

Chemistry and Technology of Fuels and Oils

5⁽⁶⁴⁵⁾'2024

Head Editor

B. P. Tumanyan – Dr. Eng. Sci., prof.

Editorial Board

I. A. Arutyunov – Dr. Eng. Sci., prof.

S. N. Volgin – Dr. Eng. Sci., prof.

I. B. Grudnikov – Dr. Eng. Sci., prof.

V. L. Lashkhi – Dr. Eng. Sci., prof.

A. Luksa – Dr. Eng. Sci., prof. (Poland)

A. M. Mazgarov – Dr. Eng. Sci., prof.

K. B. Rudyak – Dr. Eng. Sci., prof.

E. P. Seregin – Dr. Eng. Sci., prof.

Sun Tengfei – prof. (China)

Publisher— ICST «TUMA Group» LLC

Редактор

В. С. Дмитриева

Ответственный секретарь

О. В. Любименко

Графика и верстка

В. В. Земсков

Подготовка материалов

С. О. Бороздин,

А. Д. Остудин,

В. Ю. Попова

Адрес редакции:

105318, г. Москва,

Измайловское шоссе, д. 20-1Н

e-mail: httm@list.ru

Материалы авторов не возвращаются.

Редакция не несет ответственности

за достоверность информации

в материалах, в том числе

рекламных, предоставленных

авторами для публикации.

Формат 60 × 84 1/8.

Печать офсетная.

Усл. печ. л. 7.

Тираж 1000 экз.

Отпечатано в ООО ИПФ «СТРИНГ»

424006, Республика Марий Эл,

г. Йошкар-Ола, ул. Строителей, 95

Contents

| | |
|--|----|
| A. V. Andreev, O. V Durov, O. B. Berdnik, I. N. Tsareva, L. A. Krivina. Key Factors of Steam Reforming Furnace Coils Degradation in Extreme Operation Conditions | 4 |
| A. V. Andreev, D. V. Bushmanov, O.B. Berdnik, I. N. Tsareva. Research of the Impact of Heat Treatment on Changes in the Structure of Metal Material Produced by the Method of Selective Laser Sintering | 11 |
| F. M. Sultanov, S. F. Valeev, Yu. A. Uskova, S. A. Chirskov, V. V. Surkin. Optimization of Turbulator Flow Rate in the Furnace Coils of the Delayed Coking Unit | 16 |
| E. I. Kopalidi, V. A. Luzin, E. N. Levchenko, A. V. Glukhov, V. V. Kosyakin. Development and Use of MOBITECH Application to Measure the Efficiency and Accuracy of Measuring Thickness Measurements of Static Equipment | 21 |
| M. R. Usmanov, D. V. Ilyich, R. D. Balashov. The MAYAK methodology: Calculations and Analysis for Strategic and Operational Planning | 24 |
| M. R. Usmanov, D. V. Ilyich, R. D. Balashov. Transition to Economic Management: Introduction of Online Economic CONSULTant into the Refinery Management System | 28 |
| E. N. Levchenko. Methods of Modeling Virtual Quality Analyzers Based on Machine Learning. Review of Methods | 32 |
| E. N. Levchenko, A. V. Glukhov, V. V. Kosiakin, A. I. Artemov. Ensuring Automation of Supervisors' Activities during Major Repairs | 37 |
| D. V. Ilyich, E. A. Arbuzov, K. V. Chapurovskaya. Customer Management Model as a Factor for Improving the Engineering Center Performance Efficiency | 42 |
| M. Yu. Dolomatov, R. V. Garipov, R. R. Gimaletdinov, E. A. Kovaleva, O. S. Koledin Forecast of Biofuels' Cetane Numbers Taking into Consideration the Inaccuracy of Mixtures | 47 |
| A. A. Kolchin, B. M. Usmanov, E. N. Levchenko. Use of Semantic Text Analysis Based on Machine Learning to Simplify and Automate Document Control | 51 |
| KINETICS AND CATALYSIS | |
| E. G. Dzhabarov, N. N. Petrukhhina, E. M. Zakharyan, V. D. Kuz'min, B. P. Tumanyan. Competitive Hydrodechlorination and Hydrodeazotization on Unsupported Sulfide Catalysts Synthesized In Situ | 65 |
| CHEMMOTOLOGY | |
| V. D. Savelenko, M. A. Ershov, N. A. Klimov, D. R. Aleksanyan, A. A. Shevtsov, U. A. Makhova, V. E. Lazarev, A. V. Manekina, D. Yu. Mukhina, N. O. Burov, E. O. Tikhomirova, A. S. Lyadov, A. A. Kochubeev, D. V. Borisanov, P. S. Ivanov. Impact of the Composition of a Multifunctional Additive Package for Diesel Fuel on Engine Power | 71 |
| RESEARCH | |
| I. N. Kulyashova, A. D. Badikova, A. R. Muzafarova, S. R. Sakhibgareev, T. R. Vakhitov. A Lignosulfonate Drilling Reagent Modified with an Additive Derived from Acrylamide, Formalin and Malic Acid | 77 |
| K. A. Poteshkina, S. A. Borodin, V. V. Ronzhina, L.A. Magadova, M. A. Silin. Mathematical Modelling of Polyacrylamide Adsorption Process | 82 |
| A. R. Sayfutdinova, N. E. Zaytseva, A. D. Karsukova, K. A. Cherednichenko, A. S. Stoporev, V. A. Vinokurov, D. V. Voronin. Case Study of Fungal Mycelium/Eicosane Composite as an Energy Storage Additive for Gypsum Plaster in a Model Experiment | 86 |
| A. A. Novikov, N. E. Zaytseva, A. R. Sayfutdinova, M. I. Rubtsova, V. A. Vinokurov, D. V. Voronin. Thermogravimetric Analysis of Composite phase-Change Materials | 91 |
| INNOVATIVE TECHNOLOGIES OF OIL AND GAS | |
| Huiying Liu, Xinmin Song, Xinwei Wang, Bin Bai, Ruoqing Dong. Research on the Genesis Model of Geothermal Resources in Thermal Storage | 94 |

| | |
|---|-----|
| <i>Hucheng Guo, Shuhong Wu.</i> Solution to the Two-Phase Flow in Heterogeneous Porous Media Based on Physics-Informed Neural Network | 101 |
| <i>Song Hongzhi, Li Tianliang, Lin Tao, Yuan Zhongtao, Wang Ming, Han Rui, Wang Junjiang, Song Chengrui, Ji Youjun.</i> Microscopic CT Images Based Percolation Characteristics Analysis on Hot Water Flooding for Offshore Heavy Oil | 107 |
| <i>Bin Chang, Haipeng Du, Wei Yu, Yanwei Liu, Yong Wang.</i> Preparation of Crosslinked Polymer Microspheres and Evaluation of Oil Repellent Performance | 114 |
| <i>Zhuanying Zhan, Siyu Wang.</i> Development and Performance Evaluation of High Temperature Resistant Hydrophobically Bonded Polymer Fracturing Fluids | 122 |
| <i>Pengfei Wu, Shuhong Li.</i> Optimization of Heat Recovery System Based on Different Types of Finned Tube Heat Exchangers | 129 |
| <i>Yinghui Ren, Yu Huan, Ke Wu, Kangning He, Nan Jiang, Jin Han.</i> Study on the Formation Mechanism of Fracture Network in Hydraulic Fracturing of Shale Reservoirs | 136 |
| <i>Du Qiang, Zhang Jinhai, Zhou Jichun, Xie Rong, Zhou Guangliang, Xu Wei, Yin Hong, Jing Yuquan, Zhang Zhelun, Luo Dandan.</i> Identification and Capacity Analysis of Ultra-Deep Carbonate Gas Reservoirs | 143 |
| <i>Dan Lin, Dan Zheng, Jihao Liao, Jijia Liao, Tingshan Zhang, Xia Hua, Yarui He.</i> Comparison of Pore Characteristics and Constraints of Marine-Terrestrial Mud Shale | 151 |
| <i>Liu Ting, Dong Ye Shengfu, Zhang Zheng, He Minghui, Zhao Jinlin, Zhang Fashi, Li Jingrui, Jiang Tao.</i> Study on the Fracture Extension Law of Hydraulic Fracturing in Shale Reservoirs | 157 |
| <i>Xinjing Xu, Hainan Longpan, Jinfeng Ji, Hainan Longpan, Li Li.</i> A Preview of the Subsea Christmas Tree Installation Procedure | 167 |
| <i>Lifan Luo, Zhi Ji, Jingruo Yan.</i> Analysis of Reservoir Damage Mechanism and Prevention Measures for Deep Carbonate Gas Reservoir with High Sulfur Content | 173 |
| <i>Ziming Zhang.</i> Current Situation and Existing Problems of Horizontal Well Fracturing Technology | 180 |
| <i>Xiaofei Jia, Yingxian Liu, Guanglun Lei, Chuanjin Yao.</i> Oil Displacement Efficiency of High-Power Water Flooding Displacement Core Experiment and Transformation Method of Reservoir Scale in Different Well Patterns | 185 |
| <i>Zihong Wu, Min Zhao, Jinlong Liu, Jiayi Zhang, Yifeng Li.</i> Durability of Polypropylene Films in the Aspect of Petrochemical Product Safety for Packaging Materials Design | 196 |
| <i>Lv Yanjun, Mao Jiashu, Tian Yuan, Li Xinnin, Lv Jianwen.</i> Study on CO ₂ Injection Enhanced oil Recovery Method and Buried Mechanism in Low Permeability Gas reservoir | 204 |
| <i>Xiaoyu Fang, Chuixian Kong, Yanxin Lv, Gongran Liu, Jiaojiao Chen, Guifeng Wang.</i> Discontinuity Stability Analysis for Carbon Dioxide Enhanced Oil Recovery | 212 |
| BRIEF COMMUNICATION | |
| <i>I. R. Vezirov, U. R. Vezirov, E. G. Telyashev.</i> Improving Technology of Vacuum Distillation of Petroleum Products | 218 |
| <i>I. R. Vezirov, U. R. Vezirov, E. G. Telyashev.</i> Updating Vacuum Creating Systems | 221 |
| <i>I. R. Vezirov, U. R. Vezirov, E. G. Telyashev.</i> Improving Efficiency of Equipment of Two-Stage Vacuum Creating Systems | 224 |

A. V. Andreev¹, O. V. Durov¹, O. B. Berdник^{1,2,3}, I. N. Tsareva², L. A. Krivina²

¹ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК),

²Институт проблем машиностроения – филиал Института прикладной физики

им. А. В. Гапонова-Грехова РАН, г. Нижний Новгород,

³Нижегородский государственный технический университет им. Р. Е. Алексеева,

berdник80@mail.ru

Изучение причин деградации материала труб печей парового риформинга в условиях экстремальной эксплуатации

В работе приведены результаты исследования реакционных труб печей парового реформинга, показаны изменения, проходящие в материале в термонагруженных участках труб в процессе эксплуатации. Трубы изготовлены центробежным литьем из высоколегированного сплава торговой марки Manaurit XM, которая должна обеспечивать требуемый ресурс змеевиков, эксплуатируемых при температуре до 1000°C, давлении 3,7 МПа и воздействии агрессивных газов. Установлено, что для сплава марки Manaurit XM даже кратковременные высокотемпературные воздействия в присутствии агрессивной среды приводят к интенсивному протеканию коррозионных процессов, деградации материала, приводящей к появлению хрупкости, снижению пластичности и растрескиванию материала в термонагруженных зонах труб уже после эксплуатации в течение 61 000 ч. Структурные изменения в металле реакционных труб, приводят к снижению жаропрочности и пластичности, появлению склонности к образованию трещин. Это является причиной преждевременного разрушения труб, снижает ресурс высокотемпературных установок и приводит к большим материальным затратам на ремонтные и восстановительные работы.

Ключевые слова: реакционные трубы, жаропрочные стали, микроструктура, карбидные фазы, коррозия.

DOI: 10.32935/0023-1169-2024-645-5-4-10

A. V. Andreev¹, O. V. Durov¹, O. B. Berdник^{1,2,3}, I. N. Tsareva², L. A. Krivina²

¹Lukoil – Engineering Skills and Competences (LINK),

²Nizhny Novgorod State Technical University named after R. E. Alekseev,

³Institute of Mechanical Engineering Problems – branch of the Institute of Applied Physics named after

A.V. Gaponov-Grekhov RAS (IPM RAS), Nizhny Novgorod

Key Factors of Steam Reforming Furnace Coils Degradation in Extreme Operation Conditions

The article contains the results of the study of steam reforming furnace coils metallurgy, highlights the changes that occur with the coils material of the different sections, including the most thermally loaded zones after 32000 hours, 41000 and 61000 hours of run length. The quality parameters of the metallurgy of the coils are fundamental issues due to the severe operation conditions. The coils are manufactured by centrifugal casting using special high-alloy steel to withstand extreme temperatures (up to 1000 °C), pressure (3.7 MPa), and aggressive corrosion products. The core mechanism of the damage of the coils is a combination of thermal impact and tension generated by high internal pressure. Such combination triggers the creeping deformation, which initially appears either on the inner surface of the tube or in the body of metal close to the inner wall of the coil. All of the above is the cause of premature failure (destruction) of the coils, which reduces the turnaround cycle of the furnace and leads to significant costs and lost profit.

Key words: *reaction tubes, heat-resistant steels, microstructure, carbide phases, corrosion.*

А. В. Андреев¹, Д. В. Бушманов^{1,2}, О. Б. Бердник^{1,2,3}, И. Н. Царева³

¹ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК), г. Нижний Новгород

²Нижегородский государственный технический университет им. Р. Е. Алексеева,

³Институт проблем машиностроения – филиал Института прикладной физики

им. А. В. Гапонова-Грехова РАН, г. Нижний Новгород,

berdник80@mail.ru

Исследование воздействия термической обработки на изменение структуры и свойств металлического материала, полученного методом селективного лазерного плавления

В статье представлены результаты исследования структуры материала, полученного из порошковой композиции марки ПР-12Х18Н10Т-10/63, методом селективного лазерного плавления (SLM).

Показана структура и физико-механические характеристики материала, а также определено влияние температуры на структуру и твердость материала. Установлено, что применение высокотемпературной обработки приводит к перестройке структуры.

Ключевые слова: аддитивные технологии, метод селективного лазерного сплавления, металлические порошковые смеси, механические свойства, твердость.

DOI: 10.32935/0023-1169-2024-645-5-11-15

A. V. Andreev¹, D. V. Bushmanov^{1,2}, O.B. Berdник^{1,2,3}, I. N. Tsareva³

¹Lukoil – Engineering Skills and Competences (LINK),

²Nizhny Novgorod State Technical University named after R. E. Alekseev,

³Institute of Mechanical Engineering Problems – branch of the Institute of Applied Physics named after

A.V. Gaponov-Grekhov RAS (IPM RAS), Nizhny Novgorod

Research of the Impact of Heat Treatment on Changes in the Structure of Metal Material Produced by the Method of Selective Laser Sintering

The article presents the results of a study of the structure of a material obtained from a powder composition of the PR-12X18H10T-10/63 brand using the selective laser melting (SLM) method. The structure and physical and mechanical characteristics of the material are shown, and the influence of temperature on the structure and hardness of the material is determined. It has been shown that the use of high-temperature treatment leads to a restructuring of the structure.

Key words: *additive technologies, selective laser melting method, metal powder mixtures, mechanical properties.*

Ф. М. Султанов^{1,2}, С. Ф. Валеев³, Ю. А. Ускова³, С. А. Чирсков³, В. В. Суркин³

¹АО «Институт нефтехимпереработки», г. Уфа,

²Уфимский государственный нефтяной технический университет,

³ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК),

Yuliya.Uskova@lukoil.com

Оптимизация расхода турбулизатора в змеевики печей установки

замедленного коксования

Проведен анализ влияния турбулизатора на эффективность работы реакционных печей установок замедленного коксования. Показано, что основными факторами, определяющими оптимальный расход турбулизатора, являются скорость химических превращений при температуре нагрева сырья в печи, скорость потока и время пребывания парожидкостного потока в высокотемпературной зоне радиантного змеевика.

Ключевые слова: установка замедленного коксования, реакционные печи, гудрон, турбулизатор, скорость потока, время пребывания в зоне химических реакций, доля конверсии в печи.

DOI: 10.32935/0023-1169-2024-645-5-16-20

F. M. Sultanov^{1,2}, S. F. Valeev³, Yu. A. Uskova³, S. A. Chirskov³, V. V. Surkin³

¹JSC Institute of Petrochemical Processing, Ufa,

²Ufa State Petroleum Technical University",

¹ Lukoil – Engineering Skills and Competences (LINK)

Optimization of Turbulator Flow Rate in the Furnace Coils of the Delayed Coking Unit

The analysis of the impact of turbulator on the efficiency of reaction furnaces of Delayed Coking Units has been carried out. It is shown that the main factors determining the turbulator optimal flow rate are the rate of chemical transformations at the feedstock heating temperature in the furnace, the flow rate and the residence time of the vapor-liquid flow in the high-temperature zone of the radiant coil.

Key words: *delayed coking unit, reaction furnaces, short residue, turbulator, flow rate, residence time in the zone of chemical reactions, the portion of conversion in the furnace.*

Е. И. Копалиди, В. А. Лузин, Е. Н. Левченко, А. В. Глухов, В. В. Косякин

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК),

Aleksey.V.Glukhov@lukoil.com

Разработка и применение мобильного приложения «МОБИТЕХ» для повышения оперативности и точности оценки показателей толщинометрии статического оборудования

Рассматривается практический опыт применения, разработанного собственными силами, мобильного приложения «МОБИТЕХ» при выполнении толщинометрии стенок оборудования и технологических трубопроводов установки нефтеперерабатывающего завода. Для оценки технического состояния технических устройств применяемое приложение при выполнении неразрушающего контроля позволяет экспортировать результаты толщинометрии в программное обеспечение PCMS. Результатом применения приложения «МОБИТЕХ» являются корректные значения толщины стенок оборудования и трубопроводов.

Ключевые слова: автоматизация, толщинометрия, оценка технического состояния, мобильное приложение, опытно-промышленное испытание.

DOI: 10.32935/0023-1169-2024-645-5-21-23

E. I. Kopalidi, V. A. Luzin, E. N. Levchenko, A. V. Glukhov, V. V. Kosyakin

Lukoil – Engineering Skills and Competences (LINK)

Development and Use of MOBITECH Application to Measure the Efficiency and Accuracy of Measuring Thickness Measurements of Static Equipment

The practical experience of using the Mobitech mobile application when performing thickness measurements of the walls of equipment and process pipelines at a refinery installation site is considered. To assess the technical condition of technical devices, the application used when performing non-destructive testing allows you to export thickness gauging results to PCMS software. The result of using the MOBITECH application is the correct values of the wall thickness of equipment and pipelines.

Key words: automation, thickness gauging, technical condition assessment, mobile application, pilot testing.

М. Р. Усманов, Д. В. Ильич, Р. Д. Балашов

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

link@lukoil.com

Методика МАЯК: Расчеты и анализ для стратегического и операционного планирования

В статье обосновывается необходимость сопоставительного анализа (бенчмаркинга) показателей для выявления возможностей для улучшения и повышения эффективности работы. Дополнительно описывается необходимость разделения показателей на две категории: эффективности, а также устойчивости деятельности, которая приобретает все большее значение. Описаны подходы к выбору показателей, проведения самого бенчмаркинга, а также предложены направления обеспечения реализации новой методологии.

Ключевые слова: система непрерывных улучшений, новая методология бенчмаркинга.

DOI: 10.32935/0023-1169-2024-645-5-24-27

M. R. Usmanov, D. V. Ilyich, R. D. Balashov

Lukoil – Engineering Skills and Competences (LINK)

The MAYAK methodology: Calculations and Analysis for Strategic and Operational Planning

The article justifies the necessity of comparative analysis (benchmarking) of indicators to identify the strengths and weaknesses of an organization and its divisions, as well as to define opportunities for development and operational efficiency improvement. Additionally, the need to divide indicators into two categories is described: activities' efficiency, as well as sustainability, which in the light of the current geopolitical situation becomes most important. The article describes approaches to the selection of indicators, benchmarking itself on example of processing assets of the LUKOIL Group, and also suggests ways to ensure the implementation of new methodology.

Key words: continuous improvement system, new benchmarking methodology.

М. Р. Усманов, Д. В. Ильич, Р. Д. Балашов

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

link@lukoil.com

Перспективы внедрения «он-лайн экономического консультанта»

для системы управления нефтеперерабатывающим предприятием

Нефтепереработка в России сталкивается с беспрецедентными вызовами, связанными с новыми технологическими и операционными запросами, стремительным изменением на рынках энергоносителей, возрастанием требований к безопасности и экологичности производства. В этих условиях ключевую роль в успехе предприятия играет эффективное и быстрое принятие оптимальных решений, которые учитывают разнообразные сложные переменные. В статье представлен инновационный подход к управлению производством, основанный на внедрении системы «панелей экономической эффективности».

Ключевые слова: экономическая эффективность, управление производством, система непрерывных улучшений, дашборд.

DOI: 10.32935/0023-1169-2024-645-5-28-31

M. R. Usmanov, D. V. Ilyich, R. D. Balashov

Lukoil – Engineering Skills and Competences (LINK)

Transition to Economic Management: Introduction of Online Economic Consultant into the Refinery Management System

Petroleum refining in Russia is facing unprecedented challenges related to the continuous tightening of sanctions pressure, rapid changes at energy markets, and increasing of requirements for safety and production environmental compatibility. In these conditions, the key role in the success of the enterprise is played by the efficient and rapid optimal decision-making that takes into account a variety of complex variables. The article presents an innovative approach to the production management based on the introduction of "economic efficiency panels" system.

Key words: economic efficiency, production management, continuous improvement system, dashboard.

Е. Н. Левченко

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

Evgeny.N.Levchenko@lukoil.com

Методики моделирования виртуальных анализаторов качества на основе машинного обучения.

Обзор методов

Современное производство требует улучшенных систем управления, которые для контроля качества продуктов используют виртуальные анализаторы. В статье рассмотрены текущие подходы и возможности при построении виртуальных анализаторов на основе машинного обучения, их преимущества и недостатки, а также основные критерии выбора методов и подходы к построению виртуальных анализаторов в целом

Ключевые слова: методы моделирования, виртуальный анализатор, этапы моделирования.

DOI: 10.32935/0023-1169-2024-645-5-32-36

E. N. Levchenko

Lukoil – Engineering Skills and Competences (LINK)

Methods of Modeling Virtual Quality Analyzers Based on Machine Learning.

Review of Methods

Modern production requires improved control systems that use virtual analyzers to control the products' quality. This article discusses current approaches and opportunities in construction of virtual analyzers based on machine learning, their advantages and disadvantages. Main criteria for selection of methods and approaches to construction of virtual analyzers in general have been reviewed.

Key words: *methods of modeling, virtual analyzer, stages of modeling.*

E. Н. Левченко, А. В. Глухов, В. В. Косякин, А. И. Артемов

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

Aleksey.V.Glukhov@lukoil.com

Обеспечение автоматизации деятельности супервайзеров на капитальных ремонтах

Рассматривается практический опыт разработки функционала и применения средств автоматизации и повышения эффективности работы супервайзеров на перерабатывающих предприятиях Группы «ЛУКОЙЛ» во время проведения остановочных капитальных ремонтов. Исследован существующий бизнес-процесс, его слабые стороны и недостатки, а также описаны цифровые решения, направленные на их устранение. Особое внимание уделено доработкам компонентов информационной системы «Мобильный супервайзер», позволившим облегчить процесс контроля качества проводимых работ во время остановочных капитальных ремонтов.

Ключевые слова: автоматизация, бизнес-процесс, остановочный капитальный ремонт, мобильное приложение, разработка программного обеспечения, супервайзинг, чек-лист.

DOI: 10.32935/0023-1169-2024-645-5-37-41

E. N. Levchenko, A. V. Glukhov, V. V. Kosiakin, A. I. Artemov

Lukoil – Engineering Skills and Competences (LINK)

Ensuring Automation of Supervisors' Activities during Major Repairs

The practical experience of using and developing functionality for automating and improving the efficiency of supervisors at the refineries of the LUKOIL Group during stop-over overhauls is considered. The existing business process, its weaknesses and shortcomings are considered, as well as digital solutions aimed at eliminating them are described. Special attention is paid to the improvements of the components of the information system "Mobile Supervisor", which made it possible to facilitate the process of quality control of work carried out during stop-over overhauls.

Key words: *automation, business process, stop-over overhaul, mobile application, software development, supervision, checklist.*

Д. В. Ильич, Е. А. Арбузов, К. В. Чапуровская

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

Evgeniy.Arbuzov@lukoil.com

Модель клиентского менеджмента как фактор повышения эффективности работы инжинирингового центра

Определены ключевые задачи клиентского менеджмента в инжиниринговом центре, оценена применимость различных моделей клиентского сервиса и их влияние на результативность инжиниринга. Рассмотрены основные предпосылки развития инжиниринговых центров в качестве самостоятельных организаций и управленческие особенности, характерные для данного вида деятельности. Проанализированы «узкие места» различных моделей управления производственным процессом, определены факторы выбора оптимальных вариантов развития клиентского сервиса в корпоративной среде. Представленная информация содержит данные как из открытых источников, в том числе научных изданий, так и из опыта работы ПАО «ЛУКОЙЛ» в целом и ООО «ЛИНК» в частности.

Ключевые слова: экономическая эффективность, инжиниринг, клиентский сервис, менеджмент, модели управления, инжиниринговые центры.

DOI: 10.32935/0023-1169-2024-645-5-42-46

D. V. Ilyich, E. A. Arbuzov, K. V. Chapurovskaya

Lukoil – Engineering Skills and Competences (LINK)

Customer Management Model as a Factor for Improving the Engineering Center Performance Efficiency

The goal of this article is to identify the key tasks of the Customer Management in the engineering center, to assess the applicability of various customer service models as well as their impact on the engineering efficiency. The authors have considered the main prerequisites for development of engineering centers as independent organizations as well as management features characteristic for this type of activity. The article analyzes the "bottlenecks" of various production process management models, identifies the factors for choosing optimal options for development of customer service in a corporate environment. The information presented herein contains data both from open sources, including from scientific publications, as well as from the professional experience of PJSC LUKOIL in general and LINK LLC in particular.

Key words: economic efficiency, engineering, customer service, management, process management, engineering centers.

М. Ю. Доломатов¹, Р. В. Гарипов¹, Р. Р. Гималетдинов^{1,2}, Э. А. Ковалева¹, О. С. Коледин¹

¹Уфимский государственный нефтяной технический университет,

²ПАО «ЛУКОЙЛ»,

g4ripov.robert@yandex.ru

Прогноз цетановых чисел биотоплив с учетом неидеальности смесей

Предложена методика прогноза цетановых чисел неидеальных биотопливных смесей, основанная на методе «структура–свойство» с учетом Ван-дер-Ваальсовых взаимодействий молекул, обуславливающих

неидеальность. Аддитивный вклад в цетановые числа смеси рассчитывался методом QSPR. Поправку на неидеальность предложено оценивать по эмпирической формуле, учитывающей диполь-дипольное взаимодействие молекул. Предложенный подход возможно реализовать в лабораторной практике и в производственной системе автоматического контроля производства биотоплива, а также его смесей с углеводородным дизельным топливом.

Ключевые слова: биотопливо, цетановое число, модель QSPR, сложные эфиры, многофакторные регрессионные модели, дипольные моменты.

DOI: 10.32935/0023-1169-2024-645-5-47-50

*M. Yu. Dolomatov*¹, *R. V. Garipov*¹, *R. R. Gimaletdinov*^{1,2}, *E. A. Kovaleva*¹, *O. S. Koledin*¹

¹Ufa State Petroleum Technical University,

²PJSC LUKOIL

Forecast of Biofuels' Cetane Numbers Taking into Consideration the Inaccuracy of Mixtures

A method for predicting the cetane numbers of non-ideal biofuels is proposed, based on the "structure-property" method, taking into account the Van der Waals interactions of molecules that cause non-ideality. The additive contribution to the cetane numbers of the mixture was calculated using the QSPR method. It is proposed to evaluate the correction for nonideality using an empirical law that takes into account the dipole-dipole interaction of molecules. The proposed approach can be implemented in laboratory practice and in a production system for automatic control of the production of biofuel, as well as its mixtures with hydrocarbon diesel fuel.

Key words: *biofuel, cetane number; QSPR model, esters, multivariate regression models, dipole moments.*

A. A. Kolchin, B. M. Usmanov, E. N. Levchenko

ЛУКОЙЛ – Инженерные Навыки и Компетенции (ЛИНК)

Andrey.Kolchin@lukoil.com

Использование семантического анализа текста на основе машинного обучения для упрощения и автоматизации документооборота

В статье приведены методы улучшения качества семантического поиска и структуризации узкоспециализированного текста. Рассмотрен конвейер обработки, включающий анализ языковой моделью и различные стратегии разбиения на словосочетания (чанки, chunks) и формирования эмбеддингов.

Результатом работы стала программа, позволяющая осуществлять семантический поиск по корпусу неоднородных специализированных документов. Предложена инновационная стратегия создания эмбеддингов, которая повышает полноту результатов с минимальными потерями точности, выделены перспективные направления продвинутого текстового анализа.

Ключевые слова: языковые модели, анализ текста, chunking, embedding, retrieval.

DOI: 10.32935/0023-1169-2024-645-5-51-56

A. A. Kolchin, B. M. Usmanov, E. N. Levchenko

Lukoil – Engineering Skills and Competences (LINK)

Use of Semantic Text Analysis Based on Machine Learning to Simplify and Automate Document Control

The article provides methods for improving the quality of semantic search and structuring of highly specialized text. The processing pipeline has been considered, including analysis using the language model and various strategies for breaking into phrases (chunks) and forming of embeddings. The result of the work has become a program that enables to fulfill semantic search in a corpus of heterogeneous specialized documents. An innovative embedding strategy has been proposed, which increases the completeness of results with minimal loss of accuracy, and promising areas of advanced text analysis have been highlighted.

Key words: *language models, text analysis, chunking, embedding, retrieval.*

Э. Г. Джабаров¹, Н. Н. Петрухина¹, Е. М. Захарян¹, В. Д. Кузьмин², Б. П. Туманян²

¹Институт нефтехимического синтеза им. А. В. Топчиева РАН,

²РГУ нефти и газа (НИУ) им. И. М. Губкина

dzhabarov@ips.ac.ru

Исследование параллельного протекания процессов гидродехлорирования и гидродеазотирования на сульфидных ненанесенных катализаторах, синтезируемых in situ

Изучена каталитическая активность в конкурирующих процессах гидродехлорирования 1,4-дихлорбензола и гидродеазотирования хинолина ненанесенного дисульфида вольфрама, промотированного никелем.

Катализатор синтезирован in situ в реакционной среде. Исследование морфологии и фазового состава катализатора проведено посредством рентгеновской фотоэлектронной спектроскопии и просвечивающей электронной микроскопии и указывает на наличие на поверхности катализатора фазы дисульфида вольфрама, сульфида никеля, хлорида никеля и смешанной фазы NiWS. В параллельных процессах гидродехлорирования и гидродеазотирования наблюдается значительная дезактивация катализатора, что приводит к снижению степени дехлорирования 1,4-дихлорбензола. Потеря активности катализатора обусловлена прочной адсорбцией азотсодержащих соединений на поверхности катализатора, а также накоплением на поверхности катализатора солей хинолина.

Ключевые слова: сульфидный катализатор, ненанесенный катализатор, гидродехлорирование, гидродеазотирование, поливинилхлорид.

E. G. Dzhabarov¹✉, N. N. Petrukhina¹, E. M. Zakharyan¹, V. D. Kuz'min², B. P. Tumanyan²

¹ A. V. Topchiev Institute of Petrochemical Synthesis; ² Gubkin University

Competitive Hydrodechlorination and Hydrodeazotization on Unsupported Sulfide Catalysts Synthesized In Situ

The catalytic activity of an unsupported nickel-promoted tungsten disulfide catalyst prepared in situ in the reaction medium was studied in the competitive hydrodechlorination of 1,4-dichlorobenzene and hydrodeazotization of quinoline. The morphology and phase composition of the catalyst were studied by x-ray photoelectron spectroscopy and transmission electron microscopy. This study indicated the presence of nickel sulfide, nickel chloride and a mixed NiWS phase on the surface of the tungsten disulfide catalyst. A considerable decrease in catalyst activity was noted during the concurrent hydrodechlorination and hydrodeazotization reactions, leading to a decrease in the extent of hydrodechlorination of 1,4-dichlorobenzene. The loss of catalyst activity was attributed to the strong adsorption of nitrogen-containing compounds as well as the accumulation of quinolinium salts on the catalyst surface.

Keywords: *sulfide catalyst, unsupported catalyst, hydrodechlorination, hydrodeazotization, polyvinyl chloride.*

V. D. Savelenko¹, M. A. Ershov^{1,2} ✉, N. A. Klimov³, D. R. Aleksanyan¹, A. A. Shevtsov³, U. A. Makhova¹, V. E. Lazarev⁴, A. V. Manekina³, D. Yu. Mukhina³, N. O. Burov³, E. O. Tikhomirova³, A. S. Lyadov³, A. A. Kochubeev³, D. V. Borisanov¹, P. S. Ivanov¹

¹ Gubkin University; ² Additive Production Development Center (APDC LLC), Moscow;

³ A. V. Topchiev Institute of Petrochemical Synthesis, Russian Academy of Sciences;

⁴ Advanced Engineering School of Engine's Design and Special Techniques "The Heart of Ural", South Ural State University (National Research University), Chelyabinsk.

ershovma@ntwc.ru

Impact of the Composition of a Multifunctional Additive Package for Diesel Fuel on Engine Power

Multifunctional fuel additive packages (MFAPs) are critical for the production of modern diesel fuels with improved performance and environmental characteristics. The most significant property of these packages is the cleaning ability determined in relation to fuel injectors, but this property does not determine the advantages of using MFAPs, which are most often formulated by fuel and additive manufacturers as the ability to increase, restore and maintain engine power at a high level. In this study, an instantaneous and reproducible increase in engine power of 3.9–4.4 % was recorded when switching to fuel with an additive, regardless of the composition of diesel fuel and diesel engine design, while the influence of each component of the multifunctional additive on the recorded effect was determined. An assumption was made about the mechanism of power increase associated with an increase in fuel combustion efficiency, and not the cleaning mechanism of the additive.

Keywords: *diesel fuel, detergent, multifunctional additive, modern fuel, internal combustion engines, engine power.*

I. N. Kulyashova ✉, A. D. Badikova, A. R. Muzafarova, S. R. Sakhibgareev, T. R. Vakhitov

Ufa State Petroleum Technological University.

irina-0472@yandex.ru

A Lignosulfonate Drilling Reagent Modified with an Additive Derived from Acrylamide, Formalin and Malic Acid

A study was carried out on the feasibility of obtaining a modified lignosulfonate reagent by dispersing an additive synthesized using acrylamide, formalin, and malic acid. We determined the optimal component ratios for the preparation of this modifier and the modified lignosulfonate reagent through mathematical modelling using the Statistica 12 program package. The composition of the additive to the lignosulfonate drilling reagent was studied by high-performance liquid chromatography. Analysis of the two-dimensional correlation of the homo- and heteronuclear spectra, integral intensities in the 1H NMR spectra and the mass spectra of an experimental sample of the synthesized additive indicated the structure of this compound. Comparative analysis of the surface tension of the samples studied was carried out by the stalagmometric droplet counting method. The effectiveness of the synthesized additive and the modified lignosulfonate reagent for improving the parameters of the drilling mud at high temperature up to 180°C was demonstrated experimentally.

Keywords: *acrylamide, malic acid, formalin, sodium lignosulfonate, lignosulfonate reagent, liquid chromatography, surface tension, drilling mud, filtration index.*

K. A. Poteshkina, S. A. Borodin✉, V. V. Ronzhina, L.A. Magadova, M. A. Silin

Gubkin University.

borodin.s@gubkin.ru.

Mathematical Modelling of Polyacrylamide Adsorption Process

The static adsorption of hydrolysed polyacrylamide on quartz sand has been studied as a function of the concentration of the polymer solution. Two-parametric adsorption models (Langmuir, Freundlich, Temkin) and three-parametric models (Sips and Redlich–Peterson) were used to describe the data obtained. A three-model isotherm was also constructed, where each model is applied for a certain range of concentrations, which showed the best convergence with the experimental data. Among the two-parametric models, the Langmuir model showed the best result. Among the three-parametric models, the Sips model, which better describes adsorption at high concentrations. The data were obtained, which can be useful for further study of adsorption processes and development of new technologies in various industrial fields.

Keywords: *polyacrylamide, polymer adsorption, static adsorption, adsorption models, polymer concentration.*

A. R. Sayfutdinova, N. E. Zaytseva, A. D. Karsukova, K. A. Cherednichenko,

A. S. Stoporev, V. A. Vinokurov, D. V. Voronin✉

Gubkin University.

voronin.d@gubkin.ru

Case Study of Fungal Mycelium/Eicosane Composite as an Energy Storage Additive for Gypsum Plaster in a Model Experiment

The adsorption of organic phase-change materials (PCMs) on the supporting fibers has been demonstrated as a versatile and efficient method for developing stable composites with thermoregulatory properties. These composites are promising as energy saving additives in dry building mixtures. However, developing composite fibers with an optimal morphology to maximize their content and thermoregulation in the desired material is still a significant challenge. In this study, we have created stable composite fibers by depositing the organic PCM eicosane on fungal mycelial biopolymer fibers. The resulting composite has a fibrous structure with a lateral size of 1.5–2 μm and a latent heat capacity of 70 J/g. It was mixed with dry gypsum powder at a weight ratio of 30%. Electron microscopy analysis showed a uniform distribution of fibers throughout the hardened gypsum layer. The DSC analysis revealed that the inclusion of the composite to the plaster significantly improved its thermal properties, allowing for the storage and release of latent heat with heat capacity of 30 J/g. Temperature measurements within the hardened plaster showed that the presence of thermoregulating fibers slowed down the heating process between 32–38°C and cooling between 38–35°C, corresponding to the melting and solidification of eicosane in the composite structure. Finally, model experiments with a testing chamber demonstrated that the accumulation and release of the thermal energy resulted in the decrease in internal air temperature during the heating cycle and in the increase of internal air temperature during the cooling cycle, respectively.

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

A. A. Novikov, N. E. Zaytseva, A. R. Sayfutdinova, M. I. Rubtsova, V. A. Vinokurov, D. V. Voronin ✉

Gubkin University.

novikov.a@gubkin.ru

Thermogravimetric Analysis of Composite Phase-Change Materials

In this work we analyzed the thermogravimetric data on the fiber phase change composites loaded with eicosane or stearic acid. The consistency of the thermogravimetric data can be checked using the Kolmogorov–Johnson–Mehl–Avrami equation with a temperature-dependent rate constant. However, the first derivative analysis shows that the employed equation should be further modified in order to account for the asymmetry of the peaks on the first derivative of thermogravimetric curves.

Keywords: *Kolmogorov–Johnson–Mehl–Avrami equation, Arrhenius equation.*

Huiying Liu^{1,2} ✉, **Xinmin Song¹**, **Xinwei Wang²**, **Bin Bai¹**, **Ruojing Dong¹**

¹ Research Institute of Petroleum Exploration & Development, PetroChina, Beijing, China;

² Sinopec Star Petroleum Company Limited, Beijing, China.

jk15102565201@163.com

Research on the Genesis Model of Geothermal Resources

in Thermal Storage

In this paper, the hydrogeochemical analysis method was adopted to test the underground water samples in the thermal reservoir of the Wumi Mountain Formation in detail, and the genesis pattern of geothermal resources was analyzed in depth from various perspectives of geological structure, hydrogeology, and geothermal geological conditions by synthesizing the results of the previous researches. The results show that the geothermal water in the Wumi Mountain Formation is mainly neutral or weakly alkaline brackish water, and its hydrochemistry is of the Cl-HCO₃-Na type. By analyzing the chemical composition of the groundwater, we found that Na⁺ and Cl⁻ play a decisive role in the formation of TDS, with an average TDS of 2861 mg/L. In addition, the analysis of trace components showed that the concentration of Li, Sr, F, HBO₂ and SiO₂ in the geothermal water of the Wumi Mountain Formation is significant, reflecting the strong interaction between the deep groundwater and the rocks. SiO₂ content is highly correlated with the temperature, which can be used to estimate the thermal storage temperature. In the analysis of the genesis model, this study reveals that the geothermal water in the thermal reservoir of the Wumi Mountain Formation mainly originates from the atmospheric precipitation in the Taihang Mountain area and undergoes long-distance subsurface transportation through the pre-Taihang Mountain fracture zone. This study provides a new perspective and theoretical basis for understanding and developing deep geothermal resources in Xiongan New Area.

Keywords: *Xiongan New Area, Wumi Mountain Formation, geothermal resources, genesis mode.*

Hucheng Guo, Shuhong Wu ✉

Research Institute of Petroleum Exploration and Development, PetroChina, Beijing, China.

Solution to the Two-Phase Flow in Heterogeneous Porous Media

Based on Physics-Informed Neural Network

Data-driven machine learning models have weak physical interpretability and stability. Physics-Informed Neural Network (PINN) solves partial differential equations by adding partial differential equations describing physical laws and their definite solution conditions to the loss function. The physical laws of the reservoir fluids flow are clear. Aiming at the two-phase Darcy flow problem in the heterogeneous reservoir model, a surrogate model based on PINN is established, and the model control equation is added to the loss function, so that the model obeys both the training data and the governing equation constraint. The model proposed in this article calculates the loss function through the decoupled governing control equation of the implicit pressure explicit saturation method (IMPES), calculates the residual of the pressure equation based on the finite difference method, and uses the Peaceman well model to calculate the flow between the reservoir and the wellbore, thus improve continuity between neighboring grids in heterogeneous reservoirs. The results show that the PINN model agrees well with the calculation results of the reservoir numerical simulator, is insensitive to the number of observation points, has strong stability, and can be well used for simulation calculations and history matching.

Keywords: *physics-informed neural network, loss function, reservoir numerical simulation, nonlinear partial differential equation, heterogeneity.*

**Song Hongzhi^{1,2,3}, Li Tianliang^{1,2,3}, Lin Tao^{1,2,3}, Yuan Zhongtao^{2,3}, Wang Ming^{2,3},
Han Rui^{2,3}, Wang Junjiang⁴, Song Chengrui⁴, Ji Youjun⁴ ✉**

¹ State Key Laboratory of Offshore Oil and Gas Exploitation, Tianjin, China;

² CNOOC Key Laboratory of Offshore Heavy Oil Thermal Recovery, Testing and Analysing Laboratory, Tianjin, China;

³ Tianjin Branch of China Oilfield Services Limited, Tianjin, China;

⁴ School of Geoscience and Technology, Southwest Petroleum University, Chengdu, China.

254281893@qq.com

Microscopic CT Images Based Percolation Characteristics Analysis on Hot Water Flooding for Offshore Heavy Oil

In this study, CT core samples from oil sands of an LD 5-2 oilfield were prepared to conduct CT scanning experiments to obtain core pore images, and digital image processing techniques were used for the pore structure modeling of rock cores. A microscopic numerical model of hot water flooding was established, based on the actual physical process of hot water flooding, conducting pore-scale hot water throughput to hot water flooding numerical simulations and analyzing the influence law of water injection rate and temperature on hot water flooding. Through the quantification of oil and water phase mass fraction and water saturation data, hot water-driven phase infiltration curves were obtained for different temperatures. The results show limited scope for utilization during the throughput phase, a ripple coefficient below 0.4, an extraction level below 5%, an improvement of the wave coefficient after conversion to hot water to more than 0.75, an increase in extraction level by more than 15%, and greatly improved oil driving efficiency. With increasing injection temperature, the level of extraction was progressively higher throughout the simulation, but after the injection temperature increased to 110°C, the change in the magnitude of the increase in

the level of extraction in the simulation was smaller. As the rate of water injection increased, the level of extraction also gradually increased. The highest degree of extraction was achieved at an injection rate of 35 $\mu\text{m/s}$. Increased water injection temperature favors hot water oil drive, a temperature increase from 80°C to 130°C, an increased saturation of bound water, a reduced residual oil saturation, and an increased oil and water transportation capacity. The results of the study provide some references for the design of an offshore heavy oil hot water flooding program.

Keywords: *offshore heavy oil reservoirs, hot water flooding, digital core, CT scan, microscopic seepage.*

Bin Chang¹✉, **Haipeng Du**², **Wei Yu**³, **Yanwei Liu**⁴, **Yong Wang**⁵

¹ State Key Laboratory of Continental Dynamics, Department of Geology, Northwest University, Xi'an, Shaanxi, China;

² Downhole Service Company BHDC, CNPC, Renqiu, China;

³ No.3 Oil production Plant of Huabei oilfield Company, CNPC, Hejian, China;

⁴ No.1 Oil production Plant of Huabei oilfield Company, CNPC, Hejian, China;

⁵ No.8 Oil Production Plant, PetroChina Changqing Oilfield Company, Yulin, Shaanxi, China.

huajing9966961@163.com

Preparation of Crosslinked Polymer Microspheres and Evaluation of Oil Repellent Performance

A W/O microemulsion of AM/H₂O Span80/Tween80 kerosene system was prepared with acrylamide (AM) monomer aqueous solution as dispersion phase, Span80/Tween80 as emulsifier and kerosene as dispersion medium. The crosslinked polyacrylamide microspheres with nanometer size were prepared by inverse microemulsion polymerization at 70°C. The microscopic analysis shows that the internal structure of the microsphere is broken during oil displacement, the water cut decreases and the oil recovery increases. When the amount of crosslinking agent is 1.3%, the microsphere flooding effect is good. After the microsphere is injected, the water content of the high permeability pipe decreases by 29.4%, and the oil recovery of the low permeability pipe increases by 33.8%, indicating that the microsphere has a good effect of precipitation and oil increase. The injection pressure was low at the initial stage and then rose to nearly 100 kPa, indicating good injectivity of the microspheres.

Keywords: *crosslinked agent, polymer microspheres, oil repellency, permeability, injection volume, microanalysis.*

Zhuanying Zhan✉, **Siyu Wang**

¹ College of Chemistry and Chemical Engineering, Xi'an Shiyou University, Xi'an, China;

² Shaanxi Key Laboratory of Lacklustre Shale Gas Accumulation and Exploitation, Xi'an, China;

³ Shaanxi University Engineering Research Center of Oil and Gas Field Chemistry, Xi'an Shiyou University, Xi'an, China.

13931538815@163.com

Development and Performance Evaluation of High Temperature Resistant Hydrophobically Bonded Polymer Fracturing Fluids

More and more deep, low permeability and high temperature oil and gas reservoirs have been discovered by exploration, however, there are fewer types of fracturing fluids that can be used for production enhancement and modification of such reservoirs. Due to their high viscoelasticity, water-soluble hydrophobic polymers have been

widely used as thickeners of working fluids for drilling and oil repulsion, and have also been applied in fracturing, but their weak temperature resistance limits their applicability to reservoirs, and their high initial viscosity makes them difficult to be formulated in the field. To address the above problems, this paper successfully prepared a high temperature resistant thickener PAAQ based on free radical polymerization method, which is used for fracturing and production enhancement in deep low permeability and high temperature oil and gas reservoirs. The experimental results show that PAAQ has good thickening, temperature resistance, shear resistance, viscoelasticity and other properties, and is suitable for fracture acidizing in carbonate formations. The thickening mechanism of PAAQ is the formation of a three-dimensional network structure by polymer molecular aggregation and chelation of the betaine side chains with calcium ions. The storage modulus G' of PAAQ solution is always higher than that of energy dissipation modulus G'' ; $k < 1.0 \cdot 10^{-3} \text{ m/min}^{1/2}$, $R < 1.5 \cdot 10^4 \text{ m/min}$, $V_0 < 5 \cdot 10^{-23} \text{ m}^2$; the settling rate of the ceramic particles was lower than 0.48 cm/min; when the NaBO_3 dosage was 0.1%, the viscosity of the fracturing fluid was reduced to 30 mPa·s at 110 min, which indicated that the fracturing fluid system had good sand-carrying performance, filtration-loss control ability and gel-breaking performance. This paper provides a theoretical basis for the synthesis and application of high-temperature resistant polymer fracturing fluids.

Keywords: fracturing fluid, hydrophobic binding thickener, high temperature resistance, thickening mechanism, performance evaluation.

Pengfei Wu, Shuhong Li ✉

School of Energy and Environment, Southeast University, Nanjing, Jiangsu, China.

t13851979165@163.com

Optimization of Heat Recovery System Based on Different Types of Finned Tube Heat Exchangers

In order to enhance the heat recovery efficiency and net energy consumption ratio of the run-around heat recovery system applied in gas and oil field and other buildings, this study replaces the conventional heat exchangers with wavy fin tube heat exchangers, slotted fin tube heat exchangers, and fin tube heat exchangers equipped with longitudinal vortex generators. The coupling simulation model of the run-around heat recovery system is established using MATLAB and FLUENT. The coupling model is utilized to simulate and calculate the heat recovery rate and net energy consumption ratio of the heat recovery system with different types of heat exchangers in various seasons, as well as at different temperatures during winter in a hot summer and cold winter region (Wuhan). The simulation results demonstrate a significant enhancement in the heat recovery rate and net energy consumption ratio of the heat recovery system when replacing the conventional heat exchanger with a finned tube heat exchanger incorporating corrugated fins, slotted fins, and longitudinal vortex generators. Among them, the heat recovery rate of the finned tube heat exchanger with slits exhibits the highest increase, while the net energy consumption ratio of the finned tube heat exchanger with longitudinal vortex generator demonstrates the most significant enhancement. The utilization of a finned tube heat exchanger with a complex structure can enhance the optimization of the run-around heat recovery system. However, when considering the overall energy consumption reduction capability of the entire system, it is essential to account for the increased energy consumption associated with its complex structure.

Keywords: run-around heat recovery system, coupling model, finned tube heat exchanger.

Yinghui Ren¹ ✉, Yu Huan², Ke Wu³, Kangning He⁴, Nan Jiang¹, Jin Han¹

¹ School of Petroleum Engineering and Environmental Engineering, Yan'an University/Yan'an Engineering Technology Research Center of Efficient Pipeline Transportation of Oil and Gas and Flow Guarantee, Yan'an, Shaanxi, China;

² Oil Production Plant, PetroChina Changqing Oilfield Company, CNPC, Xi'an, Shaanxi, China;

³ Research Institute of Exploration and Development, PetroChina Changqing Oilfield Company / National Engineering Laboratory for Exploration and Development of Low Permeability Oil & Gas Field, Xian, Shaanxi, China;

⁴ Xi'an Shiyou University, Xi'an, Shaanxi, China.

19133727558@163.com

Study on the Formation Mechanism of Fracture Network in Hydraulic Fracturing of Shale Reservoirs

With the global energy structure transition and increasing demand for environmental protection, shale gas, as an important unconventional natural gas resource, plays an increasingly important role in China's energy strategy. However, the ultra-low permeability of shale gas reservoirs requires reliance on hydraulic fracturing techniques to enhance production. In this study, we used the Longmaxi Formation shale reservoir in Chuannan, China, to assess the stress sensitivity of the permeability of rock samples by using transient pressure-pulse permeability tests combined with aging tests, as well as to analyze the fracture extension behavior by constructing a model of hydraulic fracture extension within intersecting closed joints. The results show that permeability decreases with increasing pore pressure at low pore pressure conditions (2-6 MPa), while permeability increases with increasing pore pressure at high pore pressure conditions (8-24 MPa). Further analysis reveals the expansion behavior of the fracture network within the intersecting closed joints, where the possibility of forming a complex fracture network is higher at low (0-11°) and medium (11°-38°) intersection angles, and the cohesion (2 MPa) and tensile strength (2 MPa) of the joints, as well as lower friction coefficients (0.2) and geostress differentials (0-5 MPa), are favorable for the expanding this range. When the ground stress difference increases to 5 MPa, the fracture extension pattern reverts to a three-range pattern, indicating that the increase of the ground stress difference has a significant effect on the fracture extension pattern. This study provides an important theoretical and experimental basis for understanding the formation of fracture networks during hydraulic fracturing of shale gas reservoirs, which is of great practical significance for guiding the efficient development of shale gas in China.

Keywords: shale reservoir, hydraulic fracturing, stress sensitivity, fracture network, intersecting closed joints.

Du Qiang¹, Zhang Jinhai¹, Zhou Jichun¹ ✉, Xie Rong², Zhou Guangliang¹, Xu Wei^{3,4},

Yin Hong¹, Jing Yuquan¹, Zhang Zhelun³, Luo Dandan¹

¹ Northwest Division of Petrochina Southwest Oil & Gas Field Company, Jiangyou, Sichuan, China;

² PetroChina Southwest Oil and Gas Field Digital Intelligent Technology Branch, Chengdu, Sichuan, China;

³ Exploration and Development Research Institute, PetroChina Southwest Oil & Gasfield Company, Chengdu, Sichuan, China;

⁴ Sichuan Kelite Oil and Gas Technological Service Company, Ltd., Chengdu, Sichuan, China.

18034250008@163.com

Identification and Capacity Analysis of Ultra-Deep Carbonate Gas Reservoirs

In this study, reservoir identification and capacity analysis of ultra-deep carbonate gas reservoirs are discussed in depth, with special focus on the Middle Permian gas reservoirs in West Sichuan area. By systematically analyzing the reservoir characteristics, tectonic features and their influence on the production capacity in this region, this paper proposes a set of comprehensive evaluation methods to improve the accuracy of reservoir identification and production capacity evaluation. The study shows that the reservoirs of the Middle Permian gas reservoirs in the West Sichuan area have obvious non-homogeneity and multi-scale seam characteristics, with porosity ranging from 0.22% to 10.8% and permeability ranging from 0.0011 to 56 mD, and their production capacity is affected by a variety of factors, such as the physical properties of the reservoirs, the degree of fracture development, and the degree of active water bodies. By analyzing the meter gas recovery index curve, this study successfully identifies different types of reservoirs, and proposes a capacity evaluation model applicable to carbonate reservoirs based on the pressure drop dynamic characteristics of dual-media reservoirs. The results show that the equivalent formation coefficient F_e , the non-homogeneous coefficient λ , and the equivalent number of fracture strips N_f are the key factors affecting the production capacity of gas wells. Among them, the unimpeded flow rate q_{AOF} increases with the increase of equivalent formation factor F_e , while the production ratio α has no obvious correlation with equivalent formation factor F_e . In addition, the equivalent water intrusion intensity I_{we} has a significant effect on the gas well allotment ratio, which decreases with the increase of water body activity. This study provides theoretical support and technical guidance for the effective development of ultra-deep carbonate reservoirs, and is of great significance for guiding actual production, formulating development countermeasures and rationalizing production allocation.

Keywords: Middle Permian, carbonate gas reservoir, reservoir identification, production capacity analysis.

Dan Lin^{1,2}, **Dan Zheng**³, **Jihao Liao**⁴, **Jijia Liao**⁵ ✉, **Tingshan Zhang**⁵, **Xia Hua**⁶, **Yarui He**⁷

¹ Sichuan Engineering Research Center for Mechanical Properties and Engineering Technology of Unsaturated Soils, Chengdu University, Chengdu, China;

² Business School, Chengdu University, Chengdu, China;

³ Geological Exploration & Development Research Institute, CNPC ChuanQing Drilling Engineering Company Ltd., Chengdu, China;

⁴ Southwest Center of Reservoir Geophysics Institute, Optical Science and Technology (Chengdu) Ltd., Chengdu, China;

⁵ School of Geoscience and Technology, Southwest Petroleum University, Chengdu, China;

⁶ Central Sichuan Oil and Gas District, Petro China Southwest Oil & Gasfield Company, Suining, China;

⁷ Engineering Technology Research Institute, Southwest Oil and Gas Field Company of CNPC, Deyang, liao_jijia@163.com

Comparison of Pore Characteristics and Constraints of Marine-Terrestrial Mud Shale

Based on low temperature nitrogen adsorption experiment, the quantitative characterization of Marine mud shale from Qiongzhusi formation of the lower Cambrian and Longmaxi formation of the lower Silurian in the Upper Yangzi Massif and Terrestrial mud shale of chang 9 and chang7 oil layers in Ordos Basin is finished. The pore characteristics and influencing factors of shale reservoirs with different sedimentary environments and maturity are discussed systematically from the aspects of material composition and thermal evolution. The results show that the

brittle mineral content is negatively correlated with the specific surface area and pore volume. The content of clay minerals is weakly positively correlated with specific surface area and pore volume. TOC content is weakly positively correlated with pore volume, strongly positively correlated with specific surface area, and not correlated with average pore diameter. With the increasing of R_o , the average pore diameter decreases, and the decreasing speed decreases with the increasing of R_o . When R_o is between 0.5% and 2.8%, the specific surface area increases with R_o . When R_o is between 2.8% and 5%, the specific surface area decreases with the increase of R_o . The pore volume was negatively correlated with R_o value due to the decrease of pore diameter.

Keywords: *marine-terrestrial mud shale, comparison of pore characteristics, TOC, thermal evolution.*

Liu Ting, Dong Ye Shengfu ✉, Zhang Zheng, He Minghui, Zhao Jinlin, Zhang Fashi, Li Jingrui, Jiang Tao

Petrochina Changqing Oilfield Company Oil Production Plant No.2, Qingcheng, China.

3789066350@qq.com

Study on the Fracture Extension Law of Hydraulic Fracturing in Shale Reservoirs

This study aims to deeply investigate the fracture extension law of hydraulic fracturing in shale reservoirs, as well as the effects of rock mechanical anisotropy and engineering operation parameters on the fracture extension behavior. Matlab programming combined with the theoretical model of fracture extension was used to establish a computational model of the stress on the hole wall of a shale isotropic matrix shot hole, and the effects of injection displacement, horizontal stress difference, elastic modulus and Poisson's ratio on fracture extension were systematically analyzed through a series of true triaxial hydraulic fracturing physical simulation experiments. The results show that the injection completion can significantly reduce the fracture initiation pressure compared with the barehole completion, especially when the injection azimuth angle is 90° , the fracture initiation pressure reaches the lowest value of 52.3 MPa. The anisotropy of rock mechanics has a significant effect on the fracture initiation pressure, especially when the horizontal stress difference coefficient is more than 0.13, the larger the ratio of Young's modulus is, the lower the fracture initiation pressure is, and the larger the value of Poisson's ratio is when the value of Poisson's ratio is more than 0.25, the larger the value of Poisson's ratio is, the higher the value of Poisson's ratio is. The larger the value of Poisson's ratio is above 0.25, the higher the crack initiation pressure is. The increase of injection displacement from 0.5 mL/min to 5 mL/min increased the crack length from 15.2 cm to 66.3 cm, and the crack extension rate from 0.51 cm/min to 2.21 cm/min, which significantly increased the crack extension rate and length. While the fracture extension rate decreased from 1.8 cm/min to 0.8 cm/min when the elastic modulus increased from 20 GPa to 60 GPa, the rock with high elastic modulus formed a smaller plastic zone near the fracture tip, which limited the fracture extension rate and morphology. This study provides a new theoretical basis for the fracture expansion mechanism of hydraulic fracturing in shale reservoirs, which is of great significance for optimizing hydraulic fracturing design and improving the efficiency of shale gas development.

Keywords: *shale reservoir, hydraulic fracturing, fracture extension, rock mechanics anisotropy, physical simulation experiments.*

Xinjing Xu¹, Hainan Longpan¹, Jinfeng Ji¹, Hainan Longpan¹, Li Li² ✉

¹ Oilfield Technology Co. LTD, China;

² China University of Petroleum-Beijing, China.

LL1974922204@163.com

A Preview of the Subsea Christmas Tree Installation Procedure

In the process of deep-water gas field development, the deep-water production system plays a key role, and the deep-water production system has been widely used in the development of the world's offshore gas fields. In this paper, the author uses the X gas field as an example to introduce the subsea christmas tree installation procedure and the reliability of subsea tree production stage by using fault tree analysis (FTA). The installation procedure of the subsea christmas tree is divided into three steps: preparatory work before going in; pulling out the retracted part of the protective leg; using the tree running tool (LTRT) to install the subsea christmas tree. In this paper, the author introduces the installation procedure of subsea christmas tree detailedly, which is important in ensuring the independent and efficient development of offshore gas fields. According to the FTA analysis of throttle module, wellhead connector module and tubing hanger module, the average failure probability of subsea christmas tree production stage is 25.82 times every 106 hours, and the average failure interval is 4.42 years.

Keywords: offshore gas field, subsea christmas tree, installation procedures, tree run tool (LTRT).

Lifan Luo¹ ✉, **Zhi Ji**², **Jingruo Yan**¹

¹ Engineering and Technical Supervision Center of PetroChina Changqing Oilfield Branch, Xi'an, China;

² 7th Oil Production Plant of PetroChina Changqing Oilfield Branch, Xi'an, China.

luolifan7_cq@petrochina.com.cn

Analysis of Reservoir Damage Mechanism and Prevention Measures for Deep Carbonate Gas Reservoir with High Sulfur Content

The carbonate rock is composed of dolomite, calcite, microcrystalline chert, goethite, calcium sulfate, and pyrobitumen. The porous medium of the carbonate reservoir displays significant variations in water saturation at notably low levels. The high-risk nature of the reservoir is primarily characterized by elevated temperature and pressure conditions, stress levels, abundant presence of H₂S and CO₂ gases, intense anisotropy; as well as fractures development and mineral sensitivity. This type of reservoir is highly susceptible to damage caused by leakage induced by factors such as water flow rate, salt content, alkalinity level, and stress conditions. Furthermore, it may lead to catastrophic accidents. Drawing from a comprehensive mineral description and analysis of reservoir rock sensitivity, this study elucidates the specific mechanisms accountable for formation damage in carbonate formations. These damages stem primarily from the interactions between sensitive minerals and alkaline working fluids or acidic gases, such as H₂S and CO₂. Elevated concentrations of these gases can disrupt the natural occurrence and microstructure of minerals, leading to particle movement and plugging within the formation's flow matrix, consequently impacting overall reservoir productivity. To address this challenge, diverse prevention and control strategies have been proposed to mitigate such damage during drilling operations, well killing procedures, and reservoir renovation activities. These strategies are tailored to consider the distinctive characteristics of carbonate formations, particularly their susceptibility to alkaline or acidic fluids with an aim to minimize disruption of the formation's inherent mineralogy and microstructure. The findings presented not only contribute significantly towards controlling formation damage in highly H₂S-rich carbonate reservoirs but also establish a robust theoretical foundation for studying and applying development technologies in gas reservoirs characterized by high concentrations of H₂S. By comprehending

the specific mechanisms underlying formation damage, researchers and engineers can devise more effective strategies for preventing and managing such issues, ultimately enhancing gas reservoir productivity and longevity.

Keywords: *carbonate rock, oil and gas reservoir, high Sulphur, formation damage, sulfur deposition.*

Ziming Zhang ✉

PetroChina Liaohe Oilfield Company, Panjin, China.

rock_stress@163.com

Current Situation and Existing Problems of Horizontal Well Fracturing Technology

Horizontal wells offer numerous advantages in the petroleum industry, making them a focal point for research and practice. These wells have a large drainage area, high well output, extensive penetration, high reserve utilization, and the ability to avoid obstacles and challenging environmental conditions. However, in low permeability oil and gas reservoirs, horizontal wells face challenges such as poor connectivity and seepage resistance which hinder production from meeting economic development requirements. To address these challenges, domestic and international fracturing designs for horizontal wells have been developed. Staged fracturing technology for horizontal wells has also been implemented to improve production efficiency. Despite these advancements, there are still main issues present in horizontal well fracturing that need to be addressed This paper aims to provide insights into the various techniques used in fracturing horizontal wells both domestically and internationally. By addressing the challenges encountered in horizontal well fracturing and proposing potential solutions, this paper can serve as a valuable reference for similar reservoir developments. It is crucial for the petroleum industry to continue researching and advancing current technologies to optimize the productivity of horizontal wells in order to effectively meet economic development demands.

Keywords: *horizontal well, fracturing, stage fracturing, status quo, low permeability reservoir.*

Xiaofei Jia^{1,2}, Yingxian Liu², Guanglun Lei^{1,2,3}, Chuanjin Yao^{1,2,3} ✉

¹ School of Petroleum Engineering, China University of Petroleum (East China), Qingdao, China;

² Bohai Oilfield Exploration and Development Research Institute, CNOOC China Limited, Tianjin Branch, Tianjin, China;

³ Shandong Provincial Key Laboratory of Oilfield Chemistry, China University of Petroleum (East China), Qingdao, China.

cy375@upc.edu.cn

Oil Displacement Efficiency of High-Power Water Flooding Displacement

Core Experiment and Transformation Method of Reservoir Scale in Different Well Patterns

In this paper, mechanism for enhancing oil displacement efficiency by high-power water flooding displacement from pore-throat scale were studied by high-power water flooding and nuclear magnetic resonance (NMR) experiments. Transformation method from core scale to reservoir scale was established by high-power water flooding displacement law of core experiment and seepage characteristics in different well patterns. The results indicated that there is a logarithmic function between oil displacement efficiency and displacement multiple in the process of high-power water flooding. After water flooding 2000 times pore volume, the relaxation time peak region was moved right and

enlarged, the short relaxation time signal intensity peak was decreased, the average pore-throat radius was increased, and the ratio of pore radius to throat radius was decreased, so cluster-like residual oil, stuck-like residual oil, and island-like residual oil could be mobilized. After high-power water flooding, core wettability changed from weak-lipophilic to weak-hydrophilic active, so film-like residual oil could be mobilized. And oil displacement efficiency computing model of reservoir scale for inverted nine-spot well pattern, line well pattern, and five-spot well pattern was established. Oil displacement efficiency of reservoir scale increases with the increase of injection volume and decreases with the increase of well spacing. Oil displacement efficiency of reservoir scale in line well pattern and five-spot well pattern is higher than that in inverted nine-spot well pattern with the same injection volume and well spacing. In 2008, an inter-well infill scheme was implemented in Bohai S oil field, well pattern was adjusted from an inverted nine-spot to a line well pattern. By the end of 2020, the displacement multiple of the whole reservoir increased from 0.21 to 1.28, oil displacement efficiency of the reservoir scale increased from 38.9% to 47%, with an increase of 8.1%, which is 3.5% higher than the continued maintain the development of the inverted nine-spot well pattern. The results of the study are of great significance in guiding the actual development of the oil field.

Keywords: high-power waterflooding, core displacement experiment, NMR test, water flooding efficiency, reservoir scale, transformation method.

Zihong Wu¹ ✉, **Min Zhao**², **Jinlong Liu**³, **Jiayi Zhang**⁴, **Yifeng Li**⁵

¹ College of Fine Arts and Design/College of International Education, Hunan City College, Yiyang, China;

² Shaanxi Logistics Group Co., Ltd., Shaanxi, China;

³ Ninth Oil Production Plant, Changqing Oilfield Branch, PetroChina, Yinchuan, Ningxia, China;

⁴ Shale Oil Development Branch, Qingyang, Gansu, China;

⁵ Fifth Oil Production Plant, Qinghai Oilfield Branch, PetroChina, Mangya, Qinghai Province, China.

wytg2947@126.com

Durability of Polypropylene Films in the Aspect of Petrochemical Product Safety for Packaging Materials Design

Petrochemical products face challenges under extreme conditions like high temperatures, UV radiation, and humidity, which accelerate the aging of polypropylene (PP) films and degrade their mechanical properties. This increases the risk of material failure, potentially leading to petrochemical leaks and posing ecological and safety hazards. This study focuses on the aging behavior of PP films, aiming to understand how environmental factors contribute to their degradation and exploring design solutions that can mitigate these risks and improve material durability.

Thermogravimetric analysis and differential scanning calorimetry were employed to analyze the thermal stability of PP films under high-temperature conditions. The results show that the mass loss of modified PP materials was less than 10% at 500°C, while the decomposition temperature of multilayer composite PP materials was significantly higher than that of traditional single-layer PP materials. Furthermore, dynamic mechanical analysis (DMA) and impact tests were conducted to assess the brittleness of PP films in low-temperature environments. It was found that the impact strength of single-layer PP materials decreased by 75% at -100°C, whereas the modified PP materials maintained relatively stable impact performance. Hygrothermal aging and UV aging tests demonstrated that the tensile strength of multilayer composite PP materials decreased by only 16.3% after 1000 h of aging, and the increase in surface roughness was controlled within 0.78 μm, significantly outperforming single-layer materials. In the

moisture and permeability tests, the water vapor transmission rate (WVTR) of the composite PP sealing structure was 0.18 g/m²-day, and the oxygen transmission rate (OTR) was 3.5 cm³/m²-day, showing superior performance compared to other sealing structures. By optimizing the material structure design and introducing composite sealing technology, this study significantly enhances the overall performance of PP packaging materials under extreme conditions, providing reliable protection for the safe storage and transportation of petrochemical products.

Keywords: polypropylene films, packaging materials, weather resistance, multilayer composite materials, sealing technology, storage and transportation.

*Lv Yanjun*¹ ✉, *Mao Jiashu*¹, *Tian Yuan*¹, *Li Xinnin*², *Lv Jianwen*¹

¹ Xi'an Halix Petroleum Technology Co., Ltd., Oil and Gas Exploration Cooperation Laboratory, Xi'an, China;

² PetroChina Tuha Oilfield Branch, Xinjiang, China.

jinwen9063526@163.com

Study on CO₂ Injection Enhanced oil Recovery Method and Buried Mechanism in Low Permeability Gas reservoir

In order to improve the effect of CO₂ injection in low-permeability gas reservoir for enhanced oil recovery and buried technology, taking a sample well as an example, the experiment of CO₂ injection for gas displacement was carried out. In the study, numerical simulation method was used to optimize the gas drive scheme, water drive scheme, total CO₂ injection volume, injection timing, well soak system, the effect of diffusion on CO₂ drive and adsorption conditions, so as to enhance CO₂ injection for enhanced oil recovery in low-permeability gas reservoir. The simulation results show that CO₂ rich industrial waste gas injection can improve the recovery of shale gas to a certain extent, and the gas injection volume has an impact on the recovery of shale gas and the relative adsorption capacity of waste gas. Although the recovery of shale gas has been improved to a certain extent, the ratio of adsorbed gas to total injected gas will be reduced. Therefore, the optimal injection volume is determined to be 80000 m³/day, and 0.440PV is determined as the optimal time for reinjection. The maximum recovery of shale gas can be achieved by soaking the well in January at 1.408PV for different soaking time and duration. Under different diffusion coefficients, gas reservoir production and CO₂ storage have certain effects, and adsorption has little effect on CO₂ injection EOR. However, with adsorption, the EOR effect of CO₂ injection is 0.7% higher than that without adsorption. In terms of sequestration, CO₂ breakthrough time is later when considering adsorption, indicating that more CO₂ is left in the formation, which increases the stability of CO₂ sequestration. The simulation results show that adsorption increases the CO₂ sequestration by 17.8%, about 0.7·10⁶t, indicating that adsorption is conducive to CO₂ sequestration.

Keywords: low permeability gas reservoir, CO₂, recovery rate, burial mechanism, gas drive scheme, water drive scheme, diffusion, timing of conversion.

Xiaoyu Fang^{1,2,3}, *Chuixian Kong*⁴, *Yanxin Lv*⁵ ✉, *Gongran Liu*⁶ ✉, *Jiaojiao Chen*⁶, *Guifeng Wang*⁷

¹ State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China;

² CAS Center for Excellence in Deep Earth Science, Guangzhou, China;

³ University of Chinese Academy of Sciences, Beijing, China;

⁴ Research Institute of Exploration and Development, PetroChina Xinjiang Oilfield Company, Karamay, China;

⁵ Southern Marine Science and Engineering Guangdong Laboratory (Zhanjiang), Zhanjiang, China;

⁶ Sanya Hydrogeological Engineering Geological Survey Institute, Sanya, China;

⁷ Marine Geological Institute of Hainan Province, Haikou, China.

lv.yanxin@hotmail.com, 276952304@qq.com

Discontinuity Stability Analysis for Carbon Dioxide Enhanced Oil Recovery

Carbon dioxide (CO₂) enhanced oil recovery (EOR) is considered to be an effective measure to increase oil productivity by injecting CO₂ into reservoirs. Nevertheless, the injection of CO₂ can potentially induce instability in discontinuities such as faults and fractures within the reservoir, influencing the safety and efficiency of the operation. Qualitative analysis of fault stability was implemented in the integrated process of CO₂-EOR, by integrating fluid dynamics models, in-situ stress conditions and rock mechanics parameters. The results show that there is a pressure decreasing region around the oil producer, and CO₂ injection has a prominent influence on reservoir pressure maintenance. The reservoir pressure and liquid flow of oil producer is slightly higher from the beginning of CO₂ injection. The minimum effective normal stress and the maximum slip tolerance of the faults are aligned with the axis between the CO₂ injector and the oil producer. The fault friction angle is the primary factor in discontinuity stability analysis, influencing the slip rate and mode during CO₂-EOR. The larger the friction angle, the fewer faults are in the critical slip state. Fault stability analysis is a complete assessment, indicating that a fault may remain stable even if certain parts reach a critical state.

Keywords: CO₂ EOR, fault stability, enhanced oil recovery, gas injection, oil production.

I. R. Vezirov✉, **U. R. Vezirov**, **E. G. Telyashev**

Ufa State Petroleum Technical University.

ivezirov@yandex.ru

Improving Technology of Vacuum Distillation of Petroleum Products

The article reviews the main directions of development of vacuum units at oil refining plants. The indicators that are being subjected to updating because of growing quality requirements of the feedstock for production of fuel-lubricant materials are determined. Several types of vacuum creating system used at oil refineries and their merits and demerits are presented. The methods for separating wide vacuum distillates into narrower ones are analyzed. An improved fractionation scheme that ensures reliability of the process and less energy consumption is described.

Keywords: vacuum column, hydrojector vacuum creating system, residual fuel oil, residual pressure.

I. R. Vezirov✉, **U. R. Vezirov**, **E. G. Telyashev**

Ufa State Petroleum Technical University.

ivezirov@yandex.ru

Updating Vacuum Creating Systems

The article analyses the operation of the existing vacuum creating systems. The dependencies between the attainable degrees of vacuum on the chosen refrigerants and devices are presented. Solutions for updating existing vacuum

creating systems are offered. A comparative analysis was made of vacuum creating systems of various oil refineries where different degrees of vacuum are attained due to differences in the adopted technical measures.

Keywords: *vacuum column, hydroejector vacuum creating system, residual pressure, working fluid, “dry” distillation.*

I. R. Vezirov✉, **U. R. Vezirov**, **E. G. Telyashev**

Ufa State Petroleum Technical University.

ivezirov@yandex.ru

Improving Efficiency of Equipment of Two-Stage Vacuum Creating Systems

The article examines the distinctive features of operation of a two-stage hydroejector vacuum creating system and describes the process scheme. The dependencies of the yield of the components of the gas-vapor mixture from the working fluid of the second stage and the heat consumption of the two stages on the temperature were analyzed and the optimal conditions for the process were determined. Schemes of separators with replenishment are given. The influence of the location of the replenishment point on the separation efficiency was analyzed and the disadvantages of the existing two-stage vacuum creating systems were identified. Technical solutions are presented to improve the efficiency of the main equipment of the two-stage vacuum creating systems. The advantages are well-founded and sketches of the developed structures are presented.

Keywords: *gas-liquid mixture, hydroejector vacuum creating system, residual pressure, replenishment, working fluid.*