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Statistical Calibration of Rock Mechanical Parameters Research

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Abstract

For the purpose of oil and gas exploration, research on the modelling of rock mechanics parameters is extremely important. In reservoir prediction and other oilfield applications, the use of logging data with the Kriging interpolation to analyse rock mechanics parameters has been shown to be useful and can give additional data. However, due to the small sample size and significant layer variability, there may occasionally be a significant variation. In order to address this issue, a novel method for calibrating rock mechanical models using statistical analysis of logging data was developed. In the Wangyao region of the Ansai oilfield, a module was created to automatically calibrate rock mechanics parameters. This technique greatly increased the rock mechanics modeling's accuracy [1-3].

Keywords: Rock mechanics; High-accuracy rock; Kriging; Geostatistics

Introduction

Rock mechanics parameters, such as Young's modulus, Poisson's ratio, the effective stress coefficient, and the angle of internal friction, are essential to geo-stress simulation, wellbore stability analysis, sweet spot prediction, and simulation techniques in the exploration and development of lithological oil-gas reservoirs. High-accuracy rock mechanics modeling has received a lot of interest in recent years as the utilization of unconventional resources has expanded quickly. Experts from all over the world have studied it, and many of the study findings have been applied in the field [4, 5].

Given its unbiased optimum benefits, the Kriging approach is one of the most popular techniques for simulating rock mechanics. Numerous alternative techniques, such as simple Kriging, regular Kriging, co-Kriging, universal Kriging, and indicator Kriging, have been created to increase the applicability of Kriging due to some of its limitations in practical applications. In order to reduce some of the subjective effects, Roustant recently improved the approach to solving a covariance function by suggesting a nonnegative solution of linear equations. Erum demonstrates that Bayesian universal Kriging fits better in predicting salt concentrations than universal Kriging [6]. Hu used the Bayesian-based collocated co-Kriging method to enhance the results of Kriging, which are affected by scaling. The aforementioned techniques can mathematically increase accuracy, but they are unable to optimise the search radius and range since they do not take into account the spatial distributions of the rock mechanics characteristics. The simulation results may therefore contain significant errors as a result of these methodologies. In order to address this issue, this work examined the behaviour around the wellbore, limited the Kriging results by establishing the characteristics of the distribution law for geological data, and enhanced the mechanical modelling of rock with a calibration approach. The rock mechanics parameters were likewise constrained by the module. The Wangyao region of the Ansai oilfield successfully used the suggested method, and the findings revealed a significant improvement in the accuracy of rock mechanics modeling [7].

Materials and Methods

Materials and characterization

The study reservoir is situated in the middle of the Ordos basin, with a mild stratigraphic occurrence, a stable local structure, and no significant fault activity. The strata dip by around 0.5 degrees, with an average gradient of 8 to 10 metres per kilometre. A low angle nose-like raised structure is created by the effects of differential compaction. The concentration of hydrocarbons in this location was impacted by the delta sand-mud interaction. Although the reservoir is severely fragmented and has low porosity and permeability, the distribution of the rock mechanical properties is exceedingly heterogeneous and complex [8]. In light of the large amount of well log data, it is crucial to develop a high-resolution rock mechanics model.

Structure of rock mechanics model

By relying just on nearby qualities and local locations, traditional rock mechanics modelling ignores the entire geographical distribution trend of the parameters. In order to provide useful results, this study constrained rock mechanics modelling by looking at Young's modulus and Poisson's ratio at wellbores from a macroscopic perspective [8].

There are four sections to this study. In order to handle cross-dipole acoustic logging and density logging, data were first gathered and rock mechanics parameters at wellbores, such as Young's modulus and Poisson's ratio, were estimated using correlation analysis and the regression approach. The first rock mechanics model was then created utilising standard Kriging techniques, such as neighbourhood searching, covariance function solving, and meshing. The initial data for Kriging are obtained from the wellbore rock mechanics parameters. Young's modulus and Poisson's ratio statistical analysis were performed. To further calibrate the model, a rock mechanics parameter restriction model was created [9]. In order to calibrate the Young's modulus and Poisson's ratio and increase the precision of the rock mechanical model, a module was created using the C++ programming language.

Calculation of rock mechanics parameters at the wellbore

The measurement technique and the logging operation method are

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the two most common approaches now used to gather and compute rock mechanical characteristics. Due to its extensive data, cheap cost, and superior accuracy than seismic data, conventional logging plays a significant role in the extraction of rock mechanical parameters during the discovery and development of oil fields. Important details about the reservoir's lithology, structure, and physical characteristics are also included [10].

In this study, density logging and X-MAC logging were used to derive rock mechanics parameters near the wellbore, and the following equations were used to determine Young's modulus and Poisson's ratio: (1) (2)where ts and tp stand for the shear wave slowness and compressional wave slowness, respectively; V is for the Poisson's ratio, dimensionless; E stands for Young's modulus, MPa; is the density, g/cm3; and Young's modulus and Poisson's ratio were eventually estimated using acoustic logging, gamma ray logging, and spontaneous logging, and were ultimately established through a regression. However, using X-MAC logging data makes it feasible to revise the results [11].

Constructing the initial rock mechanics model

The foundation of geostatistics is kriging interpolation, which is widely applied in the geosciences. D.G. Krige, a mining engineer from South Africa, developed kriging in 1951 to address the issues with calculating deposit reserves and estimating errors. Since then, a sizable amount of research on Kriging has been published internationally. The fundamental goal of Kriging is to anticipate the value by calculating the moving weighted average of known values and applying weights to known sample points based on their geographical positions and correlations with the target point. The Kriging method has been employed in the field of rock mechanics parameters modeling because it uses property correlations and spatial positions between nearby sample sites to achieve excellent interpolation estimation accuracy [12].

Conclusions

1. Defects in coal and rocks are a significant role in the relationship between mechanical characteristics including elastic modulus, peak stress, and peak strain. However, the degree of influence that various defect forms have on the mechanical characteristics of coal and rocks varies.

2. As axial strain increases, the number of mesocracks in coal and rocks gradually rises, progressing through three stages: a calm period prior to the crack initiation point, a stable propagation stage from the crack initiation point to the crack expansion point, and an accelerated propagation stage following the expansion point. The number of cracks of evolution curves have a stepwise transition between the initiation points and the expansion points of cracks in coal and rocks with hole defects of various forms. The evolution curve's number of cracks is reasonably smooth in the entire coal and rock, though.

3. Among them, the coal and rock with a trapezoidal hole defect has the smallest initiation stress and dilatation stress, while the coal and rock with a circular hole defect has the largest. The initiation stress and dilatation stress of coal and rocks with different hole defects are all lower than those of complete coal and rocks.

4. When subjected to uniaxial compression, complete coal and rocks sustain more damage than coal and rocks having hole flaws. The degree of damage to coal and rocks is somewhat influenced by the forms of hole flaws. The primary cause of fracture initiation and propagation is tensile stress concentration, and the persistence of a compressive stress chain between macro cracks is the explanation for the strength that remains after coal and rock collapse.

Acknowledgement

None

Conflict of Interest

None

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