# Chemistry and Technology of Fuels and Oils

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**Формирование фазового состава многокомпонентного катализатора окислительного аммонолиза пропилена**

*Методами термографии, совмещенной со сканирующей калориметрией, термодесорбции и рентгенофазового анализа in situ были исследованы фазовые превращения, протекающие при прокалке многокомпонентного катализатора окислительного аммонолиза пропилена в акрилонитрил. Установлена последовательность формирования фаз молибдатов двух- и трехвалентных катионов: $MMoO_4$ (M = Ni, Mg) и $M_2(MoO_4)_3$ (M = Fe, Ce).*

**Ключевые слова:** акрилонитрил, окислительный аммонолиз пропилена, фазовый состав, многокомпонентный оксидный катализатор, молибдаты двух и трехвалентных катионов.
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**Development of Phase Composition of a Multicomponent Catalyst of Oxidative Ammonolysis of Propylene**

*Thermography methods combined with scanning calorimetry, thermal desorption, and X-ray phase analysis in situ have been used to study phase transformations occurring during the calcination of a multicomponent catalyst of oxidative ammonolysis of propylene into acrylonitrile. The sequence of formation of molybdates phases of two- and three - valence cations has been established:*
*$MMoO_4$ (M = Ni, Mg) and $M_2(MoO_4)_3$ (M = Fe, Ce).*

**Key words**: *acrylonitrile, propylene ammoxidation, phase composition, multicomponent oxide catalyst, molybdates of 2- and 3-valent cations.*

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***Исследование композиционных материалов на основе фторопласта для изготовления поршневых колец компрессоров***

*Выбор оптимального композиционного полимерного материала для изготовления поршневых колец определяется прежде всего условиями работы данных деталей на протяжении длительного времени эксплуатации (8 000 ч), основными из которых являются: температура (115 °С), среда эксплуатации (азот, водород) и рабочее давление. Важными критериями выбора материала для поршневых колец являются: трибологические свойства (коэффициент трения и износостойкость), механические характеристики и температурные (структурно-фазовая стабильность при нагреве в интервале температуры эксплуатации) параметры. Однако, при выборе материала кроме эксплуатационных параметров немаловажными критериями являются экономические и технологические характеристики (качество материала, стабильность технологического процесса производства, стоимость композиционного полимерного материала).*

**Ключевые слова**: композиционные полимерные материалы, фторопластовая матрица, наполнитель, углеродное волокно, бронза, дисульфид молибдена, графит, коэффициент трения, износ, микротвердость, шероховатость, механические свойства.

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**Research of Composite Materials Based on Fluoroplast for the Manufacture of Piston Rings of Compressors**

*The choice of the optimal composite polymer material for the manufacture of piston rings is determined primarily by the operating conditions of these parts over a long period of operation (8 000 hours), the main of which are: temperature (115°C), operating environment (nitrogen, hydrogen) and operating pressures. Important criteria for choosing a material for piston rings are: tribological properties (coefficient of friction and wear resistance), mechanical characteristics and temperature (structural and phase stability when heated in the range of operating temperature) parameters. However, when choosing a material, in addition to operational parameters, important criteria are economic and technological characteristics (material quality, stability of the manufacturing process, cost of composite polymer material).*

**Key words**: *composite polymer materials, fluoroplastic matrix, filler, carbon fiber, bronze, molybdenum disulfide, graphite, coefficient of friction, wear, microhardness, roughness, mechanical properties.*

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**Замкнутый цикл повышения надежности: Синергия систем предиктивной аналитики и вибродиагностики в нефтеперерабатывающей отрасли**

*В статье рассматривается концепция «замкнутого цикла повышения надежности» технологического оборудования нефтеперерабатывающих и нефтехимических предприятий на основе интеграции систем вибродиагностики и предиктивной аналитики. Описывается алгоритм снижения внеплановых простоев и оптимизации затрат на ремонт динамических агрегатов. Практическая значимость подтверждается снижением доли аварийных остановов.*
**Ключевые слова:** повышение надежности, предиктивная аналитика, вибродиагностика, интеграция систем, замкнутый цикл, машинное обучение, эллиптический конверт.
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**Closed Reliability Improvement Loop: Synergy of Predictive Analytics and Vibration Diagnostics Systems in the Oil Refining Industry**
*The article examines the concept of the «closed reliability improvement loop» for technological equipment at oil refineries based on the integration of vibration diagnostics and predictive analytics systems. It describes the necessity of reducing unplanned downtime and optimizing repair costs for dynamic units. The practical significance is confirmed by a reduction in emergency downtime.*
**Key words**: *reliability improvement, predictive analytics, vibration diagnostics, system integration, closed loop, machine learning, elliptic envelope.*

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**Изучение активности регенерированного катализатора гидрокрекинга вакуумного газойля**
*В статье представлены результаты исследования влияния окислительной регенерации вне реактора на каталитические свойства дезактивированного катализатора гидрокрекинга вакуумного газойля. Регенерация проводилась при температуре до 450°С с использованием двух типов печей: конвейерной в тонком слое без перемешивания частиц и вращающейся барабанной. Анализ показал практически полное удаление углерода и серы из катализатора, а также сохранение удельной поверхности, прочности гранул, каталитической активности и селективности, независимо от типа используемого оборудования. Сравнение каталитических характеристик свежего и регенерированного катализатора выявило снижение активности регенерированных образцов. На основании полученных данных сделан вывод о целесообразности использования регенерированного катализатора для плановой замены дезактивированного, учитывая сохранение его основных эксплуатационных характеристик.*
**Ключевые слова**: катализатор гидрокрекинга, регенерация, каталитическая активность, селективность.
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**Study of the Activity of Regenerated Catalyst for Vacuum Gas Oil Hydrocracking**

*This article presents the results of a study on the effect of oxidative regeneration outside the reactor on the catalytic properties of a vacuum gas oil hydrocracking catalyst. Regeneration was carried out at a temperature no higher than 450°C using two types of furnaces: a "conveyor" furnace (thin layer without mixing catalyst particles) and a rotating drum furnace. It was shown that almost complete removal of carbon and sulfur is achieved, and properties of the regenerated catalysts such as specific surface area, granule strength, catalytic activity, and selectivity do not depend on the type of regeneration equipment used. The activity of the regenerated catalysts is lower than that of the fresh catalyst. Based on the study results, a conclusion was made that the regenerated catalyst can be used to replace the deactivated catalyst.*

***Key words**: hydrocracking catalyst, regeneration, catalytic activity, selectivity.*

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**Применение нейросетевых технологий для прогнозирования и оптимизации маржинальности производственного объекта на примере установки глубокой переработки нефти**

*В работе исследуется проблема повышения маржинальности установки глубокой переработки нефти, за счет внедрения в процесс управления объектом программы поддержки принятия решения. Принцип работы программы заключается в построении предиктивной модели, предсказывающей будущую маржинальность установки и последующем подборе значений управляющих воздействий, приводящих к наибольшему значению прогнозной маржинальности. Подход к построению прогноза маржинальности основывается на обучении нейросетевой модели. Демонстрируется состоятельность данного подхода на примере установки гидрокрекинга гудрона. Предлагаемые программой рекомендации согласуются с мнением экспертов. Экономический эффект от ее внедрения был подтвержден в ходе проведения опытно-промышленного пробега.*

**Ключевые слова**: машинное обучение, RNN, задача оптимального управления, маржинальность.

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**The Neural Network Technologies Utilization for Forecasting and Optimizing the Economic Efficiency of a Production Facility Using the Example of a Deep Oil Refining Installation**

*The paper discusses the problem of increasing the economic efficiency of a deep oil refining unit. Efficiency is increased by introducing a decision support program into the installation management process. The principle of the*

*program is to build a predictive model that predicts the future economic efficiency of the installation and then select the values of control actions that lead to the highest value of predictive efficiency. The approach to forecasting economic efficiency is based on neural network model. The validity of this approach is demonstrated by the example of a tar hydrocracking installation. The recommendations proposed by the program are consistent with the opinion of experts. The economic effect of its implementation was confirmed during the pilot industrial run.*
**Key words**: *machine learning, RNN, optimal control problem, marginality.*

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**Перспективы рынка авиатоплив с низким углеродным следом**
**и потенциал для российских НПЗ**

*В работе представлен актуальный обзор текущих и перспективных требований к авиаперевозчикам и производителям топлив для воздушных судов, оценено влияние нормативно-правового регулирования в международном и региональном масштабах на баланс рынка авиакеросина и его альтернатив. Проведен сравнительный анализ современных технологий и способов получения устойчивого и низкоуглеродного авиационных топлив, рассмотрены экономические и экологические аспекты, сделаны выводы о применимости различных технологий и реализуемости проектов производства SAF, дана краткая справка о выполняемых работах в Компании по данному направлению.*
**Ключевые слова:** устойчивое авиационное топливо, SAF, авиакеросин, углеродный след, LCAF, выбросы углекислого газа, декарбонизация.
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**Sustainable Aviation Fuels Market Trends and Potential for Russian Refineries**

*The article provides an updated review of current and prospective requirements for air transportation companies and aircraft fuel producers, assesses the impact of international and regional regulations on the balance of the jet fuel market and its alternatives. A comparative analysis of advanced technologies and methods of production of sustainable and low-carbon aviation fuels is provided, economic and environmental aspects were considered, conclusions are presented on the applicability of various technologies and feasibility of SAF production projects, and a brief summary of the Company's activities in this area is presented in the article.*
**Key words**: *sustainable aviation fuel, SAF, LCAF, jet fuel, carbon footprint, $CO_2$ emissions, decarbonization.*

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**Практика применения современных систем управления проектами при строительстве объектов нефтехимической промышленности**

*В статье проведён анализ эффективного внедрения современных систем управления проектами на основе цифровизации процессов. При этом достигается прецизионность планирования за счет применения аналитических инструментариев, минимизации риск-факторов и динамики принятия управленческих решений. Статья также затрагивает перспективное развитие систем в углублении контроля и анализе данных в режиме реального времени на строительной площадке с использованием ретроспективных данных.*

**Ключевые слова**: управление инвестиционными проектами, корпоративные информационные системы управления проектами, цифровая трансформация, интеграция с другими корпоративными системами, мастер-система, дашборд.

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**Modern Project Management Systems' Application Practice in Petrochemical Industry Facilities' Construction**

*The article analyzes the effective implementation of modern project management systems based on the processes' digitalization. Advantages: achieving planning precision through the use of analytical tools, minimizing risk factors and dynamics of management decision-making. The article also touches on the promising development of systems in deepening real-time data monitoring and analysis at the construction site using historical data.*

**Key words**: *investment project management, corporate project management information systems, digital transformation, integration with other corporate systems, master system, dashboard.*

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**Успешный опыт по модернизации линий очистки мономеров на предприятии группы компаний ЛУКОЙЛ**

*Подробно рассмотрена проблематика наличия каталитических ядов и микропримесей в потоках нефтехимических производств, в частности, в сырье производств полиэтилена и полипропилена, а также в сырье производств других продуктов органического и нефтехимического синтеза. Представлены методы модернизации линий очисток мономеров от каталитических ядов и микропримесей на примерах успешного внедрения технических решений и продуктов компании ООО «ЮКТ» совместно со специалистами компании ЛУКОЙЛ на предприятиях группы компании ЛУКОЙЛ.*

**Ключевые слова**: очистка, мономеры, полиэтилен, полипропилен, каталитические яды.

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**Successful Experience in the Monomer Cleaning Lines' Modernization**

**at the Enterprise of LUKOIL Group Companies**

*The problem of presence of catalytic poisons and microimpurities in petrochemical production flows, in particular, in the feedstock of polyethylene and polypropylene production, as well as in the feedstock for production of other organic and petrochemical synthesis products, is reviewed in detail. Methods for modernization of monomer cleaning lines from catalytic poisons and microimpurities are presented using examples of successful implementation of YUST LLC technical solutions and products together with LUKOIL specialists at LUKOIL Group enterprises.*

**Key words**: *cleaning, monomers, polyethylene, polypropylene, catalytic poisons.*

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**Исследование структурно-химических особенностей сырья и продуктов висбрекинга**

**с применением спектроскопии**

*В работе исследовано сырье для процесса висбрекинга — нефтяные остатки высокосмолистых нефтей, обладающие низким содержанием серы с применением методов ИК- и ПМР-спектроскопии. Проведен анализ образцов сырья и продуктов процесса висбрекинга с использованием инструментальных методов ПМР и ИК-Фурье спектроскопии. Показано, что все изученные остатки являются высокопарафинистыми. «Средние» молекулы этих остатков характеризуются небольшим числом ароматических колец с длинными алкильными заместителями, в которых число атомов углерода достигает 8. Значительное количество алкильных цепочек в молекулах дисперсной фазы асфальто-смолистых веществ способствует низкой стабильности сырья и остатков висбрекинга. Исследование сырья и остатков висбрекинга показывает увеличение концентрации парамагнитных центров в остатках висбрекинга по сравнению с исходным гудроном. Результаты проведенных исследований могут быть использованы для выбора эффективных методов и оптимальных условий реализации процесса висбрекинга и подготовки котельных топлив, связанных с переработкой высоковязких и парафинистых нефтей на отечественных нефтеперерабатывающих заводах.*

**Ключевые слова:** процесс висбрекинга, фактор стабильности, ИК-Фурье спектроскопия, гудрон, электронный парамагнитный резонанс, протонный парамагнитный резонанс.

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**Investigation of the Structural and Chemical Characteristics of Raw Materials and Visbreaking Products Using Spectroscopy**

*The feedstock for visbreaking process — oil residues of highly resinous crude oils with low sulfur content have been reviewed in this study using IR and proton magnetic resonance spectroscopy. The feedstock samples and visbreaking products have been analyzed using proton magnetic resonance spectroscopy and Fourier-transform infrared spectroscopy. It has been shown that all the studied residues are highly paraffinic. The "medium" molecules of these residues are characterized by a small number of aromatic rings, with 3-6 long alkyl substituents in which the number of carbon atoms reaches 8. The presence of a significant amount of alkyl chains in the molecules of the dispersed phase of asphalt-resinous substances contributes to a low stability of the feedstock and visbreaking residue. The study of the feedstock and visbreaking residues shows an increase in the paramagnetic centers concentration in the visbreaking residues compared to the original vacuum residue. The results of the performed research can be used to select efficient methods and optimal conditions for implementation of the visbreaking process and preparation of boiler fuels associated with processing of high viscous and paraffinic crude oils at domestic refineries.*

**Key words**: *visbreaking process, stability factor, Fourier-transform infrared spectroscopy, vacuum residue, electron paramagnetic resonance, proton paramagnetic resonance.*

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**Исследование процесса межмолекулярного взаимодействия сложных структурных единиц сырья и продуктов висбрекинга**

*В работе изучены взаимосвязи между фактором стабильности сырья продуктов процесса висбрекинга парафинистой нефти с энергией межмолекулярного взаимодействия, которая, согласно кинетической теории жидкостей, оценивается через энергию активации вязкого течения. Показана возможность определения энергии активации по рефрактометрическим характеристикам парафинистых сред. Показана взаимосвязь энергии межмолекулярного взаимодействия нефтяных дисперсных систем с концентрацией парафинов в среде. Установлено влияние на фактор стабильности и общего потенциального осадка (ОПО) сырья и продуктов висбрекинга следующих показателей: энергии межмолекулярного взаимодействия нефтяных дисперсных систем (НДС), содержания асфальто-смолистых веществ, ароматических и парафино-нафтеновых углеводородов. Введение вакуумного газойля, содержащего до 30–40% мас. ароматических углеводородов, способствует стабилизации продуктов висбрекинга за счет увеличения энергии взаимодействия сложных структурных единиц. Показана взаимосвязь энергии межмолекулярного взаимодействия НДС с ОПО и фактором стабильности и парафинов. С ростом энергии межмолекулярного взаимодействия общий потенциальный осадок уменьшается и стабильность коллоидной системы возрастает.*

**Ключевые слова:** остаток висбрекинга, кинематическая вязкость, энергия межмолекулярного взаимодействия, содержание углеводородов, фактор стабильности, общий потенциальный осадок.
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**Investigation of the Intermolecular Interaction of Complex Structural Units of Raw Materials and Visbreaking Products**

*The aim of the work is to study the relationship between the stability factors of the raw materials of the products of the paraffin oil visbreaking process and the energy of intermolecular interaction, which, according to the kinetic theory of liquids, is estimated through the activation energy of a viscous flow. The paper also shows the possibility of determining the activation energy based on the refractometric characteristics of paraffin media. The relationship between the influence of the following indicators on the stability factor of raw materials and visbreaking products has been established: the energy of intermolecular interaction of petroleum dispersed systems. The influence of the following indicators on the stability and total potential precipitation (TPO) factor of raw materials and visbreaking products has been established: the energy of intermolecular interaction of petroleum dispersed systems, the content of asphalt-resinous substances, aromatic and paraffin-naphthenic hydrocarbons. Containing a significant amount of paraffin-naphthenic hydrocarbons, with a decrease in the amount of which the stability of the residue increases. In addition, the introduction of vacuum gas oil containing up to 30-40% by weight. aromatic hydrocarbons, contributes to the stabilization of visbreaking products by increasing the energy interaction with them. The relationship between the energy of the intermolecular interaction of VAT with TPO and the stability factor is shown and paraffins. As the intermolecular interaction energy increases, the total potential precipitation decreases and the stability of the colloidal system increases.*

**Key words**: *cvisbreaking residue, kinematic viscosity, intermolecular interaction energy, hydrocarbon content, stability factor, total potential precipitation.*

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**Опыт использования российской каталитической системы на установке гидрокрекинга вакуумного газойля**

*Описаны результаты применения на одном из российских нефтеперерабатывающих заводов группы «ЛУКОЙЛ» каталитической системы российского производства, включая катализатор гидроочистки,*

*гидрокрекинга и гидрофинишинга. Показано, что отечественная каталитическая система позволяет эксплуатировать реакторы при более низких температурах с конверсией и селективностью близкой по значениям для лицензионной каталитической системы. Качество непревращенного остатка и фракции 150–360оС, вырабатываемых на отечественных катализаторах, превосходило качество этих продуктов при эксплуатации лицензионной каталитической системы. Высокая активность российского катализаторов позволила осуществить комбинированную загрузку реактора гидрокрекинга с использованием 50% регенерированного лицензионного катализатора, что значительно сократило затраты на перегрузку катализаторов.*
**Ключевые слова**: катализатор гидрокрекинга, каталитическая активность, селективность, регенерированный катализатор.
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**Experience of Using a Russian Catalytic System at a Vacuum Gasoil Hydrocracking Unit**
*The results of the application of a domestic-made catalytic system, including a catalyst for hydrotreating, hydrocracking and hydrofinishing, are described one of the Russian oil refineries of the LUKOIL group. It is shown that the domestic catalytic system makes it possible to operate reactors at lower temperatures with conversion and selectivity close to that of the licensed catalytic system. The quality of the unconverted residue and the 150-360 °C fraction produced on domestic catalysts exceeded the quality of these products during the operation of a licensed catalytic system. The high activity of domestic catalysts made it possible to carry out a combined loading of the hydrocracking reactor using 50% of the regenerated licensed catalyst, which significantly reduced the cost of overloading the catalysts.*
**Key words**: *hydrocracking catalyst, regeneration, catalytic activity, selectivity.*

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**Zeta Potential of Cellulose Nanofibrils as a Function of pH**
*We studied the titration behavior and the zeta potential behavior of TEMPO-oxidized CNF. The carboxylic groups at the CNF surface provide the non-linear response to the addition of acidic and basic titrants with equivalent points estimated as pH=3.54 (acidic) and pH=6.87 (basic). Surface charge and surface potential of CNF can be estimated from the fitted titration curve. Electric potentials at various scaled distances from the CNF surface and measured zeta potentials are in good agreement if we assume that the slipping plane is located at about 3.2 Debye lengths from the CNF surface.*

**Keywords:** *adsorption, surface area, charge density, titration.*

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**Facile *n*-Decane Encapsulation through Surfactant-Free Pickering Emulsion Polymerization**

*A facile and eco-friendly method for encapsulating the organic phase change material n-decane using surfactant-free Pickering emulsions stabilized by carboxylated cellulose nanofibrils (CNFs) is presented. In this method, CNF serves as both a stabilizer and a source of reactive groups, enabling direct shell crosslinking through covalent bonding between cellulose carboxyl groups and polymethylene polyphenylene isocyanate (PAPI). Comprehensive characterization by electronic microscopy, IR spectroscopy, thermal gravimetry, thermogravimetric analysis, differential scanning calorimetry, and leakage analysis confirmed effective shell formation and n-decane encapsulation, enhanced thermal stability, and effective retention of n-decane, with an apparent encapsulation efficiency of 58.5%. Thermal analysis revealed broadening and shifting of phase transition peaks attributable to spatial confinement and interfacial effects within the microcapsules. Leakage tests demonstrated strong retention of the PCM core with the crosslinked CNF shell effectively limiting heating-induced leakage. These results underline the potential of CNF-based surfactant-free Pickering emulsion polymerization as a promising approach for encapsulating short-chain paraffin PCMs in cold storage applications, with opportunities for further optimization toward enhanced encapsulation efficiency and capsule durability.*

**Keywords:** *phase-change materials, paraffins, cold storage, interfacial polymerization, cellulose nanofibrils, polyamides, polymeric isocyanate.*

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**Comparative Analysis of Methods for the Determination of Rosin Acids in Tall Oil**

*Compared in this study are methods for determining rosin acids in crude and distilled tall oils. It is shown that the determination of rosin acids using the standard titrimetric method TS 13-0281078-119-89 results in underestimated results compared to the data obtained by the GOST R 50378-92 method. The most significant factor influencing the analysis results is the type of the alcohol used as a solvent. The measured concentrations of rosin acids increase in the following order: methanol < n-butanol < isopropanol. The GOST R 50378-92 method ensures reliable results and can be recommended for routine analysis of tall oils.*

**Keywords:** *tall oil, rosin acids, esterification, aliphatic alcohols.*

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**Study of Perovskite Catalysts for Carbon Dioxide Conversion of Methane**

*This article reviews recent studies of the action of various perovskite catalytic systems for the carbon dioxide reforming of methane (CDRM). Procedures for the improvement of such perovskite catalysts are discussed. The properties of nickel, iron, cobalt, and lanthanide perovskite catalysts were found to depend on the method of synthesis and the presence of promoters such as $ZrO_2$, $CeO_2$, $K_2O$, and MgO. Nanostructured perovskite catalysts with an active phase of metal nanoparticles have high activity and are stable at high temperatures. Perovskites are highly efficient CDRM catalysts. Their use as catalytic system precursor enhances the catalytic activity. Perovskites have shown high activity even under extreme high-temperature conditions, which makes them promising catalysts for CDRM. Various perovskite-based catalysts demonstrate high catalytic activity and stability even after prolonged use without coke formation.*

**Keywords:** *carbon dioxide, carbon dioxide capture, carbon dioxide reforming of methane, perovskite catalyst systems.*

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**Eco-Friendly Gas Hydrate Inhibitors**

*Natural gas hydrates can cause pipeline blockage during oil and gas transportation, leading to significant economic losses and environmental risks. Conventional thermodynamic hydrate inhibitors, such as methanol and ethylene glycol, can effectively prevent hydrate formation. However, these inhibitors require to be applied in high concentrations, thus being toxic to humans and the environment. Kinetic hydrate inhibitors (KHIs) have recently attracted attention due to their advantages, including environmental friendliness and the possibility of using lower concentrations. In this article, we carry out a systematic review of research literature on synthetic and natural KHIs, analyzing their inhibition mechanisms, characteristics, and limitations. Particular attention is paid to the experimental studies of urea, a new environmentally friendly inhibitor with both thermodynamic and kinetic action.*

**Keywords:** *natural gas hydrates, thermodynamic hydrate inhibitors, kinetic hydrate inhibitors, polymers, urea.*

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**Based on the Design Structure Matrix Optimization**

**of EPC Project Schedule for Petroleum Refining Engineering**

*The key to the construction progress of petroleum refining engineering project groups lies in the production sub network, and the progress management of key projects is the core of sub network project progress management. This article proposes to use a design structure matrix to express the task relationships in key projects, comprehensively adjust the sequence progress of E+P+C, and achieve the goal of overlapping execution between*

*processes by analyzing the start time, end time, and execution time of various work tasks, in order to shorten the project cycle and develop a reasonable schedule for key projects. This study can provide guidance for the preparation of EPC key project schedule plans in petroleum refining engineering project groups, and provide a scientific and effective basis for conducting research on project group schedule optimization management.*
**Keywords:** *petroleum refining engineering project group, design structural matrix, plan, sort.*

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**Study on Liquid Loading Patterns of Low-Pressure Gas Wells and Selection of Efficient Drainage Processes**

*This study addresses production issues in low-pressure gas wells. Beginning with the mechanisms, identification and diagnosis of liquid loading in such wells, we analyze the patterns of liquid accumulation. On this basis, a comparative selection of several efficient drainage processes for different types of low-pressure gas wells is carried out, laying the foundation for optimizing well-liquid removal in the later stages of low-pressure gas-field development. The results show that liquid loading in low-pressure wells is mainly influenced by critical liquid-carrying velocity, wellbore configuration and fluid properties, and exhibits distinct staged evolution. By establishing a multi-parameter comprehensive diagnostic model, precise recognition of liquid-loading status is achieved. Common efficient drainage processes include plunger lift, gas-lift drainage and various auxiliary techniques. For different low-pressure wells, appropriate selection and optimization of drainage technology, together with differentiated strategies, can comprehensively enhance well productivity and ultimately improve recovery.*

**Keywords:** *low-pressure gas well, liquid-loading pattern, identification and diagnosis, efficient drainage, process selection.*

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**Construction of Complex Well Control Scenarios and Analysis of Risk Evolution Law**

*This study establishes a multi-physics-coupled dynamic analysis model to investigate the risk evolution of oil and gas intrusion in high-temperature high-pressure (HTHP) drilling operations. By integrating genetic neural networks for seismic attribute screening with acoustic data and dynamic Bayesian networks (DBN), the evolutionary patterns of leakage, collapse, and overflow risks are systematically analyzed. The research elucidates the driving mechanisms of oil and gas intrusion under HTHP conditions, including pressure gradients, capillary effects, stress redistribution, and non-Darcy flow, and proposes a three-stage dynamic process for intrusion*

*channel formation (initial, dynamic, and sudden risk phases). Safety barrier failure analysis identifies critical failure modes of drilling fluid, blowout preventers (BOPs), and casing systems under extreme conditions: rheological degradation of drilling fluid, material performance attenuation of casing, and BOP seal failure. Quantitative assessment via DBN models evaluates the coupling effects of equipment failures, abnormal formation pressure, and human errors, constructing a multidimensional risk propagation framework encompassing equipment, environment, personnel, and management factors. A hybrid evaluation method combining data-driven analysis and numerical simulation is proposed, offering theoretical and technical foundations for proactive risk management in deep-sea drilling.*
**Keywords:** *HTHP drilling, oil and gas intrusion well control, risk evolution, well control risk assessment.*

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**Development and Performance Evaluation of a Salt-Tolerant Supramolecular Fracturing Fluid Thickening Agent**

*In the exploitation of high-salinity oil and gas reservoirs, traditional fracturing fluid thickening agents often encounter challenges such as poor solubility, reduced thickening efficiency, and unstable rheological properties due to the high concentration of salt ions. To address these issues, this study presents the design, synthesis, and comprehensive performance evaluation of a novel salt-tolerant supramolecular thickening agent (STSTA) based on hydrophobic association and electrostatic interactions. The STSTA was synthesized via aqueous solution polymerization using acrylamide (AM), acrylic acid (AA), 2-acrylamido-2-methylpropane sulfonic acid (AMPS), a non-ionic polymerizable surfactant (NPS), and a double-tail hydrophobic monomer (DHM) as the main monomers. Fourier-transform infrared spectroscopy (FT-IR), nuclear magnetic resonance (NMR), and scanning electron microscopy (SEM) were used to characterize the chemical structure and morphology of the STSTA. Performance evaluations included solubility, thickening ability, rheological behavior, salt tolerance, sand-carrying capacity, thermal stability, and compatibility with other fracturing fluid additives. The results showed that the STSTA exhibited excellent solubility in salt brines up to 200,000 mg/L, maintained high viscosity (≥80 mPa·s at 0.5 wt% concentration under 170 $s^{-1}$ shear rate in 150,000 mg/L NaCl), and demonstrated superior shear-thinning, viscoelastic, and shear-recovery properties compared to traditional guar gum-based thickeners. The unique supramolecular structure formed by hydrophobic association and ionic interactions enabled the STSTA to resist salt-induced viscosity degradation, making it a promising candidate for hydraulic fracturing in high-salinity environments.*
**Keywords:** *salt-tolerant, supramolecular, fracturing fluid, thickening agent, rheological properties, salt tolerance.*

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**Study on Carbonate Reservoir Pollution and Acidizing Deblocking via Numerical Simulation**

*Carbonate rocks are generally characterized by small pore throats and poor permeability. During the drilling and completion process, the reservoir is extremely susceptible to being contaminated by drilling fluids, and the contamination is difficult to be removed. The purpose of removing contamination can be achieved by wellbore acidizing through chemical dissolution. To deeply study the damage process and acidizing plug-removal process of carbonate reservoirs, a numerical model of wellbore contamination and acidizing plug-removal in carbonate rocks was established based on the mathematical models of drilling fluid invasion and acidizing plug-removal. The finite-element method was utilized for solving. The contamination conditions and plug-removal effects under different porosities, drilling fluid leakage amounts, injected acid concentrations, and the presence of fractures were investigated. It is shown by the results that with the increase of the original formation porosity and the drilling fluid leakage amount, the decline range of porosity and permeability after being contaminated by the drilling fluid is larger, and the contamination is more serious. At the same time, with the aggravation of the contamination degree, the acidizing plug-removal range around the wellbore is smaller. When the drilling fluid leakage amount is increased from 100 $m^3$ to 300 $m^3$, the plug-removal range is decreased from 22.8% to 8.9%. With the increase of the injected acid concentration, wormholes can communicate with the original formation more rapidly, but the plug-removal range around the wellbore is decreased. When fractures exist, the position and angle of the fractures have a significant influence on the acidizing plug-removal effect. When the fracture is close to the wellbore and the fracture angle is small, the fracture becomes the dominant flow channel, and the expansion of wormholes in other directions is affected, thus reducing the plug-removal range in the contaminated area. The research results are provided to offer theoretical guidance and reference for the contamination evaluation of drilling fluids and the analysis of wellbore acidizing plug-removal effects.*

**Keywords:** *carbonate rock, drilling fluid invasion, acidizing, numerical simulation, wormhole.*

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**The Current Status and Prospects of Cooling Technology for Offshore High-Temperature Drilling Wells**

*Deep wells and geothermal wells often face the challenge of high temperatures, which significantly affect operations such as drilling and well logging. To ensure the safe and efficient implementation of high-temperature wells, various supporting measures are commonly used to reduce the bottom-hole temperature. This paper analyzes the challenges of high-temperature drilling and discusses the commonly used cooling methods for offshore wells, such as mud cooler, mud pit cooling coils, and annular pressure-boosting pump technologies. A brief evaluation of their cooling effectiveness and applicability is provided. Since the currently used cooling methods still have certain*

*limitations, the paper explores and forecasts alternative cooling techniques with significant future potential. It provides a detailed analysis of the advantages and disadvantages of water-based cooling, phase change material cooling, and inner-coating thermal insulation drill string technologies. This paper offers valuable insights for both offshore and onshore high-temperature well cooling strategies.*
**Keywords:** *offshore, high temperature drilling, wellbore cooling, technology status, technical outlook.*

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**Algorithm Implementation of Long-distance Pipeline Pig Tracking Operation Based on Beidou Technology**

*Aiming at the issues in existing pipeline internal inspection pig tracking technologies, such as the inability to precisely monitor real-time pig status, insufficient positioning accuracy and difficulty in rapidly identifying stuck pig locations during blockage incidents, this study proposes a BeiDou-based tracking algorithm for long-distance pipeline pigging operations. The solution involves deploying BeiDou precision positioning marker devices along pipelines to leverage the systems high-precision positioning, time synchronization, and short message communication capabilities, thereby acquiring accurate positional data and pig passage timestamps. The algorithm employs a segmented velocity method integrated with pipeline GIS data and BeiDou positioning technology to calculate pig positions and predict movement trends across various terrains. By establishing an internal detector motion model that incorporates key parameters including pipeline gradient, bend pressure differentials, resistance coefficients, and detector weight for non-horizontal pipelines and curved sections, we introduce dynamic velocity adjustment factors to optimize the segmented velocity method, thereby enhancing positioning accuracy for both normal operation and stuck pig scenarios. This cloud-embedded algorithm enables real-time operational monitoring and anomaly alerts through an APP client interface. Test results indicated that algorithm outperforms traditional GPS-based pig tracking and fiber-optic vibration sensing technologies in positioning accuracy, stuck ball response efficiency and adaptability to complex terrains. Under complex terrain conditions, the measured positioning error ranged from 9 to 13 meters. Detection balls position update frequency reached 30-second intervals, enabling continuous trajectory tracking. Early warning response time for stuck balls had been reduced to within 10 minutes. This technology provides real-time and reliable technical support for pipeline safety operation and maintenance.*
**Keywords:** *beidou satellite navigation system, long-distance pipeline, automatic pig tracking algorithm, segmented average velocity method, dynamic velocity correction.*

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**Application and Algorithm Improvement of Artificial Intelligence in Petrochemical Production Optimization and Scheduling**

*This paper comprehensively explores the application of artificial intelligence (AI) in petrochemical production optimization and scheduling, along with in-depth algorithm improvement strategies. In the petrochemical industry, where complex processes, variable raw materials, and dynamic market demands pose significant challenges, AI technologies offer innovative solutions. Through an analysis of AI applications in predictive maintenance, production process optimization, supply chain management, quality control, and safety monitoring, it is demonstrated how these technologies can enhance operational efficiency, reduce costs, and improve product quality. Nine detailed tables are presented to illustrate the practical effectiveness of AI applications and the performance improvements achieved through algorithm enhancements. The research also discusses the challenges faced during implementation and proposes corresponding countermeasures, highlighting the potential of AI to drive the sustainable development of the petrochemical industry.*
**Keywords:** *artificial intelligence, petrochemical production, production optimization, production scheduling, algorithm improvement, predictive maintenance, quality control.*

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**Analysis of Chemical Properties and Enhanced Oil Recovery**
**of Binary Composite Flooding Systems**

*This paper focuses on the research of binary composite flooding systems, comprehensively analyzing their chemical properties and enhanced oil recovery (EOR) performance. The binary composite flooding systems, usually composed of two main components, such as a surfactant and a polymer, can synergistically improve the displacement efficiency of oil reservoirs. Through laboratory experiments and field application data analysis, the chemical characteristics including interfacial tension reduction ability, viscosity-building performance, and long-term stability of binary composite flooding systems are studied. Meanwhile, the EOR mechanisms and influencing factors are explored in detail. The results show that binary composite flooding systems can effectively reduce the interfacial tension between the displacement fluid and crude oil, increase the viscosity of the displacing fluid, and improve the sweep efficiency and displacement efficiency of oil reservoirs, thus achieving significant EOR effects. This research provides a theoretical and practical basis for the further application and optimization of binary composite flooding technology in the oil industry.*
**Keywords:** *binary compound flooding, surface active agent, viscosity increasing ability, oil displacement efficiency.*

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**Comprehensive Analysis of the Microscopic Acid-Etching Characteristics and Dissolution Mechanisms in Complex-Lithology Carbonate Rocks**

*This study presents a comprehensive analysis of the microscopic acid-etching characteristics and dissolution mechanisms in complex-lithology carbonate rocks, employing petrographic thin sections, scanning electron microscopy (SEM), nuclear magnetic resonance (NMR), and CT scanning. Dynamic dissolution experiments with 15% hydrochloric acid reveal that acid-etching behavior is significantly governed by the synergy between mineral composition and pore structure: calcite exhibits notably higher dissolution reactivity than dolomite, pyrite, and quartz, driving preferential dissolution at calcite-rich interfaces. Limestone demonstrates uniform surface dissolution, whereas dolomite develops abundant dissolution pores (1–8 μm) and microfractures, with significantly enhanced pore connectivity. NMR and CT scan results indicate that high-permeability rocks (≥4 mD) facilitate deeper acid penetration, forming a penetrating wormhole network with a porosity increase of up to 611% – substantially higher than the 542% observed in low-permeability samples. The dissolution process follows a two-stage evolution model: "mineral heterogeneity drives surface non-uniform dissolution, and pore connectivity promotes the formation of internal wormholes". These findings provide critical mechanistic insights for optimizing acidization processes and enhancing seepage capacity in complex carbonate reservoirs.*

**Keywords:** *complex lithologic carbonate rocks, acid etching mechanism, characteristics of acid erosion, erosion mode.*

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**Main Controlling Factors of Dolomite Reservoirs for Deep Carbonate Oil and Gas Exploration**

*The dolomite reservoirs in the Fourth Member of Ordovician Majiagou Formation in the central-eastern Ordos Basin serve as important targets for deep carbonate oil and gas exploration in the basin. Clarifying the reservoir characteristics and main controlling factors is of great significance for improving oil and gas exploration efficiency and deployment. This study is based on various geological data including core observation, thin section analysis, X-ray diffraction, and carbon-oxygen-strontium isotope analysis from Well Xiaohao-1. The petrological characteristics, reservoir space types, and reservoir physical properties of the dolomite in this interval were systematically analyzed. The influences of main controlling factors including sedimentary environment, bioturbation, dolomitization, and early diagenetic karstification on reservoir formation were discussed. Research*

*results show that the dolomite reservoirs in the Fourth Member of Majiagou Formation are mainly characterized by intercrystalline pores, intracrystalline pores, and structural fractures as the primary reservoir spaces, exhibiting a pore-fracture composite reservoir structure. The reservoirs generally display tight to low-porosity and low-permeability characteristics, but areas with well-developed coarse-crystalline dolomite locally possess good reservoir properties. The sedimentary environment controlled the formation of favorable microfacies, providing the material foundation for reservoir development. Bioturbation promoted dolomitization and pore preservation. Dolomitization not only enhanced pore structure but also improved pore stability and connectivity. Early diagenetic karstification further enlarged and modified the original pores. The superimposed coupling effects of the above factors jointly controlled the spatial distribution and quality differences of dolomite reservoirs in this area.*
**Keywords:** *Central-eastern Ordos Basin, Ordovician, Fourth Member of Majiagou formation, dolomite reservoir, reservoir characteristics, main controlling factors.*

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**Progress in Geological Core Drilling Technology**

*With the deepening of the construction of ecological civilization and the continuous growth of the demand for mineral resources, the research and promotion of green exploration equipment and technical methods is the goal of the healthy and sustainable development of geological work. This paper systematically reviews the latest progress of domestic green exploration geological core drilling technology. The advantages of low-carbon and high-efficiency drilling technology such as directional drilling, drilling instead of trench, air reverse circulation drilling, rope hydraulic impact drilling, environmental protection flushing fluid, and discusses the applicability of related drilling equipment and technology in different scenarios. China's green exploration equipment and technology system has been initially formed, but there are still problems such as insufficient research and development and promotion of automation equipment, bottlenecks in directional coring technology, and inapplicability of industry standards and related technologies. Therefore, this paper puts forward some suggestions, such as strengthening the research and development and promotion of automatic ( intelligent ) drilling equipment, innovating environmental protection flushing fluid and waste slurry treatment technology, and improving geological exploration norms, so as to promote the high-quality development of geological exploration industry in the direction of green, intelligent and efficient.*

**Keywords:** *green exploration, geological core drilling, drilling equipment, drilling technology, environmentally friendly flushing fluid, low-altitude transport.*

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**Study on Theory and New Test Method of Casing External Collapse Strength in Simulated Curved Well**

*In response to the research gap on the effect of wellbore bending on the collapse resistance of casing under external pressure, this paper aims to derive new theoretical calculation formulas and conduct experimental research to provide a reliable basis for the design and verification of casings for deep wells, ultra-deep wells, and high-displacement wells, thereby enhancing the safety of oil and gas wells. Based on the ISOTR 10400 standard, this paper proposes three casing bending collapse strength formulas and compares them with existing theories. At the same time, a finite element model for plastic large displacement deformation collapse is constructed, and casing free bending external pressure collapse tests are designed and implemented. By comparing the experimental, theoretical, and finite element analysis results, the reliability of the method is verified. The research results show that the calculated values of the newly established bending plastic collapse strength formulas are slightly lower than those of full-scale physical tests, with small errors and a safety margin. The maximum error between the finite element analysis of full-wall thickness plastic large displacement deformation collapse strength and physical tests is -7.03%, indicating high accuracy. The newly designed experimental method is highly reliable due to its force model being consistent with actual well conditions. This study provides key technical support for the design of deep well casing with high dogleg severity, solves the problem of calculating and testing the collapse resistance of bent casings, and has been successfully applied in the field, addressing casing deformation and drilling tool sticking issues caused by salt layer creep. It lays the foundation for technological progress in this field.*

**Keywords:** *external collapse strength, borehole curvature, casing of free bending, plastic large displacement deformation.*

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**Study on Evolution Law of Four Dimensional In-Situ Stress in Shale Formation**

*In situ stress, a critical parameter for shale gas development, influences well placement, drilling operations, and hydraulic fracturing design. During shale gas exploitation, fluid injection (for hydraulic fracturing) and subsequent extraction (for gas production) induce pore pressure variations, leading to time-dependent evolution of in situ stress (i.e., 4D stress). Because of this four-dimensional stress, design of shale gas well in the future can not be merely relied on original in situ stress. This dynamical change is vital for future shale gas exploitation at the oilfield. The efficient development of shale gas reservoirs places higher demands on the understanding of the dynamic evolution laws of geomechanics. Traditional static in-situ stress models cannot reveal this change of in-situ stress during hydraulic fracturing and production, and it is urgent to build a more accurate four-dimensional dynamic model. This study focuses on Longmaxi Formation shale, establishing a platform-scale 4D coupling model via fluid-solid interaction numerical simulations to systematically analyze in situ stress behaviors during fracturing and production stages, while quantifying fracturing-induced stress and its long-term impacts on the near-wellbore stress field. Results indicate that hydraulic fracturing significantly elevate in situ stress due to massive high-pressure fluid injection, with the most pronounced stress increments occurring near the wellbore. In the stage of post-fracturing, in situ stress decreases but remains elevated. During production, stress dissipates yet remains higher than initial values. Such residual stress exerts a notable influence on infill well deployment, thereby providing theoretical and technical support for fracturing design optimization and refracturing strategies in shale gas reservoir.*

**Keywords:** *shale gas, four-dimensional in situ stress, hydraulic fracturing, fluid-solid coupling.*

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**An Empirical Study of $CO_2$ Emissions Effect onto the Economics Growth and the Environmental Energy Development**

*Accurately pinpointing the historical origins of $CO_2$ releases during the course of national economic progress is a crucial foundation for emerging economies to mitigate $CO_2$ releases. Utilizing China's distinctive system of economic development objectives, this study delves into the underlying systemic reasons for China's carbon-intensive growth and endeavors to conduct an empirical examination of its environmental consequences. Studies have shown that setting absolute growth targets in horizontal competition significantly increases city $CO_2$ releases, while setting relative growth targets in vertical competition exacerbates the impact of $CO_2$ releases. In addition, the heterogeneity analysis shows that cities with high resource efficiency and low economic development emit more $CO_2$ from growth targets. Institutional tests have shown that economic development goals can result in substantial growth in the overall consumption of fossil-based primary energy sources and a reduction in the energy efficiency of businesses, but also to an increase in primary energy use and a decrease in industrial energy*

*efficiency. The results provide useful guidance for the internal institutional explanation of high levels of $CO_2$ release in China and the development of mechanisms for developing countries to reduce global releases.*
**Keywords:** *environmental chemistry, environment development, $CO_2$ release, economic development.*

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**Evaluation and Recommendations for Clean Wellbore Fluid Systems in Ultra-Deepwater Carbonate Reservoirs**

*The B oilfield is an ultra-deepwater carbonate reservoir where lost circulation of wellbore fluids during drilling and completion operations often leads to formation damage. Based on the petrophysical data of reservoir cores from the B oilfield, artificial cores mimicking the target reservoir characteristics were prepared. Multiple wellbore fluid systems (drilling fluids, completion fluids, and acidizing fluids) were configured, and their formation damage and remediation effects were evaluated through artificial core experiments. Results indicate that completion fluid systems primarily composed of NaCl and $CaCl_2$ achieved a permeability recovery rate of 80–90%. Acetic acid-based drilling fluid remediation fluids restored permeability by 88–96%, while glutamic diacetic acid (GLDA)-based completion fluid remediation fluids achieved up to 99% permeability recovery. Additionally, filtered seawater-based completion fluids exhibited a maximum turbidity of 31 NTU when mixed with formation water, and the maximum viscosity increase of crude oil reached 156.8 mPa·s, with an $EC_{50}$ value exceeding 30,000 mg/L. The study concludes that NaCl/$CaCl_2$-based drilling/completion fluids, along with acetic acid and GLDA-based remediation fluids, are viable clean wellbore fluid systems for carbonate reservoirs. Filtered seawater-based completion fluids also demonstrate potential as low-damage alternatives.*
**Keywords:** *carbonate reservoir, artificial core, wellbore fluid, formation damage, clean completion fluid.*

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**Simulation Study of Unconventional Well Killing**

*The Yingqiong Basin in the South China Sea poses significant challenges for well control operations due to its high-temperature and high-pressure (HTHP) geological conditions, complex structures, and narrow pressure windows. This study investigates the adaptability of unconventional well-killing techniques in the HTHP environment of the northern slope of the Lingshui Depression in the Qiongdongnan Basin. Using numerical simulation software (FLUENT and Drillbench), a wellbore gas-liquid multiphase flow model was developed,*

*incorporating the thermodynamic properties of drilling fluids and dynamic pressure changes during well shut-in. The model elucidates the mechanisms of bottomhole pressure variations during the shut-in process. Comparative analyses of conventional well-killing methods (e.g., the Driller's Method and the Engineer's Method) and unconventional methods (e.g., the Displacement Method and the Bullheading Method) revealed that the Displacement Method, with optimized parameters (drilling fluid density: 1.97 g/cm$^3$, displacement rate: 500-800 L/min), effectively stabilizes wellbore pressure and mitigates risks in narrow pressure windows. In contrast, the Bullheading Method exhibited limited applicability due to formation permeability constraints and excessively high pumping pressures. Orthogonal experimental analysis demonstrated that the displacement rate of the kill fluid has the most significant impact on well-killing effectiveness, followed by density and viscosity (displacement rate > density > viscosity). This study established an adaptability evaluation and sensitivity analysis of unconventional well-killing methods in the Yingqiong Basin based on orthogonal experimental methodology. The findings provide theoretical and technical support for well control safety in HTHP basins, emphasizing the importance of adaptive well-killing strategies and advanced simulation tools.*
**Keywords:** *unconventional well killing, high-temperature and high-pressure wells, yingqiong basin, numerical simulation, multiphase flow.*

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**Research on Real-Time Monitoring and Remediation System of Petroleum Contaminated Soil Based on Intelligent Sensing and Microbial Remediation**

*Petroleum hydrocarbon pollution is one of the important challenges facing the soil environment, and the traditional monitoring and remediation means generally have problems such as low efficiency and slow response. This paper systematically researches the monitoring technology of petroleum contaminated soil based on intelligent sensors and its application in microbial remediation process. By integrating electrochemical, optical, and biological sensors with IoT communication modules, a real-time soil pollution monitoring system with high spatial and temporal resolution and low power consumption is constructed, which is capable of accurately identifying the concentration of pollutants such as TPHs and PAHs, and dynamically predicting the trend of pollution diffusion by combining with machine learning algorithms. In terms of remediation, this paper thoroughly explored the mechanism of multiple petroleum degrading microorganisms and their response to key environmental factors such as temperature, initial petroleum hydrocarbon concentration and water content, etc. The experimental results showed that the degradation rate of petroleum hydrocarbons could reach up to 59.3% under the appropriate conditions (1%~3% petroleum hydrocarbon concentration, 25°C, and 20% water content). In addition, the stability and degradation activity of the bacteria in extreme environments were further enhanced by biofortification and immobilization. In this study, the integrated management strategy of "intelligent monitoring + microbial precision control" was proposed, which provides a theoretical basis and technical support for the intelligent and efficient remediation of petroleum-contaminated soil.*
**Keywords:** *intelligent sensing, microbial remediation, oil-contaminated soil, monitoring, soil remediation.*

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**A Safe and Environmental-Friendly Solid Mud Acid with Retarding Performance, and Low Corrosion for Sandstone Reservoir Acidification**

*Acidification is the key stimulation technology to realize the efficient development of sandstone oil and gas resources. The liquid configuration and transportation are complex in the traditional acidizing operation of sandstone reservoirs. The traditional liquid acid acid-rock reaction is fast, corrosive, easy to damage the reservoir and cumbersome approval. Based on the core idea of 'solid' replacing 'liquid', combined with the HSE concept, a new solid mud acid system mainly composed of solid organic anhydride (SMA), solid fluorine-containing material (FRC) and solid corrosion inhibitor is developed. It has good retardance, corrosion inhibition and inhibition of secondary precipitation performance. The experimental results show that 17wt% SMA slowly generates acid at high temperature of 120°C, and the acid concentration can reach 11.5wt % HCl in 140 min, which can meet the purpose of deep acidification of sandstone reservoirs. The new solid mud acid system can control the multi-stage stepwise ionization of H+, and complex metal ions through proton exchange and complexation effects, effectively avoiding secondary precipitation. The new solid mud acid system has good stimulation ability, the permeability is increased by 2.7 times. By reacting with sandstone minerals to generate dissolution pores, it communicates with the original independent dissolution pores, achieving the result of "expanding holes and increasing permeability". This study verifies the effectiveness of the new solid mud acid system in acidizing sandstone reservoirs, providing scientific reference for sandstone reservoirs stimulation.*

**Keywords:** *sandstone acidification, solid mud acid, retarding performance, low corrosion, increase permeability.*

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**Study on Initial Stress and Selection of Soil and Water Conservation Measures for Mountain Pipelines**

*Mountainous slope-aligned natural gas pipelines are highly susceptible to rainfall-induced geological hazards such as landslides, debris flows, and erosion, which pose significant threats to their structural safety and stability. This study investigates a slope-aligned pipeline in a gas reservoir in Dazhou, Sichuan Province. Initial stress testing was conducted using the indentation method, and a safety evaluation framework was established. Based on the ABAQUS finite element model was developed to simulate the effects of varying rainfall intensities and durations on pipeline stress, deformation, and slope safety factors under three conditions: undisturbed soil, backfill soil, and integrated soil and water conservation measures. The results show that increasing rainfall intensity and duration significantly aggravate pipeline displacement and stress concentration, while also reducing slope stability. Although undisturbed and backfill soils offer limited protection under low-intensity rainfall, their effectiveness*

*diminishes under heavy and prolonged rainfall. In contrast, integrated soil and water conservation measures consistently reduce pipeline stress and deformation while improving slope stability under all rainfall conditions. These findings underscore the importance of prioritizing integrated protection strategies in mountainous pipeline projects to mitigate rainfall-induced stability risks. The proposed approach has been successfully applied in engineering practice, demonstrating its effectiveness and providing a scientific basis for optimizing protection strategies in similar terrains.*

**Keywords:** *mountain pipeline, slope-aligned installation, initial stress monitoring, rainfall types, soil and water conservation measures.*

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**Irregular Seismic Data Reconstruction Based on Compressive Sensing**

*With the continuous advancement of petroleum exploration and development, both the exploration targets and environments have become increasingly complex, placing greater demands on seismic exploration techniques. The complexity of field acquisition environments hinders the regular deployment of shot and receiver points, which significantly affects seismic data processing and imaging quality. Seismic data reconstruction based on compressive sensing (CS) theory offers an effective solution to mitigate the adverse effects of irregular acquisition caused by complex surface conditions, thereby substantially improving seismic imaging quality. In 2020, we conducted an onshore seismic survey in western China, and we collected 2001 shot gathers with irregular shot and receiver points for seismic reconstruction experiment. The stacking and migration sections, before and after reconstruction, clearly demonstrate that CS-based seismic data reconstruction can significantly enhance seismic data imaging quality.*

**Keywords:** *petroleum exploration and development, compressive sensing, irregular acquisition, seismic reconstruction.*

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**Research on Intelligent Optimization of Steam Injection Parameters**

**for Heavy Oil Cyclic Steam Stimulation Based on Production Big Data**

*Heavy oil exploitation technology is currently at a critical stage of transformation and upgrading. Traditional experience-driven methods for steam injection parameter design can no longer meet the needs of efficient modern oilfield development. With the rapid development of big data and artificial intelligence technologies, the petroleum industry needs to deeply integrate these advanced technologies with conventional extraction processes to achieve a shift from experience-based to data-driven decision-making. To address this issue, this study combines the theoretical basis of cyclic steam stimulation and steam injection parameters, introduces the characteristics analysis and processing of production big data, and establishes an intelligent optimization model. Using a specific oilfield as an example, we conduct intelligent optimization research on steam injection parameters for heavy oil cyclic steam stimulation based on production big data. This work lays the foundation for further development in China's petroleum industry. The results show that the proposed method can effectively improve the scientific and individualized nature of parameter schemes. After optimization, the cumulative oil production of test wells increased by about 13%, and thermal energy utilization improved by nearly 10%, significantly enhancing economic benefits while ensuring safety. This approach has strong potential for wider application.*
**Keywords:** *production big data, heavy oil, cyclic steam stimulation, steam injection parameters, intelligent optimization of parameters.*

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**Research on Acidisation and Production Increase Technology of Low-Producing Wells in Yinger Depression**

*In order to improve the development effect of low-producing wells in dense sandstone reservoirs in Yinger Depression, an indoor acidification and production increase experimental study was carried out under simulated stratigraphic conditions to address the problems of poor pore permeability, low differential pressure, and weak efficiency of acid reaction. Representative core samples were selected, and a 12% HCl + 3% HF composite acid system was used at 80°C and 10 MPa to carry out a dynamic acidification test through a high-temperature and high-pressure core replacement device, which was combined with nuclear magnetic resonance (NMR), ICP-OES, XRD, SEM and other means to quantitatively analyse the changes in the physical properties of the core and the reaction products. The results showed that the porosity of the core was increased from 7.2% to 9.8% after acidification, and the permeability of was increased from 0.062 mD to 0.325 mD; the dissolution rate of the core was 6.3% on average, and the concentrations of $Ca^{2+}$ and $Mg^{2+}$ ions in the reaction solution were increased from 0.3 and 0.1 mmol/L to 3.3 mmol/L, respectively. XRD test showed that the content of carbonate minerals such as*

*calcite and dolomite decreased significantly after acidification; SEM observation showed that the expansion of the pore throat structure on the core surface was significant, forming non-homogeneous wormhole-like channels, which helped to improve the seepage capacity. Low-field nuclear magnetic resonance analysis showed that the volume percentage of small and medium-sized pore throats increased by about 18.7% after acidification. The study shows that the acid system has good reservoir reforming ability, which provides an important experimental basis and theoretical support for the optimisation of the acidizing process in low-producing wells in Yinger Depression, and has good value for on-site promotion and application.*
**Keywords:** *Yinger Depression, low-producing wells, acidisation, production increase.*

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**Research on the Internal and Downstream Flow Field Characteristics of an Axial Fan Cavitation Nozzle for Surface Cleaning**

*In order to improve the surface cleaning efficiency of fan-shaped water jet, a kind of axial fan cavitation nozzle is designed to produce fan-shaped cavitation water jet used to clean the surfaces of various equipment. A physical model of an axial fan cavitation nozzle and its computational domain for fan-shaped cavitation water jet flow fields were established. Numerical simulations were conducted using ANSYS FLUENT with the Mixture multiphase model, Schnerr–Sauer cavitation model, and Realizable k–ε turbulence model to analyze the internal and downstream flow characteristics within and downstream of the nozzle. The simulation results show that the jet velocity tends to decrease along the direction of jet flow from the front end of the cylindrical center body to the rear on the plane passing through the bottom of the V-groove (PPTBV) and the plane perpendicular to the V-groove (PPV) for different axial fan cavitation nozzles except the kind of axial fan cavitation nozzle of b/r=2. And in the direction perpendicular to the horizontal axis, the jet velocity also tends to decrease from the middle toward the sides. On the plane passing through the bottom of the V-groove (PPTBV) and the plane perpendicular to the V-groove (PPV) for different axial fan cavitation nozzles, there is a area where the vapor volume fraction is greater than 0 in front of the cylindrical central body. And the vapor volume fraction is the highest adjacent to the front end of the cylindrical central body and tends to decrease in the direction of the jet flow. On the plane perpendicular to the V-groove (PPV), there is a area where the vapor volume fraction is greater than 0 near the wall surfaces on both sides of the V-groove after the opening position of the axial fan cavitation nozzle. When $\alpha_2/r=3$, there is a area where the vapor volume fraction is greater than 0 resembling human lungs on both sides and in front of the cylindrical central body. Meanwhile, the fan-shaped cavitation water jet presents a flattening shape, which is beneficial for increasing the cleaning width of the fan-shaped cavitation water jet and realizing precise control of the cleaning process. When b/r=2, the fan-shaped cavitation water jet exhibits a bifurcation phenomenon.*
**Keywords:** *axial fan cavitation nozzle, fan-shaped cavitation water jet, numerical simulation, V-groove half angle.*