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Глубокая переработка гудрона на базе комплекса глубокой переработки тяжелых остатков АО «ТАИФ-НК»

Статья посвящена переработке гудрона и вакуумного газойля на базе технологии Veba Combi Cracking и охватывает аспекты становления процесса от первых исследований в области гидрокрекинга угля до крупнейшего в мире Комплекса глубокой переработки тяжелых остатков перегонки нефти (КГПТО).

Ключевые слова: гидрокрекинг гудрона, переработка тяжелых нефтяных остатков.
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Deep Processing of Vacuum Residue on the Basis of Heavy Residue Conversion Complex of TAIF-NK JSC

The article is devoted to the processing of vacuum residue and vacuum gasoil based on the Veba Combi Cracking (VCC) technology and covers aspects of the formation of the process from the first research in the field of coal hydrocracking to the world's largest complex for deep processing of heavy oil refining residues of TAIF-NK JSC.

Key words: *vacuum residue hydrocracking, heavy oil residue refining.*

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Влияние гидрокрекинга тяжелых остатков перегонки нефти на производственную эффективность АО «ТАИФ-НК»

Статья посвящена опыту нефтеперерабатывающего завода АО «ТАИФ-НК» в применении процесса комбинированного термо- и гидрокрекинга для глубокой переработки тяжелых остатков перегонки нефти – гудрона и вакуумного газойля. За основу был взят процесс Veba Combi Cracker (VCC), который в ходе пуско-наладочных и опытно-промышленных испытаний был существенно доработан, в результате чего комплекс глубокой переработки тяжелых остатков АО «ТАИФ-НК» стал единственным в мире, позволяющим перерабатывать тяжелые остатки (гудрон) с максимальным извлечением высококачественных светлых нефтепродуктов. Реализация технологии комбинированного термо- и гидрокрекинга на АО «ТАИФ-НК» обеспечила достижение глубины переработки 85,1% и выход светлых нефтепродуктов 80,7% за 2021 г.

Продемонстрированы ретроспектива динамики показателей глубины переработки нефти и выхода светлых нефтепродуктов от реализации проекта.

Ключевые слова: гидрокрекинг гудрона, VCC, переработка тяжелых нефтяных остатков, глубина переработки нефти, выход светлых нефтепродуктов
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Industrial Application of Hydrogenation Processes in the Processing of Heavy Residues of Oil Distillation at TAIF-NK JSC

The article is devoted to the experience of the TAIF-NK JSC in the application of the process of combined thermal and hydrocracking for deep processing of heavy residues of oil distillation — vacuum residue and vacuum gasoil. The Veba Combi Cracker (VCC) process was taken as a basis and during the commissioning and pilot tests it was significantly improved by the specialists of TAIF Group, as a result of which the Heavy Residue Conversion Complex of TAIF-NK JSC is the only one in the world, which allows heavy residues conversion with maximum recovery of high-quality light oil products. The implementation of the technology of combined thermal and hydrocracking at TAIF-NK JSC ensured 85.1% achievement of the refining depth and 80.7% yield of light oil products in 2021. A retrospective of the dynamics of indicators of the depth of oil refining and the yield of light oil products from the implementation of the project is showny.

Key words: *vacuum residue hydrocracking, VCC, Heavy Residue Conversion Complex, oil refining depth, yield of light oil products.*

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Опыт производства битумной продукции из остаточных продуктов комбинированной установки гидрокрекинга гудрона АО «ТАИФ-НК»

Статья посвящена вопросам использования остаточных продуктов комбинированного термо- и гидрокрекинга гудрона и вакуумного газойля в востребованные товарные нефтепродукты — в битумную продукцию в соответствии с российскими и международными стандартами качества.

Ключевые слова: гидрокрекинг гудрона, переработка тяжелых остатков переработки нефти, остаток гидрокрекинга, битум, полимерно-битумное вяжущее.
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Experience in the Production of Bitumen Products from the Residual Products
of the Combined Vacuum Residue Hydrocracking Unit of TAIF-NK JSC

The article is devoted to the use of residual products of combined thermal and hydrocracking of vacuum residue and vacuum gasoil into demanded marketable petroleum products – into bitumen products in accordance with Russian and international quality standards.

Key words: *vacuum residue, hydrocracking, HRCC, hydrocracking residue, bitumen, polymer-bitumen binder.*

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Способы переработки остаточного продукта комбинированного
термо- и гидрокрекинга гудрона

Статья посвящена опыту АО «ТАИФ-НК» в области эффективной, экологической и технологичной переработки остаточных продуктов процесса комбинированного термо- и гидрокрекинга со сравнительным анализом преимуществ и недостатков каждого из методов. Показано, что с учетом специфических особенностей остаточных продуктов гидрокрекинга наиболее и связанной с ними повышенной склонностью к выпадению асфальтенов и коксованию, необходимо проводить дальнейшую переработку остаточных продуктов в более мягких условиях с целью получения востребованной металлургией продукции.

Ключевые слова: гидрокрекинг гудрона, остатки гидрокрекинга, фильтрование, декантирование, испарение и окисление в тонкой пленке.
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Methods for Processing the Residual Product of Combined Thermal
and Hydrocracking of Vacuum Residue

The article is devoted to the experience of TAIF-NK JSC in the field of efficient, ecological and technological processing of residual products of the combined thermal and hydrocracking process with a comparative analysis of the advantages and disadvantages of each method. It has been experimentally shown that, taking into account the specific features of the residual products of hydrocracking and the associated increased tendency to precipitation of

asphaltenes and coking, it is necessary to carry out further processing of residual products under milder conditions in order to obtain products that are in demand by metallurgy.

Key words: *VR hydrocracking, hydrocracking residue, filtration, decanting, evaporation and oxidation in a thin film.*

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Особенности состава смол тяжелых нефтей
и их влияние на стабильность асфальтенов

Изучены особенности содержания и распределения гетероатомных компонентов в смолах на примере тяжелых нефтей месторождений Татарстана и Самарской области, а также показаны особенности структурно-группового состава выделенных фракций из смол. Фракционирование смол позволило установить степень влияния содержания гетероорганических компонентов на флокуляцию асфальтенов. Кинетические исследования с помощью УФ-спектроскопии показали, что для фракции высокомолекулярных азоторганических оснований выявлена максимальная эффективность по ингибированию осаждения асфальтенов, которая превосходит исходные нефтяные смолы.

Ключевые слова: тяжелая нефть, смолы, асфальтены, агрегация, ИК-Фурье и УФ-спектроскопия.
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Features of Heavy Oil Resins and Their Impact on the Stability of Asphaltenes

Peculiarities of heteroatomic components content and distribution in resins have been studied by the example of heavy oils of Tatarstan and Samara region fields. Peculiarities of structural and group composition of extracted fractions from resins are shown. Resin fractionation allowed to determine the degree of influence of the heterorganic component content on the asphaltene flocculation. Kinetic studies using UV spectroscopy showed that the maximum efficiency of inhibition of asphaltene deposition for the high-molecular-weight organo-nitrogen bases was detected, which is superior to the original petroleum resins.

Key words: *heavy oil, resins, asphaltenes, aggregation, Fourier IR and UV spectroscopy.*

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Синтез и исследование никель-алюминиевого катализатора для переработки тяжелого нефтяного остатка

Исследованы структурные характеристики каталитических систем, полученных модификацией активированного угля оксидами алюминия и никеля. Модификацию активированного угля проводили путем их импрегнирования гидроксидами металлов из растворов солей с соотношением Ni^{+2}/Al^{+3} 2:1 и 3:1, с последующим прокаливанием в токе азота и водорода до образования оксидных фаз. С увеличением соотношения катионов металлов в пропиточном растворе в активированном угле увеличивается удельная поверхность и количество микропор, уменьшается общий объем и средний диаметр пор. Прокаливание в токе водорода на заключительном этапе модификации активированного угля приводит к уменьшению порового пространства и снижению удельной поверхности каталитической системы. Оптимальным сочетанием значений удельной поверхности и максимальными средними диаметрами пор для переработки тяжелого нефтяного остатка обладают каталитические системы Ni/Al (2:1), полученные в среде азота и водорода.

Ключевые слова: активированные угли, оксид никеля, оксид алюминия, порометрия, тяжелые нефтяные остатки, тяжелые нефти, каталитический центр, катализаторы, импрегнирование.

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Synthesis and Study of Al-Ni Catalyst for Heavy Oil Residue Processing

Structural characteristics of catalytic systems obtained by modification of activated carbon with Al and Ni metal oxides have been studied. Modification of activated carbon was carried out by impregnating them with metal hydroxides from salt solutions with a Ni+2/Al+3 ratio of 2:1 and 3:1, followed by calcination in a stream of nitrogen and hydrogen until oxide phases were formed. With an increase in the ratio of metal cations in the impregnating solution in activated carbon, the specific surface area and the number of micropores increase, and the total volume and average pore diameter. Ignition in a hydrogen flow at the final stage of activated carbon modification leads to a decrease in the pore space and a decrease in the specific surface area of the catalytic system. The optimal combination of specific surface values and maximum average pore diameters for the processing of heavy oil residue have Ni/Al (2:1) catalytic systems obtained in nitrogen and hydrogen.

Key words: *activated carbons, nickel oxides, aluminum oxides, porosimetry, heavy oil residues, heavy oils, catalytic center, catalysts, impregnation.*

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Применение гидрокрекинга вакуумного остатка в кипящем слое на предприятии «ЛУКОЙЛ Нефтохим Бургас»

В работе обобщен опыт, накопленный за семь лет эксплуатации технологии гидрокрекинга вакуумного остатка (H-Oil) в кипящем слое. Четыре фактора были определены как основные, способствующие улучшению характеристик H-Oil: качество сырья, состояние катализатора, загрузка и использование непревращенного вакуумного остатка гидрокрекинга. Оптимальное сочетание всех этих факторов позволило достичь уровня конверсии гудрона около 90%. По-прежнему остается сложной задачей найти оптимальные пути использование неконвертированного вакуумного остатка, полученного при более высокой конверсии.

Ключевые слова: гидрокрекинг, гудрон, конверсия, групповой углеводородный состав, осадкообразование.
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Vacuum Residue Ebullated Bed Hydrocracking Application in LUKOIL Neftohim Burgas Refinery

This paper summarises the experience gained over seven years of operating the H-Oil hydrocracking technology with an ebullated vacuum residue bed. Four factors have been identified as major contributors to improved H-Oil performance: feedstock quality; catalyst condition; hydrocracking unconverted vacuum residue loading and utilisation. The optimum combination of all these factors made it possible to achieve a vacuum residue conversion rate of about 90%. It remains a challenge to find the correct use of the unconverted vacuum residue produced at higher conversion rates.

Key words: *hydrocracking, vacuum residue, conversion, SARA, sediment formation.*

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Тетраметилбензолы в нефтях как новые геохимические индикаторы по установлению аноксидных условий осадконакопления

В данной статье подробно рассмотрены тетразамещенные бензолы C_{10} и их использование при решении геохимических задач. Была установлена их генетическая связь с природными ароматическими каротиноидами из биоты, обитающей в аноксидных условиях областей осадконакомпления. На основании их термодинамического состояния было предложено условное деление нефтей по степени зрелости.

Ключевые слова: тетраметилбензолы, доманик, пренитол, дурол, изодурол, палеорениератан, изорениератан, аноксические события.
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Tetramethylbenzenes in Oils as New Geochemical Indicators

for Determining the Anoxic Conditions of Sedimentation

This article discusses in detail tetrasubstituted benzenes of composition C_{10} and their use in solving geochemical problems. Their genetic relationship with natural aromatic carotenoids inhabiting the anoxic zone was established. On the basis of their thermodynamic state a conditional division of oils by degree of maturity has been offered.

Key words: *tetramethylbenzenes, domanik, prenitol, durol, isodurol, paleorenieratane, isorenieratane, anoxic events.*

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Микроэлементы в битумоидах кристаллических пород фундамента Южно-Татарского свода

Изучен микроэлементный состав битумоидов, экстрагированных из архейских кристаллических пород фундамента, вскрытых скважиной 20009-Новоелховской. Установлено, что породы большечеремшанской серии характеризуются более высоким, по сравнению с отрадненской серией, содержанием углеводородов. Микроэлементный состав исследован отдельно в хлороформенном и спирто-бензольном экстрактах. Для пород большечеремшанской серии характерно более высокое содержание органического вещества. Битумоиды, экстрагированные из пород отрадненской серии, обладают более высокими концентрациями микроэлементов.

Ключевые слова: докембрий, кристаллический фундамент, микроэлементный состав, битумоиды, отрадненская серия, большечеремшанская серия.

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Trace Elements in Bitumoids from Crystalline Basement Rocks of the South-Tatarian Arch

The trace element composition of bitumoids extracted from Archean crystalline basement rocks recovered by well 20009-Novoelkhovskaya has been studied. It has been established that the rocks of the Bolshecheremshanskaya series are characterized by a higher content of hydrocarbons compared to the Otradnenskaya series. The trace element composition was studied separately in chloroform and alcohol-benzene extracts. The rocks of the Bolshecheremshanskaya series are characterized by a higher content of organic matter. Bitumoids extracted from the rocks of the Otradnenskaya series have higher concentrations of trace elements.

Key words: *precambrian, crystalline basement, trace element composition, bitumoids, Otradnenskaya series, Bolshecheremshanskaya series.*

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Выделение сейсмического сигнала гидроразрыва пласта с применением дискретного вейвлет-анализа

Рассмотрен способ выделения сейсмического сигнала, возникающего при проведении гидроразрыва пласта, основанный на применении дискретного вейвлет-анализа, проведены модельные эксперименты в случае регистрации сигнала сейсмометрами, расположенными на поверхности. Исследованы случаи аддитивного белого и коррелированного шумов при малом значении соотношения сигнал/шум.

Ключевые слова: выделение сейсмического сигнала, моделирование, гидравлический разрыв пласта, коррелированный шум.

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Isolation of the Seismic Signal of Hydraulic Fracturing

Using Discrete Wavelet Analysis

A method for isolating the seismic signal that occurs during hydraulic fracturing is considered, based on the use of discrete wavelet analysis, model experiments are carried out in the case of signal registration by seismometers located on the surface. The cases of additive white and correlated noise with a small signal-to-noise ratio are investigated.

Key words: *seismic signal isolation, modeling, hydraulic fracturing, correlated noise.*

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Разработка широкополосного сейсмоприемника на базе геофона GS-ONE LF

Предложена и реализована принципиальная схема сейсмического приемника на основе геофона GS-ONE LF. Разработана принципиальная электронная схема, позволяющая проводить суммирование сейсмических сигналов с геофонов для увеличения отношения сигнал/шум. Методом аппаратной коррекции реализован способ расширения частотного диапазона и чувствительности. Разработанный сейсмометр может быть применен для мониторинга операции гидроразрыва пласта в составе малоапертурной сейсмической группы.

Ключевые слова: сейсмический приемник, геофон, коррекция частотного диапазона, гидроразрыв пласта.

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Development of a Broadband Seismic Receiver Based on GS-ONE LF Geophone

A schematic diagram of a seismic receiver based on the GS-ONE LF geophone is proposed and implemented. A basic electronic circuit has been developed that allows summation of seismic signals from geophones to increase the signal-to-noise ratio. The method of hardware correction is implemented to expand the frequency range and sensitivity. The developed seismometer can be used to monitor hydraulic fracturing operations as part of a small-aperture seismic group.

Key words: *seismic receiver, geophone, frequency range correction, hydraulic fracturing.*

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Исследование удельной поверхности и порового пространства
угольных добавок процесса Veba Combi Cracking

В работе представлены результаты сравнительных исследований методом адсорбции-десорбции азота удельной поверхности (BET), объема и размера пор (BJH) угольных добавок для жидкофазных суспензионных реакторов процесса VCC. Установлены основные параметры текстурных характеристик угольных добавок влияющие на степень превращения асфальтеновых наноагрегатов в реакционной среде процесса VCC. С помощью метода лазерной дифракции были установлены размеры асфальтеновых наноагрегатов в растворе толуола, имитирующей реакционную смесь. Показано, что предлагаемая угольная добавка лицензиаром технологии VCC (США) и их российский аналог обеспечивают конверсию асфальтенов только за счет внешней удельной поверхности, поскольку поровое их пространство остается недоступным ввиду малых размеров. Установлено, что обработка угольных добавок водяным паром при температуре 800°C и термообработка в токе азота при температуре 400 °C приводит к значительному росту объема их порового пространства и увеличению диаметра пор позволяющего адсорбировать на внутри поровой поверхности асфальтеновые наноагрегаты. Вовлечение в адсорбцию асфальтенов порового пространства угольных добавок приводит к увеличению их конверсии в реакционной среде процесса VCC.

Ключевые слова: тяжелый остаток вакуумной перегонки нефти, Veba Combi Cracking (VCC), угольная добавка, асфальтены, адсорбция-десорбция азота, удельная поверхность, размеры пор.

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Choice of Carbon Support for Catalytic Systems for Deep Processing of Heavy Oils and Oil Residues

The paper presents the results of comparative studies of the specific surface area (BET), volume and pore size (BJH) of carbon additives for liquid-phase reactors of the VCC process by the nitrogen adsorption-desorption method. The main parameters of the textural characteristics of coal additives, which affect the degree of conversion of asphaltene nanoaggregates in the reaction medium of the VCC process, have been established. Using the laser diffraction method, the sizes of asphaltene nanoaggregates in a toluene solution simulating the reaction mixture were determined. It is shown that the proposed coal additive by the licensor of the VCC technology (USA) and their domestic counterpart (Russia) ensure the conversion of asphaltenes only due to the external specific surface, since their pore space remains inaccessible due to their small size. It has been established that the treatment of coal additives with water vapor at a temperature of 800 °C and heat treatment in a stream of nitrogen at a temperature of 400 °C leads to a significant increase in the volume of the pore space and an increase in the pore diameter, which makes it possible to adsorb asphaltene nanoaggregates on the inside of the pore surface. The involvement of the pore space of coal additives in the adsorption of asphaltenes leads to an increase in their conversion in the reaction medium of the VCC process.

Key words: *heavy vacuum residue, Veba Combi Cracking (VCC), coal additive, asphaltenes, nitrogen adsorption-desorption, specific surface area, pore sizes.*

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Гидротермальное превращение сверхвязкой нефти в присутствии углей, оксидов и карбонатов металлов

В работе представлены результаты сравнительных исследований по выявлению отличительных закономерностей преобразования состава и изменения реологических свойств сверхвязкой нефти при ее взаимодействии в закрытой системе с гидротермальными флюидами. Показано, что при температуре процесса 360°С степень превращения асфальтенов увеличивается с изменением давления с 4 до 21 МПа. Повышение температуры и давления процесса до 420°С и 24 МПа приводит к деструкции смолисто-асфальтеновых с увеличением выхода фракции н.к.–200°С, десульфуризации и снижению вязкости. Установлено, что присутствие древесного угля при гидротермальном превращении сверхвязкой нефти при температуре 385°С и давлении 22,5 МПа приводит к значительному снижению содержания асфальтенов, наличие в процессе каменного угля, оксидов железа и алюминия, карбонатов никеля и меди способствует образованию насыщенных и ароматических углеводородов, увеличению выхода фракции выкипающей до 200°С и снижению содержания серы в два раза.

Ключевые слова: сверхвязкая нефть, гидротермальное превращение, каменный уголь, компонентный состав, вискозиметрия.

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Hydrothermal Transformation of Heavy oil in the Presence of Coals, Metal Oxides and Carbonates

The paper presents the results of comparative studies to identify distinctive patterns of composition transformation and changes in the rheological properties of heavy oil during its interaction in a closed system with hydrothermal fluids. It is shown that at a process temperature of 360°C, the degree of asphaltenes conversion increases with a change in pressure from 4 to 21 MPa. Increasing the temperature and pressure of the process to 420°C and 24 MPa leads to the destruction of tar-asphaltene with an increase in the yield of the b.b.–200°C fraction, desulfurization and a decrease in viscosity. It has been established that the presence of charcoal during the hydrothermal transformation of heavy oil at a temperature of 385 °C and a pressure of 22.5 MPa leads to a significant decrease in the content of asphaltenes, the presence of coal, iron and aluminum oxides, nickel and copper carbonates in the process contributes to the formation of saturated and aromatic hydrocarbons, also contributes to an increase in the yield of the fraction boiling up to 200°C and a decrease in the sulfur content by 2 times.

Key words: *heavy oil, hydrothermal transformation, hard coal, component composition, viscometry.*

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Co-Deposition Mechanism of Waxes with Asphaltenes and Scales
in a Vertical Wellbore of Gas Condensate Well

With the increased exploitation of gas condensate resources, the problem of wax deposition in wellbores is increasingly severe. Hence, this paper reveals the co-deposition mechanism of vertical gas condensate wellbores with waxes, asphaltenes and scales from a microscopic viewpoint by molecular dynamics (MD) simulation techniques. Several experiments were also utilized to determine the basic physical properties of the condensate. To avoid inaccuracies caused by simplifying the condensate multiphase system using a single component, eight typical components were selected to enhance modelling precision according to actual well fluid characteristics. The wellbore, condensate, asphaltene and scale systems modelled by the MD simulation techniques were validated with the corresponding data from the National Institute of Standards and Technology (NIST), and this actual error of the results after stimulating was less than 10 %, which met the error criteria and verified the construction of the system model as realistic and feasible. The simulations investigate the co-deposition mechanism of waxes with asphaltenes and scales in vertical wellbores at three levels: diffusion mechanism, aggregation properties and co-deposition behavior. The simulation results show that as the waxy components in the models increases, the aggregated and adhered condensate layer at the wellbore becomes thinner and the "replacement" between the waxy components and condensate molecules begins happening, and this deposition phenomenon gradually strengthens. When in the asphaltene-condensate system, the promotion effect on the deposition of wax molecules becomes more obvious as these asphaltene components increases, but up to 2% asphaltene components, the wax deposition behavior is inhibited conversely. Simultaneously, asphaltenes with a larger variety and number of heteroatoms contribute more significantly to this co-deposition behavior of waxy components and asphaltene components. For these

scale-condensate systems, the most prominent influence for the aggregation and deposition behavior of waxy components is exerted by sulphate scale, with the most noticeable co-deposition effect. Its interaction energy (absolute value) is the highest, reaching 3840 kJ/mol. The results in the article can offer a basis and instruction to this targeted management for wax deposits in vertical wellbores of gas condensate wells.
Keywords: *deposition mechanism, wax, asphaltene, scale, condensates, wellbore.*

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Research and Development of Virtual Assembly and Machining System for Metal Cutting Petroleum Machinery Based on Kinect V2

Based on building the overall architecture of virtual assembly and processing on the Unity3D platform, to make the operation more immersive, this paper adds the related functions of Kinect somatosensory equipment on the basis of the original functions, realizes some functions of this system through gesture operation, and develops a virtual simulation system for metal cutting petroleum machinery assembly and processing based on this. The application results show that the application of human-computer interaction technology has significantly improved. Through several groups of experimental data, it is verified that the accuracy of gesture recognition is not 100%. Through SVM algorithm, it is verified that the angle between the middle finger and the thumb is detected with error, especially when the hand is moving.
Keywords: *Unity3D, Kinect, virtual assembly system, somatosensory interaction, SVM.*

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Study on Water-Solubility Modification of Curable Resin Cement

The curable resin has excellent water resistance, wear resistance and excellent adhesion, flexibility and impact resistance, excellent mechanical properties, high cementing quality, and a good channeling prevention effect on the system. In this paper, the cured water-based resin cementing liquid system was finally determined by modifying the resin aqueously, by preferring the curing agent and accelerator, and according to the curing gel time required by the cemented water mud in the field. The mechanical properties of the water-based resin cementing slurry system were tested, and the results showed that the addition of 15-20% water-based epoxy resin resulted in cementite with a compressive strength greater than 25 MPa and elastic modulus less than 5 GPa, with 37.8% reduction in permeability and 80-85% cost reduction compared with the complete use of epoxy resin.
Keywords: *resin, cement, modified, curable, curing agent.*

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Experimental Research on the Impregnated Diamond Bit Wear Model

The low rate of penetration (ROP) and severe wear of polycrystalline diamond compact (PDC) bits are one of the main problems restricting the exploration of deep oil and gas resources when drilling strongly abrasive formations. As a rock-breaking tool that breaks rocks in the way of diamond exposure, the impregnated diamond bit has the characteristics of high stability, long service life and high drilling speed, which are considered to improve the drilling efficiency of strong abrasive formations. one of the effective ways. However, the drilling parameters and rock abrasiveness of the impregnated drill bit have a very significant impact on the wear rate of the impregnated diamond bit. If the drilling parameters are not designed properly, the bit will be severely worn and the service life will be too low. At the same time, there is a lack of research on the wear equation of diamond-impregnated drill bits, which cannot predict the wear rate of the drill bit and the life of the drill bit well. Therefore, this paper analyzes and summarizes the experimental data of the influence law of drilling parameters and rock abrasiveness coefficient on the wear of impregnated diamond bits, and establishes a formula based on the quantitative relationship between wear rate and WOB per unit area, rotary speed and rock abrasiveness. The impregnated diamond bit wear model provides a theoretical basis for the life prediction of the impregnated diamond bit in field drilling operation.

Keywords: *abrasive formation, impregnated diamond bit, WOB per unit area, rotary speed, rock abrasiveness, wear rate.*

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Numerical Simulations of Liquid Leakage and Gas Channeling for Plunger Lift

Plunger lift is one of the commonly used processes for liquid extraction and gas production in gas wells. Owing to the gap between the plunger and the tubing wall, liquid leakage and gas channeling during the lifting process are inevitable. Liquid leakage reduces the amount of lifted liquid, and gas channeling is not conducive to the complete utilization of formation energy. Furthermore, the gas that breaks through the gap into the top of the plunger also hinders plunger movement. To address this problem, we used CFD to simulate plunger movement in the tubing and analyzed the influence of various factors, such as plunger velocity, pressure difference between the upper and lower ends, and plunger diameter, on liquid leakage and air channeling. The results indicated that when the plunger rises and drains the liquid, the plunger velocity increases, the leakage between the plunger and the tubing increases, and the gas channeling volume decreases. When the pressure difference between the upper and lower ends of the plunger increases, leakage loss is reduced. The larger the plunger diameter, smaller the interval between the plunger and the tubing, and smaller the less leakage loss. The results of the study validate the influencing factors of plunger lift leakage and gas channeling, optimizing the plunger structure and improving the efficiency of plunger lifting..

Keywords: *plunger lift, liquid leakage, gas channeling, numerical stimulation.*

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A New Re-Liquefaction System for Dynamic Boil-Off Recovery Based on Single Mixed Refrigerant

The single cycle mixed-fluid LNG (PRICO) process is the most widely used for natural gas liquefaction. But the optimized energy consumption of single mixed refrigerant (SMR) liquefaction process was still high using the existing energy saving optimization method. The main purpose of this study was to propose an optimization method to combine with the combination optimization of important parameters to improve the system energy efficiency for the SMR structure. The liquefaction process with an initial investment increase of only 6% was designed, by adding initial investment including separator, valve, mixer, etc. The genetic algorithm and liquefaction simulation were used to analyze the combination optimization of multiple parameters, such as the component ratio of the mixed refrigerant and the pressure of the liquefaction circulation node. Finally, by comparing the similar liquefaction process, it can be found that the optimized heat exchanger internal hot and cold complex curve was better matched, thus reducing the energy Irreversible loss. It indicated that operation energy consumption of the improved SMR process, of which the specific energy consumption could reach 0.247kW·h/kg, was 10.24% lower than PRICO, and the total energy consumption was decreased by 2%. It is thus clear that the optimization method of liquefaction process design and parameter combination has great energy saving efficiency.

Keywords: *genetic algorithm, combination optimization, energy consumption, PRICO process, SMR liquefaction.*

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Low-Temperature Flow Performance Improver for Saddle Diesel

Saddle Diesel is a diesel engine plant in a local city in northeast China, which is already the special designation. In this paper, a new polyhydroxy polyacid macromolecule called citric acid-1,4-butanediol-citric acid-cycloalkanic acid-tetradecyl alcohol (CTC-NT) with 1,4-butanediol as the core was designed and synthesized via an "ester-ester" copolymerization process using 1,4-butanediol and citric acid as the raw materials and then grafted sequentially with naphthenic acid and tetradecanol containing functionalized groups. The structures of the synthesized compounds were characterized by nuclear magnetic resonance and infrared spectroscopy, and the results showed that the synthetic products were consistent with the designed molecular structure. The use of the prepared CTC-NT in saddle oil light diesel was studied. The results showed that the filtration improvements of the synthesized multibranched macromolecule CTC-NT were better than those of other additives for the same oil, and the cold filter point was reduced by up to 13°C when the dosage was 900 μg/g.

Keywords: *multibranched macromolecules, spatial structures, pour point depressant, saddle diesel, cold filter plugging point – CFPP.*

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Application in Oil Field Drilling with Temperature-Resistant Natural Modified Filtrate Reducer: A Review

Natural modified filtrate reducer is an important additive in the process of oil drilling. It can reduce the fluid loss of drilling fluid, improve filter cake and protect borehole wall. However, with the continuous increase of drilling depth and the gradual increase of temperature, natural modified filtrate reducer began to appear poor stability, lower filtration effect and other problems. Therefore, scholars have studied the natural filtrate reducer to improve the temperature resistance of the natural filtrate reducer, so that the natural modified filtrate reducer can adapt to the high temperature formation. Moreover, some natural modified filtrate reducer also have calcium and salt resistance. This review provides a comparative investigation and summary for asphalt, humic acid, lignin, cellulose and starch filtrate reducers. In addition, the author also introduces the mechanism of natural modified filtrate reducers, preparation process of natural modified filtrate reducers, optimization and improvement of natural modified filtrate reducers and their application fields. Last, the author looks forward to the current key issues and future development direction.

Keywords: *filtrate reducer, natural modified, temperature-resistance, drilling fluid.*

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Application of Microwave Absorbent in Microwave Thermal Recovery of Oil and Gas Resources: A Review

In the microwave thermal recovery of unconventional oil and gas resources, the use of microwave absorbers can effectively improve the effect of microwave heating and is an auxiliary agent with wide application potential. In this paper, the mechanism of microwave absorbent is explored, and the role of microwave absorbent in viscosity reduction of heavy oil, in-situ exploitation of oil shale and pyrolysis of oily sludge is reviewed. The effect of the absorbent under different parameters was compared, and the mechanism of different parameters affecting the effect of the absorbent was analyzed.

Keywords: *microwave absorbent, viscous oil, oil shale, oily sludge, microwave thermal recovery.*

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Research on Dynamic Prediction Model of Wax Deposition in Wellbore

Wax deposition in oil wells has become an important issue, which affects the production of oil fields. According to the wax deposition in the wellbore of an oilfield in Northwest China, a dynamic prediction model of the wellbore wax deposition was established based on the molecular diffusion mechanism. The compiled software can predict the temperature and pressure of the fluid, wax deposition point, wax deposition weight, wax deposition volume, wax deposition speed, and wax removal cycle of self-blowing wells and pumping well bores and sucker rods at different well depths. The software is used to predict the influence of flow temperature and pressure, wax deposition point, wax deposition volume, wax deposition rate, wax removal cycle and water content, gas-liquid ratio and oil production on the wax deposition rate of the wellbore of M1 well in a certain northwest oilfield. The results show that the prediction results of the model are reliable. The prediction accuracy of the flow temperature and pressure of the M1 well is higher than 92%, and the prediction accuracy of the wax removal cycle is up to 89%. The law of influence is consistent with the literature results. Therefore, the research results of this article provide a quantitative basis for the formulation of wax removal cycle in an oilfield in Northwest China, and provide theoretical and technical support for optimizing wax removal and control technology.

Keywords: *wellbore wax deposition, wax deposition rate, wax removal cycle, model application.*

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Study on Performance Evaluation of Profile Control System
with High Temperature Resistant Weak Gel Prepared from the Produced Fluid

The use of highly mineralized reinjection water has low gel strength and poor stability, and the above problems are more prominent under high-temperature reservoir conditions. Based on the temperature resistance and salt tolerance polymer TSRP and phenolic resin crosslinking agent, a TSRP temperature resistant weak gel system suitable for high mineralized reinjection water was developed, and the temperature resistance mechanism of the TSRP weak gel system was tested by its temperature resistance and injection ability. The migration, retention, and plugging of the TSRP weak gel system in heterogeneous reservoirs were studied through micropore throat migration and plugging characteristics and dual-pipe parallel oil displacement experiments. The results showed that: under the condition of polymer concentration 2000 mg/L, polymer: crosslinking agent: glue promoter 1:1.5:1, the TSRP weak gel system prepared by using mineralized 12132.9 mg/L reinjection water can remain stable after 95°C aging at high temperature of TSRP. Through microscopic simulation, a glass etching model TSRP weak gel system showed good migration ability and plugging performance. In comparison with the two pipes parallel oil displacement experiment, the KY gel system injected the same amount of PV at 95°C and 20000 mg/L in the Y1L block, the average recovery of the TSRP gel system increased by 22.3% after injection of polymer gel, and the KY gel system was only 18.2%; When the same amount of PV was injected in Z1L block, 95°C and 22000 mg/L, the average recovery of TSRP gel system

increased by 24.35% after injection of polymer gel, and the KY gel system was only 17.15%, that is, under higher salinity, the TSRP gel system showed better performance.

Keywords: *temperature resistance, salt tolerance, reinjection water, crosslinked polymer, profile control.*

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Effect of Power-V on the Stick–Slip Vibration of a Drill String

A polycrystalline diamond compact (PDC) bit combined with a vertical steering tool known as Power-V has shown effective results in controlling deviation and increasing the rate of penetration in vertical wells. However, it has been found that the drill string is prone to stick–slip vibrations in this situation. At present, the mechanism of stick–slip vibrations in drill strings caused by Power-V has not been explored clearly. In this paper, an excitation model based on the working mechanism of Power-V is established, and the impact of lateral force on the PDC bit by Power-V is analysed. Based on a study of the structure and the force characteristics of PDC bits, a new dynamic torque model is proposed by using the Stribeck dynamic friction model. Then, the internal mechanism of stick–slip vibration induced by Power-V is revealed by combining the finite element analysis method of drill string dynamics with the new dynamic torque model. The stick–slip vibration characteristics caused by Power-V are clarified through a case study. This research indicates that Power-V can significantly increase the lateral force on the PDC bit during the drill process, which promotes deeper cutting between the gauge teeth of the PDC bit and the wellbore wall. Thus, the PDC bit experiences greater friction torque and rock breaking torque in the circumferential direction, which results in a greater susceptibility to stick–slip vibrations.

Keywords: *drill string, stick-slip vibration, vertical steering tool, PDC bit, frictional torque.*

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Bottlenecks and Technological Developments for Geologic Storage of CO_2

There is global consensus that geologic storage is an underpinning technology for large-scale reduction of CO_2 emissions. Although CO_2 flooding and storage has been employed to promote crude oil recovery, storage of CO_2 in aquifers has proven to be the main and fundamental technical route for large-scale geologic storage due to convenient site selection, easy source-sink matching, huge implementation scale, and low storage costs. In view of the deposition characteristics of terrestrial aquifers in China and the practices of underground storage of natural gas,

this study identifies three bottlenecks hindering large-scale aquifer storage of CO_2 in China (i.e., aquifer storage capacity, storage costs, and long-term safety), and proposes five key fields where technological breakthrough is needed (i.e., assessment of storage capacity, low-concentration CO_2 injection, large-scale high-speed CO_2 injection, low-cost engineering support, and long-term safety monitoring) to overcome key obstacles in meeting China's "3060" goals – carbon peaking by 2030 and carbon neutrality by 2060.

Keywords: *CCS (mainly in aquifers), brackish aquifer storage, large-scale storage capacity prediction, high-speed injection, dual-carbon strategy.*

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Research on Risk Analysis Method of Jack-Up Drilling Platform Pile Leg Puncture

The process of pile insertion and pile extraction for jack-up drilling platform is the key link in offshore construction of drilling platform. However, serious accidents may occur during operation of jack-up drilling platform such as pile leg puncture and platform tilt. In this paper, based on the calculation method of jack-up drilling platform pile driving, the penetration risk of jack-up drilling platform pile driving is analyzed comprehensively considering the factors of formation, pile shoe bearing capacity and pile group effect. According to the safety factor relative to puncture, the adaptability of drilling ship to insert pile at the predetermined well position is evaluated to realize the prediction of pile leg into mud in order to avoid the occurrence of complex accidents in the process of drilling and completion, guide the depth of pile leg into mud, improve the speed of offshore construction, reduce the risk of offshore operation and construction cost, and provide a scientific basis for offshore engineering design and construction..

Keywords: *jack-up drilling platform, bearing capacity, puncture risk, mud depth.*