AGH University of Science and Technology

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ABSTRACT OF PhD DISSERTATION

„GEOMECHANICAL MODEL OF GEOLOGICAL FORMATION AS A TOOL FOR EXPLORATION, STIMULATION AND EXPLOITATION OF UNCONVENTIONAL RESERVOIRS "

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Determination to ensure the energy security of the country, requiring the diversification of energy sources in the area of natural gas and crude oil, along with arising perspective for hydrocarbons exploration in the unconventional rock formations imposed a new methodological approach and new technological solutions in the full process of reservoir object exploration – at exploration stage, drilling to the target reservoir formation, well completion, stimulation of reservoir formation, as well as the operation and development of the reservoir object. Geomechanical analysis of rock formation proved to be a valuable at almost every stage of work with an unconventional reservoir object.

Geomechanics is particularly important, and even essential element in the exploration of the reservoir formation, where the local stress field and spatial distribution of mechanical properties play a key role in wellbore stability, orientation and geometry of the cracks generated during hydraulic fracturing of unconventional reservoir formation, as well as the transport properties of stimulated reservoir rock.

Presented in the dissertation extensive bibliography supplemented with examples of solutions of practical issues for polish reservoir objects allowed to create a comprehensive workflow of geomechanical modeling, including the integration of a wide range of geological, geophysical and reservoir engineering data, resulting from analysis and tests conducted on the core material, in the rock formation along the borehole, or in the entire volume of the analyzed rocks. Elaborated workflow leading to the development of parametric models describing different rock properties (including elastic and mechanical properties, but also pressures acting on the rock formation – pore pressure and principal stress) provided a set of input data needed for geomechanical simulation with the use of Finite Element Method (FEM).

Obtained geomechanical models allow to estimate the spatial distribution of stresses and strains, as well as indicate the failure zones in the analyzed rock formation. What is more, developed workflow is universal and can be used to model reservoir objects of any geometry, location and level of detail, conditioned with defined research problem and data availability.

Doctoral dissertation is presented in five chapters (a total of 215 pages). The first three chapters highlight general issues: introduction to the discipline of geomechanics and the objectives of the dissertation (Chapter I), a brief outline of the historical evolution of geomechanics (Chapter II), as well as theoretical foundations supplemented with more important definitions (Chapter III).

Chapter IV presents the application of geomechanical models based on four examples of unconventional reservoir objects - three located on Polish territory, where the subject of modeling were geological formations of different age and characteristics typical for *tight gas*, *shale gas* and *coalbed methane* reservoirs. The fourth geomechanical model was built basing on a synthetic data, allowed for construction of the model of the unconventional rock which for production of hydrocarbons at economical rates require the application of secondary fracturing treatment.

Presented in section IV.1 model was built on the basis of synthetic data from one borehole, drilled through gas bearing sandstone formation of very low permeability. Presented model constitute an example of geomechanical modeling coupled with dynamic modeling of reservoir fluid flow in the formation which petrophysical characteristics imposes the use multi-stage hydraulic fracturing.

The second example of geomechanical modeling, presented in Chapter IV.2, was performed for reservoir object B8, located within the Łeba concession, where the geological target are oil and gas-bearing sediments of Palaeozoic age, deposited in the southern part of the Baltic Basin. Reservoir formations being analyzed are subjected to production intensification treatment, by injecting water into the rock, which results in reservoir pressure reconstruction and increased levels of production. Conducted geomechanical analysis aimed at assessing the prevailing stresses and its impact on the effectiveness of applied intensification treatments.

Chapter IV.3 describes the most complete range of application of geomechanical modeling. The subject of the modelling were Lower Paleozoic shale formations deposited in the northern part of the Baltic Basin, currently regarded as prospective rocks for hydrocarbons reservoir of shale gas and shale oil type. With the use of a wide range of available data (i.e. structural maps, results of seismic processing and structural interpretation of 3D seismic survey, well log data, reservoir engineering data, as well as the results of laboratory measurements of petrophysical and mechanical properties of the reservoir rock) structural model of Palaeozoic shale formation including overburden and surrounding rocks was developed. Obtained parametric models constitute an input for geomechanical simulation. Its results allowed to determine zones most prone to fracturing treatment, and to aslo the optimal trajectory of the horizontal sections of wells, so that hydrocarbons drainage is most effective.

Chapter IV.4 presents the last example of geomechanical model, which was carried out for the coal seams localized at one of the JSW SA coal mine. Coalbed methane, as one of the unconventional hydrocarbons sources for gas production at the economical rates requires application of stimulation treatments. Presented in section IV.4. geomechanical and dynamic fluid flow model coupling allowed to assess the effectiveness of proposed stimulation treatments of coal seams.

Chapter V presents a discussion of the results and bibliography (including 128 articles and research sources).

During the five-year period of this study, a clear progress in understanding the importance of the issues in the field of geomechanics, as an element part conditioning development of Geosciences is observed. And not only in the hydrocarbon exploration related area, but also in geoengineering issues, e.g. construction of transport infrastructure in challenging geological conditions, dams, wind farms as well as underground storage of mineral resources and hazardous waste such as greenhouse gases and radioactive waste.