Chemistry and Technology of Fuels and Oils

6(628)'2021

Publisher— ICST «TUMA Group» LLC

Редактор
В. С. Дмитриева

Ответственный секретарь
О. В. Любименко

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Формат 60 × 84 1/8.
Печать офсетная.
Усл. печ. л. 7.
Тираж 1000 экз.

Отпечатано в ООО ИПФ «СТРИНГ»
424006, Республика Марий Эл, г. Йошкар-Ола, ул. Строителей, 95

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Особенности синтеза функциональных углеродных материалов
из растительных углеводов

Работа посвящена технологии получения углеродных материалов из наиболее распространенных в природе сахаров, глюкозы и целлюлозы. Химические превращения сахаров в ходе карбонизации были исследованы с помощью термогравиметрического анализа. Показано, как выбор прекурсора и способ его предобработки влияют на структуру и морфологию углеродных материалов. Морфология материалов, полученных из предобработанной на воздухе глюкозы и целлюлозы, отличается крупными частицами нерегулярной формы. В свою очередь предобработка сахаров в гидротермальных условиях позволяет получить материалы, состоящие из микросфер.

Ключевые слова: углеродные материалы, биомасса, гидротермальная карбонизация
DOI: 10.32935/0023-1169-2021-628-6-3-6

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Features of the Synthesis of Functional Carbon Materials Produced from Carbohydrates

This work is devoted to the synthesis of carbon materials from the most common carbohydrates in nature, glucose and cellulose. The chemical transformations of carbohydrates during carbonization were investigated using thermogravimetric analysis and FTIR-spectroscopy. The influence of the precursor and the pretreatment process on the structure and morphology of carbon materials was shown. The morphology of materials obtained from glucose and cellulose pretreated in the air was characterized by large irregular particles. In turn, the pretreatment of carbohydrates under hydrothermal conditions makes it possible to obtain materials consisting of microspheres.

Key words: *carbon materials, char, hydrothermal carbonization.*

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Переработка прямогонного бензина на медьсодержащих цеолитных катализаторах

В статье представлены результаты исследований по переработке прямогонной бензиновой фракции нефти на цеолите структурного типа ZSM-5 и медьсодержащих цеолитных катализаторах, полученных его смешением с наноразмерным порошком меди. Показана зависимость кислотных свойств и активности цеолитных катализаторов от содержания в них нанопорошка меди.

Ключевые слова: цеолит ZSM-5, нанопорошок меди, кислотность, прямогонный бензин.
DOI: 10.32935/0023-1169-2021-628-6-7-10

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Processing of Straight-Run Gasoline over Copper-Containing Zeolite Catalysts

The results of investigations of the processing of straight-run gasoline fraction of oil over a zeolite of ZSM-5 structural type and copper-containing zeolite catalysts are presented. The copper-containing zeolite catalysts are resulted from the mixing of a ZSM-5 zeolite with a nanosized copper powder. It is shown that the acidic properties and activity of zeolite catalysts depend on the content of copper nanopowder in these catalysts.

Key words: *ZSM-5 zeolite, copper nanopowder, acidity, straight-run gasoline.*

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Опыт разработки и производства промышленного катализатора гидроочистки смесевых дизельных фракций

В статье представлены результаты проведения ресурсных испытаний нового катализатора гидроочистки смесевых дизельных фракций компании ПАО «Газпром нефть». Проведена сравнительная оценка эксплуатационных свойств разработанного катализатора и импортного аналога. Подтверждено в промышленных условиях соответствие качества и характеристик российского катализатора мировым стандартам.

Ключевые слова: гидроочистка, катализатор, дизельная фракция, смесевое сырье, ресурсные испытания.
DOI: 10.32935/0023-1169-2021-628-6-11-14

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The Experience of the Development and Manufacturing of Diesel Hydrotreating Catalyst

The article presents the results of life tests of a new catalyst for hydrotreating mixed diesel fractions by Gazprom Neft PJSC. Technologies for optimizing the processing of carbon-containing raw materials, a comparative assessment of the operational properties of the developed catalyst and the imported analog was carried out. The conformity of the quality and characteristics of the Russian catalyst to the level of world standards has been confirmed in industrial conditions.
Key words: *hydrotreating, catalyst, diesel fraction, blended feedstock, life tests.*

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Синтез и исследование каталитической активности смешанных оксидов цинка и железа для гидротермального облагораживания тяжелой нефти

Установлено влияние мольного соотношения катионов Zn^{2+}/Fe^{3+} в предшественниках двойных гидроксидов на строение оксидов Zn–Fe смешанного фазового состава. С увеличением соотношения катионов металлов с 1:1 до 1:4, в составе смешанных оксидов Zn–Fe, состоящих из ZnO и Fe_3O_4, снижается количество сложных оксидов $ZnFe_2O_4$, обладающих изоморфной шпинельной структурой. С увеличением удельной поверхности с 27,075 до 34,556 $м^2/г$ значения диаметра пор 23,8 нм остаются постоянными. Представлены результаты исследований влияния состава и структуры смешанных оксидов Zn–Fe на компонентный состав тяжелой нефти нафтеноароматического основания в ходе ее облагораживания в гидротермальном флюиде при температуре 380 °С и давлении 22 МПа. Максимальное увеличение содержания насыщенных углеводородов на фоне заметного уменьшения количества асфальтенов характерно для гидротермально преобразованной нефти в присутствии смешанных оксидов Zn-Fe (1:4), при этом увеличивается содержание н-алканов $C_{10}–C_{14}$.

Ключевые слова: синтез, гидротермальное воздействие, смешанные оксиды, сверхвязкая нефть.

DOI: 10.32935/0023-1169-2021-628-6-15-20

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Synthesis and Study of Catalytic Activity of Mixed Oxides of Zinc and Iron for Hydrothermal Refining of Heavy Oil

The effect of the molar ratio of metal cations Zn^{2+}/Fe^{3+} in precursors of double hydroxides on the structure of Zn-Fe oxides of mixed phase composition has been established. With an increase in the ratio of metal cations from 1: 1 to 1: 4, in the composition of Zn-Fe mixed oxides consisting of oxides ZnO and Fe_3O_4, the amount of complex oxides $ZnFe_2O_4$ with an isomorphic spinel structure decreases, with an increase in the specific surface area from 27.075 to 34.556 m^2/d the pore diameter values of 23.8 nm remain constant. The results of experimental studies of the effect of the composition and structure of Zn-Fe mixed oxides on the component composition of heavy oil of naphthenic aromatic base during its upgrading in a hydrothermal fluid at a temperature of 380°C and a pressure of 22 MPa are presented. The maximum increase in the content of saturated hydrocarbons against the background of a noticeable

decrease in the amount of asphaltenes is characteristic of hydrothermally converted oil in the presence of mixed oxides Zn-Fe (1: 4), the content of n-alkanes of the composition C_{10}–C_{14} increases.
Key words: *synthesis, hydrothermal treatment, mixed oxides, heavy crude oil.*

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Исследования по очистке работающего моторного масла
и системы смазки от загрязнений

Использование топлив и масел с отклонениями от требований стандартов приводит к накоплению в масле и на деталях двигателя отложений, которые снижают срок службы свежезаправленного масла и ухудшают эксплуатационные характеристики машин. К 150–200 часам наработки масло становится малопригодным к использованию, что увеличивает износ деталей и затраты на ремонт и эксплуатацию. В результате проведенных исследований установлено, что глубокая очистка с использованием реагентов позволяет удалить растворенные в масле загрязнения. Скоагулировавшиеся загрязнения в процессе краткосрочной работы двигателя осаждаются в встроенных в систему смазки центрифугах. Использование реагентов позволяет очищать не только масло, но и обеспечивать промывку системы смазки.

Ключевые слова: моторное масло, очистка, двигатель, промывка системы смазки, компрессия, расход топлива.

DOI: 10.32935/0023-1169-2021-628-6-21-24

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Research on Cleaning Operating Engine Oil and Lubrication System from Contaminations

The use of fuels and oils with deviations from the standards leads to the accumulation of deposits in the oil and on engine parts, which will reduce the life of the freshly filled oil and reduce the performance of the machines. By 150-200 hours of operation, the oil becomes unsuitable for use, which increases the wear of parts and the cost of repair and operation. As a result of the studies carried out, it was found that deep cleaning with the use of reagents allows you to remove contaminants dissolved in the oil. The coagulated contaminants during the short-term operation of the engine are deposited in the centrifuges built into the lubrication system. The use of reagents allows you to clean not only the oil, but also to provide flushing of the lubrication system.

Key words: *engine oil, pollution, cleaning, engine, flushing of the lubrication system, compression, fuel consumption.*

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Гидротермальное преобразование органического вещества карбонатной породы вблизи критической точки воды

В работе исследованы закономерности преобразования органического вещества кремнисто-глинистой карбонатной породы в гидротермальном флюиде при температуре 340–380°С и давлении 17–20 МПа. Установлено, что в гидротермальном флюиде с избытком воды с увеличением температуры и давления в карбонатной породе, содержащей органическое вещество, доминируют реакции окисления с накоплением ароматических углеводородов, смол и асфальтенов. Показаны зависимости геохимических параметров углеводородов (экстрактов) карбонатной породы от температуры и давления гидротермального флюида. Оптимальными термобарическими параметрами гидротермального флюида для карбонатной породы являются 340°С и 17 МПа, в данных условиях происходит увеличение количества нефтяных углеводородов на фоне снижения содержания органического вещества, увеличивается диаметр пор, образуются микропоры. Полученные экспериментальные данные вносят вклад в развитие технологий разработки карбонатных пород.

Ключевые слова: карбонатные породы, органическое вещество, гидротермальные флюиды, экстракция, нефтяные углеводороды.
DOI: 10.32935/0023-1169-2021-628-6-25-29

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Hydrothermal Conversion of Organic Matter of Carbonate Rock near the Critical Water Point

The paper presents the results of comparative studies to identify the regularities of the transformation of organic matter in a siliceous-clayey carbonate rock in a hydrothermal fluid at temperatures of 340-380°C and pressures of 17-20 MPa. It was found that in a hydrothermal fluid with an excess of water with increasing temperature and pressure in a carbonate rock containing organic matter, oxidation reactions dominate with the accumulation of aromatic hydrocarbons, resins, and asphaltenes. The dependences of the values of the geochemical parameters of hydrocarbons (extracts) of carbonate rock on the temperature and pressure of the hydrothermal fluid are shown. The optimal thermobaric parameters of a hydrothermal fluid for a carbonate rock are 340°C and 17 MPa; under these conditions, the amount of petroleum hydrocarbons increases against the background of a decrease in the content of organic matter, the pore diameter increases, and micropores are formed. The obtained experimental data contribute to the development of technologies for the development of carbonate rocks.

Key words: *carbonate rocks, organic matter, hydrothermal fluids, extraction, petroleum hydrocarbons.*

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Формирование кобальтсодержащих дисперсий в жидкометаллических средах

Были сформированы кобальтсодержащие дисперсии на основе олова, висмута, галлия и сплава висмут/олово. Установлено влияние природы дисперсионной среды на формирование кобальтсодержащей дисперсной фазы. Показано влияние способа введения кобальтсодержащего компонента на стабильность дисперсии. Изучено влияние концентрации раствора прекурсора на размер частиц оксида кобальта, образующихся при формировании дисперсной системы. Показана принципиальная возможность образования каталитических систем на основе галлия с размером частиц от 450–540 нм.

Ключевые слова: жидкие металлы, катализ в дисперсных фазах, кобальтсодержащие дисперсии.
DOI: 10.32935/0023-1169-2021-628-6-30-34

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Formation of Cobalt-Containing Dispersions in Liquid-Metal Systems

Cobalt-containing dispersions were formed based on tin, bismuth, gallium, and a bismuth / tin alloy. The effect of the nature of the dispersion medium on the formation of the cobalt-containing dispersed phase has been established. The effect of the method of introducing the cobalt-containing component on the stability of the dispersion is shown. The effect of the concentration of the precursor solution on the size of cobalt oxide particles formed during the formation of a dispersed system has been studied. The fundamental possibility of the formation of catalytic systems based on gallium with a particle size of 450–540 nm is showns.

Key words: *liquid metals, catalysis in dispersed phases, cobalt-containing dispersions.*

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Термодинамический анализ реакций синтеза продуктов нефтегазохимии из оксигенатов

Проведен термодинамический анализ реакций превращения диметилового эфира в ценные продукты нефтегазохимии, в частности пропилена, формальдегида, 1,3-бутадиена. Определена температурная зависимость равновесного состава реакции получения 1,3-бутадиена из диметилового эфира. Расчет температурной зависимости концентраций равновесного состава реакции взаимодействия пропилена с формальдегидом с образованием: 1,3-диоксана, 1,3-бутандиола и 2-бутен-1-ола показал, что основным продуктом при равновесии является 2-бутен-1-ол.

Ключевые слова: оксигенаты, термодинамика, 1,3-бутадиен, пропилен, формальдегид, реакция Принса.
DOI: 10.32935/0023-1169-2021-628-6-35-40

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Thermodynamic Analysis Reactions Synthesis Valuable Products Petrochemiscals from Oxygenates

A thermodynamic analysis of the products of the transformation of dimethyl ether into valuable products, in particular, propylene, formaldehyde, 1,3-butadiene, has been carried out. The temperature dependence of the equilibrium formation of the reaction of 1,3-butadiene from dimethyl ether has been determined. Calculation of the temperature dependence of the equilibrium coefficient of the conversion coefficient of propylene with formdehyde with the formation of 1,3-dioxane, 1,3-butanediol and 2-buten-1-ol showed that the basic product in equilibrium is 2-buten-1-ol.

Key words: *oxygenates, 1,3-butadiene, propylene, formaldehyde, Prince reaction.*

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Дзета-потенциал наноразмерных частиц целлюлозы как функция pH

В настоящей работе получены дисперсии наноразмерных частиц целлюлозы и определен их дзета-потенциал при pH от 1 до 14. Установлено, что нанофибриллярная целлюлоза (НФЦ) сохраняет седиментационную устойчивость при pH от 3 до 11. При этом НФЦ, полученная кислотной обработкой с гомогенизацией, имеет максимальный дзета-потенциал около –62 мВ при pH = 6. НФЦ, полученная окислительной обработкой с гомогенизацией, имеет максимальный дзета-потенциал около –46 мВ при pH = 7. Нанокристаллическая целлюлоза, полученная окислительной обработкой с гомогенизацией, сохраняет седиментационную устойчивость при pH от 4 до 11 и имеет максимальный дзета-потенциал около –73 мВ при pH = 4.

Ключевые слова: наноцеллюлоза, гидрогель, стабильность дисперсии, коагуляция, кислотность.

DOI: 10.32935/0023-1169-2021-628-6-41-43

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Zeta Potential of Cellulose Nanoparticles as a Function of pH

In this work, we obtained dispersions of nanosized cellulose particles and measured the zeta potential of particles at pH from 1 to 14. It was found that CNF retains sedimentation stability at pH from 3 to 11. At the same time, CNF obtained by acid treatment with homogenization has the maximum zeta potential about -62 mV at pH = 6. CNF obtained by oxidative treatment with homogenization has a maximum zeta potential of about -46 mV at pH = 7. CNC obtained by oxidative treatment with homogenization retains sedimentation stability at pH from 4 to 11 and has a maximum zeta potential of about -73 mV at pH =4.

Key words: *nanocellulose, hydrogel, dispersion stability, coagulation, acidity.*

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Моделирование интенсифицированных теплообменников с различной вязкостью сред

Для решения задач модернизации промышленных установок получения нефтяных фракций на основе применения приближенного метода моделирования переноса импульса и теплоты в теплообменных аппаратах с поверхностными интенсификаторами получены выражения для средних коэффициентов трения и теплоотдачи. Использована модель турбулентного пограничного слоя Дайсслера и Ван-Дрийста для функции турбулентной вязкости для плоской гладкой стенки. С применением гидродинамической аналогии Чилтона — Кольборна получено выражение для числа Стэнтона и показано согласование с известной аналогией. При переходе к моделированию переноса импульса и теплоты в каналах с поверхностными интенсификаторами использованы идентичные локальные свойства турбулентного движения в пограничном слое на пластине и в пристенном слое трубы, а также свойства консервативности законов трения и теплообмена к возмущениям, которые учитываются параметрически. На основе диссипативной модели получены выражения для среднего касательного напряжения в каналах с интенсификаторами и числа Нуссельта. Представлены результаты расчетов и сравнения с известными экспериментальными исследованиями для труб с поверхностными проволочными вставками, со спиральным оребрением и прямоугольными выступами для трансформаторного масла при значениях числа Рейнольдса 200 < Re <2000. Установлена адекватность разработанной математической модели в широком интервале режимных и конструктивных параметров и теплофизических свойств жидких и газовых сред.
Даны примеры применения математической модели при проектировании теплообменников на ректификационных установках в России и за рубежом.

Ключевые слов: теплообмен, математическая модель, поверхностные интенсификаторы, модернизация аппаратов.
DOI: 10.32935/0023-1169-2021-628-6-44-50

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Modeling of Intensified Heat Exchangers with Different Fluid Viscosities

Equations are derived for mean friction and heat transfer coefficients to solve problems of updating industrial plants for getting oil fractions based on application of approximate method of modeling momentum and heat transfer in heat exchangers with surface intensifiers. The Dyssler and Van-Driest turbulent boundary-layer model is used for the turbulent viscosity function for a flat smooth wall. An equation for the Stanton number is written using Chilton-Colborne hydrodynamic analogy and agreement with the known analogy is shown. Identical local properties of turbulent motion in a boundary layer on a plate and in a near-wall layer of a tube and the conservative properties of the laws of friction and heat transfer to turbulences, which are taken account of parametrically, are used for modeling momentum and heat transfer in channels with surface intensifiers. An equation for mean tangential stress in channels with intensifiers and, further, an equation for the Nusselt number is derived using a dissipative model. The results of calculations and comparison with the known experimental investigations are given for tubes with surface wire inserts, with spiral finning and rectangular projections for transformer oil at Reynolds numbers 200

< Re <2000. Thus, the adequacy of the developed mathematical model is proved in a wide range of operating and design parameters and thermophysical properties of fluids and gases. Further, the hydraulic resistance of the channel is the key experimental information about the object of modeling. Examples of use of mathematical model for designing and commissioning heat exchangers in petroleum fuels fractionating plants at industrial enterprises in the Russian Federation and abroad are given.
Key words: *heat exchange, mathematical model, surface intensifiers, equipment updating, fuel production.*

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Термодинамический анализ чередующейся циклической закачки пара и дымовых газов на примере тяжелых нефтей Колумбии

В статье на примере добычи тяжелых нефтей Колумбии приводится оценка термодинамических показателей эффективности оборудования для циклической чередующейся закачки водяного пара и дымовых газов с целью повышения нефтеотдачи месторождений и решения природоохранных задач. Рассматриваемое оборудование представлено двумя подсистемами: генерации водяного пара и сжатия дымовых газов. Параметры энергоносителей выбирались исходя из глубины залегания добывающих коллекторов и экспериментальных данных, предоставленных зарубежным партнером. Термодинамический анализ предусматривал оценку потерь эксергии как отдельно по подсистемам, так и в режиме их совместной работы для обеспечения циклической чередующейся закачки агентов. При этом рассматривались различные соотношения времени закачки водяного пара к дымовым газам, приведенные к пятидневному циклу. Установлено, что энергоэффективность совместной работы подсистем, определяемая минимальными суммарными потерями эксергии, приводит к диаметрально противоположным результатам, которые зависят от того, какой источник электроэнергии используется: централизованный или на основе местной генерации. Сделан вывод о необходимости дополнить термодинамический анализ экономической оценкой переменной части приведенных затрат на реализацию процесса циклической чередующейся закачки водяного пара и дымовых газов, которая показала, что оптимальным техническим решением является режим закачки с соотношением времени закачки пара и дымовых газов, равным 4,5:0,5, в пятидневном цикле при использовании электроэнергии из централизованных источников.

Ключевые слова: тяжелая нефть, водяной пар, дымовые газы, эксергетический КПД, пятидневный цикл, чередующая закачка, приведенные затраты.
DOI: 10.32935/0023-1169-2021-628-6-51-56

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Thermodynamic Analysis of Alternating Steam and Flue Gas Injection Process in Application to Heavy Oil Fields in Colombia

This paper presents the thermodynamic analysis of the cyclic steam and flue gas injection process in application to heavy oil production for Colombian oilfields in order to improve oil recovery as well as reduce the environmental impact. The process comprises two subsystems: the steam generation subsystem and flue gas compression process. Working fluid parameters were selected based on the depth of the producing wells and the experimental data provided for Colombian oilfields. As part of the thermodynamic analysis, exergy losses were calculated for the subsystems operating separately as well as together in the cyclic flue gas-steam alternating injection process. The analysis was conducted for varying ratio between the duration and steam and flue gas injection over a five-day cycle. Is was determined that the efficiency of the subsystems operating together in the process (which is achieved by minimizing the total exergy losses) is drastically different depending on whether centralized power or local power generation is used for energy supply. It was concluded that an economic analysis is required in addition to the thermodynamic analysis. The varying part of the relative costs for the cyclic steam-flue gas injection process was assessed and it was shown that the optimal solution would be steam-flue gas injection with an injection ratio of 4.5:0.5 (for a five-day cycle) that uses a centralized power source.

Key words: *heavy oil, water vapor, flue gases, exergy, exergy efficiency, five-day cycle, alternating injection, unit costs.*

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Experimental Quantification of Oil Displacement Efficiency in Pores and Throats with Varied Sizes in Conglomerate Oil Reservoirs through CO_2 Flooding

The pilot project of CO_2 flooding has been implemented in the conglomerate oil reservoir in Xinjiang, China. The target reservoir is characterized by the low-porosity (ranging from 8.53% to 11.02%) and low-permeability (ranging from 3.30 to16.18 mD) parameters. The objective of the pilot CO_2 flooding is to overcome the water sensitiveness of the formation. However, the field application of the CO_2 injection is complicated by technical difficulties including gas channeling and low sweep efficiency. To control the oil recovery factor, it is critically important to investigate the efficiency of the oil displacement in pores and throats of the formation in the process of water and CO_2 flooding. In this paper, in order to quantitatively determine the oil displacement in the pores of different sizes, the authors have studied the process of the water and CO_2 flooding in the core samples obtained from the conglomerate oil reservoir in the Xinjiang Oilfield. The displacement efficiency is evaluated by the online nuclear magnetic resonance (NMR) method. Before testing, the samples are saturated with oil till the oil saturation reaches 48.27%. In the process of water flooding, the water content in the large pores reaches 28.70%, the displaced oil is produced mainly from the large pores, and the oil saturation is reduced to 27.78%. In the process of CO_2 flooding, the oil displacement efficiency is increased by 17.97%, including an increment of 7.17% for the middle-size pores and 8.61% for the large pores. The large and the middle-size pores contribute to the high oil recovery, while the oil in the small pores is difficult to recover. The ultimate oil saturation is 19.97%, and the overall recovery factor is 60.44%. At the late stage of CO_2 flooding, a foam-like structure is developed in the large pores, which is prone to plug the pore

throats of the large pores and boost the residual oil displacement in the small pores, thereby further enhancing the oil recovery factor. This study is focused on comprehensive research on the relationship between the pore size and the oil recovery factor in a conglomerate oil reservoir. The results can be useful for guiding the implementation of site-specific EOR technologies.

Keywords: CO_2 flooding; online flooding; experiment quantification of flooding efficiency; NMR.

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Flow Mechanism and Transient Pressure Analysis of Multi-Stage Fractured Horizontal Well

Shale gas reservoirs are typical unconventional natural gas resources characterized by low porosity and low permeability of the formation. To enhance production and provide an economically justified production rate, the multi-stage fractured horizontal well (MFHW) technology has been widely used in shale gas reservoirs. More attention has been paid recently to studying the mechanism of multi-scale flow in shale. However, the mechanism of gas seepage in shale in a multi-stage fractured horizontal well has not been systematically discussed. In the previously published conventional studies, the authors have not presented a comprehensive analysis of the adsorption, desorption, and diffusion mechanisms participating in gas seepage, particularly within a linear flow model. In this paper, the linear superposition method is applied to describe the non-Darcy flow behavior in nano/micro-scale pores and the Darcy flow behavior in macropores and natural/induced fractures in a shale matrix. Based on the flow mode, the shale reservoir and the area around the multi-stage fractured horizontal well are divided into three zones: the outer region flow, the inner region flow, and the flow in the hydraulic fractures. Based on the trilinear flow model, the authors consider the differences in properties between the initial shale reservoir and the induced fracture network of the stimulated reservoir volume (SRV). In this model, the dimensionless variables, Duhamel principle, and numerical Stehfest algorithm are combined to analyze the dynamic bottomhole pressure, adsorption-desorption behavior, multi-scale flow mechanism, and complex SRV geometry in the MFHW area. Based on the established model, the effect of the key factors and their influence on the dimensionless pressure and pressure derivate curves are considered.

Keywords: shale gas reservoir, trilinear flow model, MFHW, multi-scale flow mechanism, well testing.

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Liquid Accumulation in Horizontal Gas Wells

In the previously published studies, the calculations of critical liquid-carrying gas velocity in a horizontal well were based on conventional calculation models of a droplet in a vertical well and do not consider the influence of the inclination angle of the well on the liquid-carrying ability of gas. Horizontal wells are currently widely used in the gas fields, while the traditional critical liquid-carrying velocity models cannot be applied to evaluate gas flow characteristics in the inclined sections of horizontal wells. In this paper, based on experimental results, we established that the critical liquid-carrying conditions in an inclined well occur when the inclination angle is 55°. Considering the flow characteristics of the liquid phase in a gas well, we obtained the flow mode of the liquid film in the pipeline. The established liquid-film model provides a calculation method of the critical liquid-carrying velocity for different inclination angles. The accuracy of the new method has been verified by the field data.

Keywords: horizontal well, critical liquid-carrying conditions, fluid accumulation, critical liquid-carrying velocity.

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Explosive behavior of $CH_4/C_2H_6/C_3H_8$ mixtures in the SAGD process with CO_2 fusion gases in extra-heavy oil reservoirs

In the crude oil recovery industries, explosion accidents involving associated gases can often result in fatal damage. The main purpose of this study is to provide theoretical support and engineering background for the SAGD operations in the extra-heavy oil reservoirs. To investigate the explosive behavior of $CH_4/C_2H_6/C_3H_8$ gases and the inhibition mechanism of CO_2 gas, the authors have experimentally studied the factors influencing the explosion behavior of the associated gas in a standard-designed 20 L spherical explosion vessel at ambient temperature and pressure. Based on experimental data, they analyzed the explosive parameters of the combustible gas mixtures, including the explosive peak pressure, time to reach the maximum pressure, the velocity of flame propagation, upper explosive limit (UEL), and lower explosive limit (LEL). The results show that a small amount of C_2H_6/C_3H_8 could promote the explosive characteristics of CH_4. The addition of CO_2 gas has a different inhibitory effect on the explosive behavior of $CH_4/C_2H_6/C_3H_8$. The explosive overpressure strength of the $CH_4/C_2H_6/C_3H_8$ gas mixture decreases with increase in the CO_2 concentration. When the CO_2 gas is added to the extra-heavy-oil associated gas, the flame propagation velocity of the $CH_4/C_2H_6/C_3H_8$ mixture explosion decreases accordingly. Due to the inert effect of the CO_2 gas, with the continuous addition of CO_2 to the mixture, the UEL parameter of $CH_4/C_2H_6/C_3H_8$ decreases linearly and the LEL parameter increases exponentially. The results of the study are important for eliminating potential risks and providing safety management of the SAGD operations at the extra-heavy oil reservoirs.

Keywords: extra-heavy oil reservoir; associated gas; explosive behavior; inert gas; explosive limits.

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Development of Spontaneous Imbibition in Tight Rocks

Spontaneous imbibition of a wetting liquid in a tight reservoir is an important driving mechanism for enhancing oil recovery and providing satisfactory flow-back efficiency. In this paper, the authors experimentally study the characteristics of spontaneous imbibition in the tight sandy samples. The changes of imbibition mass with time in the samples with a different initial distribution of porosity are measured and analyzed. The nuclear magnetic resonance (NMR) method is applied to measure the development of imbibition in the pores of different diameters. The results show that the imbibition process is divided into three stages, depending on the pore size distribution in the samples. In the first stage, imbibition satisfies the Lucas and Washburn equation. In most cases, imbibition first develops rapidly in the small pores, and then the wetting phase migrates into the large pores, which is reflected by the peak shift in the T_2 spectrum. The variations in the T_2 spectra also reflect the formation of new fractures and the collapse of pores. The development of spontaneous imbibition is controlled by the pore size distribution, the formation of fractures, and boundary conditions. To simulate the imbibition process, the authors propose a simple model based on the pore size dostribution and capillary bundles. The model is used to demonstrate the three stages of imbibition in the porous media.

Keywords: spontaneous imbibition, tight reservoir, T_2 spectral.

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Experimental Study of Oilfield Water Plugging with Organic Chromium Gel

Application of water flooding technologies in the oilfield causes intensive heterogeneity of the oil reservoir and improper circulation of the injected water. The profile control and water plugging technologies are applied to adjust the heterogeneity of the formation, reduce permeability, plug the formation water, and enhance the oil recovery. The polymer gel used in the profile control and water plugging method is produced by mixing the polymer solution with an appropriate crosslinking agent. In this study, the organic-chromium gel is prepared by mixing the partially-hydrolyzed polyacrylamide (HPAM) as the main component and the organic chromium as a crosslinking agent. The resulting gel contains 1% of HPAM and 1% of the organic-chromium crosslinking agent. The gelatinization of the solution is evaluated by measuring the gel parameters in relation to temperature, pH value, and salinity parameters of the solution. The plugging effectiveness of the gel is tested experimentally in the simulated artificial strata. Based on the optimized temperature, salinity, and pH parameters, the gel solution formula has been adjusted. The optimized gel

is characterized by the gelation time in the range from 1 to 22 h, the gel strength as high as the I level, and the plugging rate of above 95%, providing a satisfactory plugging effect in the simulated formation. The experimental results can provide theoretical and practical references for developing water-plugging technologies in oilfields or mines. The study is also of interest for optimizing the formulations of the drilling fluids and the polymer-polymer compositions for enhanced oil recovery.
Keywords: gel, oilfield, water plugging, permeability, organic chromium, crosslinking agent.

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Oil Sludge Treatment by a Microemulsion System Containing Sodium Dodecyl Benzene Sulfonate

In the oil production process, a large amount of generated oily sludge causes considerable pollution to the environment. In this paper, the oil sludge samples obtained from the Jidong oilfield in China are treated by the microemulsion system containing sodium dodecylbenzene sulfonate (SDBS) as a surfactant. The microemulsion system contains kerosene as the oil phase and an aqueous solution containing SDBS, n-butanol, and sodium chloride as the water phase. This study is focused on the effects of the system's composition and treatment process on the efficiency of oil removal. The results show that when the volume ratio of kerosene to water is 1:1 and the weight concentrations of SDBS, n-butanol, and sodium chloride are 4.92%, 2.59%, and 3.94% respectively, the system provides the highest oil removal efficiency. When the initial sample mass is 10 g and the water content in the microemulsion is 100 mL, the treatment provides the removal of 79.3% of oil from the sludge. The oil removal efficiency is further optimized to 82.5% by treating the sludge at the temperature of 30°C for 2 h.
Keywords: oil sludge, microemulsion, surfactant, oil removal efficiency.

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Influence of Bubbles in Diesel Volume Measurement

Accurate measurement of diesel volume is important in both industrial and domestic applications. The accuracy of volume evaluation of diesel fuel is affected by the formation of bubbles in diesel. In this paper, the authors have studied the volume of bubbles generated in diesel in the process of transportation and the change in the volume of the bubbles with time. They measured the volume of diesel in the metal tank ($1\times10^7 mm^3$) and the metal tank volume ($5\times10^7 mm^3$) under different temperature conditions. The volume proportion of bubbles generated in diesel in the process of transportation is quantitatively analyzed. The results show that the bubble volume changes with time in accordance with an exponential function, and the convergence value of the bubble volume ratio is -3.16356×10^{-4}.
Keywords: volume measurement, diesel, bubbles, error compensation.

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Optimal Selection and Principles of Production Tubing in Deep-Water Gas Fields

During the exploitation of deep-water gas fields, the complex deep-water environment conditions result in extremely harsh requirements for the tubing selection. In this paper, the authors studied the selection of tubing in a deep-water gas field. Based on the specific practices in the deep-water gas reservoir A, they suggested the algorithm of the size selection and material selection of tubing. Assuming the flow pressure at the wellhead is 7.5 MPa, the optimized size of the tubing is selected from the most commonly used tubing sizes 5-1/2", 7", and 9-5/8". The selection of the tubing size is determined by the comprehensive analysis of the tubing sensitivity, liquid-carrying capacity, and fluid erosion rate. Based on the analysis results, as well as the safety and economy issues, the 7" tubing size is regarded as the most suitable. The selection of the tubing material is determined by the analysis of the gas composition in the reservoir, the formation water characteristics, and the acid gas corrosion. The safety of the selected tubing material and the final strength of the optimized tubing are verified by the WellCat software. The results show that the strength of the 13Cr L80 tubing is satisfactory to meet the requirements for operations in the initial gas reservoir stage, the production stage, the well shut-in stage, the well killing stage, and for tubing leak situations under the conditions of different water-gas ratios. In this paper, the selection principles of the tubing size and material are summarized. The conclusions may be vitally important for improving the production safety and efficiency of the tubing, which is important in promoting the development of production technologies in the deep-water oil and gas reservoirs.

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Fracturing Optimization of New Wells Considering Cross-Well Interference in the Mahu Conglomerate Reservoir

In recent years, the commercially developed tight conglomerate reservoirs have been benefiting from the continuous progress of fracturing technology. The overall development trend of fracturing is focused on providing small well spacing, large-scale cutting, and cross-well fracturing. The productive construction of new wells is restricted by fracture interference. In this paper, to improve the accuracy of the fracturing design and the final recoverable reserves (EUR) of the well groups, the authors have put forward a new fracturing optimization method. Based on a discrete fracture model and the dynamic in-situ stress field data, they have established a refined three-dimensional in-situ stress model. The model is solved by the coupling analysis of finite element geomechanics and seepage mechanics, combined with the production data. The model is applied to simulate the evolution of the reservoir in-situ

stress field under the condition of the formation energy deficit. Then, the fracture distribution of the new wells in the new dynamic in-situ stress field is simulated, and the fracturing parameters are optimized according to the comparison of the predicted productivity data for different schemes. Taking the well group H1 in the Jin 202 demonstration area as an example, the method has been applied to analyze the factors determining lower productivity after the new wells are put into production. Based on subsection clustering and pump-injection design, the authors have put forward the principles of design optimization of the new wells. As shown by the analysis results, the dynamic in-situ stress model incorporating the influence caused by the production of the old wells is applicable for the evaluation and interactive characterization of fractured layers of the new wells. When the new wells are characterized by significant cross-well interference of fractures, the new model provides an important basis for predicting productivity and optimizing fracturing parameters. When the target horizontal well group is fractured with a cluster spacing of 20 m and a preflush ratio of 55%, the maximum productivity is obtained and the development effect is the best.

Keywords: dynamic in-situ stress field; inter-well interference; optimization of fracturing design.

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Effect of Front Water Flooding Injection-Production Parameters on Polymer Flooding Recovery in a Conglomerate Reservoir

The conglomerate reservoir of the Xinjiang-552 oilfield is characterized by high heterogeneity and complex pore structure. After several years of water injection development, the formation pressure in the reservoir is low and the production per well is poor. The reservoir is difficult to regulate and control and does not meet the conditions for the implementation of the polymer flooding operations. In this paper, the numerical simulation method is applied to optimize the injection-production parameters, including the injection-production ratio, pressure recovery rate, reasonable production rate, and polymer injection timing of the polymer flooding in the X-552 reservoir. The objective of the research is to determine the optimal injection-production parameters and to provide sufficient injection-production capacity for polymer flooding. The front-water flooding technology is applied to ensure the successful progress of polymer flooding in the reservoir. The results show that when the reservoir formation pressure coefficient is 1.0 (the formation pressure is 16.4 MPa), the polymer flooding recovery is reasonably high, the front-water flooding injection time is 5 years, the injection-production ratio is 1.05, and the average annual pressure recovery rate is 0.52 MPa. As shown by the predicted results, the production profile and recovery degree are greatly improved, the development effect is satisfactory, and the goal of the frontal water flooding is achieved. The proposed method can be applied to provide guidance for front-water flooding in conglomerate-type reservoirs.

Keywords: front-water flooding; polymer flooding; numerical simulation; injection-production parameters.

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Influence of Mechanical Rotary Percussion Tool on Friction Drag in Horizontal Wells

Friction between the drill string and the well wall is one of the key factors restricting the rate of penetration (ROP) in the process of sliding drilling in a horizontal well. The problem is effectively solved by applying the vibrating drag-reduction technology. In this paper, the authors propose a new type of mechanical rotary percussion tool driven by the positive displacement motor (PDM) and simulate the drag reduction effect of the tool in a horizontal well. The results show that the drag reduction effect depends on how the weight on the bit (WOB) is transmitted to the bit. When the excitation frequency is high, it causes severe fluctuation of the WOB. To maximize the overall WOB, the excitation frequency needs to be optimized. The WOB fluctuation contains not only the excitation frequency but also the double-excitation frequency and triple-excitation frequency. The research results can provide theoretical guidance for the application of the rotary percussion tool in horizontal wells.

Keywords: horizontal well; friction drag; rotary percussion; vibrating drag reduction; finite element method.