Advances in Geo-Energy Research

Vol. 5, No. 1, p. 1-4, 2021

Editorial

Advances in in-situ modified mining by fluidization and in unconventional geomechanics

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Keywords:
In-situ modified mining by fluidization
unconventional geomechanics
geo-energy
geo-resources
evolving porous media

Cited as:
Liang, W., Zhao, Y., Liu, J., Elsworth, D., Feng, Z., Cai, J. Advances in in-situ modified mining by fluidization and in unconventional geomechanics. Advances in Geo-Energy Research, 2021, 5(1): 1-4, doi: 10.46690/ager.2021.01.01

Abstract:
Increasing large-scale development and utilization of new geo-energy sources and geo-resources heralds the need for worldwide implementation of sustainable development. The extreme complexity in recovery conditions, including ultra-low-permeability reservoirs, low-energy-density reserves and high temperatures and high pressures, defines a challenge in efficiently recovering such energy, fuel and mineral resources. Hence, development of efficient mining methods and the related determination of geo-mechanical properties of reservoirs remains a key topical issue. During the simultaneous 2nd International Symposium on In-situ modification of Deposit Properties for Improving Mining and the 7th Unconventional Geomechanics Symposium, held both in person and online from November 7-8, 2020, a broad array of advances in the science and technology of geo-energy and geo-resource recovery were presented. The symposia were attended by more than 200 participants from China, USA, Canada, UK, Australia, Japan, Singapore, and Turkey. Twenty-four invited talks were presented, seven of which were online, four of which were pre-recorded, and thirteen of which were in person. Twenty-two general talks were held in two parallel sessions. Participants interact freely through both online and in-person speakers. These interactions will enable future collaborations.

1. Introduction

In-situ modification of deposit properties for improved mining is defined as a new mining technology that fluidizes valuable minerals within a deposit by in-situ modification of the physical and chemical properties of the deposit-also denoted as in-situ modified mining by fluidization (IMMF). IMMF covers a very broad spectrum of geo-energy and geo-resource recovery methods including of the recovery of coalbed methane, shale gas, geothermal energy, oil shale and underground coal gasification (Zhao et al., 2019). In order to efficiently recover these resources, reservoirs will be modified by physical and/or chemical methods to enhance the recovery of valuable minerals (Zhao et al., 2015, 2017; Feng et al., 2017, 2018). Taking oil shale mining as an example, superheated vapor may be injected into the oil shale strata and the kerogen pyrolyzed to produce oil and gas (Kang et al., 2017; Zhao et al., 2017). The pyrolyzed oil and gas then are driven by the vapor from injection well to production well, which can be implemented as the fluidized mining of oil shale.

Unconventional geomechanics embodies such concepts in the extraction of geo-energy and geo-resources. It focuses on the mechanical response of the reservoir to coupled multi-

Yandy Scientific Press

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Received November 9, 2020; revised November 14, 2020; accepted November 14, 2020; available online November 16, 2020.

physical fields (Zhang et al., 2008; Liu et al., 2011; Li et al., 2020). Studies on unconventional geomechanics are of great significance in promoting the responsible and effective recovery of energy and minerals.

In order to advance and disseminate knowledge for understanding, describing, and modeling the process of IMMF and mechanical response of reservoirs to coupled multiple physical fields, Taiyuan University of Technology presented a platform for researchers to exchange and share new insights and results in the in-situ modified mining of geo-energy and geo-resources.

During November 7-8, 2020, the 2nd International Symposium on In-situ modification of Deposit Properties for Improving Mining (IMDPIM) and 7th Unconventional Geomechanics Symposium (UG) were jointly held in person and online. The invited and general lectures covered the spectrum of mining of coalbed methane, shale gas, geothermal energy, natural gas hydrate, oil shale, underground coal gasification, coal, rock salt.

2. Invited lectures for 2nd IMDPIM

2.1 Fundamentals of in-situ modified mining by fluidization

Yangsheng Zhao, Academician of the Chinese Academy of Science, from Taiyuan University of Technology, presented a talk entitled "Some problem of theory and engineering on in-situ modification mining by fluidization". The concepts and theory of in-situ modified mining by fluidization were summarized. He also discussed the in-situ modification technologies applied in the related mining industry and engineering, including for coalbed methane recovery, in-situ exploitation of oil shale, solution mining of salt and deep geothermal energy extraction.

Weiguo Liang, President of the Shanxi Institute of Energy, presented a talk entitled "Theory and technical progress of in-situ modification of deposits for improved mining". The general situation of unconventional geo-resources and geo-energy were summarized. From a theoretical basis to specific engineering applications, the concepts and technical progress of in-situ modification of deposits for improved mining were introduced in detail.

Derek Elsworth, from the Pennsylvania State University, delivered a lecture on "Triggered seismicity and permeability evolution in faulted and fractured reservoirs". He introduced the key issues in triggered and induced seismicity, including mechanisms and scaling of induced seismicity. Combined experimental observations and theoretical analysis were included to link between induced seismicity and permeability evolution.

Shuqin Liu, from the China University of Mining and Technology (Beijing), delivered a lecture on "Move and control of fire face during in-situ coal gasification (UCG)" and presented the prospects and key problems in deep underground coal gasification. She identified that the key technology of in-situ conversion is the control of chemical reactions within the coal seam.

2.2 Natural gas hydrates

Praveen Linga, from the National University of Singapore, delivered a lecture entitled "Is methane hydrate a boon or a bane". He introduced the significance of gas hydrate research, identified gas production methods and the current state of field production tests. He pointed out that natural gas hydrates are a huge energy resource, that its commercial production could be near, while environmental and safety aspects may represent a bane in its utilization.

Sükrü Merey, from Batman University, presented a talk entitled "Does the horizontal well technology provide feasible and safe gas production from methane hydrates?". He discussed the advantage and disadvantage of gas hydrate production via horizontal wellbore technology.

2.3 Solution mining of salt rock

Maurice Dusseault, from the University of Waterloo, presented a talk entitled "Modeling the aqueous dissolution of massive salt". He discussed the ubiquitous dissolution processes that occur in nature and in engineering applications. Combined theoretical analyses and numerical simulation were presented for dynamic dissolution modelling of the evolution of large caverns.

For the "Understanding and engineering application of deep composite salt-gypsum layer", Shiyuan Li, from China University of Petroleum (Beijing), discussed drilling engineering challenges in salt-gypsum formations together with deformation mechanisms and mechanical behavior of salt-gypsum layers. He also analyzed problems in some examples of worldwide drilling case studies and gave suggestions on dealing with inconsistent deformations and the prediction and application of abnormal pressure.

2.4 Geothermal energy

In the lecture entitled "Excavation enhanced geothermal system and its challenge in rock mechanics", Chun'an Tang, from Dalian University of Technology, introduced the disadvantages of current drilling-based enhanced geothermal system (EGS) techniques and proposed a new technology based on the excavation of enhanced geothermal systems, which may take advantage of advanced geotechnical excavation technology. Through drilling and blasting, excavation of an artificial lake and a large shaft, a new type of EGS may be developed with characteristics of over-sized heat source, thermal storage and heat flow all possible.

In the lecture on "Thermal analysis of a penny-shaped enhanced geothermal system during heat extraction" by Bisheng Wu, from Tsinghua University, the thermal recovery performance of an EGS for single- and double-fracture cases were compared using the extend finite element method. Simulation results showed that the double-fracture system is more productive with induced thermal stresses requiring to be considered when modelling the hydraulic fracturing and production.

Shanmin Wang, from Hangzhou Jinjiang Group, is now responsible for Yangyi geothermal power plant Co., Ltd in Teibet. He presented a talk entitled "Summary of and demonstration significance of the first stage geothermal power project

with 16MW in Yangyi of Tibet". The talk emphasized on the construction process of 16MW geothermal plant and the daily operation status. The key scientific and technical issues closely related to geothermal energy development and plant operation were raised in this talk.

3. Invited lectures for UG7

3.1 Coalbed methane extraction

Jishan Liu, from The University of Western Australia, presented a talk entitled "Permeability map for low permeable rocks". He introduced a shale/coal permeability model/map through four contrasting sets of experiments and discussed the application of permeability map-based geo-multiphysics in both laboratory experiments and in field tests.

Mingyao Wei, from China University of Mining and Technology, presented a talk entitled "Long-term effect of desorption-induced matrix shrinkage on the evolution of coal permeability during coalbed methane production". He presented long-term measurements of coal strain following methane injection and found that the deformations are heterogeneous in both time and space. A theoretical model of gas and water flow, considering the effect of matrix shrinkage was presented to illustrate that the permeability of the coal reservoir is dominated first by matrix shrinkage and finally by effective stresses.

Yixin Zhao, from China University of Mining and Technology (Beijing), presented a talk entitled "Quantification of pore modification in coals due to pulverization using synchrotron small angle X-ray scattering". He investigated the effect of pulverization on pore modification of virgin coal using small-angle X-ray scattering, and identified that the influence is significant - the pore volume per unit mass increases with a decrease in particle size. Surface fractal dimension of the pore decreases with this reduction in coal particle size.

Shimin Liu, from the Pennsylvania State University, presented a talk entitled "Characterization of submicron-/nano-scale coal dusts and their effects on pneumoconiosis for miners". The physical and chemical properties of coal dust were investigated by both low-pressure N_2 adsorption and X-ray photoelectron spectroscopy. Mechanisms of nanoparticle interaction on miners' pneumoconiosis were also discussed.

3.2 Hydraulic fracturing

In "Gas migration in damaged coal seam: multiphysical model and experimental observation", Wancheng Zhu, from Northeastern University, introduced a framework for coupled coal-gas interaction in damaged coal together with the governing equations for gas migration (desorption, diffusion and flow). Numerical simulation and experimental studies on fluid-driven fracturing with different fluids were presented. Despite significant advancements, Wancheng Zhu highlighted that further research on fracking with three dimensions numerical simulations is needed to capture the real fracture pattern and rock failure mechanism.

Fengshou Zhang, from Tongji University, delivered a lecture on "Hydraulic fracturing optimization for low permeability shale oil reservoirs in the Ordos Basin". He presented an overview of hydraulic fracturing for low permeability shale reservoirs in the Ordos Basin and introduced hydraulic fracturing optimization methods under the conditions of extreme limited entry perforating, stress shadowing of infill well fracturing and reservoir depletion.

Reporting on "Morphological characteristics of hydraulic fractures and their interaction with anisotropic layers under different pumping parameters", Yu Zhao, from Guizhou University, discussed hydraulic fracturing characteristics and effectiveness under different angles of anisotropy and variable injection rates and established intersection mechanisms describing interaction between hydraulic fractures and natural fractures. Anticipated response to pumping parameters, hydraulic fracturing characteristics and different injection rates were presented together with the modeling of fracture intersection.

3.3 CO_2 sequestration

Kyuro Sasaki, from Kyushu University, delivered a lecture on "Expected applications of gel formation from sodium metasilicate solution and CO_2 gas to enhanced oil recovery, CO_2 sequestration and inhibiting spontaneous combustion of coals". By investigating the characteristics of sodium silicate solution, and conducting core flooding tests for heterogeneous sandstone core, he discussed the possibility of injecting sodium silicate solution and its gel formation for enhanced oil recovery and carbon sequestration.

Acknowledgement

The foregoing represents the perspectives of the authors of this editorial, alone. The sterling work of the conference Program and Organization committees is thankfully acknowledged. Thanks also goes to the participating scholars who actively participated, studied presentations, left comments and questions and attended all in-person sessions. It was a remarkable and rich academic feast.

Conflict of interest

The authors declare no competing interest.

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