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Математическое моделирование макрокинетики термолиза сложных углеводородных систем

Рассмотрены стохастические математические модели кинетики термолиза сложных нефтеподобных углеводородных систем с использованием математической статистки и теории случайных процессов. Математическое моделирование показало, что процесс термолиза является коллективным, неэргодическим и нестационарным. Установлены критерии при которых углеводородные системы подчиняются кинетическим законам первого порядка и Аврами. На примере термолиза высоковязкой Альшачинской нефти показано, что кинетика выхода газообразных продуктов термолиза лучше описываются моделями стационарной кинетики, а модели выхода остатков и дистиллятов моделями нестационарной кинетики. Установленные закономерности могут быть использованы при моделировании термических и термокаталитических процессов нефтехимии и нефтепереработки.

Ключевые слова: термолиз, закон действующих масс, многокомпонентные системы, случайные процессы, высоковязкие нефти, нестационарная кинетика.
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Mathematical Simulation of Macrokinetics of Thermolysis
of Complex Hydrocarbon Systems

Stochastic mathematical models of thermolysis kinetics of complex oil-like hydrocarbon systems using mathematical statistics and the theory of random processes are considered. Mathematical modeling shows that the thermolysis process is collective, non-ergodic and non-stationary. The criteria for which hydrocarbon systems obey the kinetic laws of the first order and Abraham are established. Using the example of thermolysis of high-viscosity Alshacha oil, it is shown that the kinetics of the release of gaseous products of thermolysis are better described by models of stationary kinetics, and the models of the release of residues and distillates by models of non-stationary kinetics. The established regularities can be used in modeling thermal and thermocanalytic processes of petrochemistry and oil refining.

Key words: *thermolysis, law of acting masses, multicomponent systems, random processes, high-viscosity oils, unsteady kinetics.*

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Закономерности кинетики термолиза в сложных углеводородных системах

Обобщены закономерности процессов термолиза и карбонизации в сложных углеводородных системах — продуктах переработки нефти и их фракциях. Показано, что в углеводородных системах вследствие

бернуллевского и гауссовского распределения состава по термодинамическим функциям и энергиям активации, протекают процессы самовоспроизводимости гомологов углеводородов. Показано, что процессы термолиза и карбонизации определяются коллективным взаимодействием молекул статистической и термодинамической природы. Эти взаимодействия способствуют отклонениям от закона действующих масс, обусловливают кинетический компенсационный эффект термолиза, а также зависимость выхода углерода от энергии активации вязкого течения и средних электродонорных характеристик компонентов среды. Обнаруженные закономерности подтверждены экспериментами и могут быть использованы в расчетах для оптимизации процессов нефтехимии и нефтепереработки.
Ключевые слова: термолиз, нефтяные остатки, углеводородные системы с хаосом химического состава, компенсационный эффект, межмолекулярные взаимодействия.
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Regularities of Thermolysis Kinetics in Complex Hydrocarbon Systems
The regularities of thermolysis and carbonation processes in complex hydrocarbon systems – oil refining products and their fractions are generalized. It is shown that in hydrocarbon systems, due to the Bernoulli and Gaussian distribution of composition by thermodynamic functions and activation energies, processes of self-reproducibility of hydrocarbon homologues take place. It is shown that the processes of thermolysis and carbonation are determined by the collective interaction of molecules of statistical and thermodynamic nature. These interactions contribute to deviations from the law of acting masses, cause the kinetic compensation effect of thermolysis, as well as the dependence of carbon yield on the activation energy of the viscous flow and the average electrodonor characteristics of the medium components. The discovered patterns have been confirmed by experiments and can be used in calculations and optimization of the processes of petrochemicals.
Key words: *thermolysis, oil residues, hydrocarbon systems with chaos of chemical composition, compensation effect, intermolecular interactions.*

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Кинетические особенности термолиза газойлей каталитического крекинга
Изучена высокотемпературная макрокинетика процесса термолиза малосернистого газойля каталитического крекинга с формированием игольчатого кокса. Эксперименты проводили на лабораторной установке с кварцевым микрореактором при температуре 450–500°С и продолжительности процесса до 300 мин. Установлено, что процесс является двухстадийным и подчиняется уравнению типа Аврами — Ерофеева, константа скорости процесса на обеих стадиях имеет диффузионный характер. Показано, что первая стадия процесса связана с испарением легких фракций и деструкции слабых химических связей в компонентах. Вторая стадия включает термоконденсацию полициклических углеводородов с образованием

мезофазы и игольчатого кокса. Результаты исследования подтверждаются данными электронного парамагнитного резонанса и электронной феноменологической спектроскопии.

Ключевые слова: термолиз, макрокинетика, константа скорости, энергия активации, молекулярная масса, парамагнитные центры

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Kinetic Features of Thermolysis of Catalytic Cracking Gas Oil

The high-temperature macrokinetics of the process of thermolysis of low-sulphur catalytic cracking gas oil with the formation of needle coke was studied. The experiments were carried out on a laboratory setup with a quartz microreactor at temperatures of 450-500 °C and a process duration of up to 300 min. It was established that the process is two-stage and its kinetics obeys the Avrami-Erofeev equation, the rate constant of the process at both stages has a diffusion character. The second stage includes thermal condensation of polycyclic hydrocarbons with the formation of mesophase and needle coke. The results of the study are confirmed by optical microscopy in polarized light, data of electron paramagnetic resonance and electron spectroscopy.

Key words: *thermolysis, microkinetics, rate constant, activation energy, molecular weight, paramagnetic centers.*

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О влиянии гидродинамических условий при коксовании на структуру получаемого кокса

Получение высокоанизотропной структуры игольчатых коксов зависит не только от качества исходного сырья, но и от гидродинамической обстановки в коксовой камере, формирующейся в результате сдвиговых напряжений мезофазной матрицы потоками выделяющихся парогазовых продуктов дистиллята коксования и непрерывной подачей сырья. В работе представлены результаты исследований по изучению качества игольчатых коксов, получаемых при коксовании в статических и динамических условиях.

Показано, что микроструктурная организация коксов может достаточно сильно отличаться в зависимости от технологии коксования.

Ключевые слова: игольчатый кокс, коксовая камера, мезофазная матрица, сдвиговые напряжения, микроструктурная организация коксов.

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On the Influence of Hydrodynamic Conditions during Coking on the Structure of the Resulting Coke

The production of a highly anisotropic structure of needle coke depends not only on the quality of the raw material, but also on the hydrodynamic situation in the coke chamber formed as a result of shear stresses of the mesophase

matrix by the flows of released steam-gas products of coking distillate and continuous supply of raw materials. The paper presents the results of studies on the quality of needle coke obtained during coking in static and dynamic conditions. It is shown that the microstructural organization of coke can differ quite a lot depending on the coking technology.
Key words: *needle coke, coke chamber, mesophase matrix, shear stresses, microstructural organization of coke.*

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О выборе технологии замедленного коксования
на стадии предпроектной разработки исходных данных

Проведено сопоставление технологических схем установок замедленного коксования, эксплуатируемых в настоящее время на НПЗ. Показано, что российская технология нового поколения по сравнению с лицензионными технологиями зарубежных фирм имеет преимущества по эксплуатационной надежности, производительности и возможности производства различных видов кокса
Ключевые слова: технология замедленного коксования, коэффициент рециркуляции, производительность, стадия прогрева коксовых камер, топливный кокс, коксующая добавка.
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On the Choice of Belayed Coking Technology at the Stage
of Pre-Project Development of Initial Data

A comparison of technological schemes of delayed coking units currently operated at the refinery has been carried out. It is shown that the Russian technology of a new generation in comparisonwith the licensed technologies of foreign firms has advantages in operational reliability,productivity and the possibility of producing various types of coke.
Key words: *delayed coking technology, recirculation coefficient, productivity, coke chambers heating stage, fuel coke, coking additive.*

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Углеродные добавки нефтяного происхождения в угольные шихты и перспективы
их промышленного производства

Рассмотрена возможность квалифицированного использования тяжелых нефтяных остатков и отходов нефтепереработки в качестве углеродных добавок в угольные шихты при производстве металлургического

кокса. Вовлечение нефтекоксовой мелочи и коксующей добавки в угольные шихты позволяет существенно улучшить эксплуатационные свойства доменного кокса. Рассмотрены и сопоставлены имеющиеся и перспективные технологии получения спекающих добавок с использованием тяжелых нефтяных остатков.
Ключевые слова: угольная шихта, нефтекоксовая мелочь, коксующая добавка,
нефтяная спекающая добавка, замедленное коксование, висбрекинг.
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Carbon Additives of Petroleum Origin in Coal Mines and Prospects
for Their Industrial Production
The possibility of qualified use of heavy oil residues and oil refining waste as carbon additives in coal charges in the production of metallurgical coke is considered. The involvement of petroleum coke fines and coking additives in coal charges can significantly improve the operational properties of blast furnace coke. The available and promising technologies for obtaining sintering additives using heavy oil residues are considered and compared.
Key words: *coal charge, petroleum coke fines, coking additive, oil sintering additive, delayed coking, visbreaking.*

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Разработка полимерно-битумной композиции и асфальтобетонной смеси на ее основе
с применением нестандартных модификаторов
В работе рассматрена возможность модификации некондиционного товарного битума с целью улучшения его реологических свойств на примере использования побочного продукта селективной очистки масляных дистиллятов (экстракта) в качестве пластифицирующей добавки и полимерного промышленного отхода — пылевидного полиэтилентерефталата. В ходе лабораторных исследований выявлены основные показатели исходного битума, битума с добавлением чистого экстракта и с добавлением полимерно-экстрактного раствора. Установлена возможность утилизации полимерных отходов с улучшением свойств дорожного битума, а также получения на его основе высококачественной холодной асфальтобетонной смеси.
Ключевые слова: нефтяной дорожный битум, пылевидный полиэтилентерефталат, экстракт селективной очистки масляных фракций, полимерно-битумная композиция, асфальтобетонная смесь, холодный асфальт.
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Development of Polymer-Bitumen Composition and Asphalt-Concrete Mixture
Based on it Using Non-Standard Modifiers
The paper considers the possibility of modifying substandard commercial bitumen in order to improve its rheological properties by the example of using a by–product of selective purification of oil distillates – extract as a plasticizing

additive and polymer industrial waste – pulverized polyethylene terephthalate. In the course of laboratory studies, the authors identified the main indicators of the initial bitumen, bitumen with the addition of pure extract and with the addition of polymer-extract solution. The paper reveals the possibility of recycling polymer waste with improving the properties of road bitumen, as well as obtaining a cold asphalt concrete mixture based on it.
Key words: *petroleum road bitumen, pulverized polyethylene terephthalate, extract of selective purification of oil fractions, polymer-bitumen composition, asphalt concrete mixture, cold asphalt.*

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Полиэфирные смолы как модификаторы свойств битума
В работе показана возможность синтеза и применения для модифицирования свойств битумов полиэфирных смол. Полиэфирные смолы получали реакцией поликонденсации кубового остатка ректификации фталевого ангидрида с глицерином и диэтиленгликолем. При модифицировании битумов полученными добавками улучшаются значения растяжимости, глубины проникания иглы при 25 и 0°С, низкотемпературные свойства. Получены битумы с высокой устойчивостью к термоокислительным процессам старения. Установлено, что при использовании модифицированного гудрона полученными добавками по технологии производства битумов окисление–компаундирование можно получить битумы дорожных марок.
Ключевые слова: битум, гудрон, модифицирование, синтез добавок,
полиэфирные смолы, кубовый остаток фталевого ангидрида.
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Polyester Resins as Modifiers of Bitumen Properties
The paper shows the possibility of synthesis and application of polyester resins for modifying the properties of bitumen. Polyester resins were obtained by the reaction of polycondensation of the cubic residue of the rectification of phthalic anhydride with glycerin and diethylene glycol. When modifying bitumen with the additives obtained, the values of extensibility, the penetration depth of the needle at 25 and at 0 oC, and low-temperature properties are improved. Bitumen with high resistance to thermo-oxidative aging processes has been obtained. It is established that when using modified tar with additives obtained according to the bitumen production technology "oxidation-compounding", it is possible to obtain bitumen of road.
Key words: *bitumen, tar, modification, synthesis of additives, polyester resins, cubic residue of phthalic anhydride.*

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К вопросу о термоокислительном старении нефтяных битумов и гудронов

В работе исследованы зависимость адгезионных свойств и pH битумов различной глубины окисления и гудрона, сырья битумного производства от времени старения. Показано, что в битуме с увеличением глубины окисления при термоокислительном старении происходит изменение типа образующихся оксосоединений и как следствие адгезионных свойств. В высокоплавких битумах при старении идет интенсивное образование асфальтенов, смол и асфальтогенных кислот, которые позволяют улучшить адгезионные свойства вяжущего. Для низкоплавких битумов характерно интенсивное образование карбоксильных и гидрокарбоксильных групп соединений, которые снижают адгезию к щелочным минеральным материалам. Установлено, что скорость старения гудрона увеличивается, а для окисленных битумов она носит экстремальный характер, где максимальные значения наблюдаются в первые часы старения. Предложено использовать показатель адгезии и кислотность в комбинировании со стандартным показателем качества — температурой размягчения после старения для подбора компонентного состава битума, получаемого по технологии окисление–компаундирование, а также для разработки способов, позволяющих снизить скорость старения битумов в начальный период эксплуатации асфальтобетонных покрытий и обеспечить повышение их качества и долговечности.

Ключевые слова: битум, гудрон, старение, термоокислительная стабильность, адгезия, кислотность
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On the Question of Thermo-Oxidative Aging Oil Bitumen and Tar

The dependences of the adhesive properties and pH of bitumen of various oxidation depths and tar, raw materials of bitumen production, depending on the aging time are investigated. It is shown that in bitumen, with an increase in the depth of oxidation during CBT, a change in the type of oxo compounds formed and, as a consequence, adhesive properties occurs. In high-melting bitumen, during aging, there is an intensive formation of asphaltenes, resins and asphaltogenic acids, which allow to improve the adhesive properties of the binder. Low-melting bitumen is characterized by intensive formation of carboxyl and hydroxyl groups of compounds that reduce adhesion to alkaline mineral materials. It is established that the rate of tar aging increases, and for oxidized bitumen it is extreme, where the maximum values are observed in the first hours of aging. It is proposed to use the adhesion index and acidity in combination with the standard quality indicator – the softening temperature after aging to select the component composition of bitumen obtained using the "oxidation-compounding" technology, as well as to develop methods to reduce the aging rate of bitumen in the initial period of operation of asphalt concrete coatings and to improve their quality and durability.

Key words: *bitumen, tar, aging, thermal-oxidative stability, adhesion, acidity.*

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Оценка возможности получения мезофазы при термообработке различных видов углеводородного сырья

Показана возможность получения анизотропных пеков путем термообработки различных видов нефтяного сырья — изотропных пеков из тяжелой смолы пиролиза и тяжелого газойля каталитического крекинга. Установлены зависимости изменения группового состава остатков термообработки от продолжительности изотермической выдержки, корреляционная связь между компонентами, нерастворимыми в толуоле и хинолине. Выявлены особенности оптической текстуры остатков термообработки изотропных нефтяных пеков различного происхождения.

Ключевые слова: термообработка, тяжелая смола пиролиза, тяжелый газойль каталитического крекинга, стирол-инденовая смола, гидравличная смола, изотропный пек, мезофаза.

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Evaluation of the Possibility of Obtaining Mesophase during Heat Treatment of Various Types of Hydrocarbon Raw Materials

The possibility of obtaining anisotropic pitches by heat treatment of various types of petroleum feedstock is shown – isotropic pitches from heavy pyrolysis tar and heavy catalytic cracking gas oil. The dependences of the change in the group composition of the heat treatment residues on the duration of isothermal exposure, the correlation between the components insoluble in toluene and quinoline, have been established. Features of the optical texture of the heat treatment residues of isotropic petroleum pitches of various origins are revealed.

Key words: *teat treatment, heavy pyrolysis tar, catalytic cracking heavy gas oil, styrolindene resin, hydraulic resin, isotropic pitch, mesophase.*

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Квантово-химическое исследование электрохимических свойств ряда метанофуллеренов

В работе методами квантовой химии найдены энергии высшей занятой и низшей вакантной молекулярных орбиталей (HOMO и LUMO). Вычислена ширина запрещенной зоны и сродство к электрону для ряда соединений, предложенных для разработки в качестве акцепторного элемента в органических солнечных батареях.
Ключевые слова: фуллерен, [60]PCBM, функциональные производные фуллерена, сродство к электрону, DFT, HOMO-LUMO.
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Quantum Chemical Research of Electrochemical Properties of Methanefullerene Series
In the presented study, using quantum chemistry methods, the energies of the highest occupied and lowest unoccupied molecular orbitals (HOMO and LUMO) were found, the band gap and electron affinity were calculated for a number of compounds proposed for development as an acceptor element in organic solar cells.
Key words: *fullerene, [60]PCBM, fullerene functional derivatives, electron affinity, DFT, HOMO-LUMO.*

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On the Isothermal-Isobaric Binodal Shape in Ternary Systems
In this work, we compared the shape of a binodal curve in the ternary systems "water – methanol – chloroform", "water – methanol – dichloromethane", "water – tert-butanol – toluene", and "water – 2-butoxyethanol – toluene" in the vicinity of the liquid-liquid critical point (LLCP). We have shown that different approaches to characterize the binodal shape are not equivalent for real ternary systems. The preferred approach involves the calculation of distances based on the tangent to the LLCP and the perpendicular lines to the points on the binodal. The variability in the apparent degree of the binodal curve is revealed, contrary to the known literature.
Keywords: *liquid-liquid equilibrium, coexistence curve, critical fluctuations, solubility.*

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Change in the Concentration of Stable Free Radicals and Vanadyl Complexes in the Products of Reaction of Petroleum Asphaltenes with Sulfuric Acid
The products from the reaction of petroleum asphaltenes with sulfuric acid under various conditions, accompanied by oxidation, sulfonation, and decomposition reactions, were studied. The change in the content of stable free radicals

and vanadyl complexes in the products from the reaction of asphaltenes with sulfuric acid in relation to the time and temperature was determined by EPR spectroscopy. The chemical processes in the reaction of asphaltenes with sulfuric acid take place most strongly in the first hour, being accompanied by peak growth of the concentration of stable free radicals. With increase in the length of treatment of the asphaltenes with sulfuric acid there is a decrease in the concentration of stable free radicals accompanied by a decrease in the content of sulfo groups in the products. After only 30 min of the process there was a marked decrease in the content of vanadyl complexes in the reaction products.
Keywords: *asphaltenes, sulfuric acid, stable free radicals, vanadyl complexes.*

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Catalysis by Ion-Exchange Resins Derived
from Asphaltenes in the Salicylic Acid Acylation Reaction

Acidic and basic ion-exchange resins were prepared by chemical modification of petroleum asphaltenes. The resulting products were characterized by IR spectroscopy and MALDI mass spectrometry. Feasibility was demonstrated for carrying out catalytic acylation of salicylic acid in the presence of acidic and basic catalysts derived from petroleum asphaltenes to give acetylsalicylic acid. Asphaltene-derived ion-exchange resins containing either sulfonic acid (SA) or amino groups (AA) were used as catalysts. These catalyzed reactions gave acetylsalicylic acid in 78% and 73% yield, respectively.
Keywords: *asphaltenes, modified asphaltenes, acid catalysis, basic catalysis, acylation reaction.*

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Phase Behavior of Kalchinsk Oil in a Wide Range of Thermobaric Conditions

The results of investigation of the phase behavior of a crude oil sample from the Kalchinsk oilfield at pressure up to 1.43 GPa in the temperature range of 140-336 K are presented. It is shown that crystallization occurs in the sample with increasing pressure (decreasing temperature) in a wide range of thermobaric parameters, after which the glass transition process is observed. Based on the experimental data, a phase diagram for the studied sample was constructed.
Keywords: *glass transition, crystallization, high pressure, phase diagram, hot-wire method, DSC.*

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Effect of Fungal Mycellium/Eicosane Composites
on Thermal Energy Storage and Release in Gypsum Plaster

The deposition of organic phase-change materials (PCMs) on the supporting fibers was shown as a simple and effective way to prepare stable composites with thermoregulating properties, which are feasible as functional additives to dry building mixes. However, the preparation of the composite fibers with optimal morphology to improve their content and thermoregulating performance in the target material still remains challenging. Herein, we report on the stable composite fibers prepared by the deposition of organic PCM eicosane on the biopolymeric fibers of fungal mycelium. The prepared composite had a fibrous morphology with the longitudinal diameter of 1–1.5 μm and the latent heat capacity of 63.2 J/g. The composite was mixed with the dry powder of gypsum plaster with the mass content of 15% and 30%. The electron microscopy revealed a homogeneous distribution of the fibers within the hardened plaster layer. The differential scanning calorimetry confirmed that the addition of the composite to the plaster enhances its thermal performance and brings latent heat storage and release capability with latent heat capacity of 8.2 J/g and 18.2 J/g depending on the composite content. The measurement of the temperature in the volume of the hardened plaster demonstrated that the addition of the thermoregulating fibers effectively reduce the heating rate in the range of 37–39°C and the cooling rate in the range of 38–34°C, corresponding to melting and crystallization of eicosane in the composite structure.

Keywords: *phase-change materials, eicosane, fungal mycelium, thermoregulating composites, functional materials.*

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Additives to Biodiesel Fuels

The most important groups of functional additives for biodiesel fuels are considered, based on modern technical and environmental requirements: additives that help improve fuel combustion and reduce harmful emissions; oxygenate additives; depressants; lubricating additives. An analysis of the effectiveness of the introduced additives in mixed fuels of different compositions is given.

Keywords: *biodiesel, mixture fuels, functional additives, polluting emissions, oxygenates.*

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Thermal Insulation Performance Evaluation and Installation Length Optimization
of Inner Coating Thermal Insulation Drillpipe

With the exploration and development of oil and gas resources moving towards deeper areas, there is an increasing number of high-temperature wells being drilled. However, during drilling, the temperature of the drilling fluid at the bottom of the well may exceed the temperature limits of the rotary steerable system, logging while drilling, and other

downhole tools. This poses a significant risk to the safety of the drilling operation. Therefore, it is urgent to study temperature control technology for drilling fluids in high-temperature wells. Inner-coating thermal insulation drill pipe is a new technology with significant application prospects. In order to study the thermal insulation performance of inner-coating thermal insulation drill pipe and consider the influence of the insulation coating, an equation for the wellbore temperature field during drilling with inner-coating thermal insulation drill pipe was established. Through case analysis, the thermal insulation performance of inner-coating thermal insulation drill pipe was evaluated, and the sensitivity of parameters was analyzed. An optimization method was developed for determining the installation length of inner-coating thermal insulation drill pipe. The installation length was optimized for various temperature-resistant conditions through case calculations. The research results show that inner-coating thermal insulation drill pipe has a positive impact on controlling the temperature of drilling fluid at the bottom of the well and has promising potential for widespread application. Only by installing 3500 m of inner-coating thermal insulation drill pipe can we meet the requirement for tools that can withstand temperatures of 150°C. This study can provide valuable insights for the design and application of inner-coating thermal insulation drill pipes in high-temperature wells. It is of significant importance for ensuring safe drilling operations in such conditions.
Keywords: *thermal insulation performance, thermal insulation coating, drillpipes, high temperature well.*

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Prediction of Cutting Concentration in Horizontal Wells

for Different Well Inclination Sections

Monitoring cuttings concentration and ensuring that the wellbore is kept sufficiently clean during drilling is critical to safe drilling. Traditional analysis of cuttings concentration using mechanistic and empirical models has problems of adaptability and accuracy. To address the existing problems of cutting concentration prediction, this paper investigates the cutting concentration neural network model, and uses the established principal component analysis model to reduce the dimensionality of the parameters affecting the annular cutting concentration, and segments the well inclination according to 0-30°, 30-65° and 65+° to obtain the input parameters for cutting concentration prediction in different well inclination sections. By investigating the neural network prediction method, the mapping of non-linear relationship between cutting concentration influencing factors and cutting concentration was realized, and the cutting concentration prediction fitting function was obtained. The model was tested using a full well section, well inclination segmented training and validation approach, and the predicted and measured cutting concentrations were compared and analyzed, and the results showed that The cuttings concentration prediction model established in this paper based on PCA and ANN for horizontal wells can achieve accurate prediction of annular cuttings concentration; the cuttings concentration prediction results of the neural network model are consistent with the influence of cuttings transport mechanism on cuttings concentration in different well inclination sections, which

proves that the neural network model of cuttings concentration in separate well sections is highly adaptable and has the value of oil field application.
Keywords: *drilling, horizontal wells, cutting concentration, safe drilling.*

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Research Hotspots and Trend Analysis of Energy Security
Based on Citespace Knowledge Graph

Energy security is related to national economic development and social stability, and it is one of the significant and urgent problems faced by all countries in the world. This paper takes 36583 articles on energy security from 2013 to 2023 in the Web of Science database as the data set, using the CiteSpace Knowledge graph method to systematically analyze the status quo, research hotspots, and evolution trends of world energy security research. The results show that research hotspots are concentrated in six primary areas: energy governance, energy and climate change, renewable energy security, energy models, energy efficiency, and energy technology. The cross-research between artificial intelligence, communication technologies, and the field of energy security is one of the future research hotspots. Cross-disciplinary integration is an essential feature of research in energy security in recent years, which can provide reference for subsequent research.
Keywords: *energy security, knowledge graph, research hotspots, trend analysis, Citespace.*

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Application of Pre-Stack Geostatistical Inversion
in Horizontal Well Tracking of Thin Reservoir in Well Area

Thin oil layers have become the focus of oil and gas resources exploration due to the large number of oil layers and rich reserves. Fuyu Formation in the sag area of an oil field in the east belongs to a low porosity and low permeability reservoir, and the production of vertical wells is relatively low. The application of horizontal well technology can effectively improve the production. The third member of Fuyuquan Formation has the characteristics of thin interbed reservoir, which increases the difficulty of horizontal well implementation. The resolution of seismic

data is limited, and the difference of geophysical response between reservoir and non-reservoir is small, which makes it difficult to solve the problem of thin interbed prediction by wave impedance inversion and pre-stack simultaneous inversion. The application of prestack geostatistical inversion technology can improve the vertical resolution of reservoir prediction, and then accurately depict the spatial distribution of the reservoir. In this paper, taking well F area as the test area, combining with regional geological knowledge, the seismic inversion results with high vertical resolution are obtained through reservoir sensitive parameter analysis and prestack geostatistics inversion technology. It also guides the design of horizontal well trajectory and monitors the change of horizontal well trajectory in real time during implementation. The results show that using pre-stack geostatistics inversion technology can greatly improve the drilling rate of thin oil layers in horizontal wells.
Keywords: *glutentite reservoir, prestack geostatistical inversion, geophysical, horizontal well.*

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Research on the Destabilizing Factors of The Seabed
and the Response Methods of Well Construction

Offshore oil development is gradually advancing to deep water, and the complex seabed topography and shallow geological conditions greatly affect the difficulty of subsea well construction and threaten the safety of drilling operations. To reduce the risk during drilling and optimize the drilling plan, the cause mechanism of complex seabed topography and shallow geological conditions is outlined, and the countermeasures taken by China National Oil Corporation (CNOOC) to deal with different seabed topography and shallow geological conditions are collected. The research results are of great significance in guiding the construction of subsea wells in the South China Sea.
Keywords: *seabed destabilization, shallow gas, shallow water flow, gas hydrates, response methods.*

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Research on the Influence Mechanism of Tectonic Stress
in the «Three Hard» Coal Seam in Coalfield on Rockbursts

This paper addressed the rockburst hazards caused by tectonic stress in the "three hard" coal mine in Datong Coalfield. We analyzed tectonic stress characteristics in the mining area and the mechanism of tectonic stress inducing rockbursts. We built the stress analysis model for rockburst-inducing tectonic stress. The roadway of the coal seam 12# in Xinzhouyao Coal Mine of Datong Coalfield was explicitly analyzed as an example. It was found that roof bedding separation was very likely to happen under the action of local tectonic stress in the roadway of the "three hard" coal seam, causing rockbursts that pushed out the coal wall. Numerical simulation was performed to analyze the occurrence of rockbursts induced by tectonic stress. We validated that stress concentration was more likely to happen in the coal-rock masses under the action of the tectonic stress, causing rockbursts. Besides, a large horizontal

stress gradient would be formed near the roadway coal wall when the principal stress was perpendicular to the roadway axis. Rockbursts were highly probable in the coal-rock masses under this situation.

Keywords: *Datong coalfield, "three hard" coal seam, tectonic stress, rockbursts, mechanism.*

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Supervised Machine Learning Mode for Predicting Gas-Liquid Flow Patterns in Upward Inclined Pipe

Accurate identification of gas-liquid two-phase flow patterns during oil and gas drilling is critical to analyzing bottom hole pressure, detecting overflows in time, and preventing blowout accidents. Since the gas-liquid two-phase flow has deformable interfaces, resulting in complex gas-liquid two-phase flow patterns, the existing gas-liquid two-phase flow patterns are limited in width in terms of pipe diameter and incline, leading to adaptation problems in experimental flow patterns and mechanistic models. Machine learning methods provide potential tools for solving gas-liquid two-phase flow pattern identification. In this paper, a sample database with 5879 data points was established by reviewing and organizing existing literature focusing on normal pressure and temperature, and air-water experimental conditions to provide a data-preparation for the relationship between gas and liquid velocities, pipe diameter and incline characteristics and flow pattern objectives. Four machine learning models, including K-Nearest Neighbor, Naïve Bayes, Decision Tree and Random Forest, were investigated, and each model was trained and tested using a sample database to reveal the performance of four types of supervised machine learning methods, representing similarity, probability, inductive inference and ensemble-learning principles, for gas-liquid two-phase flow pattern recognition, and the prediction accuracy was 0.86, Naïve Bayes is 0.56, Decision Tree is 0.89 and Random Forest 0.97. Comprehensive analysis of each model confusion matrix shows that the machine learning method has the best recognition of dispersed bubble flow, better recognition of slug flow, and the worst recognition of churn flow among the nine flow patterns which proves the controversial nature of the mechanism model in the transition from slug flow to churn flow. This paper uses experimental data as model input features, making the machine learning-based gas-liquid two-phase flow pattern identification model meaningful for practical engineering applications, and also demonstrating the feasibility of using supervised machine learning methods for gas-liquid two-phase flow pattern identification at normal pressure and temperature, wide-range of pipe diameter and incline.

Keywords: *drilling, gas-liquid two-phase flow, flow pattern, machine learning, well control.*

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Optimization of Catalyst Hydrogenation Technology

for White Oil Production Based on Medium Pressure Hydrogenation

Because the requirements of environmental protection are becoming strict, the preparation of petroleum products such as white oil needs to be harmless. In order to produce high-grade white oil products, it is necessary to study the medium-pressure hydrogenation technology and the suitable high-activity hydrogenation catalyst. The medium-pressure hydrogenation technology is proposed to produce white oil by a one-stage hydrogenation process under 7-8 MPa hydrogen partial pressure. The paper optimized the optimum conditions for medium-pressure hydrogenation of white oil. The initial reaction temperature was 210°C. The reaction pressure was 8 MPa. The liquid space velocity was 0.4 h^{-1}. The hydrogen oil ratio was 500:1 V/V. The catalyst life evaluation experiment was carried out. The research results can provide a basis for the selection of hydrogenation catalysts.

Keywords: *white oil, hydrogenation technology, hydrogenation catalyst, reaction temperature, liquid space velocity.*

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Key Factors and Changing Rules of Foam Stability in Gas Well Field

In the process of natural gas production using foam to lift liquid, there exists obvious difference in the requirements of foam stability between wellbores and gathering & transportation systems. To ensure the effect foam dewatering of gas wells and highly efficient defoaming and gas-water separation on surface, it is meaningful to investigate the influencing factors of foam stability comprehensively. In this paper, a tight gas block in China which adopted foam for liquid lifting was taken as an example. It was researched that the key influencing factors and changing rules of foam stability through static and dynamic experiments on foam stability, chemical defoaming experimets and field tests. The results showed that the concentration of foaming agent used in the field, namely UT-11C, had the most significant effect on the foam stability followed by the salinity, temperature and PH value. Foam stability was also can be improved with higher pressure. Results of chemical defoaming experiments showed that even under the optimal defoaming concentration, mamely 1%, it also took about 20 minutes to completely eliminate the foam. Combined with the laboratory results and the statistical analysis of the water production in field, the optimal injection amount of foaming agent was calculated, which makes the dosage reducing by 40%. And the effective was validated by field test. This work not only ensures the high production of gas wells, but also takes the economy into account, having a strong guidance for the production of natural gas fields.

Keywords: *gas production, liquid lifting, foam stability, foam drainage, influencial factors, field application.*

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Application of Comprehensive Geophysical Prospecting Method

in Fine Detection of Goaf

The mining process involves many complex problems, which are easy to cause environmental pollution and safety. The comprehensive geophysical exploration method combined with drilling method is used to carry out fine exploration of goaf. Firstly, the high density resistivity method was carried out, the data was collected by Wenner device, and the sudden change characteristics of apparent resistivity presented in the profile map of the goaf were summarized. The first-order derivative method was proposed to process the data, which was easier to distinguish the goaf boundary and scope. Transient electromagnetic method and microtremor detection were used to deduce the goaf by high-density electrical method for measurement. The transmitting current of 15A was used in TEM, the fretting detection was a linear acquisition method, and the dispersion curve was extracted by ESPAC method. Through the comprehensive detection of multiple methods, the apparent resistivity mutation area and wave velocity change area are the mined-out range. The acceptance of goaf has been carried out by several borehole verification, and good practical results have been obtained. The research results show that the high density resistivity method, transient electromagnetic method, microtremor detection and other comprehensive geophysical exploration methods can be used to identify the goaf abnormal area, which can be efficient, economical and accurate detection of goaf.

Keywords: *mine geological environment; integrated geophysical method; micromotion detection; mine goaf;high-density electrical method.*

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Simulation Studies of Wax Deposition in Oil-Gas Inclined Shafte

Wax deposition in oil–gas two-phase pipe flow can be a significant flow assurance problem. It becomes complicated when gas phase flow is involved. In this work, a program is proposed for the wax deposition for oil-gas inclined well. The simulator is modular in struct multiphase fluid flow, wax-oil-gas thermodynamics, two-phase heat transfer, and paraffin deposition. In the thermodynamic ure and develops for predicting paraffin deposition during oil-gas two phase flow that includes coupling of calculation module, the equation of state (EOS) – the excess Gibbs energy model calculates the wax-oil-gas phase behavior of crude oil and predicts wax appearance temperature (WAT) and the solubility curves. To calculate the thickness and wax content of the wax deposition layer, the molecular diffusion and the aging theory are considered as the primary mechanisms. Predictions of the simulator are compared and tuned to the experimental data by adjusting the film heat transfer and diffusion coefficients. The adjusted simulator is used to predict the detail of wax deposition along the actual well. And then the thorough analysis upon the atypical distribution of wax deposition is carried out.

Keywords: *multiphase wax deposition, three phase thermodynamics, oil-gas tubing.*

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Bearing Capacity of Pile Foundation Considering Mud Sand

Mixing Layer Jacket Platform Limit

The design life of offshore fixed platforms is generally 20 years, but with the needs of oil field production, most of the platforms are still in service after reaching the design life, which further requires the functional expansion of active platforms and the transformation of new platforms relying on active platforms. In order to ensure the normal and safe production of the platform, a comprehensive safety assessment must be carried out on the platform. The bearing capacity assessment of pile foundation is an important part of the life extension assessment of the platform in service. This paper relies on a platform that has been in service for 25 years to carry out a certain transformation, and on the southeast side of the platform, a new platform with 8 legs and 12 piles is built as the core engineering facility. A new calculation method is adopted to calculate the ultimate axial bearing capacity of single pile of jacket platform pile foundation in the viscous soil layer and sandy soil layer. Based on the engineering geological characteristics of submarine soil, the ultimate axial bearing capacity of single pile and the mechanical analysis of jacket platform pile foundation, the load of jacket platform, bottom resistance, dead weight and lateral friction force are calculated and checked.

Keywords: *catenary platform; pile bearing capacity; depth of mud entry; mud and sand mixed layer.*

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Discovery of Microbial Mounds and Its Geological Significance

A complete and continuous Cambrian system can be found in the Qinglongshan Profile and the Xiweikou Profile in the Ordos Basin. There are five strata in total, namely, the Lower Cambrian Mantou Formation and Maozhuang Formation, the Middle Cambrian Xuzhuang Formation and Zhangxia Formation, and the Upper Cambrian Sanshanzi Formation. The microbial mounds of the two profiles were developed in the Mantou Formation of the Lower Cambrian and the Xuzhuang Formation of the Middle Cambrian respectively. The columnar stromatolites formed by microbial mounds mainly developed in the high energy intertidal environment, which is indicative of the paleoenvironment. In this study, field observation, systematic sampling and measurement of the microbial mounds in the Qinglongshan and Xiweikou Profiles in the Ordos Basin were carried out. Moreover, the macroscopic and microscopic characteristics of stromatolites were systematically analyzed from the perspective of geobiology, based on the previous research results and combined with the sedimentological characteristics of the profile. The discovery of microbial carbonates in the Qinglongshan Profile and the Xiweikou Profile in the Ordos Basin provides important

rock records for understanding the earth's microorganisms, paleoenvironment and paleoclimate in the Cambrian period.

Keywords: *stromatolites, Cambrian system, Ordos Basin.*

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Experimental Study on Microscopic Pore Structure,

Genetic Type and Evolution of Marine Shales

The genetic types and evolution characteristics of pores are the important basis for evaluating the quality of unconventional shale reservoirs. In this paper, taking the Lower Cambrian Marine shales in southern China as an example, the microscopic pore structure, genetic types and evolutionary characteristics of shales are systematically studied. The results show that circular and oval organic pores with good connectivity and non-fixed inorganic pores with poor connectivity are mainly developed in marine shale. The marine shales mostly have laminar sedimentary structures, the thickness of which is several millimeters to several centimeters. Siliceous laminae, clay laminae, organic laminae and carbonate laminae were identified. Lamination can also be retained in oxygen-rich environments with rapid sediment inflow, which may be related to high turbidity fluid. The Lower Paleozoic marine shales in southern China have experienced a complex tectonic-thermal evolution history, which aggravated the complex distribution of laminar structures. Some shale sections show very low resistivity, and resistivity has a significant negative correlation with TOC content. Organic matter is the main factor that causes the extremely low resistivity of shale. This study is of great significance to accelerate the process of Marine shale exploration and development.

Keywords: *marine shale, pore structure, pore type, lamellar structure.*

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Experimental Study on the Evaluation Model of Cementing Quality

fr Ultra Low Density Cement Well Cluster

In order to improve the accuracy of cementing quality evaluation for ultra-low density cement, a full-scale cementing quality evaluation model well group was constructed based on the real underground environment and the requirements for cementing quality and cement filling. A calibration method for cementing quality evaluation indicators was established, and the influence of factors such as logging time and cement density on cementing quality evaluation indicators was analyzed. The results were compared with theoretical calculations, The experimental results are in good agreement with the theoretical calculation results. According to the experimental results, the evaluation indicators of ultra-low density cement cementing quality are inversely correlated with cement density &

logging time. The research results indicate that the accuracy and pertinence of cementing quality evaluation can be significantly improved by applying the ultra-low density cement slurry cementing quality evaluation model well group and verifying the ultra-low density cement cementing quality evaluation indicators.
Keywords: *cementing quality, ultra low density, model well, evaluating indicator.*