Incorporation of Ionic Liquid (ILs) In Commercial Solvent Agents for Better Downhole Reaction

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Abstract

The volatility of oil & gas market in recent years prompt industrial player to adapt fast in optimizing operation to ensure profitability. Production chemistry is a part of the operation in which chemical is used in the production of oil & gas such as to control and dissolve scale formation. Tighter regulation in environmental policy as well as the complexity of the operation push for the need of production chemistry to fulfill the regulatory and operation need. Lack of understanding on the mechanism on how the solvent plays a role to control solid scale should be understood for oil & gas production. Thus, this project is to disseminate the knowledge of the molecular interaction mechanism on the role of the chemical ILs-solvent complex active functional group on the solid precipitation rate in oilfield environment through molecular dynamics simulation of ILs-solvent agents complex to control the sandstone solubility in an oilfield environment. Computational calculation for industrial application of the solvent agent, an ionic liquid (IL) & solid scale properties was applied to understand the molecular interaction of the solvent agent and solute chemical compound using molecular charged calculation on the production chemistry. The knowledge was transferred through knowledge sharing workshops to the petroleum engineers and operators of Setegap Ventures Petroleum Sdn. Bhd. Industry benefits from the potential of IL in well stimulation to control the solid scale such as SiO_2, $CaCO_3$, and $Fe2O_3$. The company economic potential gains through ILs-solvent agent complex for product improvement and staff expertise. The academicians would strengthen and widen the industrial partnership and networking as well as increase their expertise in solving the actual industrial problems industrial problem.

Keywords: *Solvent Agent, Ionic Liquid, Solid Scale, Molecular Dynamic Simulation*

1. Introduction

Solvent agents are part of production chemical that is used to control undesirable reactions of metal ions that cause precipitation of solid scale in well formation and tubing. In oilfield chemical treatments, solvent agents are frequently added to stimulation acids to prevent precipitation of solids as the acid spends on the formation being treated (Frenier et al., 2000). Some of the major solid scale precipitation in oil and gas are calcite, barite and iron sulfide.

The solid scale is the formation of solid sedimentation or crystallization of dissolved salt or mineral compound in liquid. In oil and gas production, precipitation or deposition of dissolved solid commonly inorganic salt from aqueous solution in well tubular will caused the formation of scales (Kelland, 2014). Oilfield scale might contain several minerals, sand, organic precipitates, wax as well as corrosion product (Mackay, 2007). This precipitation may grow to the extent disrupting oil and gas operations such as blocking wellbore tubes. Scale formation in the piping system may lead to valve failure, corrosion of pipe or tube surface underneath the scale, restriction or blockage of the flow or damaging the equipment (Crabtree et al., 1999; Merdhah, 2007).

The deposited material forming scale has been considered as one of a major problem in oil and gas production (Dunn & Yen, 1999). One of the recorded scale problems was in the North Sea, Miller field where scale causes the production fall from 4770 m^3/d to zero in just 24 hours (Brown, 1998).

Solvent agent is a chemical compound that reacts with metal ions to form stable, non-toxic water-soluble metal complexes and easily extractable complexes with toxic metals. It contains two or more reactive groups (ligand) such that can hold metal from two sides (Frenier et al., 2003; Mahmoud et al., 2011). A ligand is a functional group capable of forming coordinate bond mostly O, N, or S atom in a hydroxyl, carboxyl, sulfhydryl, disulphate, amino, and phosphate.

At present, application of solvent agent is without the understanding of the mechanism on how the solvent plays a role at the molecular level to control the solid formation and dissolution in an oilfield environment. The molecular modeling work would benefit the industry to further understand the chemical interaction mechanism between solvent agent, ionic liquid and solid such as sandstone. From molecular dynamics simulation approach and application, the solution structure and mass transfer rate can be understood as an input for petroleum engineers and operators to control the dissolution and precipitation of solid in oil field environment and well.

Ionic liquids (ILs) has received much attention in green chemistry as an environmentally friendly solvent for many applications albeit not all ILs can be considered as green. The unique properties of ILs such as consist of only cation and anion, make it part of the research towards "green" chemistry. ILs has been generally described as having a negligible vapor pressure, high thermal conductivity and stability, non-flammable, high density and high heat capacity (Carda-Broch et al., 2003; Domańska, 2005; Wei et al., 2010). Despite its versatility, application of IL in oil and gas in upstream, midstream or upstream are still at early stage of laboratory study. The unique properties of IL can be promising to be used in a various stage in petroleum industries. Several laboratory studies have successfully utilized ionic liquid 1-ethyl-3-methyl- imidazolium tetrafluoroborate ([Emim][BF4], to recover bitumen from oil sand. This mainly contributed to the changes of the adhesive force between bitumen and silica after IL addition due to its unique behavior at the surfaces and the charged interface resulting from the high ion concentration. (Li et al., 2011; Painter et al., 2010).

Setegap Ventures Petroleum (SVP) Sdn. Bhd. would apply the knowledge of industrial computational calculation and physical chemistry of solvent agent and ILs to improve and increase the existing solvent performance in their daily industrial application and operation. Hence, the production chemistry knowledge would benefit and enhance the technical staffs (petroleum engineers and operators) in the SVP actual operation. The ILs technology also would benefit the present industrial problem in well stimulation to control the target solid scale.

2. Program Objective

Setegap Ventures Petroleum (SVP) Sdn. Bhd. is a vendor that mainly focus on well stimulation and services. As chemical service provider company, SVP interested to involve in production chemistry of the chemical product for well stimulation. However, the lack of knowledge and understanding of mechanism on how solvent chemical work becoming the main challenge. Basic understanding of the molecular interaction of solvent agent in dissolving solid scale is important to stimulate their organization with the necessary knowledge and skill in preparation for venturing into production chemistry. With encouragement from their client mainly local oil & gas producers for industrial-university cooperation, and locally produce chemical, SVP will greatly benefit in this knowledge transfer program.

This program also aims to transfer knowledge of production chemistry i.e. solvent agent-ILs on solid scale control as well as to produce graduate intern who is competent in production chemistry field.

3. Knowledge Transfer Process

The program started with the knowledge transfer to graduate interns (GIs) in all aspects of the molecular dynamic simulation, chemical properties of the solvent agent and ionic liquid. The GIs were taught in utilizing Material Studio, a software use as a tool to generate molecular interaction of the solvent agent with solid scale. The GIs were also taught to conduct laboratory analysis of solid scale obtained from the oilfield, characterization of solvent agent and optimization of the solvent agent by incorporating ionic liquid.

The knowledge transfer program was implemented in this project through two separate workshops. The first workshop was held in 2016 participated by 12 staff and operation engineers from SVP to disseminate knowledge about the molecular interaction mechanism on the effect of chemical ILs-solvent complex active functional group on the solid precipitation rate in an oilfield environment.

Other than workshops, the transfer of knowledge is also through a regular meeting between graduate intern-SVP technical staff held throughout the project. In this meeting, GIs will present and transfer the knowledge regarding the mechanism of solid scale dissolution characterization of solvent agent and classification solid scale. GI has also transferred the knowledge related to ionic liquid and its role in solid scale dissolution. As the main objective of SVP is in the involvement in production chemistry, knowledge regarding chemical synthesis was also transfer to operation engineers of the chemicals conducted in well stimulation by the GIs.

4. Outcomes and achievement

Throughout this programme, two main workshops have been held to disseminate knowledge regarding

the molecular interaction of important functional group in solvent agent and role of ionic liquid as a potential solvent to be incorporated with currently available solvent. The first workshop (**Figure 1**), "Industry Workshop on the Roles of Chemicals for Scale Control during Oil and Gas Well Stimulation Operations", was held on 22 August 2016 for one day at Ibis Style Hotel, Kuala Lumpur, near SVP headquarters. This workshop attended by 13 industries staffs from SVP and UZMA Sdn. Bhd., a shareholder of SVP.

Figure 1: Industry Workshop on the Roles of Chemicals for Scale Control during Oil and Gas Well Stimulation Operations

The second workshop (**Figure 2**), "Technical & Operation of Well Operation and Stimulation for Flow Assurance", was held on 16 October 2017 at Mangala Resort & Spa, Gambang, Pahang. This workshop involves eight staff from SVP and SVP clients.

Figure 2: Technical & Operation of Well Stimulation for Flow Assurance

Other than workshops, regular meeting (**Figure 3**) was held between GI and SVP to continuously transfer the knowledge regarding the application of ionic liquid to be incorporated in the commercial solvent agent as well as the knowledge that will prepared SVP for their involvement in production chemistry. This meeting is to ensure continuous communication between SVP and UMP. The regular meeting was conducted every three months.

Figure 3: GI presented dissolution of solid scale using ionic liquid to the SV technical staffs.

The close relationship forged from this program had led to further collaboration between UMP-SVP. One memorandum of understanding (MoU) had been signed to further strengthened the current relationship between SVP-UMP (**Figure 4**). This MoU involves a bilateral contribution from both parties involved. UMP through its academia will assist SVP for product development specifically in production chemical. SVP in return will contribute its technical expertise to academia for understanding the industrial problem as well as field testing. SVP also had contributed an industrial funding amounting to RM 20 000 for the production chemistry development.

Figure 4: Memorandum of understanding signing ceremony in conjunction with 3rd International Conference of Chemical Engineering and Industrial Biotechnology on 29th November 2016, Melaka.

4.1 Benefit to Industry

Throughout this program, the industry understands the mechanism and chemistry behind well stimulation and potential of ionic liquid-chelate solvent in well stimulation to control the solid scale such as SiO_2, $CaCO_3$, $BaSO_4$ and FeS (Figure 5). They gained knowledge on molecular dynamics simulation as a tool for understanding chemistry in solid scale dissolution. Industry gains knowledge on the potential of ionic liquid in solid scale dissolution through an explanation of important functional group and how it can be applied in the real production process.

(a) (b)

Figure 5: Solid scale obtained from oil field; (a) silicate and (b) barite

In addition, engineers and operators with no chemical background in oil & gas gained some understanding of the products they use in well stimulation. This would have prepared SVP toward involvement in production chemical business (Figure 6 & 7). Collaboration between SVP-UMP also has gained an interest form SVP client such as local oil & gas producer. At present, production chemistry has a significant interest in local oil & gas producer. As a result, UMP has been invited to join Production Chemistry Open Day in Kuala Lumpur to get an insight of specialized studies and key technology being trialed and developed by Petronas (Figure 8). Such interest from Petronas has a great increase in good perception of SVP as a company with production chemistry capability.

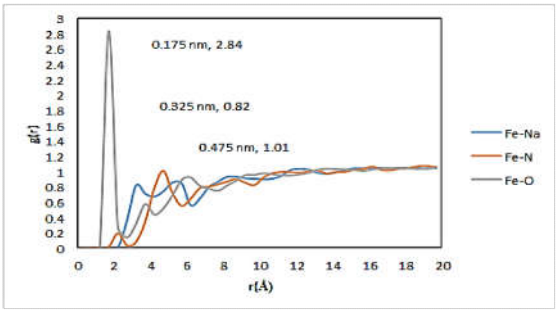

Figure 6: Knowledge of molecular interaction of chemical solvent application to control solid scale transferred

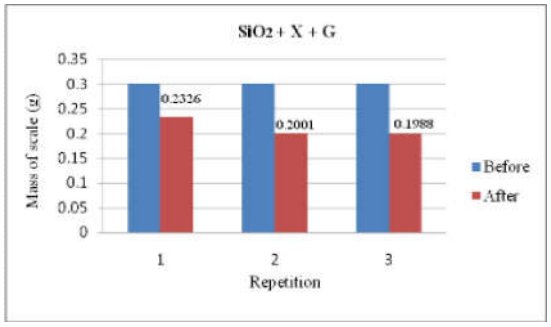

Figure 7: Knowledge of dissolution of silica solid scale using ionic liquid incorporated in commercial solvent agent.

Figure 8: Production Chemistry Open Day, attended by the graduate intern and UMP academia.

4.2 Human Capital Development

Throughout this program, the GI soft skills within the context of molecular dynamic simulation, well stimulation, and the ionic liquid application had been developed. In addition, the GI indirectly developed communication skill as they involve directly in meeting arrangement, presentation, and training with the industry. The knowledge and skills have elevated the potential and the marketability of the GIs.

On 6th-7th December 2016, SVP had sponsored the GI and a student to attend "Pumping Service Training" conducted by at Awana Kijal Resort and Kemaman Base Yard, Terengganu (Figure 9). This training provides technical knowledge and skill for participants for their future career in oil & gas field.

Figure 9: SVP Well Pumping Service Training to graduate intern.

Conclusion

This project has successfully disseminated knowledge regarding the molecular interaction of important functional group in solvent agent and role of ionic liquid as a potential solvent to be incorporated with current commercial solvent. This would benefit SVP towards their involvement in production chemistry and chemical service provider.

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