



Extended Abstract

Simulation of In-situ Stress and Deformation Induced by Reservoir Depletion Using a Coupled Geomechanical Model

Hamid Ghalibaf Mohammad abadi^{1*}, Naser Hafezi Moghaddas², Elham Mahdipour³, Mojtaba Hydarizad⁴
Hossein Talebi⁵

1-Computer Engineering Department, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

2-Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad, Iran

3-Computer Engineering Department, Khavaran Institute of Higher Education, Mashhad, Iran

4-State Key Laboratory of Marine Geology, Tongji University, Shanghai, 200092, China

5-Department of Geological survey & Development, National Iranian South Oil Company, Iran

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Abstract

Traditional static geomechanical models are widely used for stress analysis in oil and gas reservoirs; however, problems such as stress field rotation and related errors arise in the analysis of heterogeneous stresses. These issues are particularly observed in salt intrusions, salt domes, and fault reactivation due to gas injection. Pore pressure changes, primarily due to field depletion

or gas injection, occur nonlinearly in heterogeneous formations, making it impossible to predict these changes in time-independent static models. Therefore, a dynamic physical simulation model is required to investigate four-dimensional stresses, strains, and reservoir deformation. The aim of this paper is to develop a coupled geomechanical simulation model to simulate changes in stress, pore pressure, and strain resulting from hydrocarbon depletion, subsidence, and reservoir deformation. To this end, static and dynamic data obtained from well logs in one of the oil fields in the southern oil-rich regions of Iran were utilized. Initially, data preprocessing and the identification of geomechanical units were performed using machine learning algorithms, along with the construction of a one-dimensional geomechanical model that includes rock strength, unconfined compressive strength, tensile strength, friction angle, deformation parameters, Young's modulus, Poisson's ratio, shear and bulk moduli, and pore pressure, all accurately implemented using Python programming. The in-situ stresses were determined using poroelastic relationships. Subsequently, a three-dimensional static, dynamic, and geomechanical simulation model was designed and implemented. In this model, a finite difference reservoir simulator (FDM) was utilized with dynamic data to evaluate thermal, hydrological, and chemical (THC) processes using the "ECLIPSE" software. Additionally, a finite element reservoir simulator (FEM) was employed for thermal, hydrological, and mechanical (THM) process calculations using "VISAGE" software, and the calculations were performed in a one-way coupled manner within the "PETREL" environment. As a result, changes in stress, strain, pore pressure, and reservoir deformation over a ten-year period from 2021 to 2031 were obtained for the Bangestan reservoir. In 2031, due to overburden stress, the Ilam reservoir is expected to experience about 30 cm of subsidence in its upper part, while subsidence in the Sarvak reservoir is estimated to be between 10 and 15 cm.

1. Introduction

In recent years, commercial simulators have extensively employed numerical solutions to couple reservoir flow models with geomechanical models in various forms, including partial

coupling, one-way coupling, two-way coupling, and full coupling. Among the comprehensive methods, software packages such as OpenGeoSys, FEMH, TOUGH2/TOUGH and FLAC3D, COMSOL, Eclipse and Abaqus,

* Corresponding Author: Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
h.ghalibaf@yahoo.com

Retraso and Codebright, and ATHOS and VISAGE has been presented. The results obtained from these simulation protocols mainly involve coupling between a finite difference reservoir simulator (FDM) and a finite element geomechanical simulator (FEM). Additionally, other couplings, including one-way and two-way couplings using Jewelsuite with Abaqus, Eclipse with VISAGE, have been introduced.

2. Methodology

In this article, data preprocessing was initially conducted using the Python programming language, which involved a significant portion of time spent on handling well log data. In some cases, up to 90% of the effort was dedicated to understanding, editing, and interpreting the data to a suitable format for interpretation. The remaining 10% of the time was allocated to the analysis of petrophysical log data[1-2]. Instead, to construct a Coupled geomechanical reservoir simulation, all reservoir geomechanical parameters were input as logs into the Petrel software environment. Consequently, a static and dynamic structural simulator of the Bangestan reservoir was developed. Subsequently, using the poroelastic relations, reservoir stresses were recalculated through coding in Petrel software, determining that the stress regime within the Ilam and Sarvak formations is reversed, with $\sigma_H > \sigma_h > \sigma_v$. It is worth mentioning that, through analyzing image logs and brittleness breakouts in this field, the minimum stress azimuth along the Zagros trend was determined to be approximately 320 degrees. Following this, utilizing static and dynamic parameters from this field, a static and dynamic model was constructed. As indicated by the title of the article, the objective of this study is to construct a four-dimensional reservoir geomechanical simulator. For this purpose, in geomechanical modeling, the pressure of overburden layers, underburden layers, sideburden layers, and surrounding model plates needed to be considered for numerical modeling. All necessary geomechanical parameters for these layers were input into the model. After this stage, pore pressure, geothermal gradient, and degree of saturation under initial conditions were entered. Additionally, boundary conditions were introduced using the stress tensor method in the simulator. To construct a four-dimensional model over a ten-year time step, the pore pressure parameter was assumed to decrease by one

megapascal per year due to hydrocarbon extraction. Consequently, this pressure drop yielded results for changes in stress, strain, pore pressure, geothermal gradient, and reservoir deformation over a ten-year period from 2021 to 2031. It is noteworthy that due to the large number of images, results are only shown for the initial reservoir conditions and the year 2031. Therefore, as shown in Figure 1, in 2031, the Ilam reservoir will experience approximately 30 centimeters of subsidence in its upper part due to stress overburden, while this amount will be around 10 to 15 centimeters for the Sarvak reservoir.

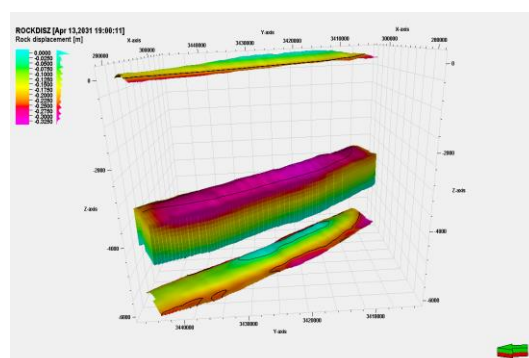


Fig. 1. Reservoir Deformation Over a Ten-Year Time Interval from 2021 to 2031

3. Results and Conclusions

To construct a geomechanical coupling model over a ten-year time span, the reservoir's pore pressure parameter was reduced by one megapascal annually due to hydrocarbon extraction. The results indicate that by the year 2031, the Ilam reservoir will experience approximately a 30-centimeter subsidence in its upper portion due to overburden stress. However, this value will be around 10 to 15 centimeters in the Sarvak reservoir.

4. References

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