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Н. Н. Лунева, Н. Г. Евдокимова

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

nat_luneva@mail.ru

Особенности управления рисками на предприятиях нефтехимии и нефтепереработки

В работе представлен анализ факторов риска на предприятиях нефтехимии и нефтепереработки в целом. На примере нефтехимической компании ООО «Газпром нефтехим Салават» представлена блок-схема процесса управления рисками, которая позволяет определить возможные стратегии и рекомендации по их уменьшению. Выполнен расчет показателей эффективности разработки и внедрения новой технологии в трех вариантах на примере битумного производства в ООО «Газпром нефтехим Салават». Методом анализа чувствительности проведен расчет показателя NPV при изменении основных факторов риска — капитальных затрат, цены, себестоимости и объема производства. Показано, что все варианты технологий очень чувствительны к изменению цены на реализуемую продукцию и ее себестоимости и достаточно устойчивы к факторам объема производства и уровню инвестиций. Предложена методика расчета показателей эффективности внедрения и оценки рисков новых технологий на предприятиях нефтепереработки и нефтехимии, которая позволит учитывать особенности управления рисками при многовариантном сценарии осуществления технических проектов.

Ключевые слова: управление рисками, расчет показателей эффективности, сценарный анализ, оценка рисков, метод анализа чувствительности.

N. N. Luneva, N. G. Evdokimova.

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

Features of Risk Management at Petrochemical Enterprises and Oil Refining

The paper presents an analysis of risk factors at petrochemical and oil refining enterprises in general. Using the example of the petrochemical company Gazprom Neftekhim Salavat LLC, a flowchart of the risk management process is presented, which allows you to determine possible strategies and recommendations for reducing them. The calculation of the efficiency indicators of the development and implementation of the new technology in three variants is carried out on the example of bitumen production in Gazprom Neftekhim Salavat LLC. The sensitivity analysis method is used to calculate the NPV indicator for changes in the main risk factors – capital costs, price, cost of production and volume of production. It is shown that all variants of technologies are very sensitive to changes in the price of products sold and their cost and are quite resistant to factors of production volume and the level of investment. A method for calculating the efficiency indicators of the introduction and risk assessment of new technologies at oil refining and petrochemical enterprises is proposed, which will allow taking into account the peculiarities of risk management in a multi-variant scenario of technical projects.

Key words: *risk management, calculation of performance indicators, scenario analysis, risk assessment, sensitivity analysis method.*

М. Г. Баширов, Э. М. Баширова, И. Г. Юсупова

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

eapp@yandex.ru

Повышение эксплуатационной безопасности технологических трубопроводов установок по переработке углеводородного сырья

Рассмотрено современное состояние обеспечения эксплуатационной безопасности технологических трубопроводов установок по переработке углеводородного сырья, причины их отказов, которые могут сопровождаться взрывами и пожарами, образованием смесей, оказывающих токсическое воздействие на людей и окружающую среду. Показана недостаточная эффективность применяемых при проведении экспертизы безопасности данных объектов методов и средств оценки их технического состояния, ориентированных на выявление уже развитых дефектов, необходимость выявления зарождающихся дефектов структуры металла на фоне напряженно-деформированного состояния. Предложено при оценке технического состояния и ресурса технологических трубопроводов использовать передаточную функцию — динамическую математическую модель объекта контроля, отражающую его эксплуатационные свойства. Эксплуатационные свойства трубопровода выражаются через механические, акустические, магнитные и электрические свойств материала, которые изменяются при изменении напряженно-деформированного состояния трубопровода, зарождении и развитии повреждений. Таким образом, передаточная функция позволяет оценивать текущее техническое состояние трубопровода.

Ключевые слова: экспертиза промышленной безопасности, напряженно-деформированное состояние, поврежденность, передаточная функция, интегральный параметр безопасности.

M. G. Bashirov, E. M. Bashirova, I. G. Yusupova.

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

Improving the Operational Safety of Process Pipelines for Hydrocarbon Processing Units

The current state of ensuring the operational safety of technological pipelines of plants for the processing of hydrocarbon raw materials, the reasons for their failures, which can be accompanied by explosions and fires, the formation of mixtures that have a toxic effect on people and the environment. Insufficient efficiency of the methods and means for assessing their technical state, which are aimed at identifying already developed defects, the need to identify incipient defects in the metal structure against the background of a stress-strain state, are shown. It is proposed to use the transfer function, a dynamic mathematical model of the controlled object, reflecting its operational properties, when assessing the technical condition and resource of technological pipelines. The operational properties of the pipeline are expressed through the mechanical, acoustic, magnetic and electrical properties of the material, which change with a change in the stress-strain state of the pipeline, the initiation and development of damage. Thus, the transfer function makes it possible to assess the current technical condition of the pipeline.

Key words: *industrial safety expertise, stress-strain state, damage, transfer function, integral safety parameter.*

М. В. Клыков, Т. В. Алушкина

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

alu1@yandex.ru

Разработка технологических схем

по увеличению отбора вакуумного газойля

Анализ работы вакуумных колонн установок ЭЛОУ АВТ показал, что в ряде случаев полугудрон содержит до 30 % вакуумного газойля с температурой выкипания до 560°С. Выполнен сравнительный анализ трех вариантов углубления отбора тяжелого вакуумного газойля при ректификации мазута. Рассмотрена традиционная схема со снижением давления на верху вакуумной колонны, ректификация полугудрона без его нагрева после основной вакуумной колонны в дополнительной вакуумной колонне и ректификация мазута по двухколонной схеме, без нагрева мазута в первой колонне с отбором только легкого газойля и с нагревом полугудрона первой колонны с последующей ректификацией его во второй колонне, с отбором тяжелого вакуумного газойля. Проведен анализ работы вакуумной колонны установки вакуумной ректификации ЭЛОУ АВТ-6. Выполнено моделирование процесса в среде программного продукта Aspen HYSYS, теоретически доказана возможность увеличения отбора тяжелого вакуумного газойля в процессе глубоковакуумной ректификации гудрона. Рассмотрены достоинства и недостатки двухколонной вакуумной ректификации мазута. Предложено конструктивное оформление ректификационной колонны и устройства ввода сырья.

Ключевые слова: тяжелый вакуумный газойль, глубина переработки, полугудрон, вакуумная колонна, насадка, моделирование.

M. V. Klykov, T. V. Alushkina.

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

Development of Technological Schemes

for Increasing the Selection of Vacuum Gas Oil

The analysis of the operation of the vacuum columns of the ELOU AVT units showed that in a number of cases the half-gas contains up to 30% of vacuum gas oil with a boiling point of up to 560 ° C. A comparative analysis of three options for deepening the selection of heavy vacuum gas oil during the distillation of fuel oil has been carried out. A traditional scheme with a pressure reduction at the top of the vacuum column, the rectification of a half-sludge without heating it after the main vacuum column in an additional its subsequent rectification in the second column, with the selection of heavy vacuum gas oil. The analysis of the operation of the vacuum column of the vacuum rectification unit ELOU AVT-6 was carried out. The process was simulated in the environment of the software product Aspen HYSYS, the possibility of increasing the selection of heavy vacuum gas oil in the process of deep vacuum rectification of tar was theoretically proved. The advantages and disadvantages of two-column vacuum distillation of fuel oil are considered. Structural design of the rectification column and raw material input device is proposed.

Key words: heavy vacuum gas oil, processing depth, flux-oil, vacuum column, pressure, nozzle, modeling.

Р. Г. Хасанов, Т. В. Алушкина, М. В. Клыков

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

ugntu.khas@yandex.ru

Каталитический пиролиз вакуумного газойля

Проведены исследования по термическому и каталитическому пиролизу вакуумного газойля в реакторе проточного типа. Выявлены основные закономерности по выходу целевых продуктов процесса — этилена, пропилена и бутиленов. Описано влияние катализатора на изменение условий каталитического пиролиза по сравнению с термическим пиролизом. Предложена математическая модель процесса.

Ключевые слова: пиролиз, катализатор, олефины, этилен, пропилен, вакуумный газойль, математическая модель.

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

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

Catalytic Pyrolysis of Vacuum Gas Oi

Studies of thermal and catalytic pyrolysis of vacuum gas oil in a flow-type reactor have been carried out. The main regularities in the yield of the target products of the process – ethylene, propylene and butylenes – are revealed. The influence of the catalyst on the change in the conditions of catalytic pyrolysis in comparison with thermal pyrolysis is described. A mathematical model of the process is proposed.

Key words: *pyrolysis, olefins, ethylene, propylene, catalyst, vacuum gas oil, mathematical model.*

Р. Г. Хасанов, Н. М. Захаров, Р. Р. Газиев

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

ugntu.khas@yandex.ru

Некоторые закономерности термоконтактного пиролиза пропана

Для сопоставления равновесных выходов продуктов пиролиза и реальных кинетических данных проведены исследования по термоконтактному пиролизу пропана. Для определения равновесных выходов продуктов пиролиза использовался метод минимизации энергии системы, преимуществом которого является необходимость знания только начального и конечного состава компонентов реакционной системы. Показана возможность прогнозирования выходов продуктов пиролиза пропана с помощью расчётных равновесных термодинамических выходов. Показано, что точность расчётных данных зависит от задаваемых в начале расчёта образующихся в ходе пиролиза компонентов пирогаза. Установлено, что реальные концентрации продуктов пиролиза в пирогазе могут быть как выше, так и ниже расчётных равновесных концентраций, что будет свидетельствовать только о достижении или не достижении равновесного состояния системы в ходе процесса. Данный способ можно применять для пиролиза других углеводородов с целью предварительной оценки максимально возможных выходов продуктов в ходе процесса.

Ключевые слова: пиролиз, пропан, этилен, пропилен, кинетика, термодинамика, прогнозирование выходов.

R. G. Khasanov, N. M. Zakharov, R. R. Gaziev.

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

Some Regularities of Thermocontact Pyrolysis of Propane

To compare the equilibrium yields of pyrolysis products and real kinetic data, studies on the thermal contact pyrolysis of propane were carried out. To determine the equilibrium yields of pyrolysis products, the method of minimizing the energy of the system was used, the advantage of which is the need to know only the initial and final composition of the components of the reaction system. The possibility of predicting the yields of propane pyrolysis products using calculated equilibrium thermodynamic yields is shown. It is shown that the accuracy of the calculated data depends on the pyrogas components formed during pyrolysis specified at the beginning of the calculation. It is established that the actual concentrations of pyrolysis products in the pyrogas can be both higher and lower than the calculated equilibrium concentrations, which will only indicate that the equilibrium state of the system is reached or not reached during the process. This method can be used for pyrolysis of other hydrocarbons for the purpose of preliminary assessment of the maximum possible yields of products during the process.
Key words: *pyrolysis, propane, ethylene, propylene, kinetics, thermodynamics, yield prediction.*

П. В. Кугатов, Б. С. Жирнов, А. Е. Еременко
Филиал Уфимского государственного нефтяного технического университета в г. Салавате
kugpv@mail.ru

**Исследование зависимости температуры размягчения от содержания мезофазы
в нефтяных пеках, полученных из тяжелой пиролизной смолы и декантойля**

*Получены образцы нефтяных пеков из тяжелой пиролизной смолы и декантойля (тяжелого газойля каталитического крекинга) путем термополиконденсации при атмосферном давлении, температуре 380–400 и 410–440°C (для смолы и декантойля соответственно) и продолжительности изотермической выдержки 30–480 мин. Анализ зависимости температуры размягчения от содержания мезофазы
для полученных образцов показал, что при одинаковом содержании мезофазы пеки из декантойля проявляют более низкую температуру размягчения по сравнению с пеками из пиролизной смолы, для которых уже при 30% мезофазы температура размягчения приближается к 300°C. Это говорит о невозможности получения пеков из смолы пиролиза с высоким содержанием мезофазы без предварительной подготовки.
С другой стороны, показано, что для пеков из декантойля возможно выделение мезофазы вплоть до 65%
и более с температурой размягчения не выше 250°C.*
Ключевые слова: нефтяной пек, мезофазный пек, температура размягчения,
мезофаза, тяжелая смола пиролиза, декантойль.

P. V. Kugatov, B. S. Zhirnov, A. E. Eremenko.
Ufa State Petroleum Technical University, Branch of the University in the City of Salavat

**Study of Dependence of Softening Point on Mesophase Content
of Petroleum Pitches from Heavy Pyrolysis Resin and Decantoil**

Samples of petroleum pitches were obtained from heavy pyrolysis resin and decantoil (heavy gas-oil of catalytic cracking) by thermal polycondensation at atmospheric pressure, temperatures of 380–400 and 410–440°C (for resin and decantoil, respectively) and isothermal holding time of 30–480 min. Analysis of the dependence of the softening point on the mesophase content for the obtained samples showed that at the same mesophase content, decantoil pitches exhibit a lower softening point compared to pyrolysis resin pitches, for which, even at 30 % mesophase, the

softening point approaches 300°C. This suggests that it is impossible to obtain pitch from pyrolysis resin with a high mesophase content without preliminary preparation (for example, by hydrogenation). On the other hand, it has been shown that for pitches from decantoil, it is possible to isolate the mesophase up to 65% or more with a softening point not higher than 250°C.

Key words: *petroleum pitch, mesophase pitch, softening point, mesophase, heavy pyrolysis resin, decantoil.*

А. В. Сусликов, Б. С. Жирнов, Ф. Р. Муртазин

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

suslikov-1991@mail.ru

Исследование кинетических закономерностей взаимодействия нефтяного кокса с фосфогипсом до сульфида кальция

В данной работе описаны результаты исследования реакции нефтяного кокса и фосфогипса ($CaSO_4$) и методика, использованная для этого. В ходе выполнения работы были подготовлены стехиометрические смеси нефтяного кокса и фосфогипса. Нефтяной кокс предварительно измельчался, просеиванием выделялась необходимая фракция (0,25–0,315 мм) и просушивалась при температуре 110°C. Образец фосфогипса также измельчался, просеиванием выделялась аналогичная фракция и подвергалась предварительной термической обработке при температурах от 100 до 200°C до постоянной массы. Приготовленные навески смесей подвергали термическому воздействию в диапазоне температур от 900 до 1000°C, характерных для протекания одной из стадий взаимодействия фосфогипса с коксами, а именно его разложение до сульфида кальция и углекислого газа. Для различных температур реагирования получены зависимости скорости и степени превращения исходных материалов от времени. В результате обработки соответствующих зависимостей определены константы скорости реакции, рассчитана энергия активации процесса.

Ключевые слова: нефтяной кокс, коксовая мелочь, утилизация отходов, топохимические реакции, фосфогипс, цемент.

A. V. Suslikov, B. S. Zhirnov, F. R. Murtazin.

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

Investigation of the Kinetic Regularities of the Interaction of Petroleum Coke with Phosphogypsum to Calcium Sulfide

This study describes the research results of petroleum coke (carbon) and phosphogypsum reaction and the methods used for the above. Stoichiometric petroleum coke and phosphogypsum mixtures were prepared for the study. The coke was cut and screened with particle size distribution of 0.25-0.315 mm and dried at 110 °C temperature. The phosphogypsum sample was also cut and screened with the same particle size and was pre-heated within the 100-200 °C range up to permanent mass. The weighed samples were heated within 900 till 1000 °C, the range being typical to one of reaction stages between coke and phosphogypsum, i.e. the decomposition reaction with the products of calcium sulfide and carbon dioxide. The extend and rate of samples conversion and their time correlations were obtained for the number of reaction temperatures. Reaction rate constant and activating energy were calculated based on this correlations results.

Э. К. Аминова, В. В. Фомина

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

k.elmira.k@yandex.ru

Соли сульфатированных амидов олеиновой кислоты как ингибиторы

кислотной коррозии

Данная работа является продолжением в серии исследований получения ингибиторов кислотной коррозии на основе карбоновых кислот. Разработана методика синтеза ингибиторов кислотной коррозии на основе амидов олеиновой кислоты. Для повышения ее ингибирующих свойств проведены несколько синтезов. На первой стадии к олеиновой кислоте были добавлены аминоспирты, далее полученные соединения были сульфированы серной кислотой. Для расширения поля различных ингибиторов, проведены реакции с основаниями. В результате получены соли сульфатированных амидов олеиновой кислоты синтезированной с аминоспиртами, серной кислоты и водных растворов оснований. Для установления эффективности полученных соединений проведена оценка защитной способности в разбавленной соляной кислоте. Установлено, что некоторые полученные вещества проявляют соответствующие свойства ингибиторов, при этом наиболее эффективным является аммонийная соль сульфатированного диэтаноламида олеиновой кислоты.

Ключевые слова: олеиновая кислота, ингибиторы коррозии, амиды, аминоспирты, кислотная коррозия.

E. K. Aminova, V. V. Fomina.

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

Salts of Sulfated Oleic Acid Amides as Acid Corrosion Inhibitors

This work is a continuation in a series of studies on the preparation of acid corrosion inhibitors based on carboxylic acids. A method of synthesis of acid corrosion inhibitors based on oleic acid amides has been developed. Several syntheses have been carried out to increase its inhibitory properties. The substances were obtained in several stages. At the first stage, amino alcohols were added to the OA, then the resulting compounds were sulfonated with sulfuric acid. To expand the field of various inhibitors, reactions with bases are produced. As a result, salts of sulfated amides of oleic acid synthesized with amino nitrates, sulfuric acid and aqueous solutions of bases were formed. To establish the effectiveness of the compounds obtained, the protective ability in dilute hydrochloric acid was evaluated. It is established that some of the obtained substances exhibit the corresponding properties of inhibitors.

In this case, the most effective is the ammonium salt of sulfated diethanolamide oleic acid.

Key words: *oleic acid, corrosion inhibitors, amides, amino alcohols, acid corrosion.*

Н. Г. Евдокимова, Н. А. Егорова, Н. Н. Лунева

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

ruskih1.r@yandex.ru

Определение прочностных характеристик битумоминеральных смесей

В работе представлены результаты по разработке и апробации лабораторной методики определения прочностных характеристик битумоминеральных смесей на прочномере Линтел ПК-21-01. Выбраны условия проведения испытания битумоминеральных смесей на прочность. Показана зависимость между показателем адгезии битума и пределом прочности при сжатии образцов битумоминеральных смесей на его основе, определенном по разработанной методике. Установлено снижение прочностных и адгезионных свойств вяжущего с увеличением содержания полимера марки ДСТ-30–01 в битуме. Предложено на основе стандартизированных методов испытания битумов и разработанной методики определения прочностных характеристик битумоминеральных смесей оценивать возможность выполнения исследований для разработки новых видов битумной продукции, разрабатывать различные технологии производства и подбирать оптимальные параметры его получения.

Ключевые слова: битум, битумоминеральная смесь, сила разрушения, предел прочности, адгезия, полимерсодержащих битум.

N. G. Evdokimova, N. A. Egorova, N. N. Luneva.

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

Determination of the Strength Characteristics

of Bituminous-Mineral Mixtures

The paper presents the results of the development and testing of a laboratory method for determining the strength characteristics of bitumen-mineral mixtures on the Lintel PK-21-01 strength meter. The conditions for testing the strength of bitumen-mineral mixtures are selected. The dependence between the bitumen adhesion index and the compressive strength of samples of bitumen-mineral mixtures based on it, determined according to the developed method, is shown. A decrease in the strength and adhesive properties of the binder was found with an increase in the content of the DST-30-01 polymer in bitumen. It is proposed to evaluate the possibility of performing research for the development of new types of bitumen products, to develop various production technologies and to select the optimal parameters for its production on the basis of standardized methods of testing bitumen and the developed methodology for determining the strength characteristics of bitumen-mineral mixtures.

Key words: bitumen, bituminous mixture, breaking strength, tensile strength, adhesion, polymer-containing bitumen.

И. Н. Михольская[1], Е. А. Данилова[2], Н. С. Осинская[2], А. А. Борисова[1], В. В. Спаскова[1], Б. С. Жирнов[1]

[1]Филиал Уфимского государственного нефтяного технического университета в г. Салавате,

[2]Институт ядерной физики Академии наук Республики Узбекистан, г. Ташкент

colbine@mail.ru

Мониторинг экосистемы вблизи градообразующих предприятий нефтепереработки и нефтехимии

Методом нейтронно-активационного анализа проведено комплексное исследование поверхностного слоя почв, питьевой (водопроводной) воды и как показателя техногенной нагрузки на организм человека – волос жителей города Салават. Показано, что в поверхностном слое почвы, повышенно содержание таких элементов как мышьяк, кальций, кобальт, хром, никель, торий, уран, цинк, большая часть из которых используется в органическом синтезе. В водопроводной воде выше предельно допустимых значений обнаружено содержание железа, марганца, никеля. Анализ волос жителей города выявил группы риска по

некоторым заболеваниям: по сердечно-сосудистым заболеваниям (74%); по заболеваниям желудочно-кишечного тракта (71%) и др., что свидетельствует о неблагополучной экологической ситуации.

Ключевые слова: микроэлементы, нейтронно-активационный анализ, почва, водопроводная вода.

I. N. Mikholskaya[1], E. A. Danilova[2], N. S. Osinskaya[2], A. A. Borisova[1], V. V. Spaskova[1], B. S. Zhirnov[1].

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

[2] Institute of Nuclear Physics Academy of Sciences of the Republic of Uzbekistan, Tashkent

Ecosystem Monitoring near the City-Forming Enterprises

of Oil Refining and Petrochemicals

A comprehensive study of the surface layer of soils, drinking (tap) water, and the hair of the residents of the city of Salavat as an indicator of the anthropogenic load on the human body was carried out by the method of neutron activation analysis. It is shown that in the surface layer of the soil, the content of As, Ca, Co, Cr, Ni, Th, U, Zn is increased, most of which are used in organic synthesis. In tap water above the maximum permissible concentrations, the contents of Fe, Mn, Ni were found. The analysis of the hair of residents of the city revealed risk groups for some diseases: for cardiovascular diseases (74%); for diseases of the gastrointestinal tract (71%), etc., which indicates a poor environmental situation.

Key words: *trace elements, neutron activation analysis, soil, tap water.*

Е. А. Захарова, Н. А. Лихачева

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

sacharova_08@mail.ru

Оценка экологической эффективности нефтеперерабатывающих производств

Проанализированы критерии оценки экологической эффективности и механизмы отбора экологических индикаторов. Предложено использовать новый критерий — интенсивность выбросов парниковых газов, который определяет соотношение объема выбросов парниковых газов и результата деятельности организации. Результаты оценки экологической эффективности позволяют оценить экологические риски, выработать пути снижения антропогенной нагрузки на окружающую среду и разработать перспективные планы развития производства с учетом возможных изменений в состоянии окружающей среды в регионе нефтеперерабатывающего производства.

Ключевые слова: экологическая эффективность, нефтеперерабатывающее производство, экологические индикаторы, парниковые выбросы, загрязнение окружающей среды.

E. A. Zakharova, N. A. Likhacheva.

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

Assessment of the Environmental Efficiency of Oil Refineries

The criteria for assessing environmental efficiency and mechanisms for selecting environmental indicators are analyzed. It is proposed to use a new criterion - the intensity of greenhouse gas emissions, which determines the ratio of the volume of greenhouse gas emissions and the result of the organization's activities. The results of the environmental efficiency assessment allow us to assess environmental risks, work out ways to reduce the

anthropogenic load on the environment and develop long-term production development plans, taking into account possible changes in the state of the environment in the region of oil refining production.

Key words: *environmental efficiency, oil refining, environmental indicators, greenhouse emissions, environmental pollution.*

Н. А. Лихачева, Е. А. Захарова

Филиал Уфимского государственного нефтяного технического университета в г. Салавате

likhacheva_n@mail.ru

Исследование детоксицирующей способности окисленных гуминовых веществ

в условиях нефтяного загрязнения почв

В статье представлены результаты исследований по окислительной модификации гуминовых веществ бурого угля Тюльганского месторождения. Изучен детоксицирующий эффект полученных веществ по отношению к нефтяным углеводородам с использованием метода биотестирования. В ходе оценки обнаружено заметное возрастание детоксицирующей способности в результате химической модификации гуминовых веществ. Наибольший детоксицирующий эффект по отношению к нефтяному загрязнению почвы был отмечен для модифицированных окислением гуминовых веществ и составил 19 и 42% при дозах 0,01 и 0,1% мас. соответственно. Детоксицирующий эффект нативных гуминовых веществ значительно ниже: 9 и 2% при дозах 0,01% и 0,1% мас. соответственно. Таким образом, показана перспективность использования окисленных гуминовых веществ в качестве сорбентов-детоксикантов при проведении фиторемедиации нефтезагрязненной почвы.

Ключевые слова: бурый уголь, гуминовые вещества, детоксицирующий эффект, метод биотестирования, нефтяное загрязнение почв, окисление, уровень детоксикации, химическая модификация.

N. A. Likhacheva, E. A. Zaharova.

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

Study of Detoxifying Ability of Oxidized Humic Substances

under the Conditions of Oil Pollution of Soils

The article presents the results of research on the oxidative modification of humic substances of brown coal of the Tyulgan deposit. The detoxifying effect of the obtained substances in relation to petroleum hydrocarbons was studied using the bioassay method. During the evaluation, a noticeable increase in the detoxifying ability was found in the result of chemical modification of humic substances. The greatest detoxifying effect in relation to oil pollution of the soil was observed for humic substances modified by oxidation and amounted to 19 and 42% at doses of 0.01 and 0.1% by weight. accordingly. The detoxifying effect of native humic substances is significantly lower: 9 and 2 % at doses of 0.01% and 0.1% by weight. accordingly. Thus, the prospects of using oxidized humic substances as sorbents-detoxicants during phytoremediation of oil-contaminated soil are shown.

Key words: *brown coal, humic substances, detoxifying effect, bioassay method, oil pollution of soils, oxidation, detoxification level, chemical modification.*

Бо Цао[1], В.С. Дергунов[2], С.Н. Челинцев[2]*

[1]College of Petroleum Engineering, Xi'an Shiyou University, Xi'an, China,

[2]РГУ нефти и газа (НИУ) имени И. М. Губкина

caobo@xsyu.edu.cn

Влияния гибридного микроволнового нагрева на структурно-механические

свойства тяжелой нефти

В настоящее время создание инновационных технологий перекачки товарных тяжелых нефтей ориентировано на использование малоэнергетических воздействий на транспортируемое сырье. В работе приведены результаты исследований структурообразования в тяжёлой нефти после гибридного микроволнового воздействия, которые были выполнены на основе активационной теории течения и материалах реологических исследований образцов тяжёлой нефти.

Ключевые слова: нефтяные дисперсные системы, эффективная вязкость, микроволновая обработка, углеродный наполнитель, фазовый переход, термодинамические параметры активации вязкого течения.

Cao Bo[1], V.S. Dergunov[2], S.N.Chelintsev[2]

[1]College of Petroleum Engineering, Xi'an Shiyou University, Xi'an, China,

[2] Gubkin Russian State University of Oil and Gas

Influence of Hybrid Microwave Heating on the Structural And Mechanical Properties of Heavy Oil

Currently the creation of innovative technologies for commercial heavy oils pumping is focused on the use of low-energy impacts on the pumped raw materials. The paper presents the results of studies of structure formation in heavy oil after hybrid microwave exposure, which were carried out on the basis of the activation theory of flow by Ya.I. Frenkel and G. Eyring and of the materials of heavy oil samples rheological studies.

Keywords: oil viscosity, oil disperse systems, microwave treatment, carbon filler, phase transitions, viscous flow activation parameters.

Zhao-zhong Yang[1], Zi-jia Liao[1], Xiao-gang Li[1], Liang-ping Yi[1**],Hao Chen[1], Longhai Ran[1]*

[1]State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu, China

A Model to Calculate Fracture Conductivity Considering Proppant Transport

and Embedment Depth

The accuracy of predicting fracture conductivity is very important in hydraulic fracturing. However, most models pay more attention to the solution of fracture conductivity value, without considering the distribution of the fracture conductivity. It is also important to couple the proppant embedment depth and fracture conductivity, especially for the coal bed and shale formations with strong plasticity. In this paper, analytical models were derived to compute fracture conductivity considering the proppant transport and embedment. The proppant transport model is coupled with the fracture propagation model, which describes the distribution of fracture conductivity. The calculation of proppant embedment depth considering the rock plasticity is derived from the underground stress equilibrium, which provides a calculation basis of the propped fracture width. The proppant-pack permeability is calculated based on the Carman-Kozeny formula. Finally, fracture conductivity is defined as the product of fracture width and permeability.

Based on the comparison with the previously established models, the proposed model is employed for sensitivity studies of parameters influencing the fracture conductivity. The effects of closure pressure, proppant size, rock plasticity, fluid viscosity, proppant concentration, and proppant carrying liquid volume on fracture conductivity are analyzed. Analysis results contribute to a better understanding of the effects of related factors on fracture conductivity. The new and more accurate model for calculating the fracture conductivity considering proppant transport and embedment is of great significance for fracturing design and helps to achieve high fracture conductivity and high oil and gas production in conventional and unconventional reservoirs.
Keywords: hydraulic fracturing, fracture conductivity, proppant transport, proppant embedment, Carman-Kozeny formula.

Xu Han[1,2], Xiang-yi Yi[2], Chang-lin Zhou[1], Xing-xiang Che[2], Lin Hou[2], Xin Huang[1], Yang Wang[1,2], Ji Zeng[1]*
[1] Engineering Technology Research Institute of Petrochina Southwest Oil and Gas Field Company, Sichuan Province, China,
[2] Cheng Du University of Technology, Sichuan Province, China
finalhanfang@163.com

Study on Rock Mechanics Parameters and In-Situ Stress Profile Construction
and Correction Method Based on Well Log Interpretation

Hydraulic fracturing of tight sandstone reservoirs is an important method of developing this type of unconventional oil and gas resources. The evaluation of in-situ stress distribution and rock mechanical parameters of fractured wells is the prerequisite for fracturing design. Therefore, the development of a calculation method to evaluate the stress distribution and mechanical parameters of rocks, based on a single well in-situ stress data, is the key to establish the optimal fracturing design. In this paper, based on the correlation between the laboratory experimental data and the logging response, we have plotted the initial stress profile and then applied the proposed method of combining density curve and natural gamma curve to correct the calculation results. In the case of a limited number of wells, the obtained profile correction model demonstrated satisfactory matching with laboratory experimental data.
Keywords: tight sandstone, logging data, rock mechanical parameters, in-situ stress.

Yingwei Li[1], Yuntong Yang[1,2], Jingchao Zhang[1], Xingbin Liu[3], Ronghua Xie[3], Lina Yu[1]*
[1] School of Information Science and Engineering, Yanshan University, Qinhuangdao, Hebei, China
[2] School of Physics and Electronic Engineering, Northeast Petroleum University, Daqing, Heilongjiang, China
[3] Logging and Testing Services Company, Daqing Oilfield Limited Company, Daqing, Heilongjiang, China
yln@ysu.edu.cn

Theoretical Research on Output Response Characteristics
of Vertical Longitudinal Multipole Conductance Sensor by Discrete Phase Distribution

In oilfield development, vertical longitudinal multipole conductance sensors (VLMCS) have been widely used to measure the water holdup in the oil-water two-phase flow. When water is a continuous phase and oil is a discrete phase, the oil phase distribution has a great influence on the VLMCS output. In this paper, a 3D theoretical model of the VLMCS is established, and the output response characteristics are studied, considering an oil bubble behavior in

the 3D model. The task is performed by establishing a spherical coordinate system and a cylindrical coordinate system with varying mesh sizes and axial and radial positions. At the same time, finite element analysis is used to study the VLMCS output response characteristics of multiple oil bubbles. The results reveal the effect of oil bubble size and position on the VLMCS output response characteristics, which is of great significance for the measurement of the oil-water two-phase flow parameters and optimization of the VLMCS design. The established model provides a theoretical basis for the engineering applications of the VLMCS.

Keywords: vertical longitudinal multipole conductance sensor; theoretical research; oil bubble; sensitive field; output response characteristics.

Chaoyang Hu[1], Fengjiao Wang[1], Qingjun Deng[3], Jianjun Xu[3], Chi Al[1]
[1]College of Petroleum Engineering, Northeast Petroleum University, Daqing, China,

[2] No. 1 Oil Production Plant of Daqing Oilfield Co. Ltd., Daqing, China,

[3] Chongqing Branch of Daqing Oilfield Co. Ltd., Daqing, China

wangfengjiao8699@126.com

Study on Reservoir Internal Stress Variation and Mud Shale Horizontal Section Slippage Induced by Interregional Pore Pressure Based on Stick-Slip Theory

Casing damage caused by shear stress has been detected in several areas of the Daqing oilfield. Such damage can be caused by marker bed slip in mud shale sections. However, the mechanism of slippage stress in mud shale horizontal sections is currently not well understood. Based on the effect of differences in interregional pore pressure, we have established a mechanical model of a cracked horizontal plane and obtained analytical solutions for the formation stress and displacement. In order to quantitatively characterize the relative slip distance in a horizontal section, the fault stick-slip and sliding weakening theories have been used. In this paper, based on a stick-slip theory, we propose a model to calculate the slip of a mud shale horizontal section under differing interregional pore pressures. The results show, that under the influence of differing formation pore pressure between the regions, the upper layer of the horizontal section intermittently slips towards the high-pressure center. When the pore water enters the formation, the friction between the sections decreases, causing a decrease in the weakened slip phenomenon. Consequently, the slippage of the formation section will increase under the conditions. The results of the study can provide useful background for preventing casing failures in mud shale marker beds.

Keywords: mud shale; marker bed; regional pore pressure; stick-slip theory; horizontal section slip.

Jie Zhang [1], Wenyong Bai[1,2]✉, Jianchen Zhang[1,2], Cheng Chen[1], Tao Yang[1],
[1]School of Energy Engineering, Xi'an University of Science and Technology, Xi'an, China;

[2]School of coal engineering, Datong University, Shanxi, China;

793758313@qq.com

Investigation of Fracture Development and Oilfield Protection in the Extraction of Carbon Materials

China is rich in primary energy resources. Due to specific terrain conditions, different types of problems may occur in the process of development. When the coal seams are located under the oil layers, due to the physical characteristics of oil, the exploitation of coal seams will cause losses to the oil layers, and the volatile oil may also cause threats to

coal mining. To analyze the fracture development and leakage characteristics of overburden strata for this type of geological conditions, we have carried out physical simulation experiments and performed a further numerical simulation to study and verify the evolution of fractures. Based on numerical simulation results, methods have been proposed that may effectively reduce the air leakage in the working face and control the parameters, including viscous resistance, distance, and the construction period of the blocking. In this paper, based on the 30100 face in the Nanliang coal mine as an example, we have proved that the proposed measures can provide good theoretical guidance for the prevention of spontaneous combustion of residual coal and control of water in coal mine production. The developed method offers good economic benefits for safe production in coal mines.

Keywords: shallow coal seam; full-thickness cut; fracture development; leakage law; physical simulation.

Chuanlong Jiang[1], Yang Zhang[1*], Tengfei Sun[1],Hui Zhang[2], Zhongshuai Chen[2], Haoyu Sun[2]

[1]College of Mechanical and Electrical Engineering, Beijing University of Chemical Technology, Beijing, China;

[2]Drilling Technology Research Institute of Shengli Oilfield Service Corporation, Sinopec, Dongying, Shandong, China;

zhangyang@mail.buct.edu.cn

Sample Fidelity of Formation Sampling While Drilling

Formation sampling while drilling (FSWD) technology has become a research hotspot in oilfield development at home and abroad. The technology is characterized by a comparatively short operation time. Since the operation time is short, the obtained formation data are closer to the real situation in the reservoir. After the formation fluid enters the sample chamber from the sampling module, sealed, and returns from the downhole to the surface, the change in ambient temperature and pressure causes the sample volume to shrink and the sample pressure to decrease correspondingly. The change in temperature and pressure leads to irreversible phenomena such as phase transformation or degassing, which can affect the quality analysis of the sample. To avoid the phenomenon, the pressure in the sample chamber is maintained above the bubble point pressure by pre-charging nitrogen on the ground and boosting adjustment in the downhole, so that the formation sample fluid is consistent with the phase state in the original formation when it is retrieved from the ground. The described method is used to provide results close to the real parameters in the reservoir. As the pre-charged nitrogen and the final sample occupy different cavities of the same vessel, and the volume of the vessel is constant, the change in the parameters, including the sampling volume, temperature difference, and pressure difference between the ground and the well bottom, will cause a change in the pressure of the pre-charged nitrogen. Therefore, the problem of ensuring sample fidelity has become the key to sampling technology. To solve the problem, the method of combining ground pre-charged nitrogen pressure with downhole sample chamber pressurization has been introduced.

Keywords: sample fidelity; phase change; bubble point pressure; nitrogen pre-charge; downhole pressurization.

Jia Jia [1], Yi Nao Su[1,2*], Yue Shen[3], Gai Xing Hu[4] , Ling Tan Zhang[3], Long Wang[3], Li Min Sheng[2]

[1] School of Petroleum Engineering, China University of Petroleum (East China), Qingdao, China.

[2] CNPC Engineering Technology R&D Company Limited, Beijing, China.

[3] College of science; China University of Petroleum (East China), Qingdao, China.

[4] PetroChina Changqing Oilfield Company, Xi'an, China.

suyinao1949@163.com

Influence of the Blowout Preventer Shut-Off Process on Wellbore Pressure

The prevailing research analyzing the transient pressure in the blowout preventer shut-off process using water hammer theory is not in accordance with the real-world situation due to the long blowout preventer shut-off periods. In this paper, to solve the well-control problem in the case of gas invasion, using downhole telemetry information, we propose a new mathematical model for analyzing the generating mechanism of transient pressure in the blowout preventer shut-off process and its effect on wellbore pressure. The mathematical model of transient pressure generated in the blowout preventer shut-off process is established using a fluid inertial pressure analysis of unsteady flow. The model clearly shows the influence of ram moving velocity, fluid velocity, fluid density, and blowout preventer structural parameters on the transient pressure. The propagation characteristics of the transient pressure along the wellbore are analyzed using Lamb's law. The results show that the transient pressure amplitude generated in the blowout preventer shut-off process is small and rapidly decays when it propagates along the wellbore, so its influence on the wellbore pressure is negligible. The wellhead backpressure plays a major role in affecting the wellbore pressure. This study theoretically solves the dispute between choosing "hard shut-in" or "soft shut-in" of the blowout preventer, thus providing an alternative to relying on engineering experience, offering guidances for the accurate analysis of the influence of the blowout preventer shut-off process on wellbore pressure, and giving new operation advice for blowout preventer operation when gas invasion occurs.

Keywords: blowout preventer; transient pressure; wellbore pressure; wellhead backpressure; closing degree.

Hong-Feng Wang[1,2], Xiao-Ping Li[1],Song-Bai Zhu[2],Lu Zhang [1],Yong-bing Liu[1,3]*

[1]State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation,Southwest Petroleum University, Chengdu, China

[2]Tarim Oilfield Company, PetroChina, Korla, Xinjiang, China

[3]Faculty of Engineering and Applied Science, University of Regina, Regina, Saskatchewan, S4S 0A2, Canada

lixiaoping@swpu.edu.cn

Prediction of gas/water relative permeability using the GWO-LSSVM model under HTHP condition

The most common methods of predicting a gas/water two-phase relative permeability include experimental measurement, theoretical simulation, and numerical calculation. The experimental method is relatively accurate but time-consuming and laborious. The method of theoretical modeling involves a complicated solving process, and the range of application of the numerical calculation method is comparatively narrow. In this work, based on the least square support vector machine (LSSVM) combined with the gray optimization algorithm (GWO), the prediction model (GWO-LSSVM) of the gas/water phase permeability is established. The model was validated by the gas-water two-phase relative permeability data obtained by a non-steady-state method from a gas reservoir under high pressure/high temperature (133~152.5°C, 50.3~55 MPa) conditions. The irreducible water saturation (S_{wc}), absolute permeability (K), porosity (φ), and gas saturation (S_g) have been set as the input parameters. The water phase relative permeability (K_{rw}) and the gas phase relative permeability (K_{rg}) have been set as output variables. The training data of water phase and gas phase relative permeability were 147 and 141, respectively. The prediction data were 32 and 58, respectively. The results show that the absolute relative deviation (AARD) of K_{rw} for the presented GWO-LSSVM model is 3.69%,

while that of K_{rg} is 2.92%, showing that the model can accurately predict the gas-water relative permeability at high temperature and high pressure. The method provides a new and effective instrument for estimating the gas-water two-phase relative permeability parameters in the development of gas reservoirs.

Keywords: gas-water relative permeability parameter; least square support vector machine; grey wolf optimizer; gas reservoir.

Jiqiang Zhi[1,2] , Yikun Liu[1,2], Guohui Qu[1,2]*

[1] School of Petroleum Engineering, Northeast Petroleum University, Daqing, China

[2] Key Laboratory of Enhanced Oil Recovery, Northeast Petroleum University, Ministry of Education, Daqing, China

liuyikun111@126.com

Numerical Simulation and Sensitivity Evaluation of Fracture Flooding in a Class III Reservoir

In this paper, based on studies of the fracture-flooding technology in a third-class reservoir, a mathematical model is established, conforming to the law of fracture initiation and propagation and the seepage mechanism of the surfactant-containing fracturing fluid. Third-class reservoir mathematical models are used to study the influence of fracture-flooding injection volume, displacement, reservoir permeability, effective thickness, remaining oil saturation, and other factors on the enhanced oil recovery effect in the fracture-flooding technology. The Sobol method is used to analyze the influence of various factors on the overall sensitivity of the enhanced oil recovery effect. The study shows that the cumulative oil increase is the major response variable for third-class reservoir fracture-flooding, the remaining oil saturation is the most sensitive factor, and the injection volume and effective thickness parameters are also sensitive. Thus, the oil-increasing effect of third-class reservoir fracture-flooding is mainly based on the remaining oil potential of the reservoir, expressed by the remaining oil saturation and effective thickness parameters, and the fracture range, defined by the fracturing fluid injection volume.

Keywords: fracture-flooding; numerical simulation; impact assessment; sensitivity analysis; the Sobol method.

Nan Jiang [1], Guohui Qu[2,3], Rongzhou Zhang[2,3], Mingda Li[1], Jiqiang Zhi[2,3]*

[1.] School of Electrical Engineering & Information, Northeast Petroleum University, Heilongjiang Daqing, 163318, China

[2.] School of Petroleum Engineering, Northeast Petroleum University, Heilongjiang Daqing 163318, China

[3.] Key Laboratory of Enhanced Oil Recovery, Northeast Petroleum University, Daqing 163318, China

Corresponding author: Guohui Qu✉ – E-mail: quguohui1001@126.com

Research on Covariance Localization of Enkf Reservoir-Assisted History

Fitting Method Based on Fast Marching Method

The Ensemble Kalman filter (EnKF) is a widely used intelligent algorithm in the field of automatic history fitting. The method has a number of drawbacks, such as inaccurate gradient calculation, filter divergence, and pseudo-correlation of parameters, leading to parameter correction errors and model inversion distortion in the process of historical fitting. A history fitting method based on the fast marching method and covariance-localized Ensemble Kalman filter (FMM-CLEnKF) is established to reduce pseudo-correlation in the calculation process of the traditional distance truncation method. According to the static parameter field information of the reservoir geological

model combined with the state equation, the fast marching method (FMM) is used to quickly track the propagation time of the pressure wave in every well, determine the sensitive area of a single well, and construct the localization matrix. Combined with the covariance localization Ensemble Kalman filter method, the gradient correction of the data assimilation method is realized, and the pseudo-correlation of parameters is reduced. Finally, the optimal model is improved by gradually fitting and updating the reservoir parameter model. The calculation results of a field example show that the FMM-CLEnKF method has a higher reservoir parameter inversion accuracy, data fitting speed, and production data fitting accuracy than the ensemble Kalman filter method.