abs/1803.08323 | Rock mass characterization software |
| 2 | Scalable Surface Reconstruction from Point Clouds with Extreme Scale and Density Diversity | Christian Mostegel, Rudolf Prettenthaler, Friedrich Fraundorfer, Horst Bischof | 2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR) | 2017 | 10.1109/CVPR.2017.268 | https://arxiv.org/abs/1705.00949 | Rock mass characterization software |
| 3 | SLIM: Technology for blasting to improve mining | J.A. Sanchidrián | Fragblast 12 | 2018 | | | Project overview |
| 4 | Application of an in-house MWD system for quarry blasting | J. Navarro, P. Segarra, J.A. Sanchidrián, R. Castedo, A.P. Pérez Fortes, M. Natale, L.M. López | Fragblast 12 | 2018 | | | New application for quarry blasting |
| 5 | Emulsion characterization with cylinder test and JWL parameters determination | L.M. López, R. Castedo, J.A. Sanchidrián, M. Natale, A. P. Santos, J. Navarro, M. Chiquito | Fragblast 12 | 2018 | | | Rock – emulsion interaction |
| 6 | Comparison between coupled SPH-FEM numerical model of a single hole blast and experimental test | M. Natale, R. Castedo, L. M. López, J. A. Sanchidrián, P. Segarra, A. P. Santos, J. Navarro | Fragblast 12 | 2018 | | | Blast design software |
| 7 | Das europäische Horizon 2020-Forschungsprojekt „Sustainable Low Impact Mining – SLIM | Finn Ouchterlony, Nikolaus A. Sifferlinger, Angelika Brechelmacher | BHM Berg- und Hüttenmännische Monatshefte | 163/2 | 10.1007/s00501-018-0701-4 | https://link.springer.com/article/10.1007%2Fs00501-018-0701-4 | Project overview |
| 8 | Entwicklung eines Systems zur Auskleidung von Sprengbohrlöchern beim Einsatz von losem Emulsions Sprengstoff | Thomas Seidl, Christian Heiss, Maximilian Föger | BHM Berg- und Hüttenmännische Monatshefte | 163/4 | 10.1007/s00501-018-0724-x | http://link.springer.com/10.1007/s00501-018-0724-x | Rock – explosives interaction |

| | | | | | | | |
|----|---|--|--|------------------|-------------------------------|---|---------------------------------------|
| 9 | Calibration and validation of reactive flow model parameters for an emulsion explosive | C. Yi, U. Nyberg and D. Johansson | Fragblast 12 | 2018 | | | Rock – explosives interaction |
| 10 | Numerical investigation for timing effects on fragmentation based on a coupled FEM-BPM-PBM model | C. Yi, D. Johansson and U. Nyberg | Fragblast 12 | 2018 | | | Rock mass characterization software |
| 11 | UAVs zur Qualitätssteuerung im Tagebau | Alexander Tscharf, Gerhard Mayer, Friedrich Fraundorfer, Andreas Gaich | BHM Berg- und Hüttenmännische Monatshefte | 163/4 | 10.1007/s00501-018-0725-9 | http://link.springer.com/10.1007/s00501-018-0725-9 | Rock mass characterization software |
| 12 | Der Einsatz unbemannter Flugsysteme zur Charakterisierung von gesprengtem Haufwerk | A. Tscharf, C. Mostegel, A. Gaich, G. Mayer, F. Fraundorfer, H. Bischof | 18. Geokinematischer Tag des Institutes für Markscheidewesen und Geodäsie am 10. und 12. Mai 2017 in Freiberg | Bd. 2017-1 | | http://nbn-resolving.de/urn:nbn:de:bsz:105-qucosa-228495 | Rock mass characterization software |
| 13 | Sustainable Blasting Strategies for Long-term Mining Projects | P. Couceiro, M. Lopez Cano, A. Jafa, S. Burgada & J. Fresnillo | 45th Annual Conference on Explosives and Blasting Technique | Jan. 27–30, 2019 | | https://www.isee.org/conferences/2019-conference | Economic and environmental assessment |
| 14 | Diameter-Effect Modelling in Unconfined Steady Non-ideal Detonations | P. Couceiro | 45th Annual Conference on Explosives and Blasting Technique | Jan. 27–30, 2019 | | https://www.isee.org/conferences/2019-conference | Rock – explosives interaction |
| 15 | Effects of in-situ stresses on the fracturing of rock by blasting | Changping Yi, Daniel Johansson, Jenny Greberg | Computers and Geotechnics | 104 | 10.1016/j.compgeo.2017.12.004 | | Rock – explosives interaction |
| 16 | Estimation of Jones-Wilkins-Lee parameters of emulsion explosives using cylinder tests and their numerical validation | R. Castedo, M. Natale, L.M. López, J.A. Sanchidrián, A.P. Santos, J. Navarro, P. Segarra | International Journal of Rock Mechanics and Mining Sciences | 112 | 10.1016/j.ijrmm.2018.10.027 | https://www.sciencedirect.com/science/article/pii/S1365160918302776 | Rock – explosives interaction |
| 17 | Automatic Muck Pile Characterization from UAV Images | Fabian Schenk, Friedrich Fraundorfer | Unmanned Aerial Vehicles in Geomatics | 6/2019 | | | Rock mass characterization software |
| 18 | RESLAM: A real-time robust edge-based SLAM system | Fabian Schenk, Friedrich Fraundorfer | International Conference on Robotics and Automation | 5/2019 | | | Rock mass characterization software |
| 19 | UAV-Anwendungen im Bergbau-Modellversuche als Beitrag zur photogrammetrischen Forschung und Entwicklung | Alexander Tscharf, Fabian Schenk, Gerhard Mayer, Friedrich Fraundorfer, Horst Bischof | 19. Geokinematischer Tag des Institutes für Markscheidewesen und Geodäsie am 17. und 18. Mai 2018 in Freiberg, Germany | 5/2018 | | http://nbn-resolving.de/urn:nbn:de:bsz:105-qucosa-237262 | Rock mass characterization software |
| 20 | Holistische Erfassung und Beurteilung von unterschiedlichen Einflussfaktoren auf das Sprengergebnis | Seidl, Thomas | Kolloquium Bohr- und Sprengtechnik Clausthal, Germany | Jan. 30-31, 2019 | | https://www.bergbau.tu-clausthal.de/veranstaltungen/bus2019/ | Blast design software |

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|----|---|---|---------------------------|---------------|--|--|-----------------------|
| 21 | Seismic velocities from traveltime tomography at the iron ore mine Mt. Erzberg, Austria | Cornelia Tauchner, Franziska Reiner, Bernd Trabi, Josep de la Puente, and Florian Bleibinhaus | EGU General Assembly 2019 | EGU2019-15195 | | | Blast design software |
| 22 | Passive Imaging of Active Source Data: Seismic Ambient Noise Interferometry in a Mining Environment | Deepankar Dangwal, Michael Behm, and Florian Bleibinhaus | EGU General Assembly 2019 | EGU2019-11898 | | | Blast design software |

Table 1: SLIM Scientific Publications and Papers

The list shows that the already produced scientific publications of the SLIM project cover primarily the project topics dealing with basic research of the problems associated with the project. This means that drawing conclusions from this and final results including their economic and ecological assessments are expected for the final third of the project lifetime.

A full list of all project publication will be issued at the end of the Project in project deliverable D8.6.

ANNEX : ABSTRACTS OF SCIENTIFIC PUBLICATIONS AND PAPERS

Paper No 1

Prioritized multi-view stereo depth map generation using confidence prediction

Abstract

In this work, we propose a novel approach to prioritize the depth map computation of multi-view stereo (MVS) to obtain compact 3D point clouds of high quality and completeness at low computational cost. Our prioritization approach operates before the MVS algorithm is executed and consists of two steps. In the first step, we aim to find a good set of matching partners for each view. In the second step, we rank the resulting view clusters (i.e. key views with matching partners) according to their impact on the fulfilment of desired quality parameters such as completeness, ground resolution and accuracy. Additional to geometric analysis, we use a novel machine learning technique for training a confidence predictor. The purpose of this confidence predictor is to estimate the chances of a successful depth reconstruction for each pixel in each image for one specific MVS algorithm based on the RGB images and the image constellation. The underlying machine learning technique does not require any ground truth or manually labeled data for training, but instead adapts ideas from depth map fusion for providing a supervision signal. The trained confidence predictor allows us to evaluate the quality of image constellations and their potential impact to the resulting 3D reconstruction and thus builds a solid foundation for our prioritization approach. In our experiments, we are thus able to reach more than 70% of the maximal reachable quality fulfilment using only 5% of the available images as key views. For evaluating our approach within and across different domains, we use two completely different scenarios, i.e. cultural heritage preservation and reconstruction of single family houses.

<https://www.sciencedirect.com/science/article/abs/pii/S092427161830087X>

Paper No 2

Scalable Surface Reconstruction from Point Clouds with Extreme Scale and Density Diversity

Abstract

In this paper we present a scalable approach for robustly computing a 3D surface mesh from multi-scale multi-view stereo point clouds that can handle extreme jumps of point density (in our experiments three orders of magnitude). The backbone of our approach is a combination of octree data partitioning, local Delaunay tetrahedralization and graph cut optimization. Graph cut optimization is used twice, once to extract surface hypotheses from local Delaunay tetrahedralizations and once to merge overlapping surface hypotheses even when the local tetrahedralizations do not share the same topology. This formulation allows us to obtain a constant memory consumption per sub-problem while at the same time retaining the density independent interpolation properties of the Delaunay-based optimization. On multiple public datasets, we demonstrate that our approach is highly competitive with the state-of-the-art in

terms of accuracy, completeness and outlier resilience. Further, we demonstrate the multi-scale potential of our approach by processing a newly recorded dataset with 2 billion points and a point density variation of more than four orders of magnitude - requiring less than 9GB of RAM per process.

<https://arxiv.org/abs/1705.00949>

Paper No 3

SLIM: Technology for blasting to improve mining

Abstract

SLIM (Sustainable Low Impact Mining) is a cooperative research initiative by a group of academic and industrial organizations in Europe. SLIM addresses a number of technical and scientific topics in rock blasting. Among these, numerical modelling of non-ideal detonation, automatization of rock mass characterization, integration of emerging technologies – ground-based and UAV-borne photogrammetry, LiDAR and MWD, among others – into fragmentation prediction and measurement. The project includes monitoring of the processing plant in order to assess the influence of blasting in two mining operations, an iron ore medium-size mine and a small fluorite mine. Environmental affections from blasting are being studied: seismic far field (vibrations) modelling, dust emissions and nitrates leaching. The project started November 2016 with a duration of four years. An overview of the project is presented and some of its highlights are described.

Paper No 4

Application of an in-house MWD system for quarry blasting

Abstract

The high cost and the difficulty of installing the drill monitoring system commonly known as MWD (Measurement While Drilling), especially in older drills, restrain the use of this technology in numerous small quarries and mines. An in-house MWD system is presented here as a low-cost alternative that allows monitoring the information of any rig while drilling. The digitization and automatic sampling of the analogical signals of the sensors involved in the operation have been carried out for their logging and retrieval. The prototype has been installed in a top hammer rotary-percussive vertical rig and has been tested in the monitoring of six blastholes. The MWD parameters have been combined, considering their variation and magnitude, to obtain a fracturing index to be used as an engineering tool for geotechnical rock characterization. The index has been assessed against photographic records of the blastholes walls made with an optical televiewer.

Paper No 5

Emulsion characterization with cylinder test and JWL parameters determination

Abstract

A microspheres-sensitized emulsion, to be used in blasting tests in the SLIM project, is characterized by means of the cylinder test. This test measures the expansion of a copper tube after the detonation of an explosive charge inside. A total of 8 tests have been made with two diameters (50 mm and 100 mm) and two densities (1.18 g/cm³ and 1.03 g/cm³) in a 2×2×2 test matrix. The influence of density and diameter on the expansion energy has been studied, showing that the density affects but the diameter apparently does not, which suggests that this explosive, at the densities studied, behaves close to ideal already at 50 mm. The Jones–Wilkins–Lee (JWL) equation of state parameters have been obtained for this emulsion at the densities and diameters tested. These parameters have been validated with LS-DYNA Lagrangian models, with an outstanding correlation between the model and the test results. The JWL parameters are being used for the explosive modelling in rock blasting tests simulations.

Paper No 6

Comparison between coupled SPH-FEM numerical model of a single hole blast and experimental test

Abstract

This paper aims to provide a coupled finite element method (FEM) and smoothed particle hydrodynamics (SPH) 3D approach capable of reproducing the acceleration and stress wave velocity induced by a single blast hole. The numerical simulations are carried out using the software LS-DYNA and have been validated by experimental tests during the EU project SLIM. In the proposed approach, SPH is used to simulate large deformation of the explosive and stemming, while the FEM is adopted to capture the response of the rock. In the present study, the Riedel-Hiermaier-Thoma constitutive model is used for rock (a metamorphic rock called mylonite) while the Jones–Wilkins–Lee (JWL) model is used to describe the explosive expansion (emulsion type), the constants determined from cylinder tests carried out in the project. The SPH kernel form used is the fluid particle with renormalization approximation in order to obtain better results when materials with very different stiffness are used (products of detonation and rock). The interaction of the SPH particles and FEM elements was modelled by the automatic nodes-to-surface contact. The good agreement between numerical and experimental results (measured with accelerometers, seismograph and geophone) indicate that the coupled SPH-FEM method can be applied to predict the near field stresses in rock from blasting.

Paper No 7

Das europäische Horizon 2020-Forschungsprojekt „Sustainable Low Impact Mining – SLIM“

Abstract

Die wesentlichen wirtschaftlichen, technologischen und umweltmäßigen Herausforderungen kleiner Bergbaubetriebe beinhalten die Reduktion der hohen Investmentkosten, des anfallenden Taubmaterials und der Halden oder Schlammbecken sowie die Verringerung der Einflüsse auf die Umwelt. Gleichzeitig soll die Flexibilität, der Automationsgrad und die Sicherheit der Betriebsabläufe verbessert werden. Das europäische Horizon 2020 Forschungsprojekt „Nachhaltige, umweltfreundliche Bergbau-Methode zur Gewinnung kleiner Lagerstätten durch fortschrittliche Sprengtechnologien und Umwelttechnologien – SLIM“ begann im November 2016, hat eine Dauer von 48 Monaten und ein Budget von 6.979.200€. SLIM zielt auf die Entwicklung einer kosteneffizienten und nachhaltig selektiven Bergbaumethode, basierend auf nicht-linearer Gesteinszerkleinerung durch neue Sprengplanungsmodelle. Dabei sollen Staub, Vibrationen und Nitrat-Leckage reduziert werden. Durch eine neue Generation von Sprengstoffen und eine fortschrittliche Sprengplanungssoftware, die verbesserte Rock Mass-Charakterisierung und Zerkleinerungsmodelle bietet, soll die Sprengwirkung optimiert und die Umwelteinflüsse reduziert werden.

<https://link.springer.com/article/10.1007/s00501-018-0701-4>

Paper No 8

Entwicklung eines Systems zur Auskleidung von Sprengbohrlöchern beim Einsatz von losem Emulsionssprengstoff

Abstract

Der Einsatz von vor Ort sensibilisiertem Pumpsprengstoff bietet gegenüber patroniertem Sprengstoff Vorteile hinsichtlich Sicherheit, Arbeitsabläufen, Lagerhaltung und Transport. Klüfte und Hohlräume mit Verbindung zum Bohrloch werden allerdings ebenfalls mit Sprengstoff gefüllt, wodurch keine homogene Ladesäule besteht. Der somit unkontrollierte Energieeintrag ins Gebirge erhöht das Risiko von Steinflug und beeinflusst die Erschütterungs- und Lärmemissionen negativ. Durch unvollständige Detonation im Hauwerk verbleibende Sprengstoffreste können Nitratemissionen verursachen.

https://www.researchgate.net/publication/323496494_Entwicklung_eines_Systems_zur_Auskleidung_von_Sprengbohrlochern_beim_Einsatz_von_losem_Emulsionssprengstoff

Paper No 9

Calibration and validation of reactive flow model parameters for an emulsion explosive

Abstract

A series of tests for a pure emulsion explosive were carried out with PVC confinement to obtain the velocity of detonation (VoD) and the curvature of the detonation front for different charge diameters. The burning process of the pure emulsion explosive has been modelled with a reactive flow model in LS-DYNA code. The parameters in the burning rate function were calibrated with the detonation velocities and the front curvature radii from the tests. The calibrated parameters were used to predict the VOD and the detonation front curvature radii for the emulsion explosive with mortar confinement. The results indicate that both the VoDs and the detonation front curvature radii from numerical modelling are in good agreement with the experimental results for big charge diameters. For small charge diameters, the predicted VoDs are in good agreement with the experimental results while the differences between the predicted and the experimental detonation front curvature radii are obvious.

Paper No 10

Numerical investigation for timing effects on fragmentation based on a coupled FEM-BPM-PBM model

Abstract

A series of small-scale laboratory tests were carried out to investigate the effects of short delay times on fragmentation. The aim is to test the hypothesis that improve fragmentation through stress wave superposition. These tests have subsequently been modelled using a coupled FEM-BPM-PBM model in LS-DYNA code. In the model, the remaining rock is represented by a finite element model (FEM) and the rock to be blasted is represented by a bonded particle model (BPM). The detonation of explosive is described with a particle blast method (PBM). The fragment size distribution was obtained with a code developed in Perl programming language. The numerical results showed that although the short delay times induced improved fragmentation compared to the simultaneous initiation, the longer delay times also resulted in improved fragmentation, implying that stress wave superposition may not be the primary factor governing fragmentation.

Paper No 11

UAVs zur Qualitätssteuerung im Tagebau

Abstract

Die erreichte Zerkleinerung und die Form des Hauwerks sind die beiden wichtigsten Ergebnisse einer Tagbausprengung. Schnelle Informationen über die Eigenschaften des gesprengten Hauwerks ermöglichen eine zielgerichtete und effiziente Produktionsplanung und Kenntnisse über die erreichte Zerkleinerung ermöglichen außerdem Anpassungen in der weiteren Zerkleinerungskette. Durch den Einsatz von UAVs (unmanned aerial vehicles) gemeinsam mit modernen Algorithmen aus dem Bereich Computer Vision und des maschinellen Lernens soll

eine schnelle Erfassung und Interpretation der Daten bei gleichzeitiger Integration in die herkömmlichen betrieblichen Abläufe ermöglicht werden. Im vorliegenden Beitrag wird einerseits auf den relevanten Stand des Wissens und der Technik eingegangen und andererseits werden die verfolgte Stoßrichtung bei der Systementwicklung dargelegt sowie erste Arbeiten präsentiert.

<https://link.springer.com/article/10.1007%2Fs00501-018-0725-9>

Paper No 12

Der Einsatz unbemannter Flugsysteme zur Charakterisierung von gesprengtem Haufwerk

Abstract

The fragmentation and the shape of the muck pile are the two major outcomes of open pit mine and quarry blasts. Fast information about the muck pile properties will help to improve the production scheduling and furthermore this information could be used to optimize the blasting patterns of future production blasts. The combined use of unmanned aerial vehicles (UAVs) and modern machine learning and computer vision systems offers a new way of acquiring spatial data to determine on-site fragment size distribution, while at the same time enabling integration into common work flows and mitigating the weaknesses of ground-based systems with special regard to completeness and representativeness. In the present paper, we will discuss the relevant related work, present the planned path for system development and give examples of first work.

[http://tubaf.qucosa.de/landing-page/?tx_dlf\[id\]=http%3A%2F%2Ftubaf.qucosa.de%2Fapi%2Fqucosa%253A23149%2Fmets](http://tubaf.qucosa.de/landing-page/?tx_dlf[id]=http%3A%2F%2Ftubaf.qucosa.de%2Fapi%2Fqucosa%253A23149%2Fmets)

Paper No 13

Sustainable Blasting Strategies for Long-term Mining Projects

n/a

Paper No 14

Diameter-Effect Modelling in Unconfined Steady Non-ideal Detonations

Abstract

Since explosives are the source of all energy used for rock blast fragmentation and heave, multidimensional effects in the detonation driving zone become essential to better describe the detonation process. In order to use the explosive as an energy source-information for more realist blasting performance simulations, a simple and effective modelling strategy is desirable. Facing this challenge, an engineering approach to two-dimensional unconfined non-ideal detonation is proposed. Based on the elliptical construction of the shock locus, the model combines the axial cylindrical stick Q1D solution with some additional limiting conditions to determine the sonic edge of the charge. For a given set of rate law parameters and velocity of

detonation, a complete axial solution is firstly computed through the Q1D model. From this solution, a vital relationship between the axial shock curvature with the shock shape parameters can be established. Once this relationship is found, the problem simply reduces in finding the shock shape parameters subject to the sonic edge condition. As a result of this calculation, the corresponding charge diameter can be found. Consequently, the proposed model can map the diameter-effect curve by relating the unconfined velocity of detonation with its corresponding diameter. Finally, because of its low computation cost, the proposed engineering approach can be also used for characterizing the rate law parameters by fitting to data from unconfined detonation experiments.

https://www.researchgate.net/publication/331132593_Diameter-Effect_Modelling_in_Unconfined_Steady_Non-Ideal_Detonations

Paper No 15

Effects of in-situ stresses on the fracturing of rock by blasting

Abstract

Blasting is widely applied in deep rock excavation. The effect of in-situ stresses on the fracturing of rock due to blasting was investigated. A theoretical model was used to explain the effect mechanism of in-situ stresses on crack propagation due to blasting. Four cases with different in-situ stress conditions were numerically investigated. The numerical results indicate that the crack propagation is governed by the blast load in the vicinity of the blasthole while the high in-situ stresses can influence the crack propagation in the far-field. The crack propagation trends towards the direction in which the high initial pressure is applied.

<https://www.sciencedirect.com/science/article/pii/S0266352X17303373?via%3Dihub>

Paper No 16

Estimation of Jones-Wilkins-Lee parameters of emulsion explosives using cylinder tests and their numerical validation

Abstract

A microspheres-sensitized emulsion explosive, to be used in rock blasting tests, is characterized by means of the cylinder test. This test measures the expansion of a copper tube upon detonation of an explosive charge inside. Eight cylinders tests have been made with two different diameters (50 mm and 100 mm) and two different densities (1180 kg/m³ and 1030 kg/m³) in a 2 × 2 × 2 test matrix. The expansion energy is affected by the density but not by the test diameter, which suggests that this explosive, at the densities studied, behaves close to ideal already at 50 mm. The explosive velocity of detonation had been also measured within the trials. In addition, velocities of detonation were measured in six production blasts and reported here. The Jones–Wilkins–Lee (JWL) equation of state parameters have been obtained for this emulsion at the densities and diameters tested. The calculation method includes a radial expansion function, with a non-zero initial velocity at the onset of the expansion. The equations

reflecting the CJ state conditions and the measured expansion energy were solved for the JWL parameters by a non-linear least squares scheme. These parameters have been validated with three different LS-DYNA models (Lagrangian-Lagrangian, Smooth Particle Hydrodynamic-Lagrangian, Arbitrary Lagrangian Eulerian-Lagrangian). All models show a good correlation with the test results when comparing them against the detonation pressure, the cylinder wall expansion, the Gurney limit velocities and the radial wall velocities. The Smooth Particle Hydrodynamic is the best numerical model for replicating the detonation pressure, the Lagrangian for the cylinder wall expansion radius and velocity history, and Arbitrary Lagrangian Eulerian on the overall performance. Arbitrary Lagrangian Eulerian and Smooth Particle Hydrodynamic techniques are widely used to describe the materials subjected to large deformations, such as explosives, on full-scale simulations for civil and mining applications. The good agreement between numerical and experimental results justifies the use of these methods to model the expansion of detonation products.

<https://www.sciencedirect.com/science/article/pii/S1365160918302776?via%3Dihub>

Paper No 17

Automatic Muck Pile Characterization from UAV Images

n/a

Paper No 18

RESLAM: A real-time robust edge-based SLAM system

Abstract

In this work, we present RESLAM, a robust edge-based SLAM system for RGBD sensors. Edges are more stable under varying lighting conditions than raw intensity values, which leads to higher accuracy and robustness in scenes, where feature- or photoconsistency-based approaches often fail. The results show that our method performs best in terms of trajectory accuracy for most of the sequences indicating that edges are suitable for a multitude of scenes.

<https://github.com/fabianschenk/RESLAM>

Paper No 19

UAV-Anwendungen im Bergbau-Modellversuche als Beitrag zur photogrammetrischen Forschung und Entwicklung

Abstract

Als Grundlage für die fortschreitende Digitalisierung und Automatisierung im Bergbau, kommt der Herstellung von optisch realistischen und hochgenauen 3D Modellen, sowie deren automatischer Interpretation und Weiterverarbeitung, eine besondere Bedeutung zu. Insbesondere für Vermessungs- und Inspektionsanwendungen sind mit Kameras ausgerüstete unbemannte Flugsysteme mittlerweile weit verbreitet und zählen zum aktuellen Stand der

Technik. Der größte zukünftige Forschungsbedarf besteht mit Sicherheit in der Datenverarbeitung, wobei einerseits die erreichbare Modellqualität, und andererseits die automatisierte Dateninterpretation für spezielle bergtechnische Fragestellungen wie zum Beispiel die Haufwerkscharakterisierung oder geologische Charakterisierung im Zentrum der Arbeiten steht. Insbesondere aufgrund der möglichen Reproduzierbarkeit, aber auch aufgrund der oft einfacheren Durchführbarkeit nehmen - neben klassischen realmaßstäblichen Untersuchungen im Feld - auch Modellversuche derzeit einen gewichtigen Stellenwert in der photogrammetrischen Forschung an der Montanuniversität ein. Im vorliegenden Beitrag werden Beispiele aus der angewandten und grundlagenorientierten Forschung gegeben, wobei der Mehrwert von Laborversuchen, bei gleichzeitiger kritischer Gegenüberstellung mit der Realität, hervorgehoben wird.

<http://tubaf.qucosa.de/api/qucosa%3A23243/attachment/ATT-0/>

Paper No 20

Holistische Erfassung und Beurteilung von unterschiedlichen Einflussfaktoren auf das Sprengergebnis

Abstract

Im Rahmen des EU Horizon 2020 Projekts „Sustainable Low Impact Mining“ (SLIM) forscht der Lehrstuhl für Bergbaukunde an der Montanuniversität Leoben gemeinsam mit einem Konsortium von europäischen Partnerinstitutionen und Firmen an effizienten und nachhaltigen Sprengtechniken zur Gewinnung von kleinen und komplexen Rohstofflagerstätten. Der Fokus liegt dabei an der Reduktion von Emissionen (Erschütterungen, Staub, Sprengstoffrückstände und -reaktionsprodukte) sowie der besseren Prozesskontrolle und -vorhersage. Die erarbeiteten Methoden und Technologien werden im Rahmen von Validierungsversuchen auf ihre Praxistauglichkeit erprobt. Die Aufgabenstellung liegt in der Bewertung der Sprengergebnisse, um einen negativen Einfluss der sprengtechnischen Änderungen auf die nachgeschalteten Prozesse auszuschließen. Betrachtet werden mögliche Einflussparameter und Leistungskennzahlen entlang der gesamten Prozesskette beginnend mit der Geologie, über Bohren, Sprengen, Laden und Fördern bis zum Primärbrecher der Aufbereitung. Erste Versuche zum Erproben und Verfeinern der Datenerfassung wurden bereits abgeschlossen, die Hauptversuchsserie ist für Sommer 2019 geplant. Die Versuche in Österreich werden am Steirischen Erzberg durchgeführt. Hier werden im Tagebau jährlich rund 12 Mio. Tonnen Gestein mittels Bohr- und Sprengarbeit hereingewonnen. Etwa ein Drittel davon ist Roherz, welches zu 2,8 Mio. Tonnen Eisenerz für den Versand aufbereitet wird.

https://www.bergbau.tu-clausthal.de/fileadmin/BuS_2019_Tagungsband.pdf

Paper No 21

Seismic velocities from travelttime tomography at the iron ore mine Mt. Erzberg, Austria

Abstract



The overall goal of this project is to minimize vibrations from mine blasts through optimized blast array configurations. Among other things, this requires an accurate prediction of seismic wave propagation at the site. In order to perform a seismic site characterization of the iron ore mine Mt. Erzberg 125 3-component-stations were distributed in a 4 km² sized area in and around the mine. During the 4-week-long deployment, 21 small seismic shots and 10 production blasts were recorded. A low signal to noise ratio, due to small charges, leads to no visible S waves in the seismic shot dataset. In contrary, the large amounts of explosives used in the production blasts provide very good data quality. Yet one production blast consists of an array of several individual shots, which are ignited with a certain time interval in between. Thus creating a spatially extended blasting sequence followed by the fall of the rock mass which can last more than half a second. This adds to the complexity of the deconvolution. Still, S-waves arrivals can be seen in some of the data after the deconvolution. The P-wave velocity model was obtained from a first arrival travel time tomography with an eikonal solver using `simulr16`. Due to the small amount of S-wave observations, the S-wave velocity model was derived from the P-wave velocity model with an empirical relation. An elastic FD code that accounts for topography ("BSIT") was used to predict seismic wave fields in those models. These simulations can then be used to create blasting patterns that optimize vibrations at certain sensitive targets. (See contribution by Trabi et al.) This study is part of a large interdisciplinary EU funded project called SLIM, which focuses on sustainability in mining. The 3 component stations were provided by the GFZ – Geophysical Instrumental Pool Potsdam.

<https://meetingorganizer.copernicus.org/EGU2019/EGU2019-15195.pdf>

Paper No 22

Passive Imaging of Active Source Data: Seismic Ambient Noise Interferometry in a Mining Environment

Abstract

Active source acquisition with cable-free systems ('nodes') implies recording of continuous data over the entire acquisition period (e.g. days to months). Due to the lack of well-defined seismic sources, data outside the shot windows are usually not considered for processing and interpretation, despite the potential useful information contained in the continuous data. Ambient seismic noise interferometry is a suitable method to extract complementary subsurface information from other sources of abundant environmental seismic energy such as road traffic. We present a case study from the ore quarry 'Erzberg' located in central Austria. Seismic investigation of this area aims at characterizing the site response to blasting and subsequently, to optimize the mining process. Furthermore, the subsurface distribution of potential new ore veins is of interest. In November 2016, 125 3C – stations were deployed for three weeks to record both production blasts and specifically designed seismic shots. The acquisition area is 2.5 km by 2.0 km wide and covers both the active mine and its surroundings. The active source data have been processed towards a 3D P-wave velocity model with average velocities ranging from ca. 4 km/s to 5 km/s. Beamforming analysis of the continuous passive data indicate a

dominant noise source outside and towards the east of the deployment area. Coherent signals are found in the frequency band 1 Hz to 6 Hz, which is in agreement with the assumption of traffic noise originating from a nearby state road. Ambient noise interferometry is performed by converting each of the recording stations into a virtual source. The resulting virtual source gathers show clear Rayleigh and Love waves on the vertical and transverse components. The move out of the arrivals indicate apparent surface wave velocities between 1.7 km/s and 1.9 km/s, which would suggest P/S wave velocity ratios in the range of 2 – 2.5. The inversion of surface wave dispersion for a 3D shear-wave velocity model will allow to extract localized P/S ratios and as such contribute to the seismic site characterization. We conclude that active source data acquisition with nodes offers complementary information at negligible additional costs. Traffic noise from a few weeks or even days is sufficient to generate shear wave velocity models, which can be combined with results from active source processing and in turn benefit the interpretation.

<https://meetingorganizer.copernicus.org/EGU2019/EGU2019-11898.pdf>