JOURNAL OF PETROLEUM GEOMECHANICS
(JPG)

Extended Abstract

Elastic properties of Carbonate Reservoir Rocks: Laboratory Measurement and Numerical Simulation using X-ray Computed Tomography Images on Kangan Carbonates

Shirin Samani[1], Ali Uromeihy[1*], Behzad Mehrgini[2], Hassan Eshraghi[3]

1- Department of Engineering Geology, Tarbiat Modares University, Tehran, Iran
2- Department of Civil and Mineral Engineering, University of Toronto, Canada
3- Pars Oil and Gas Company, Tehran, Iran

Received: 16 April 2023; Accepted: 26 May 2023

DOI: 10.22107/JPG.2023.393366.1194

Keywords

Young's modulus
Poisson's ratio
Representative Element Volume
Micro-CT
Kangan Formation

Abstract

Elastic properties (Young's modulus and Poisson's ratio) represent important parameters in geomechanical investigations of reservoirs and hydrocarbon fields. These parameters can be calculated using common geomechanical tests in the laboratory. However, due to the lack of access to suitable samples, laboratory equipment, and high costs, in many cases, empirical equations, and statistical and mathematical methods have been used to estimate these characteristics. We present a Digital Rock Simulation (DRS) approach using high-resolution CT images to estimate Young's Modulus and Poisson's ratio of carbonate samples following a non-destructive approach. In the numerical simulations we use a voxel model of reconstructed 3D geometry that is evaluated using Finite Element Method (FEM). We extract Representative Volume Elements (REV) of Kangan carbonates with different porosity and mineralogy. In laboratory experiments, we quantified the modulus based on Axial Stress-Axial Strain Curve that was obtained from Triaxial Compression Tests. Finally, we compare the simulation results and laboratory measurements. Our analysis shows that obtained Young's Modulus of modeling are between 4.3% and 18.9% higher than compared to the results of laboratory tests. The highest error is related to the samples with the more porous, which are mainly dolomite. The assumptions about solid fraction properties regarding to mineralogy differences remains challenging.

1. Introduction

A comprehensive understanding of elastic properties of reservoir rocks as the most important hydrocarbon reservoir rocks in the world is essential in all stages of exploration and exploitation [1,2]. While direct measurements are the most reliable, they are often impractical due to limited sample numbers, high costs, and expensive equipment. Therefore, several researchers focused on estimating these parameters using different indirect methods based on statistical, mathematical and numerical methods. [3,4,5,6,7]. In recent decades, making and using Digital Rock Physics has been given attention by various researchers. [8,9,10]

2. Methodology

In this study, 19 samples with differences in mineralogy (consisting of Calcite, Dolomite, and Anhydrite) and porosity (between 2 and 34%) have been selected for micro-CT scanning. Also, porosity and mineralogy have been obtained by using laboratory measurement. Using the 2D CT images 3D samples have been made by Avizo. In the next step, a cubic was selected as a representative element volume and converted into

*** Corresponding Author:** Engineering Geology Group, Faculty of Basic Sciences, Tarbiat Modares University, Tehran. Postal Box:175-14115, Email: aliuromia55@gmail.com

suitable geometries for importing Abaqus using VoxTex software. After preparing the geometry (voxel file), the elastic properties of the samples are analysed using a script written in ABAQUS software. To extract the stiffness matrix in the homogenization process, it is necessary to apply 6 types of loading. For this reason, 6 static steps were created and 3 tensile loads and 3 shear loads, were applied to the sample in these 6 steps. After completing the job and solving the problem in all 6 steps, its output, which includes the stress and strain fields at the end of each step in the sample, was processed by a C++ code. The purpose of this post-processing is to homogenize and obtain the effective properties of the material.

3. Results and Conclusions

The results of modeling compared to the results of laboratory tests show higher values between 4.3 and 18.9 percent. Although the data in the graph shown in is very scattered, the most error is related to the samples with the highest porosity values. These samples are mainly dolomite. Since the samples were divided into 4 groups based on mineralogy, Table (1) shows the average error percentage in each group.

According to the data, the lowest error percentage is in calcite samples (more than 90% calcite) and the highest error rate is related to dolomite samples (more than 90% dolomite). According to the obtained results, this method can be considered successful for the general estimation of elastic properties in reservoir carbonate rocks. However, this method like other numerical modeling has some uncertainties. Therefore, using this method suggests as a complement for laboratory measurements.

Table 1. Average error percentage based on mineralogy

Mineralogical groups	Number of sample	Average error percentage
More than 90% calcite	3	5.02
More than 70% calcite More than 20% dolomite	3	10.92
Between 60-90% dolomite and between 10-40% anhydrite	6	9.32
More than 90% dolomite	7	12.88

4. References

[1] Abdideh, M., & Ghasemi, A. (2014). A comparison of various statistical and geostatistical methods in estimating the geomechanical properties of reservoir rocks. Petroleum science and technology, 32(9), 1058-1064.

[2] Xu, H., Zhou, W., Xie, R., Da, L., Xiao, C., Shan, Y., & Zhang, H. (2016). Characterization of rock mechanical properties using lab tests and numerical interpretation model of well logs. Mathematical Problems in Engineering, 2016.

[3] Aboutaleb, S., Behnia, M., Bagherpour, R., & Bluekian, B. (2018). Using non-destructive tests for estimating uniaxial compressive strength and static Young's modulus of carbonate rocks via some modeling techniques. Bulletin of Engineering Geology and the Environment, 77, 1717-1728.

[4] Anemangely, M., Ramezanzadeh, A., & Behboud, M. M. (2019). Geomechanical parameter estimation from mechanical specific energy using artificial intelligence. Journal of Petroleum Science and Engineering, 175, 407-429.

[5] Beiki, M., Majdi, A., & Givshad, A. D. (2013). Application of genetic programming to predict the uniaxial compressive strength and elastic modulus of carbonate rocks. International Journal of Rock Mechanics and Mining Sciences, 63, 159-169.

[6] Ghasemi, E., Kalhori, H., Bagherpour, R., & Yagiz, S. (2018). Model tree approach for predicting uniaxial compressive strength and Young's modulus of carbonate rocks. Bulletin of Engineering Geology and the Environment, 77, 331-343.

[7] Hadi, F., & Nygaard, R. (2022). Estimating unconfined compressive strength and Young's modulus of carbonate rocks from petrophysical properties. Petroleum Science and Technology, 1-23.

[8] Dvorkin, J., Tutuncu, A., Tutuncu, M., Nur, A. and Mese, A., (2003 September),. *Rock property determination using digital rock physics*. In Geophysics of the 21st Century-The Leap into the Future (pp. cp-38). European Association of Geoscientists & Engineers.

[9] Claes, S., Soete, J., Cnudde, V., & Swennen, R. (2016). A three-dimensional classification for mathematical pore shape description in complex carbonate reservoir rocks. Mathematical Geosciences, 48, 619-639.

[10] Cnudde, V., & Boone, M. N. (2013). High-resolution X-ray computed tomography in geosciences: A review of the current technology and applications. Earth-Science Reviews, 123, 1-17.