Contribution ID: **117** Type: **Oral Presentation**

Digital rock reconstruction considering high stress

Monday, 13 May 2024 14:40 (15 minutes)

Abstract

As the development of medium and shallow oil and gas reservoirs progresses into the mid-to-late stages, the focus of petroleum exploration is shifting towards deep and ultra-deep reservoirs. Deep oil and gas reservoirs are defined as those with burial depths exceeding 4500 m, while ultra-deep reservoirs refer to those buried beyond 6000 m. These reservoirs exhibit characteristics of high stress, significantly impacting the pore structure of reservoir rocks and, consequently, influencing microscopic flow of oil and gas. Digital rocks serve as a crucial platform for simulating flow at the pore scale. However, existing methods for reconstructing digital rocks fail to account for the effects of high stress. In this study, we propose a novel method for reconstructing digital rock cores considering high stress based on the discrete element method (DEM). The first step involves transforming scanned results obtained under room temperature and pressure conditions into a DEM model. We employ the watershed algorithm to segment CT scan images, utilize spherical harmonic functions to represent particle contours, and transform them into clump particles in PFC3D. Subsequently, a DEM model is established with porosity matching that of the actual rock. The accuracy of the model is evaluated using two-point correlation and linear path correlation functions. The second step involves setting micro-mechanical for the contact constitutive model between particles, applying stress simulation calculations, and converting the results into voxel data. The third step analyzes the geometric and topological structure of pores under different stress combinations, along with the evolution of permeability. The feasibility of the proposed digital rock core reconstruction method is validated through the analysis of Bentheim sandstone as a case study.

Keywords: digital rock reconstruction; the discrete element method; high stress; pore structure

Acknowledgments

This project was jointly supported by the National Natural Science Foundation of China (Grant No. 52034010), Sinopec Science And Technology Entry Program (No. P21072-1).

Acceptance of the Terms & Conditions

Click here to agree

Student Awards

I would like to submit this presentation into the InterPore Journal Student Paper Award.

Country

China

Porous Media & Biology Focused Abstracts

References

[1] Yao J, Huang Z Q, Liu W Z, et al. Key mechanical problems in the development of deep oil and gas reservoirs (in Chinese). Sci Sin-Phys Mech Astron, 2018, 48(04): 5-31. [2] Jia C., Pang X., Research processes and main development directions of deep hydrocarbon geological theories[J], Acta Petrolei Sinica, 2015,36(12): 1457-1469. [3] Xu C., Zou W., Yang Y., et al. Status and prospects of exploration and exploitation of the deep oil & gas resources onshore China[J], Natural Gas Geoscience, 2017, 28(8): 1139-1153. [4] Zhu L., Zhang C., Zhang C., et al. Challenges and Prospects of Digital Core-Reconstruction Research[J]. Geofluids, 2019, 2019(2): 1-29. [5] Yang Y., Zhang W., Gao Y., et al. Influence of stress sensitivity on microscopic pore structure and fluid flow in porous media[J]. Journal of natural gas science and engineering, 2016, 36(Pta1): 20-31. [6] Erik, H., Saenger, et al. Analysis of high-resolution X-ray computed tomography images of Bentheim sandstone under elevated confining pressures[J]. Geophysical Prospecting, 2016, 64(4): 848-859. [7] Maxim, Lebedev, Yihuai, et al. Residual Trapping of Supercritical CO2: Direct Pore-scale Observation Using a Low Cost Pressure Cell for Micro Computer Tomography[J]. Energy Procedia, 2017, 114: 4967-4974. [8] Yang Y., Yao J., Wang C., et al. New Pore Space Characterization Method of Shale Matrix Formation by Considering Organic and Inorganic Pores[J]. Journal of natural gas science and engineering, 2015, 27: 496-503. [9] Song W., Liu L., Wang D., et al. Nanoscale confined multicomponent hydrocarbon thermodynamic phase behavior and multiphase transport ability in nanoporous material[J]. Chemical Engineering Journal, 2020, 382: 122974. [10] Yang Y., Liu F., Yao J., et al. Multi-scale reconstruction of porous media from low-resolution core images using conditional generative adversarial networks[J]. Journal of natural gas science and engineering, 2022, 99: 104411. [11] Øren P.-E., Bakke S. Process based reconstruction of sandstones and prediction of transport properties[J]. Transport in porous media, 2002, 46(2-3): 311-343. [12] Zhao X., Numerical Rock Construction andPore Network Extraction[D], 2009. [13] Huang J., Xiao F., Labra C., et al. DEM-LBM simulation of stress-dependent absolute and relative permeabilities in porous media[J]. Chemical Engineering Science, 2021, 239: 116633. [14] Fan M., McClure J., Han Y., et al. Interaction between proppant compaction and single-/multiphase flows in a hydraulic fracture[J]. SPE Journal, 2018, 23(04): 1290-1303. [15] Khaleghi K., Talman S., Shokri A. R., et al. A Coupled Pore-Scale Modelling Approach to Capture Macro-ScaleStress-Dependent Permeability of Rocks[A]. Proceedings of the Asia Pacific Unconventional Resources Technology Conference, Brisbane, Australia, 18-19 November 2019[C]. Unconventional Resources Technology Conference, 2020: 610-628. [16] Li G.-y., Zhan L.-t., Hu Z., et al. Effects of particle gradation and geometry on the pore characteristics and water retention curves of granular soils: a combined DEM and PNM investigation[J]. Granular Matter, 2021, 23: 1-16. [17] Zheng J., Hryciw R. D. Segmentation of contacting soil particles in images by modified watershed analysis[J]. Computers and Geotechnics, 2016, 73: 142-152. [18] Zhao S., Zhao J. A poly-superellipsoid-based approach on particle morphology for DEM modeling of granular media[J]. International Journal for Numerical and Analytical Methods in Geomechanics, 2019, 43(13): 2147-2169. [19] Andrade J. E., Lim K.-W., Avila C. F., et al. Granular element method for computational particle mechanics[J]. Computer Methods in Applied Mechanics and Engineering, 2012, 241: 262-274. [20] Bowman E. T., Soga K., Drummond W. Particle shape characterisation using Fourier descriptor analysis[J]. Geotechnique, 2001, 51(6): 545-554. [21] Garboczi E. J. Three-dimensional mathematical analysis of particle shape using X-ray tomography and spherical harmonics: Application to aggregates used in concrete[J]. Cement and concrete research, 2002, 32(10): 1621-1638. [22] Taghavi R. Automatic clump generation based on mid-surface[A]. Proceedings of the Proceedings, 2nd international FLAC/DEM symposium, Melbourne[C]. 2011: 791-797. [23] Li Z., Liu Z. Influence of particle shape on the macroscopic and mesolevel mechanical properties of slip zone soil based on 3D scanning and 3D DEM[J]. Advances in Materials Science and Engineering, 2021, 2021: 1-14. [24] Lai Z., Chen Q. Characterization and discrete element simulation of grading and shape-dependent behavior of JSC-1A Martian regolith simulant[J]. Granular Matter, 2017, 19(4): 69. [25] Lai Z., Chen Q., Huang L. Fourier series-based discrete element method for computational mechanics of irregular-shaped particles[J]. Computer Methods in Applied Mechanics and Engineering, 2020, 362: 112873. [26] Kawamoto R., Andò E., Viggiani G., et al. Level set discrete element method for three-dimensional computations with triaxial case study[J]. Journal of the Mechanics and Physics of Solids, 2016, 91: 1-13. [27] Li J., Huang Y., Li W., et al. The 3D reconstruction of a digital model for irregular gangue blocks and its application in PFC numerical simulation[J]. Engineering with Computers, 2022, 38(Suppl 5): 4617-4627. [28] Cundall P. A., Strack O. D. A discrete numerical model for granular assemblies[J]. Geotechnique, 1979, 29(1): 47-65. [29] Itasca C. PFC (particle flow code in 2 and 3 dimensions), version 5.0 [User's manual][J]. Numer Anal Methods Geomech, 2014, 32(6): 189-213. [30] Wei D., Wang J., Zhao B. A simple method for particle shape generation with spherical harmonics[J]. Powder Technology, 2018, 330: 284-291. [31] Herring A., Robins V., Sheppard A. Topological persistence for relating microstructure and capillary fluid trapping in sandstones[J]. Water Resources Research, 2019, 55(1): 555-573. [32] Zhao B., Wang J. 3D quantitative shape analysis on form, roundness, and compactness with μCT[J]. Powder Technology, 2016, 291: 262-275. [33] Klein E., Baud P., Reuschlé T., et al. Mechanical behaviour and failure mode of Bentheim sandstone under triaxial compression[J]. Physics and Chemistry of the Earth, Part A: Solid Earth and Geodesy,

2001, 26(1-2): 21-25.

Conference Proceedings

I am interested in having my paper published in the proceedings.

Primary author: WANG, Chunqi

Co-authors: Prof. HUANG, Zhaoqin (China University of Petroleum (East China)); YAO, Jun (China University of Petroleum)

Presenter: WANG, Chunqi

Session Classification: MS09

Track Classification: (MS09) Pore-scale modelling