

# Chemistry and Technology of Fuels and Oils

## 5<sup>(627)</sup>'2021

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Publisher— ICST «TUMA Group» LLC

Редактор

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Адрес редакции:

119991, ГСП-1, Москва, В-296,

Ленинский просп., 65. РГУ нефти и газа  
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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

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### **Применение биоугля в качестве наполнителя полимочевинных смазок**

*В работе изучена возможность использования биоугля растительного происхождения в качестве наполнителя полимочевинных пластичных смазок и оценено его влияние на их эксплуатационные свойства. При получении смазок в качестве дисперсионных сред использовали нефтяное масло III группы и сложный эфир диоктиладипинат, а в качестве загустителя — димочевину концентрацией 20%. Установлено, что смазки, содержащие 5–15% мас. биоугля, лучше уменьшают диаметр пятна износа и характеризуются более высокой коллоидной стабильностью по сравнению с образцами, не содержащими биоуголь. Добавка к дисперсионным средам 1% мас. загущающей полиизобутиленовой присадки ПИБ 10 улучшает эксплуатационные свойства смазки.*

**Ключевые слова:** биоуголь, полимочевинные смазки, трибологические характеристики, реологические характеристики.

DOI 10.32935/0023-1169-2021-627-5-3-8

**B. P. Tonkonogov, A. Yu. Kilakova, D. I. Daudi, A. D. Spiridonova, A. Yu. Krylova, R. Z. Safieva**

Gubkin Russian State University of Oil and Gas (National Research University)

### **Application of Biochar as a Filler of Polyurea Lubricants**

*The possibility of using plant-based biochar as a filler for polyurea greases was studied and its effect on their performance properties was evaluated. In the preparation of lubricants, group III petroleum oil and dioctiladipinate ester were used as dispersion media, and dimourea with a concentration of 20% was used as a thickener. It was found that lubricants containing 5-15 wt.% biochar, better reduce the diameter of the wear spot and are characterized by higher colloidal stability compared to samples that do not contain biochar. Additive to dispersion media 1 wt.% of the thickening polyisobutylene additive PIB 10 improves the performance properties of the lubricant.*

**Key words:** biochar, polyurea lubricants, tribological characteristics, rheological characteristics.

**Р. Р. Закиева<sup>1</sup>, Н. Ю. Башкирцева<sup>1</sup>, С. М. Петров<sup>1</sup>, А. И. Лахова<sup>1,2</sup>**

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### **Облагораживание тяжелой нефти**

#### **в гидротермальной среде в присутствии модифицированных алюмосиликатов**

*Представлены результаты облагораживания сверхтяжелой нефти плотностью 0,9857 г/см<sup>3</sup> с содержанием серы 3,6% мас. в среде перегретого пара при температуре 355–375°C и давлении до 14 МПа в присутствии модифицированных железом природных алюмосиликатов. Использование модифицированных алюмосиликатов, содержащих оксиды железа, алюминия и кремния, в процессе облагораживания тяжелой нефти привело к двукратному снижению содержания в ней смолисто-асфальтеновых компонентов. Кроме того, процесс облагораживания привел к увеличению содержания в легких фракциях, выкипающих*

до температуры 300°C, преобразованной нефти разветвленных алканов обладающих высоким октановым числом, а также к снижению вязкости нефти на 60%.

**Ключевые слова:** гидротермальные системы, тяжелая высоковязкая нефть, железосодержащий алюмосиликат, SARA анализ.

DOI 10.32935/0023-1169-2021-627-5-9-13

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### **Upgrading of Heavy Oil in a Hydrothermal System in the Presence of Modified Aluminosilicates**

*The results of upgrading heavy crude oil with a density of 0.9857 g/cm<sup>3</sup> and a sulfur content of 3.6% wt. are presented. In an environment of superheated steam in the temperature range 355-375°C and pressures up to 14 MPa in the presence of iron-modified natural aluminosilicates. The use of modified aluminosilicates containing oxides of iron, aluminum and silicon in the process of upgrading heavy oil led to a twofold decrease in the content of resinous-asphaltene components in it. In addition, the upgrading process led to an increase in the content in light fractions, boiling up to a temperature of 300°C, of the converted oil of branched alkanes with a high octane number, as well as to a decrease in oil viscosity by 60%.*

**Key words:** hydrothermal systems, heavy crude oil, iron-containing aluminosilicate, SARA analysis.

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### **Конверсия сверхвязкой нефти Ашальчинского месторождения в присутствии активного угля и сверхкритического водного флюида**

*В статье представлены результаты первичной переработки тяжелой сверхвязкой нефти в присутствии угля и сверхкритического водного флюида, позволяющей значительно снизить в ее составе содержание серы и смолисто-асфальтеновых веществ, увеличить количество светлых топливных фракций. Выявлены отличительные особенности изменения состава и свойств жидких продуктов конверсии сверхвязкой нефти в гидротермальном флюиде при температуре 420°C, а также в присутствии активного угля при температуре 375°C. Показана возможность снижения температуры конверсии сверхвязкой нефти за счет наличия в реакционной среде активного угля. Установлено, что образование светлых фракций в преобразованной сверхвязкой нефти в гидротермальном флюиде в присутствии активного угля происходит за счет деструкции смолисто-асфальтеновых компонентов. Разрабатываемая технология направлена на экологически безопасную и безостаточную переработку тяжелых углеводородных ресурсов с получением качественного сырья, обогащенного топливными фракциями.*

**Ключевые слова:** акватермолиз, тяжелая сверхвязкая нефть, активный уголь, рентгеноструктурный анализ, электронная микроскопия.

DOI 10.32935/0023-1169-2021-627-5-14-19

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### **Processing of Heavy Crude oil in the Presence of Coal and a Supercritical Aqueous Fluid**

*The article presents the results of the primary processing of heavy crude oil in the presence of coal and a supercritical aqueous fluid, which makes it possible to significantly reduce the content of sulfur and resinous-asphaltene substances in its composition, and to increase the amount of light fuel fractions. The work revealed the distinctive features of the change in the composition and properties of liquid products of the conversion of crude oil in a hydrothermal fluid at a temperature of 420 ° C, as well as in the presence of activated coal at a process temperature of 375 ° C and a similar pressure. The possibility of reducing the conversion temperature of crude oil due to the presence of active coal in the reaction medium is shown. It has been established that the formation of light fractions in the transformed heavy crude oil in a hydrothermal fluid in the presence of active coal occurs due to the destruction of resinous-asphaltene components. The developed technology is aimed at environmentally safe and residue-free processing of heavy hydrocarbon resources to obtain high-quality raw materials enriched with fuel fractions.*

**Key words:** *aquathermolysis, heavy crude oil, activated coal, X-ray diffraction analysis, electron microscopy.*

*A. A. Кучиерская, А. В. Дияковская, А. Р. Сайфутдинова, А. П. Семенов, А. А. Новиков*

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### **Аппроксимация границы расслоения в тройных системах вода — гидротроп — масло**

*В данной работе изучены тройные системы вода — 2-бutoксиэтанол–толуол, вода – метанол — хлороформ и вода – метанол – дихлорметан. Экспериментально определено положение границы расслоения и проведена ее аппроксимация различными функциями. Выявлены основные причины, препятствующие удовлетворительной аппроксимации границ расслоения эмпирическими функциями с малым числом оптимизируемых параметров. Установлено, что аппроксимация границ расслоения в тройных системах может быть проведена полиномиальными и кусочно-гладкими функциями с погрешностью, сравнимой с ошибкой эксперимента.*

**Ключевые слова:** *равновесие жидкость — жидкость, адсорбция, критические флуктуации, растворимость.*

DOI 10.32935/0023-1169-2021-627-5-20-22

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Gubkin Russian State University of Oil and Gas (National Research University)

### **Approximation of the Separation Boundary in the Water-Hydrotrope-Oil Ternary Systems**

*In this work, we studied the ternary systems water – 2-butoxyethanol – toluene, water – methanol – chloroform and water – methanol – dichloromethane. The separation boundary was experimentally located and approximated by various functions. The main reasons are revealed that prevent a satisfactory approximation of the separation boundaries by empirical functions with a small number of optimized parameters. It is found that the approximation of the separation boundaries in ternary systems can be carried out by polynomial and piecewise smooth functions with an error comparable to the uncertainty of the measurement.*

**Key words:** *liquid-liquid equilibrium, adsorption, critical fluctuations, solubility.*

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### **Адсорбция фенола нитро- и аминопроизводными нефтяных асфальтенов**

*Изучены сорбционные свойства нативных и модифицированных нефтяных асфальтенов по отношению к фенолу в статических условиях. Модификация асфальтенов осуществлялась нитрованием с последующим восстановлением сульфидом натрия. На основании полученных данных построены изотермы сорбции фенола и рассчитаны уравнения процессов адсорбции. Найдено, что наиболее корректно изотермы адсорбции могут быть описаны уравнениями Фрейндлиха и Ленгмюра. Выявлено, что процесс осуществляется за счет физической адсорбции.*

**Ключевые слова:** асфальтены, нитроасфальтены, аминоасфальтены, сорбенты, фенол, сточные воды, модель Ленгмюра, модель Фрейндлиха, модель Дубинина — Радушкевича.

DOI 10.32935/0023-1169-2021-627-5-23-27

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### **Nitro- and Amino Derivatives of Petroleum Asphaltenes: Application to Phenol Adsorption**

*The sorption properties of native and modified petroleum asphaltenes with respect to phenol have been studied under static conditions. Modification of asphaltenes was carried out by nitration, followed by reduction with sodium sulfide. Based on the data obtained, phenol sorption isotherms were constructed and the equations for the adsorption processes were calculated. It was found that the adsorption isotherms can be described most correctly by the Freundlich and Langmuir equations. It was revealed that the process is carried out due to physical adsorption.*

**Key words:** asphaltenes, nitroasphaltenes, aminoasphaltenes, sorbents, phenol, wastewater, Langmuir model, Freundlich model, Dubinin – Radushkevich model.

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### **Определение естественной убыли бензина и дизельного топлива при хранении в резервуарах**

*В данной работе изучены процессы испарения бензина и дизельного топлива при их хранении. Проведена оценка температурной зависимости содержания паров углеводородов в газовой фазе над нефтепродуктами. Установлено, что экспериментальные данные наилучшим образом*

описываются эмпирическим уравнением на основе уравнения Антуана. Предложен алгоритм расчета естественной убыли бензина и дизельного топлива, а также возможности ее снижения.

**Ключевые слова:** потери из-за испарения, уравнение Антуана, равновесие газ — жидкость, колебания температуры.

DOI 10.32935/0023-1169-2021-627-5-28-31

*D. S. Kopitsyn<sup>1</sup>, P. A. Gushchin<sup>1</sup>, A. A. Panchenko<sup>1</sup>, F. V. Timofeev<sup>2</sup>, D. N. Sokolov<sup>2</sup>, A. A. Novikov<sup>1</sup>*

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### **Determination of Natural Loss of Gasoline and Diesel Fuel during the Tank Storage**

*In this work, we studied the processes of evaporation of gasoline and diesel fuel during their storage. We assessed of the temperature dependence of the content of hydrocarbon vapors in the gas phase over petroleum products. It was found that the experimental data are best described by the empirical equation based on the Antoine equation. An algorithm is proposed for calculating the natural loss of gasoline and diesel fuel, as well as approaches to its reduction.*

**Key words:** evaporative losses, Antoine equation, vapor-liquid equilibrium, temperature oscillations.

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### **Хроматографические методы исследования углеводородного состава дизельных топлив**

*Проведено исследование группового углеводородного состава базовых летних дизельных топлив различных нефтеперерабатывающих заводов России с применением методов газовой и высокоэффективной жидкостной хроматографии. Показано, что экспериментальные результаты, полученные с помощью данных методов, а именно содержание нормальных парафинов, суммарное содержание парафино-нафтеновых и ароматических углеводородов, не дают достаточной информации для прогнозирования физико-химических и эксплуатационных свойств дизельных топлив. Для более детального изучения углеводородного состав дизельных топлив был применен метод двумерной газовой хромато-масс-спектрометрии, позволяющий определить соотношение нормальных и изоалканов, содержание моно-, би- и полициклических нафтеновых и ароматических углеводородов и объяснить различия между углеводородным составом топлив, характеризующихся схожими эксплуатационными показателями.*

**Ключевые слова:** дизельное топливо, эксплуатационные свойства, групповой углеводородный состав, газожидкостная хроматография, высокоэффективная жидкостная хроматография, двумерная газовая хромато-масс-спектрометрия.

DOI 10.32935/0023-1169-2021-627-5-32-38

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## **Chromatographic Methods for Analysis of Hydrocarbon Composition of Diesel Fuel**

*A study of the hydrocarbon-type content of the base summer diesel fuels of various oil refineries in Russia was carried out using the methods of gas chromatography and high-performance liquid chromatography. It is shown that the experimental results obtained using these methods, namely the content of normal paraffinic, the total content of paraffin-naphthenic and aromatic hydrocarbons, do not provide sufficient information to predict the physicochemical and performance properties of diesel fuels. The method of two-dimensional gas chromatography-mass spectrometry was applied for a more detailed study of the hydrocarbon composition of diesel fuels, which made it possible to determine the ratio of normal and isoalkanes, the content of mono-, bi- and polycyclic naphthenic and aromatic hydrocarbons, and to explain the differences between fuels with similar performance characteristics.*

**Key words:** *diesel fuel, performance properties, group hydrocarbon composition, gas liquid chromatography, high-performance liquid chromatography, two-dimensional gas chromatography-mass spectrometry.*

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## **Влияние конструкции крана-дозатора на эффективность анализа нестабильного газового конденсата**

*При анализе нестабильного газового конденсата с использованием прямого ввода пробы в хроматограф существенное влияние на точность и повторяемость анализа оказывает конструкционные особенности и рабочие параметры крана-дозатора. В данной работе изучено влияние на эффективность анализа нестабильного газового конденсата (ГСО 10525–2014) при вводе пробы в хроматограф без разгазирования характеристик кранов-дозаторов двух типов: дозатора проб высокого давления в высокотемпературном исполнении и крана-дозатора с инжектором бесшприцевого ввода. Показано, что использование крана дозатора с обогреваемым штоком позволяет достичь высоких метрологических характеристик.*

*При использовании крана-дозатора с инжектором без обогрева штока наблюдалось существенное отклонение результатов анализа от нормативных требований для углеводородов начиная с C<sub>28</sub>.*

**Ключевые слова:** кран-дозатор, нестабильный газовый конденсат, устройство ввода пробы, разгазирование.

DOI 10.32935/0023-1169-2021-627-5-39-44

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## **Influence of the Dispenser Valve Design on the Efficiency of Analysis of Unstable Gas Condensate**

*When analyzing unstable gas condensate using direct sample injection into the chromatograph, the design features and operating parameters of the sampling device have a significant impact on the accuracy and repeatability of the analysis. In this work, the influence of the characteristics of two types of sampling devices was studied: a high-pressure sampler in a high-temperature design; a sampler with a syringe-free injector, on the efficiency of the analysis of unstable gas condensate (GSO 10525–2014) using the direct injection method. It was shown that the use of a high-pressure sampler in a high-temperature design allowed achieving high accuracy and repeatability of analysis (data correspond to STO Gazprom 5.5–2007). When using a standard sampler, a significant deviation from the regulatory requirements for hydrocarbons starting from C<sub>28</sub> was observed.*

**Key words:** *sampling device, unstable gas condensate, probe degassing, accuracy, repeatability, gas chromatography.*

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### **Производные 2,5-димеркапто-1,3,4-тиадиазола в качестве многофункциональных присадок к смазочным маслам**

*Исследования в области присадок по сей день остаются значимыми для многих нефтяных компаний. Динамично развивающийся рынок смазочных материалов требует поиска перспективных продуктов для их производства и составления новых рецептур. В последнее десятилетие стратегическим контекстом для отечественной нефтепереработки является разработка собственных присадок, композиций и пакетов. В статье рассмотрены направления по выбору перспективных продуктов на основе соединения, которое является базисным для синтеза многофункциональных присадок.*

**Ключевые слова:** 2,5-димеркапто-1,3,4-тиадиазол, многофункциональные присадки, смазочные материалы  
DOI 10.32935/0023-1169-2021-627-5-45-52

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### **Derivatives Based on 2,5-Dimercapto-1,3,4-Thiadiazole as Multifunctional Additives for Lubricating Oils**

*Additives' research remains relevant to many oil companies for this day. The dynamically developing market of lubricants requires the search for promising products for their production and the preparation of new compositions. In the last decade the strategic context for domestic oil refining has been the development of its own additives, compositions and packages of additives. The article discusses the trend of the selection of promising products based on a compound, which is the basis for the synthesis of multifunctional additives.*

**Key words:** *2,5-dimercapto-1,3,4-thiadiazole, multifunctional additives, lubricants.*



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### **Абиотическая деградация нефтяных асфальтенов**

*В работе обобщены и систематизированы имеющиеся литературные данные, посвященные процессам абиотической деградации асфальтенов, которые могут протекать в естественных природных условиях. В частности, показано, что воздействие солнечного света, а особенно ультрафиолетового излучения, запускает в асфальтенах реакции фотолиза и фотоокисления, приводящие к увеличению содержания в них доли кислорода, тем самым смещая гидрофильно-липофильный баланс в сторону гидрофильности, увеличивая доступность продуктов реакции для последующей биотической деградации микроорганизмами. Воздействие ионизирующего излучения, не приводит к значительному изменению молекулярного состава асфальтенов, в силу их высокой радиационной стойкости. Исключение составляет облучение асфальтенов интенсивными электронными пучками, приводящее к их значительной деградации.*

**Ключевые слова:** асфальтены, абиотическая деградация, фотодеградация, радиолиз.

DOI 10.32935/0023-1169-2021-627-5-53-56

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### **Abiotic Degradation of Oil Asphaltens**

*This review is devoted to the generalization and systematization of the available literature data on the processes of abiotic degradation of asphaltenes, which can occur in natural conditions. In particular, it was shown that exposure to sunlight, and especially UV radiation, triggers photolysis and photooxidation reactions in asphaltenes, leading to an increase in the oxygen content in them, thereby shifting the hydrophilic-lipophilic balance towards hydrophilicity. At the same time the availability of reaction products for subsequent biotic degradation by microorganisms is increased. Exposure to ionizing radiation does not lead to a significant change in the molecular composition of asphaltenes, due to their high radiation resistance. As exception there is the irradiation of asphaltenes with intense electron beams, which leads to their significant degradation.*

**Key words:** asphaltenes, abiotic degradation, photodegradation, radiolysis.

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### **Scalar and Vector Evaluation Methods for Remaining Oil Potential of Water-Driven Reservoirs**

*In recent years, numerical simulation and streamline simulation methods have been commonly used for characterizing and evaluating oil reservoirs. The conventional characterization parameters include oil saturation, remaining*

reserves abundance, flow path, etc. However, information obtained from the conventional characterization parameters is limited. For instance, the residual oil saturation and remaining reserves abundance do not consider the remaining oil flow capacity, and the flow path characterization does not consider the remaining oil potential. In this paper, based on numerical simulation and streamline simulation techniques, the authors have established new scalar and vector evaluation methods for the remaining oil potential in water-driven oil reservoirs. First, to reflect the displacement effect in different areas from a scalar perspective, we propose new parameters characterizing the remaining oil potential abundance: the remaining oil flow capacity ( $J$ ) and hydrodynamic strength ( $HS$ ). Based on the established  $J$  and  $HS$  values, the oilfield is divided into four regions. Second, to reflect the fluid flow between injection and production wells from a vector perspective, we propose the parameters of total flow rate ( $F$ ), the remaining oil development potential ( $P$ ), and the oil cut of the fluid in the flow path ( $f_o$ ). To verify the theoretical model, the developed scalar and vector evaluation methods were applied in the Bohai Bay oilfield in China. Based on the evaluation results, measures to increase oil production were proposed. The field tests results show that after the proposed measures were implemented in two test wells, the resulting average daily oil production increased by 40%. The scalar and vector evaluation methods proposed in this study can provide support for the quantitative evaluation of the reservoir development potential. The evaluation results can be used as the basis for the selection of further steps in the middle and late stages of oilfield development.

**Keywords:** remaining oil evaluation; scalar evaluation; vector evaluation; flow field reconstruction.

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### **Analysis of Casing Instability and Factors Influencing It in Thermal Production Oil Wells**

*In the process of thermal recovery of heavy oil, the casing in oil production wells is subjected to complex stress conditions, which may cause potential damage and affect the lifecycle of the casing. The factors influencing the casing instability and the mechanism of the process in thermal production wells need to be comprehensively researched, particularly in the case where oil extraction is accompanied by sand production. In this paper, the authors have applied the three-dimensional finite element method to simulate the casing instability characteristics in the sand production section of a thermal recovery well. We have also analyzed the effect of sand production, perforation parameters, and the casing strength parameters on the axial and circumferential instability of the casing. The results show that sand production can cause a significant decrease in the lateral support of the casing and greatly reduce the buckling resistance of the casing in a thermal horizontal well. With increase in perforation diameter and perforation density, the critical buckling load of the casing decreases. On the other hand, the buckling load is less affected by the perforation phase. When the combination of the perforation density and perforation phase angle results in a bigger number of perforation holes in the row, it can significantly reduce the casing collapse strength and increase the risk of circumferential instability. The research results provide a theoretical basis in the design of casing in horizontal sections of thermal production wells.*

**Keywords:** thermal production well, casing instability, perforation parameters, collapse strength, sand production, finite element modeling.

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### **Comparative Analysis of Fracture Characteristics and Mechanical Properties of Shale and Slate Based on Triaxial Compression Test**

*In this paper, to study the failure characteristics and mechanical properties of slate and shale, the authors have conducted triaxial tests on shale and slate samples. To evaluate the peak stress and the destruction mode in the samples, the tests are performed on a triaxial rock-mechanical testing system. The experimental results show that compression would cause multiple cracks in shale. The cracks are characterized by a small width, and none of them are through cracks. When a slate sample is subjected to compressive failure, the developed cracks are characterized by a comparatively large opening, and some cracks are through. The compressive strength of shale is three times higher than the compressive strength of slate, and the Poisson's ratio of shale is lower than that of slate. In the process of compressive failure of shale, the deformation is small, and the strain increases linearly along the direction of the principal stress. In the process of deformation of slate, the deformation is great, and the strain increase is divided into two stages – fast increase and slow increase. Comparison of mechanical properties of these types of rock with different lithology can provide important background for shale gas reservoir fracturing and slate foundation consolidation.*

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### **Production of Hydrocarbon Fuel Precursors From Bamboo in the Acetone/Lithium Bromide System**

*The process of liquefaction catalyzed by acid in the acetone/lithium bromide system is an efficient method of transforming lignocellulosic biomass into hydrocarbon fuel precursors. In this study, the authors have investigated the effect of reaction temperature, residence time, and dosage of the catalysts on the liquefaction yield and composition of bio-oil precursors produced from the bamboo powder. To understand the liquefaction mechanism, the reaction of liquefaction is compared with the reaction of transformation of sugars and bamboo cellulose under the same conditions. The results show that 140°C is the optimum temperature of the liquefaction reaction. When the temperature is 140°C and the reaction time is 4 h, the bamboo liquefaction yield can reach 98.77%. It was also found that the acid dosage has a significant effect on both the liquefaction yield and the composition of the hydrocarbon fuel precursors. With increase in the dosage of the acid, the yield increases. Most phenols produced in the reaction of liquefaction originate from lignin, while most ketones and hydrocarbon precursors are produced by the transformation of cellulose and hemicellulose.*

**Keywords:** bamboo, acetone/lithium bromide system, catalytic liquefaction, hydrocarbon precursors.

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**Analysis of flow characteristics and influencing factors of severe slugging flow in an underwater pipe-catenary riser**

*Most of the earth's surface is covered by seas. Deep underwater reservoirs have abundant resources of oil and gas. In the development of offshore oil and gas reservoirs, oil and gas transportation is performed by a pipe system combining a deep-water pipeline and a riser. In the process of transportation, differences in phase properties of the gas and liquid phases can cause severe slugging accidents. Therefore, studying the characteristics and influencing factors of the severe slugging phenomenon is important for the effective development of deep underwater fields. In this paper, the authors have established a three-dimensional numerical model of a deep-water pipeline-catenary riser. Based on the model, simulation of the transient multiphase is performed using the COMSOL simulation software. Applying the controlling variable method, we analyzed the flow characteristics, fluid velocity field, and bottom pressure of the riser for different types of severe slugging phenomenon and the influence of the angle and pressure in the inclined pipe on slugging. The results show that with decrease in the angle of the inclined pipe or with increase in the pipe diameter, the severe slugging period will increase; with increase in the angle of the pipe or decrease in the pipe diameter, the bottom pressure of the riser will also increase. The results of the research provide a theoretical basis for ensuring safe operation and maintenance of submarine pipelines.*

**Keywords:** offshore oil and gas field; deepwater pipeline-catenary riser system; severe slugging; flow characteristics; sub-marine pipeline.

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**Mechanical Properties of Shale under the Coupling Effect of Temperature and Confining Pressure**

*In this paper, the authors have studied the changes in the mechanical properties of shale caused by temperature and pressure changes in the process of shale gas development. The mechanical properties of shale are evaluated by the rock triaxial test method in the temperature range from 25°C to 120°C. Then, we have analyzed the influence of the temperature and pressure parameters on the stress-strain curves, peak stress, and elastic modulus characteristics of shale. The results show that the mechanical properties of shale change with change in temperature and confining pressure. With increase in temperature, the peak stress and the elastic modulus characteristics gradually decrease. With increase in the confining pressure, the peak stress increases significantly, and the elastic modulus also tends to increase. The research results have an important theoretical and practical significance for shale gas development.*

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### **Device and Method For Measuring the Efficiency of Spontaneous Imbibition and Displacement in a Low-Permeability Reservoir**

*In this paper, the authors have developed a new device and method for measuring the efficiency of spontaneous imbibition and displacement in a low permeability reservoir. The innovative design of the new experimental device effectively combines the traditional volumetric method and the weighing method. The improved reliability of experimental results is provided by the mutual verification of data of the two conventional techniques. The performance and effectiveness of the new method and the device have been verified by experimental tests on a low-permeability core. The results can be useful for understanding the self-priming oil displacement efficiency in a low permeability reservoir.*

**Keywords:** low permeability; spontaneous imbibition; oil displacement efficiency; measuring device.

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### **Research and Performance Evaluation of an Autogenic Acidic Fracturing Fluid System for High-Temperature Carbonate Reservoirs**

*Carbonate reservoirs in Western China are characterized by deep burial, high temperature, and strong heterogeneity. In this paper, based on the physical properties of high-temperature carbonate reservoirs, the authors have developed an autogenic acidic fracturing fluid suitable for high-temperature carbonate reservoirs. The performance of the new acidic fluid has been experimentally evaluated. The results show that the fluid demonstrates satisfactory viscosity-temperature performance, and after continuous shear tests at 140°C for 2 h the viscosity of the fluid remains about 100 mPa·s. At room temperature (RT), the pH value of the fluid is neutral, and the titratable acid concentration could reach 15.49% at 90°C. When subjected to high temperatures, the fluid is characterized by a high acid concentration, low acid generation rate, and moderate corrosion inhibition rate. The static rock corrosion rates of the fluid at room temperature and 140°C are 0.00009125 and 0.009575 g/min, respectively. The corrosion rate is slow, and the effective action distance of the fluid can be five times higher than that of a thickened acid and three times higher than that of a cross-linked acid. The experimental results verify the acid's ability to transform high-temperature carbonate reservoirs and good applicability in high-temperature carbonate reservoirs. The proposed autogenic acidic fracturing fluid system provides essential technical support for the efficient development of high-temperature carbonate reservoirs.*

**Keywords:** carbonate rock; autogenic acid; acidification; high temperature.

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### **Gas Overflow Model and Analysis in a Fractured Formation**

*At present, the wellbore overflow in a fractured gas reservoir is mainly characterized by qualitative methods. The development of quantitative methods would need a thorough theoretical study of the correlation between the overflow phenomenon and the complex drilling characteristics of the formation. In this paper, the authors have established a mathematical model of the deep-wellbore multiphase flow considering the parameters of wellhead pressure, annular equivalent diameter, wellhead gas flow, and drilling fluid displacement. The model has been solved by the Runge-Kutta method. The results show that the increase in the surface overflow increment correlates with the increase in the well depth. With increase in the surface overflow, the wellbore gas volume increases. When the local surface overflow is  $Q_g = 0.2 \text{ m}^3$  and the well bottom depth is 6000 m, the overflow volume at the bottom of the well increases from 0.000505 to 0.000649  $\text{m}^3$ . When the ground overflow increment is doubled, the gas volume at the depth of 6000 m increases by 34.72%.*

**Keywords:** overflow; void fraction; pressure wave velocity; two-phase; frequency.