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Analytic Modelling for Wellbore Stability Analysis

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Abstract

1D geomechanical model based on cross-dipole wideband acoustic logging for unconventional reservoir is calculated. TIV anisotropic zones were highlighted and corresponding anisotropic elastic properties were confirmed by core samples tests. Final minimal stress profile was calibrated on the data set including log and laboratory studies, drilling and hydrofracturing. Calibrated model was used to optimize frac design for multiple hydrofracing in the horizontal wells.

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Keywords: numerical simulation, geomechanics, hydraulic fracturing, refracturing, pore pressure, coupled simulation, principal stress reorientation, micro-seismic observation

Introduction

The textural anisotropy of mechanical properties long time has been considered as negligible and didn't take into account by geophysicists in seismic and acoustic logging data interpretation. Despite the fact that nearly 30 years ago L. Thomsen [1] proposed a simple method of mathematical description of transversely isotropic medium with vertical axis of symmetry (TIV), in practice it is still rather difficult to make estimation of rock properties anisotropy. However, the worldwide unconventional shale reservoirs development trend demonstrated the need to take TIV-anisotropy into account because of its significant influence on hydraulic fracturing procedure design. On

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the other hand, the appearance of more sophisticated acoustic logging instruments has been greatly simplified TIV-anisotropy measurements. Bajen formation rocks characterize by pronounced stratification, which leads to the appearance of vertical anisotropy of acoustic and mechanical properties. It is necessary to know TIV elastic properties of interesting medium for the correct calculation of the horizontal stress profile which govern hydrofrac design. For goals to raise wells productivity and project profitability in whole the last one should be chosen in the best way what lead to appropriate well trajectory and perforation zones requirements. Such calculations were made for Bajen Formation of Yujno-Priobskoye and Palyanovskoye fields.

Unconventional reservoirs development implies drilling of horizontal wells and its following treatment with multiple hydraulic fracturing which volume extremely exceed the current practice at traditional collectors in Russia. It is assumed that pumping large amount of low viscous liquid at high rate allow to stimulate natural fractures network. In addition, main cost of well construction is borne by well completion and frac operations, therefore they are the goal of optimization as well as the cost of drilling. At the same time, optimization of multifrac works begins at the stage of work programs drawing up and includes optimization along the wellbore - laterally, and along the formation - vertically, which requires rock mechanical properties and stress tensor understanding, accordingly, understanding of anisotropy of the medium.

Rock elastic anisotropy is one of the fundamental properties of the geological environment and closely related to the geodynamic conditions of its formation. It is believed that most sedimentary rocks have a transverse isotropic symmetry. This intuitive assumption is confirmed by several complete measurements of the elastic constants, which are generalized in a well-known paper by L. Thomsen [1].

It is standard practice to take into account anisotropic stress properties. Almost immediately, from the hydraulic fracturing method emergence, the determination of the preferential fracture propagation orientation became one of the key tasks in the design of reservoir development. In modern conditions, it is difficult to imagine that field development which involves hydrofracturing and reservoir pressure maintaining system is conducted without understanding of the preferred fracture moving direction. During the transition to horizontal wells with multifracing, cracks orientation also became an important tool for wellbore locating, wells grid determination and fracturing stages initiation. During fracture geometry modeling in an unconventional reservoir the fundamental importance of mechanical properties inhomogeneity increases and TIV-anisotropy acquires particular importance.

Rock properties study

Hard-to-recover deposits development has exceptional priority for Gazprom Neft company [2]. This paper highlights unique aspect of the project dedicated to developing of hard-to-recover reserves of the Bajen-Abalak complex, associated with mechanical anisotropic properties estimation. Given interval is remarkable by its increased fracture gradients, which in the case of stress underestimation could lead to the absence of barriers to contain the fracture. It was demonstrated that the containment of the hydraulic fracture in the interval J0-J1 is crucial factor for the fracturing operation application success.

The set of conducted researches includes:

1. Anisotropic dynamic elastic moduli determination based on cross-dipole wideband acoustic logging (Sonic Scanner) in an open trunk and elastic and strength properties determination on core samples;
2. 1D geomechanical model creation and its calibration to drilling and core data;
3. Hydraulic fracturing design calculation based on the obtained geomechanical models with subsequent correction by fracture monitoring information.

Geomechanical model of the field is a numerical representation of the overburden and pore pressures, horizontal tectonic stresses, mechanical and strength properties of the rock. The main input information for this model construction is acoustic and density logging data, as well as laboratory core study results.

Modern acoustic devices allow to estimate the acoustic wave velocities not only along the direction of well trajectory (in a vertical well case it gives vertical velocities) but also in the perpendicular plane (horizontal velocities). This possibility due to the Stoneley wave sensitivity to the shear modulus in a plane perpendicular to the axis of the well. Stoneley wave parameter inversion let to compute horizontal shear wave velocity in addition to measured vertical wave velocities [3].