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Влияние термопаровой обработки на активность пилярированного железом монтмориллонита в крекинге вакуумного газойля

Рассмотрено влияние термопаровой обработки на активность пилярированных железом монтмориллонитов в крекинге вакуумного газойля и изменение их физико-химических характеристик. Показано, что термопаровая обработка приводит к уменьшению удельной поверхности, содержания железа и кремния, а также к упрочнению катализаторов. После термопаровой обработки снижаются выходы бензина и газа, а также уменьшается конверсия сырья. Количество ароматических углеводородов в бензинах крекинга до термопаровой обработки не превышает 24,1%, содержание изопарафинов составляет 24,5%. После термопаровой обработки увеличивается ароматизация бензина и снижается содержание парафино-нафтеновых углеводородов. Основной составляющей газов крекинга является бутан-бутиленовая фракция, содержание которой до термопаровой обработки составляет около 40% и остается неизменным после обработки.

Ключевые слова: каталитический крекинг, термопаровая обработка, пилярированные железом монтмориллониты.

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The Effect of Thermo-Steam Treatment on the Activity of Iron- Pillared Montmorillonite in the Cracking of Vacuum Gas Oil

The effect of thermal steam treatment on the activity of iron-pillared in cracking of vacuum gas oil and on the change of their physicochemical characteristics are considered. It was shown that steam treatment leads to a decrease of the specific surface, the content of iron and silicon, and also to the strengthening of the catalysts. After steam treatment yields of gasoline and gas are reduced, and also conversion of raw is reduced. The content of aromatic hydrocarbons in gasolines of cracking before steam treatment does not exceed 24,1%, the content of isoparaffins is 24,5%. After steam treatment aromatization of gasoline increases and the content of paraffin-naphthenic hydrocarbons decreases. The main component of cracking gases is the butane-butylene fraction, the content of which is about 40% and it remains unchanged after steam treatment.

Key words: catalytic cracking, thermo-steam treatment, iron- pillared montmorillonites.

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Влияние размера наночастиц рутения на активность катализаторов гидрирования бензола

Под воздействием микроволнового облучения синтезированы наночастицы рутения различного размера, нанесенные на природные алюмосиликатные нанотрубки. Исследованы каталитические свойства полученных

материалов в реакции гидрирования бензола и изучено влияние размеров наночастиц рутения на активность синтезированных катализаторов. Определены конверсии, энергии активации, частота оборотов и константы скорости реакций.

Ключевые слова: галлуазит, гидрирование бензола, рутений, наночастицы.

Ya. A. Chudakov, V. D. Stytsenko, G. O. Zasyalov, V. V. Nedolivko, V. A. Vinokurov.

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Effect of the Size of Ruthenium Nanoparticles on the Activity of Benzene Hydrogenation Catalysts

Under the influence of microwave radiation, ruthenium nanoparticles of various sizes are synthesized deposited on natural aluminosilicate nanotubes. The catalytic properties of the obtained materials in the reaction of hydrogenation of benzene were studied, and the effect of the sizes of ruthenium nanoparticles on the activity of the synthesized catalysts was studied. Conversions, activation energies, speed, and reaction rate constants are determined.

Key words: halloysite, hydrogenation of benzene, ruthenium, nanoparticles.

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Исследование процесса регенерации закоксованного железооксидного огарка

В работе изучен процесс регенерации закоксованного железооксидного огарка, предложенного в качестве эффективного контакта (теплоносителя) в процессе пиролиза легкого углеводородного сырья.

Проведены исследования по окислительной регенерации огарка при различных температурах.

Дано математическое описание процесса регенерации закоксованного контакта (определение зависимости степени выжига кокса от времени). Сопоставлена реакционная способность закоксованного огарка в процессе окисления кислородом воздуха с другими катализаторами. Дополнительно проведены исследования динамического изменения массы закоксованного огарка по методике динамической термогравиметрии на дериватографе. Выявлены основные закономерности по изменению массы контакта от времени, температуры и скорости подъема температуры в ходе его окисления кислородом воздуха. Доказана возможность циклического использования железооксидного огарка в качестве теплоносителя процесса термоконтактного пиролиза путем проведения изысканий по многократному повторению цикла пиролиз/регенерация. Выходы целевых продуктов при этом остаются неизменными.

Ключевые слова: термоконтактный пиролиз, пропановая фракция, бутановая фракция, кокс, регенерация, дериватограф, железооксидный огарок, реакционная способность.

R. G. Khasanov, T. V. Alushkina.

Ufa State Petroleum Technical University, Branch of the University in the city of Salavat

Research of the Regeneration Process of the Coked Iron Oxide Cinder

The process of regeneration of coked iron oxide cinder, proposed as an effective contact (heat carrier) in the process of pyrolysis of light hydrocarbon raw materials, was studied in this work. Researches on oxidative regeneration of the cinder at different temperatures have been carried out. A mathematical description of the process of regeneration of

the coked contact was given (determination of the dependence of the degree of coke burning on time). The reactionary ability of the coked cinder in the process of air oxygen oxidation with other catalysts is compared. Additionally, researches of the dynamic change of the mass of the coked cinder were performed using the method of dynamic thermogravimetry on a derivatograph. The main regularities for changing the contact mass from time, temperature, and rate of temperature rise during its oxidation with air oxygen are revealed. The possibility of cyclic use of iron oxide cinder as a heat carrier of the thermocontact pyrolysis process is proved by conducting research on the repeated repetition of the pyrolysis/regeneration cycle. The outputs of the target products remain unchanged.

Key words: *thermal contact pyrolysis, propane fraction, butane fraction, coke, regeneration, derivatograph, iron oxide cinder, reactionary ability.*

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Влияние группового углеводородного состава дизельных топлив на эффективность действия депрессорных присадок

Проведено сравнительное исследование физико-химических свойств 9 различных базовых летних дизельных топлив. На примере двух топлив, обладающих схожими физико-химическими свойствами, рассмотрено влияние группового углеводородного состава на их низкотемпературные свойства. Показано, что физико-химические характеристики топлива не являются определяющими, важен его детализированный групповой химический состав, отражающий молекулярно-массовое распределение n-алканов, соотношение моно-, би- и полициклических ароматических углеводородов, что влияет на приемистость присадок в топливе.

Исследование предельной температуры фильтруемости (ПТФ) и температуры застывания данных топлив в присутствии двух депрессорных присадок на основе сополимеров этилена с винилацетатом показало, что присадка 1 проявляет более универсальные свойства в топливах, отличающихся по групповому химическому составу, в то время как присадка 2 эффективно снижает ПТФ в топливе с меньшим содержанием высокоплавких n-алканов, а в топливе с повышенным содержанием данной группы углеводородов проявляет практически сравнимую с присадкой 1 депрессию температуры застывания.

Ключевые слова: *дизельное топливо, детализированный групповой углеводородный состав, депрессорные присадки, предельная температура фильтруемости, температура застывания.*

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Influence of a Group Hydrocarbon Composition of Diesel Fuels on the Effectiveness of Depression Additives

A comparative study of the physicochemical properties of 9 different summer base diesel fuels was carried out. Using two fuels with similar physicochemical properties as an example, the influence of group hydrocarbon composition on their low-temperature properties is considered. It is shown that the physicochemical characteristics of the fuel are not determinative, its detailed group chemical composition, which reflects the molecular mass distribution of n-alkanes, the ratio of mono-, bi- and polycyclic aromatic hydrocarbons, which affects the injectivity of additives in the fuel, is

important. The study of the cold filter plugging point and the pour point of these fuels in the presence of two depressant additives based on ethylene vinyl acetate copolymers showed that additive 1 exhibits more universal properties in fuels that differ in group chemical composition, while additive 2 effectively reduces the cold filter plugging point in fuels with a lower content of high-melting n-alkanes, and in fuels with a high content of this group of hydrocarbons it exhibits a rate of depression comparable to additive 1.

Key words: *diesel fuel, detailed group hydrocarbon composition, depressant additives, cold filter plugging point, pour point.*

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Исследование влияния отложения пироуглерода в пористой структуре активных углей

В данной работе был исследован процесс отложения пироуглерода из паровой фазы на поверхности различных активных углей: промышленных (СКТ и АГ-3) и специально приготовленных путем добавки гидроксида калия к композиции сажи с нефтяным пеком с последующей карбонизацией и промывкой. Процесс уплотнения проводили путем пропускания паров бензола в токе азота через нагретую навеску активного угля. Полученные модифицированные образцы исследовали методом молекулярных щупов, для чего измеряли изотермы адсорбции бензола и тетрахлорметана при 20°C на одних и тех же образцах. Результаты показали, что с увеличением времени уплотнения от 60 до 450 мин величина привеса увеличивается от 3 до 15% в зависимости от образца, а также увеличивается объем микропор шириной 0,4–0,6 нм до величины 0,07–0,15 см³/г. Полученные таким образом модифицированные активные угли могут быть использованы в дальнейшем для получения углеродных молекулярных сит с размерами пор от 0,3 до 0,4 нм.

Ключевые слова: активный уголь, активированный уголь, углеродное молекулярное сито, пироуглерод.

P. V. Kugatova, B. S. Zhirnov.

Ufa State Petroleum Technical University, Branch of the University in the City of Salavat

The Study of the Influence of Pyrolytic Carbon Deposit in the Porous Structure of Activated Carbons

In this study the process of pyrolytic carbon deposition from the vapor phase on the surface of various activated carbons: industrial (SKT and AG-3) and specially prepared by adding KOH to the composition of carbon black with petroleum pitch, followed by carbonization and washing has been studied. The deposition process was carried out by passing benzene vapor in a stream of nitrogen through a sample of activated carbon heated to 800 °C. The obtained modified samples were studied by the method of molecular probes, for which the adsorption isotherms of benzene and carbon tetrachloride were measured at 20°C on the same samples. The results showed that with an increase in deposition time from 60 to 450 minutes, the weight gain increases from 3 to 15% depending on the sample, and the micropore volume also increases with a width of 0.4 – 0.6 nm to 0.07–0.15 cm³/g Thus obtained modified activated carbons can be used in the future to obtain carbon molecular sieves with pore sizes from 0.3 to 0.4 nm.

Key words: *activated carbon, carbon molecular sieve, pyrocarbon, carbon, vapour, deposition.*

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Особенности межфазных явлений на границе углеводородных систем с кислотами

В статье рассматриваются аспекты поведения на межфазной границе кислот и углеводородных систем различной степени сложности. Характер явлений на границе раздела фаз оценивался по данным межфазного натяжения, определенного по методу «профиля капли». Представлены результаты по выявлению особенностей взаимодействия соляной и сульфаминовой кислот как с индивидуальными углеводородами, так и с со сложными углеводородными системами. Выявлен сложный характер зависимости межфазного натяжения от состава и свойств углеводородной фазы, вида и концентрации кислоты, химического состава асфальтенов.

Ключевые слова: кислотная обработка, асфальтены, межфазное натяжение, соляная кислота, сульфаминовая кислота.

M. A. Silin, L. A. Magadova, L. F. Davletshina, V. D. Vlasova, T. I. Yunusov, K.K. Merzlyakov.

Gubkin Russian State University of Oil and Gas

Features of Interfacial Phenomena at the Phase Boundary between Hydrocarbon Systems and Acids

This paper discusses the aspects of Interfacial phenomena at the phase boundary between acids and hydrocarbon systems of different complexity. Interaction at the face boundary was assessed with interfacial tension measurement using pendant drop method. Paper reveals peculiarities of interaction between hydrochloric and sulfamic acid with individual hydrocarbons as well as complex systems such as crude oils, deasphalted oils, model oils. Complex effect of hydrocarbon system composition, acid type and concentration, asphaltenes chemical composition at the interfacial tension was determined.

Key words: acid treatment, asphaltenes, interfacial tension, hydrochloric acid, sulfamic acid.

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Анализ риска при эксплуатации насосного оборудования

Определено, что центробежные насосы обладают большей надежностью по сравнению с шестеренными. Однако, при увеличении вязкости перекачиваемой жидкости их коэффициент полезного действия снижается, что делает их применение на некоторых объектах не целесообразным. Проведена оценка риска аварии на опасном производственном объекте при использовании различных типов насосов. Разработан ряд мероприятий, позволяющих снизить риск аварии при оснащении объекта шестеренными насосами. Сделан

вывод о возможности оснащения шестеренными насосами некоторых нефтехимических и нефтеперерабатывающих производств Российской Федерации.

Ключевые слова: анализ риска, насосы, разрушение насосов, шестеренные насосы, центробежные насосы.

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Risk Analysis of Operated Pumping Equipment

It is determined that centrifugal pumps are more reliable than gear pumps. However, However, when the viscosity of the liquid pumped by the centrifugal pump increases, their efficiency decreases, which makes their use at some oil facilities not advisable. The risk assessment of an accident at a hazardous production facility when using different types of pumps was carried out. A number of measures have been developed to reduce the risk of an accident when the facility is equipped with gear pumps. It is concluded that it is possible to equip some petrochemical and oil refining industries of the Russian Federation with gear pumps.

Key words: risk analysis, event tree analysis, pump failure, gear pump, centrifugal pump.

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Физико-химия и технология контроля производства полиальфаолефиновых масел

Рассмотрен метод олигомеризации α -олефинов на гетерогенном катализаторе с целью получения базовых моторных и трансмиссионных масел, отличающийся от гомогенных высококоррозионных катализаторов на основе фторида бора и хлорида алюминия высокими технико-экономическими и экологическими характеристиками. Разработаны новые методики и технология онлайн анализа реакционных масс и технологических потоков, что позволяет осуществлять автоматизированный контроль и управление процессом.

Ключевые слова: α -олефины, олигомеризация, полиальфаолефиновые масла, спектроскопия комбинационного рассеяния, гель-проникающая хроматография.

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Physical Chemistry and Process Control for Polyalphaolefin Oils Production

The method of alpha-olefin oligomerization employing a heterogeneous catalyst for production of base oils used in motor and transmission oils manufacturing, which is different from methods employing homogeneous highly corrosive catalysts like BF_3 or $AlCl_3$ in aspects of much better performance and more eco-friendliness, is considered. New methods and technology for online analysis of the reaction products and process flows, which allows automated process control, have been developed.

Key words: α -olefins, oligomerization, polyalphaolefin oils, Raman spectroscopy, gel permeation chromatography.

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**Метод повышения информативности оценки уровня эксплуатационных свойств
горюче-смазочных материалов**

Предложен оперативный экономичный метод повышения информативности оценки уровня эксплуатационных свойств горюче-смазочных материалов, обеспечивающий количественное интегральное выражение и сравнение потенциальной склонности горюче-смазочных материалов к превращениям, по-разному проявляющейся в зависимости от условий эксплуатации и конструкции техники.

Приведены результаты апробации нового метода при оценке свойств моторных топлив.

Ключевые слова: горюче-смазочные материалы, эксплуатационное свойство, химмотологический процесс, математическая модель, прогнозирование.

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**Method of Informative Content Enhancement With Regards to Estimation
of Fuels and Lubricants Performance Property Level**

A smart and inexpensive method of enhancing the informative content for estimation of the performance properties level of new and modernized fuels and lubricants is proposed. It ensures the quantitative generalized (integral) expression and comparison of the potential propensity of fuels and lubricants for transformations coming out in different ways depending on the operation conditions and the engineering construction. The examples of advantages of the new method are provided when estimating the properties of diesel fuels and gasoline. Application of the suggested method will allow the expenses reduction of feasibility study of the requirements for performance properties of the new and modernized fuels and lubricants and will enhance the effectiveness of the solutions intended for their application in future engineering.

Key words: *fuels and lubricants, performance property, chemmotology process, engineering, operation, simulation, experiment, informative content, forecasting.*

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**Переработка резервуарного нефтешлама методом гидротермического диспергирования
с помощью поликомплексонв и солей аминокислот**

Диспергирование резервуарных нефтешламов с помощью композиции катионных, анионных и неионогенных ПАВ с последующим выделением синтетической нефти как метод его переработки имеет ряд недостатков

в виде остаточных серосодержащих соединений и токсичности отработанных растворов. В работе предлагается использовать перспективную и доступную замену традиционным ПАВ — поликомплексны (натриевые соли иминодиацетатных производных триглицеридов жирных кислот и мукосахаридов). Приведена методика переработки нефтешламов с помощью данных веществ и результаты лабораторных испытаний — снижение содержания серы, значительное понижение плотности и вязкости нефтешлама.

Ключевые слова: переработка нефтешлама, поликомплексон, диспергирование, синтетическая нефть, декарбоксилирование.

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Processing of Tank Oil Sludge by Hydrothermal Dispersion

Using Polycomplexons and Amino Acid Salts

Dispersion of tank oil sludge using a composition of cationic, anionic and nonionic surfactants followed by the isolation of synthetic oil as a method for its processing has several disadvantages in the form of residual sulfur-containing compounds and toxicity of spent solutions. In this study, it is proposed to use a promising and affordable replacement of traditional surfactant – polycomplexones (sodium salts of iminodiacetate derivatives of triglycerides of fatty acids and mucosaccharides). The methodology for the processing of oil sludge using these substances and the results of laboratory tests – a decrease in sulfur content, a significant decrease in the density and viscosity of oil sludge are given.

Key words: *oil sludge processing, polycomplexon, dispersion, synthetic oil, decarboxylation.*

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Контроль начальных стадий фазообразования

в нефтяных дисперсных системах

В статье представлен краткий сравнительный обзор методов контроля фазообразования в нефтяных системах, среди которых рассмотрены те, что регистрируют начальные стадии фазообразования и направлены на применение превентивных мер по предупреждению нежелательных осложнений в технологических процессах подготовки, добычи и транспортировки нефти. Переход от статических методов контроля к динамическим особенно важен при организации устойчивого режима течения многофазного флюида для дальнейшего развития технологий подводной добычи углеводородов, в том числе, и в России. Приведены экспериментальные результаты определения точек начала образования парафинов и солей в модельных нефтяных системах, иллюстрирующих их эффективность при химическом ингибировании соответствующих нежелательных явлений на ранних стадиях фазообразования.

Ключевые слова: начальные стадии фазообразования, точка onset, температура начала кристаллизации парафинов, осаждение солей, нефтяные дисперсные системы, устойчивый поток.

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Control of Initial Stages of Phase Formation in Oil Disperse Systems

This article provides a brief comparative overview of methods for controlling phase formation in oil systems, among which are considered those that record the initial stages of phase formation and are aimed at the application of prophylactic measures to prevent undesirable complications in the technological processes of preparation, production and transportation of oil. The transition from static to dynamic control methods is especially important when organizing a stable regime of multiphase fluid flow for the further development of underwater hydrocarbon production technologies, including in Russia. The experimental results of determining the onset points of the formation of paraffins and precepitation salts in model oil systems are presented, illustrating its effectiveness in the chemical inhibition of the corresponding adverse events in the early stages of phase formation.

Key words: initial stages of phase formation, onset, WAT, salt precipitation, oil disperse systems, flow assurance.

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Screen Running Friction Analytical Solution in Horizontal Well

Sand control measures in horizontal wells are mainly based on screens. Horizontal wells have a certain length of horizontal displacement and the kick-off section with large curvature. Therefore, it is necessary to evaluate the safety of the screen downhole run before it runs into the hole, in order to minimize the running risk. In this paper, the pipe string is divided into sections, and the equivalent force for each elementary section is analyzed.

Then, the axial force and friction resistance of the pipe string are calculated. According to the buckling criterion of the string and the mechanical strength theory, this paper evaluates whether the screen can safely and smoothly run down to the bottom of the well. This analytical method of solving the physical model is feasible and easy to understand, and could be calculated by computer programming application.

Key words: horizontal well, friction, screen, analytical solutions.

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Finite Element Analysis of Effect of Flexible Pup Joints on Push-the-Bit Rotary Steering Deflecting Force

As one of the most advanced international drilling technologies at present, rotary steering has been extensively applied to large-displacement, long-distance horizontal, and complex structural wells with numerous advantages, such as strong steering deflecting capacity and good borehole quality. Push-the-bit rotary steering is nowadays commercially applied on a large scale. In the bottom hole assembly (BHA) design of push-the-bit rotary steering drilling, flexible pup joints are the main components which exert an important effect on the exertion of steering deflecting capacity of push-the-bit rotary steering tools. The effect of flexible pup joints on steering capacity of BHA used in the push-the-bit rotary steering drilling process was investigated through a finite element analysis and their action laws were summarized. The results indicated that in order to optimize the deflecting capacity of rotary steering drilling tools, flexible pup joints should be installed cooperatively so as to obtain greater steering drilling capacity. In the rotary steering drilling process, as the outer diameter of flexible pup joints increased, the maximum stress of the BHA decreased. Side cutting force of the drill would increase with the length of pup joints, but this would result in degradation of anti-torsion performance of the BHA.

Key words: *push-the-bit rotary steering, flexible pup joints, BHA, finite element analysis.*

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Research on Optimizing the Size and Structure of Tube Shoes

of Undisturbed Uniform Rope Drilling Coring Tools

The non-interference uniform speed rope drilling coring device is a tool for ingesting samples of submarine underground leakage hydrate rock formations. In the process of coring, the penetration resistance of the shoe is large, and the rock stratum is disturbed, which results in disturbance of the rock sample's original state. In order to solve this problem, the standard core diameter is 72 mm and the length is the length of a single cylinder. For example, a drilling coring device with a working outer diameter not more than 90 mm is used to optimize the size and structure of the shoe. On the premise of ensuring the strength of the tube shoe, the related dimensions of the shoe were optimized using finite element analysis software, and the structure of the shoe was improved basing on the optimized dimensions. The results of the size optimization are: $\alpha = 20^\circ$, $l_1 = 13$ mm, and $\delta = 1.5$ mm; the structural improvement results are: the front cone surface at the lower end of the tube shoe is changed to a regular mesa, and the number of regular mesa sides is 32. The LS-DYNA dynamic simulation results show that the penetration resistance of the tube shoe after size optimization and structure improvement is significantly reduced, so the disturbance of the drilling and coring device to the rock formation is also reduced, and the quality of the sample is improved.

Key words: *tube shoe, finite element, size optimization, structural improvement, maximum stress, penetration resistance, disturbance.*

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Application of Analytic Hierarchy Process in the Layout of Jack-up Drilling Platform

The scientific and reasonable layout of jack-up drilling platform can improve the efficiency and safety of drilling platform operation. Through the application of analytic hierarchy process and the establishment of comprehensive evaluation and analysis model, this paper analyzes the commonly used drilling platform layout scheme and optimizes the scheme to meet operational requirements and to improve the ability of the drilling platform operation.

Key words: jack-up drilling platform, analytic hierarchy process, platform layout scheme.

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Leakage Flow Mechanism of Gap Seal Structure of Oil Well Pump with Rectangular Groove

For oil wells with high sand content, traditional oil well pumps are easy to get stuck. Increasing the gap between the plunger and the pump cylinder can effectively prevent the stuck, but the gap leakage also increases, resulting in a decrease in the volumetric efficiency of the pump. As shown in this paper, when a rectangular groove is formed in the plunger of the oil well pump, it can significantly reduce the leak rate. In order to reveal the flow resistance mechanism of the gap seal structure with rectangular groove and the reasonable design of the seal structure parameters, the flow characteristics in the gap seal structure with rectangular groove are studied by CFD technology. The results show that the gap seal structure with rectangular groove reduces the leakage amount by 87% compared with the prototype gap seal structure. The optimal number of rectangular grooves is 3-4. The sealing effect of the rectangular groove at the inlet of the pump is better than that at the pump outlet. The rectangular groove spacing has little effect on the leak rate.

Key words: oil well pump, rectangular groove, gap seal, leak flow, flow resistance.

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Experimental and Numerical Evaluation of Acidizing Effect Duration for Diverting Acids in Reservoir

In this paper, the viscosity of diverting acid, reaction kinetics of acid rock, and residual acid limit are experimentally determined, as well as numerically simulated using pressure, temperature, seepage, and geological models via the MATLAB software. The relationship between diverting time and peak viscosity time of diverting acid is studied and analyzed. For the formation temperatures below the DA gel-breaking temperature, the DA with large displacement and low acid concentration should be selected. For the formation temperatures close to the gel-breaking temperature, the medium acid concentration with large discharge should be selected. For the formation temperature exceeding the breaking temperature of acid liquids, high acid concentrations with small discharge should be selected. When the formation temperature is lower or close to the acid breaking temperature, the acidizing effect of DA can be improved by adjusting the amount of injected acid. When the formation temperature is higher than the acid breaking temperature, high-temperature corrosion inhibitors and adsorbents should be added, in order to reduce the acid-rock reaction rate and improve the acidizing effect. The research results are of great significance to the field acidizing construction.

Key words: *diverting acid, peak viscosity, gel-breaking, acidizing.*

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Optimizing Injection Process of Water-Alternate-Gas

Using Different Produced Gas Densities in Enriched-Gas Flooding

An efficient optimization and design method has proposed and developed for water-alternating-gas (EWAG) injection process. The proposed technique is able to quantitatively determine the sizes of the enriched-gas slug and water slug for each cycle of the water-alternating-gas (WAG), as well as the total number of injection cycles. Applying this method provides this opportunity to implement the WAG scenario more efficient and economical. The numerical simulation showed that in comparison with other conventional WAG scenarios with traditional optimization approach, the EWAG has the obvious advantages of evaluation indices, such as the oil recovery factor and cumulative net cash flow.

Key words: *enriched-gas flooding, condensate, produced gas density, displacement efficiency, EWAG.*

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An Experimental Study of Whirling Motion and the Relationship between Torque and Rotary Speed for Simulated Casing Drilling

To gain a better understanding of the whirling motion of rotating casing, the energy method was adopted to calculate the critical whirling speeds of casing for both pinned-pinned and fixed-fixed types of support. The calculated critical whirling speed of rotating casing for fixed-fixed supports was found to be 2.35 times than that of pinned-pinned supports. To observe the motion patterns of rotating casing in different cases, experiments were conducted in a transparent wellbore. Rotary speed and inclination angle were found to be the two main factors that affect the motion pattern of rotating casing. For the case of 300 gallons per minute (gpm) flow rate with annular fluid of water, whirling motion was observed to initiate with rotation speed of 120 rpm. Steady whirling motion was observed at ~155 rpm and higher. With increasing inclination angles, whirling motion was found less likely to occur. The backward whirling was not observed in the experiments, because the friction between casing and simulated wellbore was not large enough. The variations of torque as a function of rotary speed at different flow rates, inclination angles and rates of penetration (ROP) were also investigated, and the results were found useful for predicting the quality of borehole cleaning. It was shown that flow rate, inclination angle, and ROP have notable influence on the torque required to rotate casing. With increasing inclination angle, torque was found to increase, and reach the maximum value at the horizontal position. For a given ROP, torque was found to decrease with increase in flow rate. For a given flow rate, torque was found to increase with increased ROP.

Key words: *whirling, casing drilling, torque, flow rate, inclination angle, rate of penetration.*

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Strength Softening Characteristics of Shale Clay Mineral Expansion

In recent years, the exploration and development of shale oil and gas reservoirs has become a hot topic in various countries around the world. The mechanical properties of shale are an important basis for evaluating the mining effect. Previous studies have shown that shale swells with water, which greatly affects its mechanical properties. Based on the analysis of shale composition, a clay mineral swelling test and 3D compression test were carried out to analyze the influence of clay minerals on the mechanism of shale swelling and softening in water. The results show that hydration of clay minerals results in interlayer and intergranular swelling. Furthermore, an expansion force will be exerted on the rock skeleton. The clay minerals expansion will cause decrease in the uniaxial compressive strength, decrease in the elastic modulus, and increase in the Poisson's ratio, both in normal and parallel directions to the shale plate bedding. The brittleness index calculated basing on the elastic modulus and Poisson's ratio values also decreases. The work is significant for further engineering development of shale reservoirs.

Key words: *shale, swelling, clay mineral, strength softening.*

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Research on Development Characteristics of Micro-Fractures in a Soft Coal Seam Based on the Water-Injection Effect

The development characteristics of micro-fractures in the soft coal seam, which are often neglected in water-injection and exploitation of coalbed methane, are more complex compared to the hard coal seam. To investigate the influences of micro-fractures on the water-injection effects in soft coal seams, the research took the dust control through water injection in a soft coal seam with soft roof and floor as the object. By using an optical microscope, a scanning electron microscope (SEM), and an X-ray diffractometer (XRD), the development characteristics of micro-fractures in the soft coal seam were obtained. The relationship between the development characteristics of micro-fractures and the wetting effect of the coal was analyzed by studying the change of water content in the coal after water injection in the coal seam. Research results demonstrated that micro-fractures were well developed in the soft coal seam and the fractures showed poor directivity and connectivity, some of which were filled with minerals. In addition, the fractures were mainly 0–10 μm wide and there were more than 6 fractures per millimetre in terms of the linear density. Fracture width and linear density were positively correlated with the water content of the coal after water injection, while clay minerals in the coal mass exhibited a negative correlation with the water content.

Key words: *soft coal seam, micro-fractures, fracture width, fracture density, filling minerals, water content.*