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Editorial

Oil and Gas Well Engineering Measurement and Control

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Oil and gas wells represent a unique channel in regard to oil and gas exploration and production [1,2]. The measurement, control, and optimization of oil and gas wells are crucial for ensuring the safety, efficiency, and cost-effectiveness of drilling, logging, completion, stimulation, and production operations [1–4]. Indeed, the application and development of information theory, cybernetics, system theory, and optimization theory have led to significant advancements in well-drilling, logging, completion, stimulation, and production operations, with more scientific approaches being utilized to help improve these areas of oil and gas production [1–4]. Furthermore, numerous advanced technologies have becoming significantly involved in the fields of well-measurement, control, and optimization. The accelerated exploration and development of deep-water, deep-formation, and unconventional oil and gas resources has led to the continued challenges that are frequently faced in the realm of oil and gas well engineering currently, such as high risks, low efficiency, and high costs [5–8]. These challenges are further compounded by the complicated surface conditions [9], complex geological conditions [10], high temperature and pressure (HTHP) [11], strong vibrations [12], strong corrosions [13], multi-physics [14], and multi-phase effects [15]. Due to the rapid development and progress of measurement and control technologies, big data, machine learning (ML), and artificial intelligence (AI) [16–18], the abovementioned issues are expected to become even more challenging, with interventions being required in order to ensure the safety, high efficiency, and low costs of drilling, logging, completion, and stimulation moving forward.

This Special Issue, "Oil and Gas Well Engineering Measurement and Control" (https://www.mdpi.com/journal/processes/special_issues/Oil_Gas_Well_Engineering_Measurement_Control), showcases the latest advancements in the measurement, control, and optimization technologies related to oil and gas well drilling, logging, completion, and stimulation, featuring a total 33 original articles authored by 167 scientists from China, Egypt, Germany, Iraq, Kuwait, Russia, Saudi Arabia, Slovakia, Thailand, and the USA.

1. Advances in Oil and Gas Well Design and Drilling

Contribution 1 proposed a site selection model for multi-well pads of shale gas development in mountainous areas that incorporates both surface pad and underground wellbore construction costs, and it is based on digital elevation model (DEM) data. The optimal site selection can help to minimize the environmental damage and total costs of shale gas well construction.

Contribution 2 developed an optimization method for the lateral length of shale-gas horizontal wells, integrating geological, engineering, and economic factors. The economic lateral length was determined through a net present value model, and comprehensive assessments were conducted to identify the cost-optimal lateral lengths of shale gas horizontal wells in the Changning Block.

A mechanical specific energy (MSE)-based approach was formulated in Contribution 3, with the aim of detecting deep formation pore pressure. This new technique involved correcting downhole torque on bit (TOB), weight on bit (WOB), and revolution per minute

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(RPM) data in order to obtain a more accurate MSE value under the conditions of compound drilling. This approach is anticipated to overcome the limitations of the compaction theory, creating a significant advantage over traditional pore pressure detection methods.

A cutting-edge method for detecting gas kicks using modern drilling technology and sophisticated software was detailed in Contribution 4. An investigation into the most appropriate procedure for gas well control, utilizing both the "driller's method" and the "wait and weight method", was conducted, and the correctness of the procedure in regard to gas well control was verified using the reaction to a gas kick from a well drilled in Hungary.

Contribution 5 involved the establishment of an experimental device for examining the friction between planes throughout periodic changes in normal force. The results of this experiment were used to modify the amplitude distribution model, featuring an average error between experiment and calculation of 3.28%. It is anticipated that this innovative concept will be implemented to reduce drill-string drag in drilling engineering.

The authors of Contribution 6 designed a new downhole robot actuator that incorporates a planetary roller screw mechanism (PRSM). The mechanical behaviors, contact load distribution, and fatigue life of this PRSM in the downhole robot system were investigated. It is believed that the work of this contribution will establish a solution to the challenges of high-accuracy and long-life transmission in downhole robot systems.

Contribution 7 discussed a discrete element model that could simulate the cutting of pebbled sandstone via a polycrystalline diamond compact (PDC) cutter, and the influence of composite impact load on the cutting performance and vibration behavior was also simulated and examined. The results revealed that the composite impactor can markedly enhance the rate of penetration (ROP), diminish vibration, and also safeguard drill bits and measurement while drilling (MWD) instruments in gravel-bearing formations.

Contribution 8 hypothesized a thermal-hydro-mechanical coupling model capable of investigating the bottomhole stress and rock breakage mechanism involved in deep-well drilling. The influence of formation properties and wellbore conditions on the bottomhole stress was also simulated and evaluated. In future, this detailed article should assist in comprehending the bottomhole stress and rock breakage mechanisms involved in the in deep-well drilling process.

Contribution 9 proposed a surface axial vibration technology to reduce the drag force of the drill-string in horizontal wells. This would consequently enhance the WOB transfer efficiency, the ROP, and the extended-reach limit of horizontal wells. The results demonstrated that the amplitude and frequency of the exciting force are the primary factors influencing the efficacy of surface vibration.

A stick–slip vibration model of the drill-string based on the multidimensional torsional vibration model was put contemplated in Contribution 10, and the impact of WOB, rotary torque, and rotary speed on stick–slip vibration was also emulated and discussed within the article. Finally, the drilling parameters were optimized for three different types of formations, namely those that were soft, medium-hard, and hard.

Contribution 11 conducted a comprehensive evaluation of global well-killing technology while also developing a formula for the blocking compositions that prevent the fluid loss during well-drilling operations. The physico-chemical, rheological, and filtration properties were subjected to rigorous testing, and the efficacy of the formula in complex conditions was validated. The solution provides a valuable means for enhancing fluid-loss control in carbonate reservoirs.

2. Advances in Oil and Gas Well Cement and Completion

Contribution 12 presented a potential breakthrough pressure model for the cement matrix and interfacial transition zone in underground gas-storage wells. The proposed model was verified by using a breakthrough-pressure-testing device and program. This work can be employed to assess the sealing capacity and sustained casing pressure of the cement–casing system in underground gas-storage wells.

Contribution 13 put forward a novel elastoplastic model for the cement sheath under acid fracturing conditions. The 3D yield state of cement and temperature stress were taken into account. The generation and evaluation mechanisms of the microannulus were analyzed and clarified. This study can provide theoretical guidance for the preventing of cement sealing failure and sustained casing pressure.

Contribution 14 provided a comprehensive overview of the characteristics of casing deformation observed in shale gas wells in the Sichuan Basin. The primary factors that exert a significant influence on casing deformation in shale gas wells were identified. To prevent casing deformation, it is recommended to optimize well trajectory, improve casing strength and cementing quality, or optimize fracturing operations.

Contribution 15 proposed an improved wellbore temperature and pressure model in offshore HTHP production wells. The implementation of the gas−liquid two-phase separated method has resulted in a notable improvement in the accuracy of the calculations in comparison to that of the traditional model. This model can be utilized to facilitate a comprehensive safety assessment of offshore HTHP production wells.

Contribution 16 hypothesized an elastic-plastic assessment model of the gas sealability of a sphere-type premium connection. The influence of make-up torque on gas sealability and contact pressure was investigated, and the additional make-up torque exerted a profound influence on gas sealability. This method can be utilized to optimize the structural design and technical parameters.

Contribution 17 presented a novel 3D stress analytical solution for the casing-cement-formation system in an inclined well. A comparative analysis of the previous models indicates a tendency to overestimate the absolute values of stress components and the potential for failure of the casing and cement in both 2D and 3D scenarios. This novel solution provides a foundation for benchmarking numerical simulation and a rapid assessment of wellbore integrity.

Contribution 18 proposed a transient surge pressure model for casing running. A multi-density slurry column structure integrated with an accurate wellbore pressure calculation and exerting annular back pressure was utilized to address the issue of casing running in a narrow safety mud-window formation. This approach is capable of achieving the desired outcomes of leak-proofing and pressure stabilization.

Contribution 19 developed a numerical temperature and pressure prediction model for steam injection in shale oil wells. The utilization of this model allows for the optimization of completion methods and injection-production parameters, thereby reducing the incidence of casing damage and enabling the extension of the casing's operational life.

3. Advances in Oil and Gas Well Production and Monitoring

Contribution 20 proposed a novel water holdup measurement approach, which can be utilized for monitoring the oil−water two-phase production profile in horizontal wells. The test prototype was used for dynamic testing on the horizontal well simulation facility. This novel approach is anticipated to address the challenges associated with water holdup profile measurements in horizontal wells.

Contribution 21 introduced an accurate detection system for the scale thickness in three-phase flow inside the oil pipes based on the attenuation of gamma rays. This detection system consists of a dual-energy gamma source and a sodium iodide detector. The system is capable of accurately detecting the scale value with the use of a single detector, thereby providing a solution to the problem of sediment scale settlement.

Contribution 22 conducted a computational fluid dynamic (CFD) simulation to investigate the impacts of fluid state, pressure distribution, sand volume, and particle sizes on the erosion rate of the electric choke valve in HTHP gas wells. This study can be utilized to optimize the layout of the electric choke valve, thereby reducing the associated costs and the number of required switching wells.

Contribution 23 conducted a CFD simulation to investigate the methane movement in the goaf drained by a large-diameter drilling machine under "U"-shaped ventilation.

The ideal spacing between large-diameter boreholes and the optimal distance between the borehole and the upper corner were deliberated.

Contribution 24 saw the proposal of a dynamic model of sealing surfaces for the premium connection, and the hysteresis features and energy dissipation mechanism of sealing surfaces were analyzed. The results demonstrated the effectiveness of energy dissipation theory in the analysis of the sealing performance of the premium connection, which contrasts with the traditional static contact analysis.

Contribution 25 developed a novel perforation-creating approach for thorough hydro jetting fracturing. This approach allows for the precise control of the perforation position, angle, and length in true triaxial hydraulic fracturing specimens. The true triaxial acid fracturing experiments were conducted. The perforation created by the novel approach exhibited a high degree of similarity to that observed in situ. The acid pretreatment was found to be an effective method of dissolving minerals, resulting in a notable reduction in breakdown pressure of 7.7 MPa.

Contribution 26 developed a dynamic simulation system for HTHP ignition. The system is designed to facilitate real-time monitoring and recording of oxidation parameters during the combustion process of crude oil. The experiments were performed to determine the ignition point of crude oil under a range of pressure conditions, heating rates, oil–water ratios, and gas injection rates. This system can provide essential data for the implementation of the project and numerical simulation.

4. Application of ML and AI in Oil and Gas Well Engineering

A new approach involving the combining of supervised and unsupervised ML was postulated by Contribution 27. This method is aimed at joint predicting produced water and natural gas associated with oil production from unconventional reservoirs. The approach has been demonstrated to achieve an accuracy of 91% in joint prediction. Such model-derived outlooks can assist operators in formulating management or remedial solutions.

Contribution 28 put forward a comprehensive artificial neural network (ANN) model for the prediction of formation permeability. The ANN model was trained using approximately 500 core data points collected from the Western Desert and Gulf regions of Egypt. The results demonstrate that the ANN model is capable of accurately forecasting core permeability with a high degree of precision, achieving a 98% accuracy rate.

Contribution 29 presented a finite element model (FEM) for shale gas production with free and adsorbed gas in both the matrix and fractures, and an ANN model was developed to predict the gas rate and inflow performance in shale reservoirs. The proposed ANN model exhibits considerable robustness and predictive capability in relation to gas rate prediction in shale reservoirs.

Contribution 30 developed a multiscale generative adversarial network-based image inpainting method for the treatment of formation micro imager (FMI) images. The residual blocks were incorporated into the U-Net network with the objective of enhancing the quality of the filled logging images. In contrast to the majority of existing filling algorithms, the proposed method demonstrated superior performance when applied to images of complex lithology.

Contribution 31 proposed a novel pattern-recognition-based approach to the early detection of kick in offshore drilling. This approach integrated data filtering, pattern recognition, Bayesian framework, and multiphase flow models. The results demonstrated that the proposed approach exhibited a high precision in monitoring early kick while maintaining a low false positive rate.

Contribution 32 established an integrated framework combining the sparrow search algorithm (SSA) with the long short-term memory (LSTM) neural network. The integration of data-driven techniques and mechanistic models has resulted in an improvement in the precision of forecasting formation fluid-loss pressure, as well as the generation of valuable insights for the prevention of lost circulation during drilling.

Finally, Contribution 33 proposed a lost circulation prediction model combining the improved whale optimization algorithm (WOA) and bidirectional long short-term memory (BiLSTM) algorithm. In comparison to the LSTM, the BiLSTM, and WOA-BiLSTM models, the improved WOA-BiLSTM model demonstrated superior performance in terms of lost circulation prediction, as proposed in this study. This was evidenced by a 22.3%, 18.7%, and 4.9% higher prediction accuracy, respectively.

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Abbreviation

AI	artificial intelligence
ANN	artificial neural network
BiLSTM	bidirectional long short-term memory
CFD	computational fluid dynamic
DEM	digital elevation model
FMI	formation micro imager
FEM	finite element method
HPHT	high-temperature high-pressure
LSTM	long short-term memory
ML	machine learning
MSE	mechanical specific energy
MWD	measurement while drilling
PDC	polycrystalline diamond compact
PRSM	planetary roller screw mechanism
ROP	rate of penetration
RPM	revolution per minute
SSA	sparrow search algorithm
TOB	torque on bit
WOB	weight on bit
WOA	whale optimization algorithm

List of Contributions

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