Session 1

Abstract (#19350)

Title: The Synergy of Surfactant and Nanoparticles: Towards Enhancing Foam Stability

Authors: Zuhair AlYousif, Daivd Schechter

Saudi Aramco

Gas injection has been used widely for enhancing oil recovery in petroleum reservoirs. One of the major challenges facing this technique is the high mobility of gas caused by its lower viscosity compared to reservoir fluids. Injecting the gas in a foam phase can solve the mobility challenge by increasing the gas apparent viscosity. Surface active agents such as surfactants are usually used to generate foams. However, the long term stability of the surfactants is challenging. The synergistic effect of surfactants and nanoparticles (NPs) may offer a novel technique to solve the foam stability issue and generate stronger foams. This study evaluates the role of NPs on stabilizing surfactant foams in porous media. An anionic surfactant and surface modified silica NPs were used in this assessment. Dynamic foam tests were conducted to study the foam stability and strength in porous media. The major parameter to evaluate the foam strength is the mobility reduction factor (MRF). The experiments were conducted using nitrogen gas at elevated pressure. The influence of NPs on surfactant foam strength was conducted at different NPs concentrations and fixed surfactant concentration.
The results demonstrated that the presence of NPs in surfactant solution resulted in a more stable foam compared to surfactant alone. NPs used in this study seem to enhance the foam stability by either one or two mechanisms: particle arrangement during film drainage or increasing the capillary pressure of coalescence. Based on the dynamic foam tests, higher pressure drops were reported for the mixtures of NPs and surfactant compared to surfactant alone. This clearly indicated the higher resistance to gas flow caused by the foam generated using the mixture. The results also showed that as the NP concentration increased, MRF increased, too. The MRF for the sample contains only surfactant was 72. However, the addition of 0.50 and 1.00 wt% of NPs to the surfactant solution resulted in higher MRF: 75 and 85, respectively.

The need for generating strong foam is very important to ensure the long term stability of foam and, consequently, reducing the gas mobility in porous media. The addition of solid NPs to surfactant solutions might strengthen the aqueous film that separating gas bubbles and, eventually, enhancing the foam stability.

Abstract (#19281)

Title: Formulating Water-based Environmental Friendly Pre-flush System

Authors: Islam Hassan.

Modern National Chemicals

Aromatic based chemistries have been used extensively as additives in the pre-flush systems of acid stimulation programs. The need for these solvents stems from the requirement to displace oil or break asphaltic or waxy materials ahead of the main stimulation treatment. These chemicals while effective, are highly flammable, difficult to handle and have negative impact on the enviroment. Aromatic additives are always mixed with diesel-based pre-flush systems in acid stimulation jobs. If water is added to this system, the resultant emulsion damages the productivity of the formation. Water wetting surfactants typically of aqueous nature pose the same problems when mixed with diesel systems. The main challenge, however, is to mix these hydrocarbon-based fluids with water and surfactant to clean the wellbore and water-wet the formation face in preparation for the acid stimulation treatment.

The objective of this work was to evaluate new environment-friendly water-based pre-flush formulations for oil and injector wells. The new aqueous Pre-flush formulations was developed to avoid the aformentioned problems with using diesel. The new Pre-flush formulations include between 10-15% blend of specialty surfactants and solvents, successfully homogenized with low-cost field water. These formulations are able to alter the wettability of the formation face by breaking the oily phase and separating it from the surface of the formation. The new formulations have high flash points and are biodegradable which results in easier handling and an environment-friendly alternative to existing diesel pre-flush systems. Wettability, stability and interfacial tension tests at reservoir conditions helped optimized the new formulation.

The results showed excellent dissolving power for oily sludges and surfaces in addition to excellent stability and wettability. The new pre-flush formulations can enhance the reactivity of the acid with the formation and improve treatment results. It will enhance the flowback and post-treatment cleaning of the well.

Abstract (#19369)

Title: “First of its Kind” Application of Novel Conformance Chemical Technology in South Kuwait Field

Authors: Kutbuddin Bhatia, Abdullah Al Enezi, Bu-Mijdad Mohammed, KOC, and Alaa Alboueshi, Amr Abdelbaky, Halliburton.

Halliburton

A significant challenge in the mature South Kuwait Burgan field is assuring maximum hydrocarbon flow through high water-prone sandstone intervals. Recently, water control or conformance treatments have been considered to make oil production from these reservoirs more economically feasible. This paper discusses the application of a novel downhole chemical methodology, that has created a positive impact in overall productivity from this field.

The production profile in this field has been challenging in terms of increasing water volume, which poses a great threat to continued economic viability and may lead to lower production rates, reduction in recoverable reserves and to premature abandonment. Some of the production gathering centers cannot handle the ever increasing volumes of produced water and operate beyond design capacity. In order to solve this challenge, a downhole chemical treatment was modified as a fit-for-purpose treatment to address the unique challenges of electric submersible pump (ESP)-driven well operations, formation technical difficulties, high-stakes economics, and high water potential from these formations. A unique hydrophobically modified water-soluble polymer (HRPM) was implemented in a high water-cut well to selectively reduce water production. Because this well was producing with an ESP, the treatment was pumped down the annular space. A pre-flush was pumped ahead of the HRPM treatment to remove deposits that could prevent the polymer from effectively adsorbing to the rock surface. The treatment was then over displaced with brine.

This technology incorporates HRPM that is adsorbed on the rock surface resulting in the alteration of rock surface characteristics. The hydrophobic modification to the base polymer chain adds unique associative properties to the system, which selectively reduces the water\'s effective permeability in the reservoir, impeding water flow and facilitating increased hydrocarbon flow. A direct result of the implemented treatment is that the post-operation well test and production data show a high sustained hydrocarbon production at smaller choke size with significantly reduced water cut. This successful treatment confirmed the optimized conformance technology as a solution for the first well in this field.

In order to achieve maximum reduction in water production, this technology is customized based on the temperature and permeability of the treatment zones thus ensuring it is ‘fit for purpose’. Furthermore, this paper summarizes the candidate selection, design processes, challenges encountered, production response, and lessons learned from this treatment and can be considered a best practice for addressing high water production challenges in similar conditions in other fields.

Abstract (#19294)

Title: Development of new Kinetic Hydrate Inhibitors for gas field applications

Authors: Henry Delroisse, Frédéric Moser, Gilles Barreto

ARKEMA

The increase of the energy demand, over 25% by 2040 [1], and the will to reduce the environmental impact induce the growth of the gas production and the multiplication of the gas fields operated in extreme conditions. Low temperature conditions in addition of wet gas, water phase and potentially a condensate phase are generally conducive to hydrate formation. In such cases, Kinetic Hydrate Inhibitors (KHIs) may be used to delay gas hydrate nucleation and growth for a period. They are an interesting alternative to the addition of Thermodynamic Hydrate Inhibitors such as methanol or MEG. The main objective of this work is to evaluate the performance of new KHIs, Inipol® AH 36 (called AH36) and Inipol® AH 53 (called AH53), answering to the gas production scope of word. It is known that KHIs are less efficient to prevent the formation of structure I hydrate (sI) than structure II hydrate (sII).[2] Hence, the use of KHI with a structure I gas hydrate risk at high subcooling is a challenge. The KHIs were tested in the presence of two differents sI- or sII-forming gas mixtures. The KHI

performance was evaluated in batch reactor by induction time measurements for subcoolings from 5 to 15 °C. The ease of use and the effect of the KHIs on the process were evaluated by viscosity measurements, the emulsion and gel/sludge/deposit formation tendency tests with salt (30 % NaCl) and thermal stability test. In batch reactors, the additives showed very good KHI performance even at subcooling of 15 °C with sII-forming gas.
In presence of sI-forming gas, AH36 gave the best result and both products, AH53 and AH36, remained efficient for subcoolings higher than 10 °C. Both KHIs are thermally stable, do not promote the formation or stabilization of emulsion and no gel, sludge or deposit were observed.
From the experimental results obtained in this work, the use of KHI to prevent the formation of sI gas hydrates at high subcooling (> 10°C) is possible.

[1] https://www.iea.org/weo/
[2] Abrahamsen, E. ; Kelland, M. A., Comparison of kinetic hydrate inhibitor performance on structure I and structure II hydrate-forming gases for a range of polymer classes, Energy&Fuels, 2017.

Session 2

Abstract (#19535)

Title: Evaluation of Compatibility and Synergisms Between Completion Chemicals Using A Non-Ideal Mixing Mod

Authors: Liang Xu and James Ogle

Halliburton

Objectives/Scope
Chemical additives perform many functions during a hydraulic fracturing (HF) operation, which attributes about 30% of the total stimulation cost in the US, while pumping horsepower and proppant cost comprise the remaining 50% and 20%, respectively. Approximately 10 to 20 chemical additives, such as surfactants, clay stabilizers, scale inhibitors, biocides, and friction reducers, are pumped to treat the reservoir formation to enhance initial production and sustain long-term production. The success of these chemical treatments relies on the compatibility and synergisms among the additives.
Methods, Procedures, Process
Current industry practices use a combination of quantitative methods (i.e. rheology, friction reduction, scale inhibition, etc.) and qualitative testing (i.e. bottle testing) to understand the chemical compatiblities of fracturing fluids with chemical additives. Furthermore, current technologies based on surface science could not directly provide the quantitative information of synergisms between these additive interactions, which is the key to further optimizing and improving products for enhanced well performance. This paper uses principles founded in surface science to describe a non-ideal mixing model as a complementary method to quantitatively evaluate the compatibility and identify any synergisms present between completion chemicals.
Results, Observations, Conclusions
To demonstrate the new method, binary mixtures of several additives were prepared at different mole ratios. Surface tension (?) was measured for different combinations. The critical micelle concentrations (CMC) were obtained from the ?-log c curve, where c is the concentration of the mixture. These experimental data were further analyzed using a non-ideal mixing model, where the maximum surface excess concentration (?max) and minimum molecular area (Amin) were calculated. Notably, the interactions between chemicals in the micelles and interface have also been determined by the interaction parameters ?m and ?S, respectively. Negative values of ?m and ?S indicate an attractive interaction in both the mixed micelle and interface. Additionally, synergism was achieved when the CMC values of the individual components were comparable, |ln(CMC1/CMC2)|<|?|. The results of this study demonstrate the micellar and interfacial properties of those chemical mixtures, and thus the optimized ratios between those additives were determined.
Novel/Additive Information
This method has been extensively used to quantify the degree of compatibility and synergisms between completion chemicals and further optimize the ratios between chemical additives, and seems to be reliable for further tailoring of chemical packages for well stimulation treatments.

Abstract (#19565)

Title: Investigation of Sacrificial Agents for Surfactant Injection in Carbonates

Authors: Annie Wang, Zhenpeng Leng, Ming Han, Alhasan Fuseni

Sandi Aramco

One of the effective ways to improve oil recovery after water flooding is by the use of surfactants. A typical water flood may leave behind a substantial amount of original oil and surfactant flooding has been shown to recover up to 15 percent of additional oil when applied effectively. The success of this application depends among other factors, on the extent of surfactant loss is the reservoir attributed to adsorption on the rock surface. When adsorption is significant, the economic viability of the process is unfavorable as chemical cost reduces the profitability.
This paper presents a laboratory investigation on reducing surfactant adsorption in carbonates by means of sacrificial agents. The objective is to include a pre-flush treatment of low cost chemicals before regular surfactant-related chemical flooding processes. The treatment is able to reduce the chemical expenses while it does not have negative effects on the performance of the selected surfactant. Dynamic adsorption tests of an anionic sulfonate surfactant dissolved in synthetic seawater were conducted in natural carbonate core plugs at reservoir temperature of 95?C to set up the baseline of the surfactant adsorption. Sodium carbonate and lignosulfonate were used as sacrificial agents on the carbonate core plugs for the surfactant injection. A combination of total organic carbon (TOC) analysis and UV-Vis analysis was used to determine the concentration of the chemical components in the effluent solutions. The adsorption values were compared with the baseline of the surfactant adsorption. Laboratory experimental results demonstrated that sodium carbonate was an effective sacrificial agent at a concentration of 1 wt.%, reducing significantly the surfactant adsorption by 60%. The applicability relied strongly on the removal of the divalent metal ions like Ca2+ and Mg2+ from the make-up brines and the pre-flush of the formation using fresh water. On the other hand, sodium lignosulfonate was applicable as a sacrificial agent in seawater without the necessity to remove divalent metal ions. It reduced the surfactant adsorption by 30-40%. It is worth to note that this method is particularly beneficial in avoiding water treatment costs. The design with a slug of sacrificial agent solution prior to surfactant injection can meaningfully improve the economics of chemical flooding projects.

Abstract (#19506)

Title: Novel Nanoparticles for Produced Sand and Water Management in Oil and Gas Applications

Authors: Rajendra Kalgaonkar, Khalid Alnoaimi and Vikrant Wagle

Saudi Aramco

Preventing the occurrence of produced water and sand are important criteria for achieving uninterrupted and optimal production of hydrocarbons. This paper describes a single unique chemistry based on nanomaterials that can be used for mitigating both sand and water production. The novel nanomaterial compositions comprise of environmentally acceptable nanomaterial dispersions with surface properties modified to either bind the unconsolidated formation sand or seal the water producing zones. Three different nanoparticles with different surface modifications were used in the study. Two types of

nanoparticles had negative surface charge whereas one cationically modified nanoparticle dispersion were used in this study. The sealing and binding mechanisms of the nanoparticles are based upon triggered chemistries to achieve delayed gelling activation to ensure proper placement of the treatment into the target zone and avoid premature plugging of pipe lines, coiled tubing or other tubulars. Two different triggering mechanism based on organic and inorganic chemistries, respectively, were also used. The effect of these triggered chemistries on the gelation properties of the nanoparticles based dispersion was investigated. The gelation times in static and dynamic states were evaluated at different temperatures up to 300°F. The effects of shear rate on gelation time and viscosity buildup are presented. Effects of pH and concentration of different triggering chemistries on gelation times of the nanoparticle dispersion were also investigated. The effectiveness of the newly developed composition as a sand control or water shutoff treatment was also evaluated by performing permeability tests to test the regain permeability and plugging efficiency of this novel system based up on the targeted application. It was shown that the gelation time of the nanoparticles can be controlled by their surface modification, pH alterations, as well as by adjusting the concentration of the activator. The system gives predictable and controllable pumping time, ranging from few minutes to several hours over a wide range of temperatures. This is an important advantage of the new treatment fluid as it allows the treatment composition to remain pumpable for sufficient time for placement and develops a network structure that leads to gelation, over a predictable period of time. Regain permeability and plugging efficiency studies showed that permeability could be controlled by specific surface modifications of the nanoparticles. A major advantage of this new nanoparticles based treatment fluid is that it not only can be used as a sand control treatment but also as a water shutoff treatment by the surface modifications of the nanoparticles. Another advantage is the controllable gelation time of the treatment fluid by utilizing triggered chemistries to ensure the fluid placement in the target treatment zone without premature gelation.

Abstract (#19368)

Title: 2D Materials Hybrid Structure Effect on Rechargeable Lithium Battery at Elevated Temperature

Authors: edreese alsharaeh, Zahra Bayhan, Yasmin Mussa,Muhammad Arsalan

Alfaisal University

Over the past few decades, lithium-ion batteries (Li-ion) have revolutionized the energy storage market owing to their high energy and power density as well as their high lifetime when compared to other battery technologies. The demand for Li-ion batteries continues to increase rapidly, driven by the growth in hybrid and electric vehicle (EV) productions. However, as Li-ion batteries approach their theoretical limits with high cost, there is a need for new battery chemistries that go beyond lithium-ion intercalation in response to the ever-growing energy demand.
Given the above, lithium-sulfur (Li-S) batteries based on a conversion mechanism hold great promise for next-generation batteries. The combination of metallic lithium with elemental sulfur enables a theoretical energy density of 2,500 Wh/kg, which is three times higher than Li-ion batteries. Moreover, the natural abundance and environmental friendliness of sulfur make Li-S batteries a green and low-cost alternative. However, a limitation of this technology is the rapid capacity fading resulting from the generation of long-chain lithium polysulfides (Li2Sx), a phenomenon called shuttle effect. Another problem is the insulating nature of sulfur.

In this work, a two-dimensional (2D) based on hexagonal Boron Nitride and Graphene Oxide Nanocomposites (h-BN/GO) is prepared via a simple, cost-effective route and investigated as a sulfur host to avoid shuttle effect. X-ray diffraction (XRD) reveals the effective utilization of sulfur in h-BN/GO. Moreover, band gap studies indicate that the incorporation of h-BN can tailor the electronic structure of GO. The high mechanical robustness (hardness: 0.072 GPa and modulus: 5.22 GPa) of the material can account for the volume expansion caused during the charge/discharge process. Electrochemical measurements showed that the h-BN/GO hybrids based Li-S batteries have an enhanced electrochemical property when compared to h-BN and GO revealing the synergistic effect between h-BN and GO. Moreover, this h-BN/GO hybrids also showed excellent performance at elevated temperatures from room temperature up to 100 °C which is attributed to the high thermal stability of the h-BN/GO Nanocomposites

Session 3

Abstract (#19262)

Title: A Novel Non-Damaging Fracturing Fluid: From Lab to Field

Authors: Prasad Karadkar, Mohammed Alabdrabalnabi, Feng Liang and Mohammed Bataweel

Saudi Aramco

Guar gum and its derivatives based fracturing fluids are most commonly used in hydraulic fracturing. For high temperature wells, guar-based fracturing fluids need to be formulated with higher polymer loading and at high pH which leaves insoluble residue and tends to form scales with divalent ions. Thermally stable acrylamide-based polymer with reduced polymer loading of 30-40% less than guar-based fracturing fluid was considered to minimize formation damage concerns. For successful field deployment, a novel non-damaging fracturing fluid was evaluated in the following sequence: chemical management and quality control, optimization of fracturing fluid formulations, field mixing procedure, on-site QA/QC, friction analysis, leak-off analysis, data frac injection test analysis and execution of main fracturing treatment. The friction of crosslinked fluid was analyzed by using downhole measurement gauge and fluid efficiency was evaluated during data frac analysis.

The rheological studies at reservoir temperature and the cool-down temperatures of selected well candidates have demonstrated superior thermal stability of this novel fracturing fluid. With polymer loading of 25 lb/1000 gal, the fluid viscosity stayed above 300 cP at 100 1/s shear rate for 2 hours at 290°F. The fracturing fluid formulations were optimized using both live and encapsulated breakers with rheometer. Due to the fast hydration of the base polymer, the linear gel was mixed both in batches and on-the-flying during the main fracturing treatment. Slightly higher friction at higher pumping rate was observed by the downhole gauge during data frac for this novel fracturing fluid as compared to guar-based fracturing fluid. The main fracturing treatment was successfully executed with 45-50 bbl/min pumping rate with increased proppant concentration up to 5 ppa using 30/50 HSP and 20/40 HSP proppant.

The fracturing fluid system based on the novel acrylamide copolymer offers advantages over guar-based fracturing fluid such as low polymer loading, excellent high temperature stability and less formation damage. This work presents a systematic approach and lesson learnt during lab to field development of a novel low-polymer loading, non-damaging acrylamide-based fracturing fluid.

Abstract (#19198)

Title: Fracture Conductivity Study in Carbonate Formation Using a Solid Acid System: A Laboratory Study

Authors: Mohammad Alqam, Caliboso

Saudi Aramco

Most of acid fractured wells, using the conventional 15-28% acid treatment, have experienced a sharp decline in conductivity. This is mainly attributed to the high reactivity of hydrochloric acid with the formation which will cause it to be spent rapidly near the wellbore resulting in a short fracture length. This problem is particularly severe when the acid reaction rate is high due to high reservoir temperature. To overcome this problem of high reactivity of conventional acid systems, a new solid acid system, has been applied in the field for the first time worldwide. This new system is injected in the reservoir as inert solid particles similar to proppant materials, thus allowing for a further travel into the reservoir to achieve significantly higher fracture length. Once the length is created, the solid material hydrolyses and becomes acid when exposed to water at reservoir temperature to generate conductivity of the created fracture.

An experimental study, on this new acid system, has been performed to evaluate its effectiveness in creating fracture conductivity under in-situ conditions of stress and temperature. Core plugs have been selected from carbonate formation representing both the dolomite and limestone facies of the reservoir. The roles of closure stress, temperature, water content, and hydrolysis time on generating etched fracture surface following solid-acid hydraulic fracturing treatment have been investigated.

An integrated approach was followed to study this system before field application. The behavior of this system as a function of independent variables; curing time, closure stress, and temperature have been investigated. These parameters play a significant role in the success of solid-acid hydraulic fracturing treatment.

This study has yielded the following conclusions and recommendation:

1. This study has shown that water content inside the fracture is not sufficient to generate enough fracture conductivity before fracture closure. The cooling effect will prevent the hydrolysis to occur before fracture closure. The key is to design the treatment such that acid hydrolysis occurs before fracture closure.

2. The hydrolysis will not occur before fracture closure due to the cooling effect caused by the cold-fluid injection of pre-pad, pad, and solid-acid laden fracturing gel.

3. The hydrolysis process for the laboratory-scaled test occurred during the temperature range of 75-85 oF. Therefore, the closure time should be designed such that the in-situ temperature reaches a projected field-scale temperature range to ensure complete hydrolysis.

Keywords: Conventional acid, Solid acid, XE-100, Carbonate formation, Curing time, Closure stress, Hydrolysis"

Abstract (#19554)

Title: Application of Sand and Impact of Sand Properties in Enhancing Hydrocarbon Production

Authors: Muzzammil Shakeel, Waseem Abdulrazzaq

Halliburton

Phanerozoic sandstone geologic deposits encompass large areas within the sedimentary cover and provide a potential source of sand applicable to petroleum and other engineering applications. A few of these deposits are currently exploited for various industrial applications. For proppants in hydraulic fracturing applications, good quality sand with high mechanical strength that is uniform throughout the sand reserve, high mineral purity, with enough supply potential to meet market need, minimal processing requirements and easily extractable usually represents the essential potential target. This paper discusses a detailed geological study conducted in the Phanerozoic succession in the Kingdom of Saudi Arabia.

Establishing exploration criteria for identifying and recognizing these potential sand deposits is important for selecting the right target and its eventual exploitation. Phanerozoic sand deposits in the Saudi Arabian stratigraphic succession are composed of a variety of facies ranging from alluvial, fluvial, deltaic, shallow, and deep-marine settings. Outcrop samples were collected from different locations within Saudi Arabia, and a detailed study was conducted in the field and in the laboratory.

Multiple factors and controls have shaped the evolution of these sand reserves and their eventual properties and quality, including the hinterland (source area) geology, relief, processes of sediment transport, and climate. These controls affected the sand deposits in terms of grain type (mineralogy), grain size, shape, and matrix percentage. Therefore, considering these different controls and their evaluation at field and laboratory scale might provide guides for exploring and selecting suitable potential targets within the Phanerozoic succession in Saudi Arabia for sand that can be used as hydraulic fracturing proppants.

In addition to API Recommended Practice 19C/ISO 13503-2, this paper discusses a different approach to the study of sand deposits and their geological aspects to provide guides for sand application in hydraulic fracturing applications in the upstream petroleum industry. Additionally, it highlights important geological aspects and controls that play an essential role in the deposition of quality sand that meets the expectations of fracturing stimulation use.

Abstract (#19218)

Title: The Role of Microstructural Characterization and Exothermic Reaction in Optimizing Hydraulic Fractur

Authors: Hmeed AL-Badairy Ayman Al-Nakhli and Mohammed Alqam

Saudi Aramco

Unconventional hydrocarbon resources are of great importance to oil and gas industry where economically viable amounts of gas and oil are available for production however, due to the nature of the unconventional formation external simulation is required. For example, hydraulic fracture method is one of the commonly applied methods to enhance the production of hydrocarbons from tight formation. Also, an exothermic reaction is another method that is utilized to fracture tight formation. The concept is based on injecting chemical components during hydraulic fracturing treatment that upon reacting heat and gas is generated. The gas and temperature increase create localized pressure that results in thermal and mechanical fracturing; thus, improving near fracture surface permeability. Exothermic chemical reaction that generate huge amount of heat and gas will be incorporated with fracturing fluid. The reactants will be activated and reacting downhole to generate high pressure and high temperature in a very tight formation.

In this paper the microstructural and coreflood tests assessments are detailed. For evaluating the microstructures of selected and tested core plugs were conducted using high resolution environmental scanning electron microscopy techniques and computerised tomography technique was applied to analyse the coreflood samples. MR-CT Microscopy is a new suit of core analysis tools that utilize nuclear magnetic resonance combined with X-ray computed tomography to improve the description of pore property changes as a result of core flooding with different types of fluids (Kwak, 2012). MR-CT Microscopy allows observing microscopic events within reservoir porous media and provides fluid-rock interaction with proper mineralogy quantification information.

The microstructural evaluation showed the presence of microcracks in the treated sample. The study showed that the microcracks were originally initiated from the inner diameter extending to the outer diameter of the cylindrical core plug. This may suggest that pores and microcracks were initiated during the fracturing treatment. During the treatment the pressure and temperature were most likely increased

and subsequently the trapped gas inside the formation causes fracturing of the sample resulting in the formation of pores and microcracks. Moreover, the MR- CT revealed that the core pugs have disconnected microspores prior to testing and after testing microspores and their connectivity increased as indicated by increased permeability

Keywords: Unconventional Formation, ESEM, MR-CT, Exothermic Reaction and Microcracks"

Session 4

Exploration & Production:

Abstract (#19581)

Title: Innovative Permanent Down-Hole Scale and Corrosion Monitoring System Using Ultrasound Guided Waves

Authors: Abubaker Saeed, Arno Volker

Saudi Aramco

1. OBJECTIVE

Scale and corrosion is a major challenge facing maturing oil and gas wells. Scale build-up reduces flow and ultimately could completely shut down production. Corrosion of the tubing wall occurs very often simultaneously with scale build-up and affects the integrity of the tubing wall. Vital information about the integrity is essential for safe operation and flow assurance. The objective of this research is to develop a scale and corrosion monitoring system based on ultrasonic guided waves.

2. METHODS

The innovative approach is based on transmitting axisymmetric ultrasound guided waves to a receiver array around the circumference of the pipe. Both torsional and longitudinal waves are used over a wide frequency range. These modes are sensitive to variations in tubing wall thickness, scale thickness and scale properties. The complicated wave fields are analyzed using a time-frequency analysis. The first arrival time as function of frequency for both wave modes provides a unique finger print that can be used to estimate the average scale thickness and wall loss. Numerical simulations are used to investigate various scaling /corrosion scenarios and proof the concept theoretically.

3. RESULTS, OBSERVATIONS

Numerical simulations of complicated scaling scenarios are performed to investigate the robustness of the concept. Results indicate that the concept work properly even on rough scaled surfaces. The obtained sizing accuracy is in the order of 0.5 mm.

The simulations also provide the requirement for specially designed EMAT's (ElectroMagnetic Acoustic Transducers), which are capable of withstanding downhole conditions, i.e., pressure and temperature. These transducers cover a wide frequency range of 100 to 500 kHz, such that there will be a number of higher order modes present. This is required for accurate sizing. The used wave modes are only sensitive for changes in tubing wall thickness and scale build-up. Due to the dominant shear motion of these wave modes, they will not couple to the liquid in the annulus between tubing and casing.

The newly developed transducers are tested on a 4.5 inch tubing with artificial scale. During the experiment the artificial scale thickness is varied to evaluate the sizing accuracy. Moreover the scale and corrosion monitoring technology is tested on a number of real well samples.

4. Additive Information

It is a great advantage when corrosion and scale build-up in production tubing can be detected and measured by means of permanent sensors without the need of logging operations. Such a permanent down-hole monitoring system shall provide production engineers with essential data about down-hole scale and corrosion, as well as be used to optimize the dose of inhibitors, adjust process settings and more importantly, to plan interventions on a timely basis, maximize production and ensure safety."

Abstract (#19582)

Title: A new chemical approach for managing iron sulfide: an effective alternative to THPS, acrolein, acid

Authors: Dr. Alsu Valiakhmetova, Martijn Huijgen, Scott Rawlins, Tawfik Al-Ghamdi, Dr. Ping Chen

Halliburton

MultiChem "Iron sulfide scale has been reported to cause significant production and integrity issues in sour gas-producing fields, particularly across the Middle East region. To mitigate the deposition of iron sulfide, dissolvers are commonly applied, typically, THPS and THPS-based products, hydrochloric acid, or acrolein. Each of these solutions have drawbacks. Acrolein is a highly toxic material, signifying high handling risk of its application. THPS offers limited performance and treatments applying activated THPS product or acids significantly increase corrosion integrity risks and cause toxic H2S gas generation. In addition, some of the FeS2 scales found downhole, namely pyrite and marcasite, have very low solubility in acid, and the current mechanical removal is more expensive than applying the chemical methods. Herein, we discuss the development of a novel and innovative chemical approach to iron sulfide deposition management – providing effective performance without the undesirable drawbacks. This paper presents the evidence of the benefits over conventional solutions, including:

- High dissolution performance
- Minimal H2S gas evolution
- Low corrosivity to carbon and stainless steels
- No chloride content
- Cost effectiveness"

Abstract (#19)

Title: Corrosion Behavior of 90/10 Cupronickel Heat Exchanger Tubing Material in Chloride Solutions Contain

Authors: Hosni M A Ezuber, Abdulla Al-Shater

University of Bahrain

Copper nickel alloys and in particular 90 Cu-10 Ni type have been extensively used in desalination plants as heat exchanger and condenser materials. This alloy has an attractive combination of properties including remarkable corrosion resistance characteristics, good machinability, high thermal conductivity allied with outstanding anti-fouling properties and relatively low cost. In this study the electrochemical performance of 90-10 cupronickel alloy in stagnant and aerated 3.5% sodium chloride containing sulfide species was investigated using polarization technique at 23, 50 and 80oC. Surface examination and morphological studies were employed. Polarization measurements revealed that 90-10 cupronickel alloys possess higher corrosion rates with increasing electrolyte temperature and dramatically increased with the addition of sulfide species due to the catalysis of the sulfide ions or sulfide scale for both the cathodic and anodic reactions. surface morphology revealed the involvement of the sulfide species in the corrosion product suggesting the non-protective corrosion product layer formed on the alloy in aerated sulfide-containing chloride solutions was mainly a mixture of CuCl, Cu2S, Cu2O and NiO and that the most significant component was Cu2S.

Abstract (#19510)

Title: Corrosion Control During Acidizing Treatment in Oil Wells

Authors: Hicham El Hajj, Muzzammil Shakeel

Halliburton

Acidizing is one of the most common and effective stimulation techniques to enhance hydrocarbon productivity from tight reservoirs, especially carbonate reservoirs. Acidizing is performed on new wells to maximize productivity from the initial stage and on mature wells to restore productivity and maximize the recovery of hydrocarbons. The acid treatment is injected into the formation below the formation fracture pressure for matrix acidizing. During fracture acidizing, the acid is pumped above the fracture pressure of the formation.

Hydrochloric acid is the commonly used acid for effective stimulation of carbonate reservoirs. However, the higher rate of reactivity of hydrochloric acid with increase of temperature contributes to reduced acid penetration. This limits the acid fracture geometry and increases corrosion of the metal tubular.

To reduce corrosion of the metal tubing, corrosion inhibitors are used in acidizing treatments. The corrosion inhibitor forms a thin film on the metal, which inhibits the rate of corrosion of the metal tubular. A study was conducted to investigate the effects of a hydrochloric acid solution on C-95 metallurgy. The laboratory evaluation of the effects of metal ions in the case of C-95 metallurgy concluded that fewer additives are required compared to conventional metallurgies making it more cost effective than conventional techniques.

Experiments were conducted using high pressure and temperature autoclaves at 300°F to prove the efficiency and performance of the corrosion inhibitor. Metal coupons were exposed to HCl under pressure and temperature conditions for various time periods. Corrosion is an atomic level phenomenon, thus the corrosion impact on the metal coupons was analyzed using atomic force microscopy images. X-ray diffraction analysis was performed to determine the corrosion layer of the sample coupons. The metal coupon was exposed to the corrosion inhibitor under consideration, under the same conditions as acid, in order to observe the performance of corrosion inhibitor. The corrosion inhibitor is effective for inhibiting corrosion occurring on metal and proves to be a viable solution."

Session 5

Abstract (#19566)

Title: Investigation of Dynamic Interfacial Tensions of Surfactant Solutions for Improving Oil Production

Authors: Limin Xu, Ming Han, Dongqing Cao, and Alhasan Fuseni

Aramco Beijing Research Center

Various surfactants have been applied in oilfields for improving oil production by reducing interfacial tension (IFT) of the surfactant solutions with crude oils. It is a common practice to screen surfactants based on IFT values using spinning drop tensiometer, which requires an extra-low IFT (< 10-2 dynes/cm) to significantly increase oil production by increasing the capillary number. The challenge is to determine an appropriate IFT value as the criteria to estimate the oil production potential, since the IFT value changes during the IFT measurement. The dynamic IFT profiles raised an argument in the literature regarding whether the minimum IFT or the equilibrium IFT played dominant role in improving oil production.

In this work, the experimental results revealed two kinds of dynamic IFT profiles: 1) IFT decreases with time to an equilibrium value (an “L” shape); and 2) IFT decreases sharply and then increases with time to an equilibrium value (a “V” shape). A linear relationship was observed between IFT values and time-1/2, which suggests the diffusion of surfactants in the aqueous solution dominates the dynamic IFT process. The factors that affect the diffusion, such as surfactant solution viscosity and concentration, play important roles in the performance of the surfactants in aqueous solution. In order to demonstrate the oil production potential, micromodel displacement experiments were conducted using surfactant systems with the 2 different dynamic IFT profiles. The results show the system having a low minimum IFT value presents 15% more incremental oil production than that from the system having a high initial IFT value, with the same equilibrium IFT value. This finding suggests that the minimum IFT value needs to be taken into account when screening surfactants for improving oil production.

Abstract (#19266)

Title: Melioration in the properties of drilling mud using surfactant modified graphene

Authors: Muhammad Azeem Akbar Rana, Tawfik A. Saleh

KFUPM

The improved rheological properties of the drilling fluid are very critical for the oil well drilling operation. The present work reports the effect of sodium dodecyl sulfate modified graphene (SDS-Gr) on the rheological features, fluid loss and swelling inhibition mechanism of clay. The rheology and filtration test of drilling mud were conducted after being hot rolled for 16 h at 150oF and under 500 Psi pressure. The

inhibition characteristics were evaluated by the dispersion test and shale inhibition durability test, where SDS-Gr modified drilling mud shows the highest recovery as compared to KCl and traditional drilling mud. The inhibition mechanism was investigated by various kind of techniques such as thermogravimetric analysis, scanning electron microscopy, and energy dispersive X-Ray spectroscopy. The outcomes revealed that the addition of SDS-Gr to the traditional drilling mud clearly affect the rheological properties and make it more suitable for the drilling. Moreover, SDS-Gr additive reduces fluid loss by 20% as compared to the mud without SDS-Gr. The Fourier transform infrared spectroscopic study also confirms the adsorption of SDS-Gr on clay. SDS carries the negatively charged functional group that help SDS-Gr to binds to the cations present on the clay surface and graphene plug the pores in the clay. The intercalation and adsorption of SDS-Gr on to the surface of clay hinder water molecules from invading the clay that helps in mitigation of swelling due to hydration. We report for the first time the SDS modified graphene (SDS-Gr) that successfully binds to the clay surface. In order to combine the features of SDS and graphene, the graphene surface is factionalized with SDS that modify the drilling mud rheology, control fluid loss and inhibit the clay swelling.

Abstract (#19430)

Title: NanoSurfactants: Crude to Advanced Materials for Enhanced Oil Recovery Applications

Authors: Ayrat Gizzatov Afnan Mashat, Amr I. Abdel-Fattah

Saudi Aramco

Significant volumes of crude oil are remaining after primary and secondary oil recovery processes have been implemented. Addition of certain chemicals such as surfactants into the waterflood is proven to help with mobilization of the remaining oil. Amount, cost and performance of these surfactants play an important role in the economics of the enhanced oil recovery (EOR) process and need to result in net profit for additionally produced oil. Therefore, developing surfactants that can be produced and implemented in a cost-efficient way is of great need and interest. This work describes the development of Nano-Surfactant (NS) formulations made of petroleum sulfonate surfactants, synthesized directly from crude oil, and stabilized with zwitterionic co-surfactant for applications in hot and salty oil reservoir conditions. The concept is to use part of the crude oil to make highly-efficient and highly-economic surfactants that can be used to recover additional oil EOR operations. Here, we will present the lab scale synthesis procedures of petroleum sulfonates directly from crude and further formulation into NS formulations. Results of performed tests show that developed material is potent in mobilizing remaining oil from small pores of the reservoir rock and have a great potential for operational success in the field.

Abstract (#19572)

Title: Surfactant Partitioning in Oil-Water Systems for Improving Oil Production

Authors: Jian Hou, Han Ming, Fuseni Alhasan

Aramco Asia

Surfactant mediated enhanced oil production technique have received increased attention due to their ability to reduce capillary forces and mobilize oil. In order to improve the economics of such processes, a better understanding of the interaction of surfactant-oil-water systems is needed. This work studied the partition behavior of several types of surfactants (cationic, anionic, non-ionic, zwitterionic and non-ionic/anionic mixtures) between water phase and crude oil phase with various salinity and water/oil ratio. The resultant partition coefficients were correlated with the hydrophilic-lipophilic difference (HLD) model for surfactant selection.

Seven surfactants were used to conduct the partitioning experiments at 95?C. The partition coefficient K was calculated by the ratio of surfactant concentrations in excess oil phase and excess water phase. High performance liquid chromatography (HPLC) method was used to determine the surfactant concentration in water phase before and after partition experiment with crude oil. Specifically, the preferential partitioning of anionic and nonionic surfactants from the aqueous phase to oil phase is greatly determined by the salinity of water phase. On the contrary, the partitioning of cationic and zwitterionic surfactants is almost impervious to salinity in the test range. This could be attributed to the undesirable solubility of the cationic and zwitterionic surfactant in oil phase. It can be concluded that the ionic type of the surfactants plays an important role in the performance of the surfactant partitioning in the two different phases, which can further affect the overall surfactant flooding process. In addition, the logarithm of partition coefficient K between oil and water phases is linearly related to logarithm of salinity. With the help of HLD model, the characteristic surfactant parameter can be obtained. To make surfactants more efficient, a mixture of nonionic-anionic surfactant and cationic surfactant was applied, which showed the synergistic effect of both surfactants in balanced partitioning. The results were aligned with oil/water interfacial tension results.

Session 6

Abstract (#19265)

Title: Microbiologically Influenced Corrosion Investigation for Refinery Crude Stabilization

Authors: Abdulmohsen Al-Humam, Husam Khanfar, Michael Davidson, Ayman Janbi, Abdulkarim Al-Ghahtani, Fahad Hamidi, Ammar Alsaqer

Saudi Aramco

A comprehensive microbiologically influenced corrosion (MIC) study was conducted in a crude stabilization facility to determine the root cause of repetitive failures that began with a tube leak that had developed in a stabilizer reboiler eleven days after high salts and water were observed in two NGL plant feeds. Twelve subsequent failures occurred over the next 29 months in the two plants, which had previously been very reliable. Each plant had degassing and crude stabilization facilities. All of the observed corrosion was in the crude stabilization operations area where the feeds enter the top of 17-tray stabilizer columns and undergo separation, using heat provided by two thermosiphon reboilers under 60-psig steam. Failures also exhibited severe saucer-shaped pitting

Samples were collected from seven locations for MIC investigation. Although the results confirmed the suitability of the operating conditions for microbial growth and the co-existence of different types of corrosion-causing microorganisms in microbial counts ranges that often indicate indicates sever MIC in a system, other substantial MIC criteria supporting the incidence of MIC were not observed. The observed co-existing groups of microorganisms can separately or collectively cause a system failure with the generation of highly aggressive species such as sulfide. However, to confirm the involvement of MIC in corrosion, further steps are required beyond isolate microbe with MIC potential and demonstrating end products of MIC corrosion of possible biological origin and a comprehensive sampling regimen."

Abstract (#19436)

Title: Reduce The Growth of Biofouling in Seawater Industrial Cooling Towers by Alternative Oxidants

Authors: Mohammed Albloushi, S. Al-Sayegh, A. Al-Refaie and T. Leiknes

SABIC

Due to the shortage of drinking water in many regions of the world, the demand for seawater as an alternative medium in industrial cooling towers increased significantly in recent years. Biofouling in the open recirculating cooling water systems may cause biological corrosion, which can reduce the performance, increase the energy consummation and lower heat exchange efficiencies of the cooling tower (CT). Seawater CTs are prone to biofouled due to the presences of organic and inorganic compounds

in the seawater. The availability of organic and inorganic nutrients, along with sunlight and continuous aeration of the CT contributes to an environment that is ideal for microbial growth. Various microorganisms (algae, fungi, and bacteria) can grow in a CT system under certain environmental conditions. The most commonly being used method to control the biofouling in the CT is the addition of biocides such as chlorination.

A pilotscale cooling tower has been designed to assess the performance of three types of oxidizing biocides or disinfectants, namely chlorine, chlorine dioxide and ozone, in the column of seawater operating at assorted concentrations (or cycle of concentration). In this study, diatom and green algae were added to the CT basin and its viability was monitored in the recirculating cooling seawater loop as well as in the CT basin. Continuous addition of biocides was employed in pilotscale seawater CTs and it was operated continuously for 60 d. Three different types of oxidizing biocides, namely chlorine, chlorine dioxide (ClO2) and ozone, were tested. The results showed that all biocides were effective in keeping the biological growth to the minimum regardless of algal addition. Amongst the biocides, ozone could reduce 99% of total live cells of bacteria and algae, followed by ClO2 at 97%, while the conventional chlorine showed only 89% reduction in the bioactivities."

Abstract (#19602)

Title: Fingerprinting Bacterial Populations in Compacted Clay Cores Imitating Well Cement

Authors: Alexander Grigoryan, Darren Korber

Saudi Aramco

Cementing is one of the conventional completion methods for vertical and directional wells. Used for a number of different reasons, cementing protects and seals the well bore. The low quality of cements decreases their performance and therefore poses an engineering challenge. Microbial contamination is one such quality hazard. Bacteria produce a number of deleterious by-products (i.e. acids, gases, hydrogen sulfide, etc.) which can compromise well-seal integrity. However, there is a lack of data on microbial abundance in sealing blends, as well as on environmental conditions affecting the viability and propagation of microorganisms in cements after compaction and solidification.

Here, we report on the bacterial diversity in compacted bentonite clay (85% smectite) cores which had been infused continuously with a high-pressure brackish water for a period of 40 weeks, mimicking some oil-well compacted cement and clay sealants. Background levels of microorganisms in uncompacted clay used in this study were 10^2-10^3 MPN/gdw of sulfide-producing bacteria and 10^4-10^5 MPN/gdw of aerobic and anaerobic bacteria. Throughout the experiment, the swelling pressure (Psw) in the water-infused clay cores increased, while the water activity (?w) reduced, reaching values of Psw>8 MPa and ?w<0.96 in clays compacted to the bulk density of 1.6 g/cm^3. The number of culturable aerobes from the interfacial and internal regions of the cores was 10^4 CFU/gdw and 10^2 CFU/gdw, respectively. A combination of culture- and molecular-based approaches for fingerprinting bacterial populations from the compacted clays revealed a predominance of Gram-positive, spore-forming organotrophic bacteria of the phylum Firmicutes. For instance, wide-spread occurrence of aerobic heterotrophs of the families

Bacillaceae and Paenibacillaceae, as well as anaerobic acid-producing bacteria of the families Clostridiaceae and Peptococcaceae were revealed. In addition, detected clostridia of the genus Desulfosporosinus are potentially capable to reduce sulfate to detrimental sulfide.

Overall, we suggest that during the 40-week incubation period, the bacteria indigenous to the clay proliferated on the interfaces of highly-compacted material; however, bacterial activity inside the core was negligible due to adverse environmental factors, i.e. low water activity, elevated swelling pressure, etc. Microorganisms with dormant forms, such as the identified spore-forming bacilli and clostridia, were found to exclusively survive these inhibitory conditions. It is proposed that the observations from the clay core model can be extended to microbial processes in other artificial (i.e., cement) or natural (i.e., geological) highly-compacted porous sealing media, where low water activity and high hydrostatic pressure, along with other environmental stresses (i.e., near-extreme pH, temperature, mineralization), control microbial activity.

Abstract (#19390)

Title: Anti-Adhesive and Biocidal Thin-Film Coatings for Improved Biofouling Resistance of RO Membranes

Authors: Ismail Abdulazeez, Asif Matin, Majad Khan, Khalid Al-Hooshani, Mazen Khaled

KFUPM

This study reports the sol-gel preparation of dual functional anti-adhesive and biocidal membrane surfaces by dip-coating of a single silane, N1-(3-trimethoxysilylpropyl) diethylenetriamine and characterized using FTIR, SEM, XPS and contact angle measurement. To improve the bacterial killing capabilities, the silane films were quaternized using ethyl iodide. Contact angle measurements showed a significant increase in surface hydrophilicity after silane deposition (from ~ 85º to58º) and a slightly further increase upon quaternization (~ 58 to 53º). Bacterial adhesion and antimicrobial studies with B. subtilis species showed much significantly lower number of bacterial cells on the coated and quaternized surface with a killing rate of more than 80%. Cross-flow filtration tests using a custom-built laboratory setup showed that the presence of coating did not compromise on the permeation characteristics; in fact, quaternization resulted in a significant improvement (~ 50%) in the permeate water flux.
