

Experimental investigation of supercritical methane injection in oil fields on salt deposit formation by gas anti-solvent process



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ABSTRACT

Salt precipitation and salt block formation are the common problems in the gas injection wells. The salt precipitation may produce a severe loss of well injection which leads to a complete blockage of injection. The wells which located at south oil field of Iran are faced with such problems. The analysis of produced sediments shows that more than 93% of those compounds are sodium chloride (NaCl). Different mechanisms can affect the formation of deposit. By injecting supercritical methane into oil fields, it was proved that one of the most probable mechanisms in such condition is gas anti-solvent. In this work, two formation waters at different temperature and pressure conditions were evaluated. The results showed that significant amount of precipitation was observed in one of those water formations while in the other one no precipitation was detected. Furthermore, the effect of operating variables including temperature and pressure on the quantity of formed deposit has been investigated. Moreover, the obtained experimental results were simulated using the PHREEQC software.

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1. Introduction

Gas injection into oil fields is performed in order to prevent the decrease of oil reservoir pressure. The ultimate purpose of gas injection in comparison with other conventional methods is to provide higher recovery coefficient for oil reservoirs. One of the important problems in the injection wells is the formation of deposit. This condition gradually obstructs the passing route of gas flux. Nowadays, one of the most important methods to enhance the oil recovery in oil reservoirs of Iran is gas-injection. So, the ASMARI and the GACHSARAN wells which are located in the south of Iran are faced with such problem. The deposits in these injection wells are generally mineral. It is proved that one of the possible mechanisms of deposit formation is gas anti-solvent. The reason is that when supercritical methane is used as the injection gas, the mineral deposit cannot be dissolved in the injected methane, while the injected methane is dissolved in water. In this process, the gas absorption in liquid occurs with liquid expansion. When a solution is sufficiently expanded by a gas, the liquid phase is no longer a good solvent for the solute. Furthermore, the solution becomes saturated and salt is precipitated from the solution.

In 1879, Mr. Hannay and Mr. Hoghart [1] explained the capability of particle deposits in supercritical solutions. They showed

that the solvability of mineral salts in supercritical ethanol would be increased by increasing the pressure; whereas, decreasing the pressure would lead to salt deposition as snow. The commercial worth of this phenomenon was ignored for more than one century but in the last twenty years, the application of supercritical fluid technology has been considered in the formation of particles. However, the usage of this technology to produce particles had not been presented in any sources until 1984, when Krukoniš [2] and his colleagues achieved good results of material reactivation of nuclear. Numerous studies have been done to investigate the effect of operational parameters on particle morphology using gas anti-solvent process. The effect of several parameters such as temperature, pressure, concentration and solvent type on particle morphology has been studied. Temperature effect on the particle size varies in different systems. For example, the temperature drop in some cases showed particle size reduction in some cases [3–7] while in others it showed the increase in particle size [8] and in some cases no changes was found in particle size [5,9]. Also, the pressure has different effects on particle size that have been studied in several trials [3–10]. As we know, there is no experimental data on the quantity of deposit formation by gas anti-solvent process. In this work, the effect of parameters such as pressure and temperature on the quantity of deposit formation through gas anti-solvent mechanism has been investigated. Additionally, the experimental results have been simulated using the PHREEQC software.

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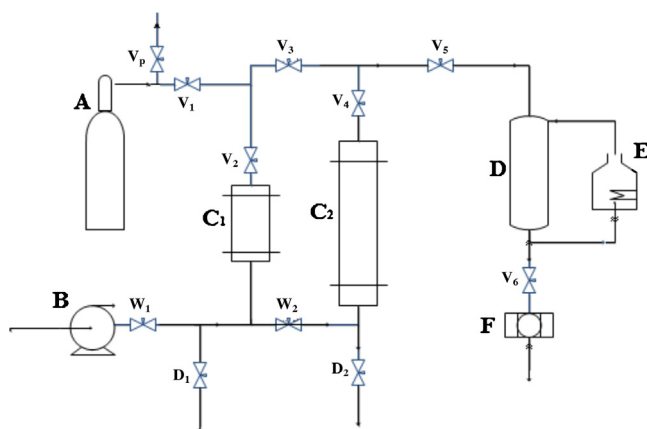


Fig. 1. The schematic illustration of experimental setup.

2. Experimental

2.1. Apparatus and procedures

The gas anti-solvent laboratory equipment is shown in Fig. 1. The description of the used apparatus is as follows.

In the initial state, hand valves V_1 , V_2 , V_3 , V_6 are closed and cylinders C_1 , C_2 must be filled with water. Then hand valve V_2 is opened slowly while hand valves D_1 , D_2 and W_1 , W_2 are closed. Hand valve D_1 which expels water from cylinder C_1 is opened and through entrance gas pressure, water is sent out from cylinder C_1 by a piston and then occupies its interior space. Gas is supplied from a gas cylinder. By closing hand valve D_1 and opening hand valve W_1 , the water is pumped into the cylinder C_1 . By the entrance of water into the cylinder C_1 , gas pressure increases with reducing its volume. Gas pressure is monitored by a pressure gauge ranged up to 250 bar with the division of 1 bar. Hand valve V_3 , V_4 are opened and gas expels their interior water by replacing the piston in cylinder C_2 and enters their space. The injection of water by pump (Haskel Mark, USA) will continue in cylinder C_1 until the gas pressure stops increasing by water injection. In this condition, the pressure of water will increase without increasing the gas pressure. In other words, piston reaches to the end of cylinder and all its volume is filled with water. All the above operations can be repeated several times, until the gas pressure reaches to desired pressure. The pressurized gas then enters into tank D (180 ml). This tank is surrounded by a regulating hot water jacket to set the temperature of system up to 100 °C. Also, one digital barometer (± 0.5 bar and pressure range of 0–400 bar) is connected to analog barometer which is equipped by a sensor (VIKAI, Germany). This sensor records pressure and also transmits flows of 20 mA to digital indicator, so that the pressure will be readable on monitor in terms of the bar. The maximum level of pressure changes is ± 0.2 bar. During the experiment, the tank temperature could be controlled easily by a PT-100 thermocouple (fluid is in the form of supercritical in operation's pressure and environment temperature). In each experiment 100 ml solution has been used, it is being kept in the desired operation conditions for 2 h to ensure that complete equilibrium has been obtained. Then the solution is expelled from a container exit valve which has been installed in the back of the metal filter (stainless steel type). After that, additional gas is injected into the tank, so that the injected gas can rinse all solvent and also deposit solid materials on the filter. These materials have been deposited during the static period.

2.2. Materials

Two kinds of formation water and injected gas have been used in this study. These materials were supplied from National Iranian

Table 1

The characterization of injected gas by GC–MS method.

Component	Mole fraction
N ₂	0.36
CH ₄	88.39
C ₂ H ₆	3.60
C ₃ H ₈	2.13
iC ₄ H ₁₀	0.41
nC ₄ H ₁₀	0.78
iC ₅ H ₁₂	0.31
nC ₅ H ₁₂	0.30
C ₆ H ₁₄	0.43
CO ₂	3.04
C ₇ H ₁₆	0.25

Table 2

The characterization of formation water.

	Formation water of GACHSARAN (ppm)	Formation water of ASMARI (ppm)
Na	70,836	46,469
K	9345	5462
Ca	18,800	13,200
Mg	9309	3699
Cl	180425	113863
SO ₄	472	354.1
CO ₃	375	398
Fe	0	141.1

Oil Company and their content provide by the suppliers are shown in Tables 1 and 2.

2.3. XRD analysis

Verification for the crystal structures is done through XRD. The Produced deposit was evaluated using an X-ray powder diffractometer (Bruker, D8 ADVANCED, Germany). The sample was irradiated using a Cu target tube, and exposed to all lines. A monochromator was used to select the K_{α1} line ($\lambda = 1.54056$). The scanning angle ranged from 10° to 100° of the diffraction angle (2θ), and the counting time used was 1 s/step in steps of $2\theta = 0.05^\circ$. The scanning rate used was 3°/min. The excitation current used was 40 mA and the excitation voltage used was 30 kV.

2.4. SEM analysis

The morphology and size of the produced deposit were examined by scanning electron microscopy (S360-CAMBRIDGE). In brief, prior to monitoring the samples by SEM the produced deposit particles were collected on the conductive stubs and then were coated by sputter-coater (SC-7640-Polaron) with Pd–Pt under the presence of argon (99.9% < purity) at room temperature for a period of 100 s under an accelerating voltage of 20 kV. The mean particle size, standard deviation, and 95% confidence interval were calculated by a written program which randomly selected 100 particles of the SEM images.

2.5. PHREEQC program

PHREEQC is a computer program for simulating chemical reactions and transport processes in natural or polluted water. The program is based on equilibrium chemistry of aqueous solutions interacting with minerals, gases, solid solutions, exchangers, and sorption surfaces, but also includes the capability to model kinetic reactions with rate equations that are completely user-specified in the form of Basic statements. Kinetic and equilibrium reactants can be interconnected [10].

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