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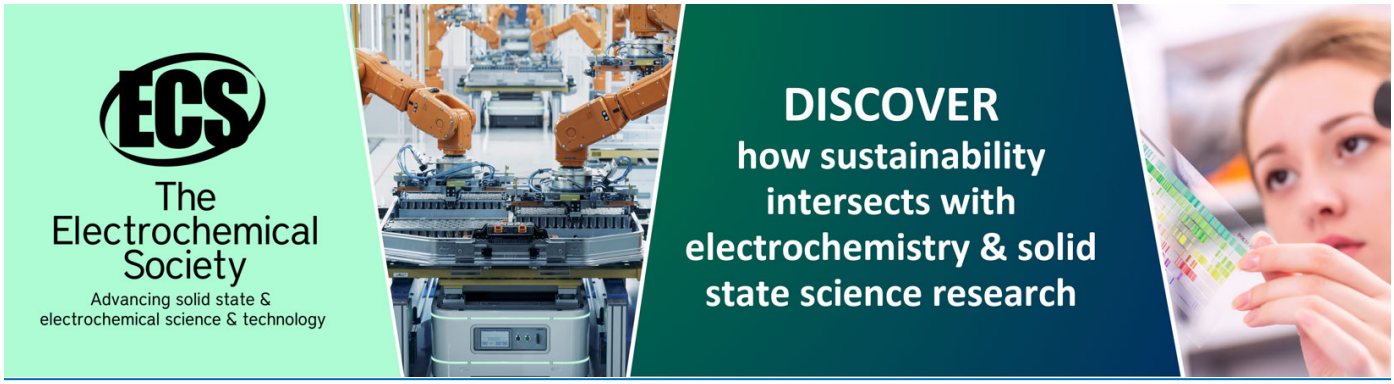

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The Influence of Various Vibration Frequency on Barium Sulfate Scale Formation Of Vibrated Piping System In The Presence Citric Acid

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Abstract. In this paper, the influence of vibrated piping system for BaSO4 scale formation was investigated. The vibration frequency and presence of citric acid were independent variables determining the kinetics, mass deposit and polymorph of the crystals. Correspondingly, induction time and mass of scale were obtained during the experiments. The crystalline scale was observed by scanning electron microscopy (SEM) and X-Ray Diffraction (XRD) to investigate the morphology and the phase mineral deposits, respectively. This effect indicated that the increase in vibration frequency promoted the increased deposition rate, while the pure barite with a plate-like morphology was produced in the experiments.

1. Introduction

Barium sulfate is commonly found in the nature[1,2] and also in industrial components such as heat exchanger, condenser, sea water pipe and oil drilling processes[3,4,5]. In the offshore oil production, the sulfate ions rise of wellbore instead of barium is found abundantly in sea water. When they met in a wellbore, barium sulfate is formed as a mineral scale, namely barite[6,7]. Such scaling process is called as internal scaling because the scale is performed by scale constituent itself[8]. In the last decade, barium sulfate was investigated by many researchers because the scale can occur in almost all industries that seawater was used for industrial processes such as in offshore oil production and steam electrical power plant[9]. In the industrial plant, many mechanical types of equipment are operated by a blower, extruder, generator, turbine, compressor[10] which can generate the vibration. If the maintenance program is not well established, such mechanical equipment would produce vibration in seriously. Generally, mechanical vibration propagates in the floor and wall of the industrial building at where the pipe is mounted on[11]. This vibration is suspected to bear upon the scaling process in the inner tube, once mechanical energy is generated by the fluid flow12 and at the same time, the fluid flow in the inner pipe promotes scaling process. Correspondingly, the existence of scale in the piping system make disturbance of the processes[13] which can reduce the flow rate and lead to unscheduled shutdown[14,15] and sometimes promotes to damage the industrial instrumentation[16]. To undertake the scale inhibiting process requires the knowledge of the crystallization mechanism in the solution and material characterization

experiments. Therefore, this research was aimed to conduct the scaling experiments in the vibrated pipe and how to inhibit the scaling process by citric acid addition, whereas XRD and SEM analysis were used to confirm the crystals formed in the solution.

2. Material and Method

2.1. Material

In this research, barium sulfate was synthesized from a stock of solution containing $BaCl_2 \cdot 2H_2O$ and Na_2SO_4 powder supplied by Merck® to guarantee the purity. In this way, Ba concentration was determined at 3.500 ppm and SO_4 was set as its stoichiometry accordingly. Later, 62.191gr of BaCl2·2H2O and 36.189 gr of Na_2SO_4 powders were then dissolved into 10 l volume of demineralized water and both were finally filtered by strain paper 0.20 μ m pore® and saved in a covered vessel prior to running the experiment. Moreover, the citric acid (5.00 and 10.00 ppm) was used as the additive which was diluted into the stock solutions in either to vibrated and non-vibrated experiment. The scales obtained from the experiments were characterized by SEM to investigate the morphology and XRD to investigate the phase.

2.2. Experimental rig

Laboratory equipment of a scale simulator used in the study was schematically illustrated in Figure 1. A vessel (1) contained the solution of BaCl2.2H2O and a vessel (2) contained a solution of Na2SO4. An electrical heater was employed in each vessel (3) to control solution temperature automatically at the value needed and helped by a sensor (4) under computerized program control (12). To provide the solution inhomogeneous either in temperature and chemical substance, a stirrer (4) was employed and set at 30 rpm automatically by a computer program. Subsequently, the solutions in the vessels (1) and (2) were pumped by a dosing pump of CHEM FEED Ca-92683 (6) to provide a flow rate of 30.00 ml/min and they met in the coupon(8). The piping system was mounted on the Table (7) and vibrated mechanically by an electrical motor (8) which was set-up with a computer program (12). The vibration was operated at a frequency of 0.00; 3.00 and 6.00 Hz. Vibration meter (Lutron VT-8204) (9) was selected to record the vibration parameter. A filter paper of 0.22 m (13) was used to screen the precipitate brought by the flowing solution. A flask tube (14) and a vacuum pump (15) were employed to help in the seizure those crystals. The filter paper was replaced in every ten minutes to avoid the blockage. Finally, the solution was sent to waste vessel (16).

2.3. Characterization

Scanning electron microscopy (SEM) (FEI Inspect S50) was employed to analysis of morphology. Powder crystals were mounted on a circular metallic sample holder and subsequently sputtered with gold. After coating process, the crystal was mounted at the anchor for scanning and recording imaging data. XRD pattern was obtained by Rigaku SmartLab X-Ray Diffractometer with Bragg-Brentano system and Scann axis Gonio; start position of 2θ 10.0100; end position 89.9900; step size (2θ) 0.02^0. Kα 1.54060 and Kβ 1.39225. Generator set at 35 mA 40 kV. All of the XRD pattern was then matched with line pattern of ICDD-PDF Card of barite.

3. Results and Discussion

3.1. Induction time

The conductivity of the solution, leaving from the coupon was measured by TDS meter and recorded by the computer program. Change in conductivity showed that ions in solution had reacted and precipitated as scale. Time of the first measurable change of conductivity is called as an induction time. Figure 2 shows a graph of conductivity over time. The induction time found in this work was 19; 17 and 15 minutes for the vibration frequency of 0.00; 4.00 and 8.00 Hz respectively. The data proved that the vibration affects the barium scale formation in which the increase of vibration frequency leads to the crystal forming faster.

3.2. Deposition rate

To investigate the deposition rate using the analytical balance by weighing scale mass after drying the sample at 60 ^{0}C for 6 h. The weighing was done for the coupon with and without the scale, here the real scale mass was calculated from the coupon mass minus the coupon mass without the scale. The result of calculation of the deposition rate is given in Table 1 shows that the deposition of 0.1389 g; 0.1421g and 0.1687 g for non-vibration and vibration at frequencies of 0.00; 4.00 and 8.00 Hz. The increase of vibration frequency affects the scale deposition with increasing scale mass. The phenomenon could be related to the vibration generating mechanical energy to the system that can decrease the activation energy as the barrier of the reaction process. The deposition of added citric acid provided the scale, mass of 0.1687 g; 0.1531 g and 0.1462 g for the vibration frequency of 8.00 Hz and additive of 0.00; 5.00 and 10.00 ppm, respectively. The data show the synergistic effects of vibration and additive to scale deposition in which the scale formation decreased in a certain magnitude.

3.3. Morphology

Morphology of the scale was found after it was characterized by SEM analysis. The morphology of crystals resulted from the non-vibration, vibration and vibration piping flow water with citric acid are shown in Figs. 3a, b and c, respectively. Crystal morphology shows no difference in the shape, but shows the difference in the dimension. Morphology of blank-vibrated experiment shows crystal aggregates with a flower-like shape similar to the blank-non vibration, but crystal of the citric acid-vibration experiments show smaller size than that of the blank-vibrated experiment. The result justified that the vibration influenced the size of crystal morphology.

3.4. XRD analysis

The measured XRD data were subsequently confirmed by the ICDD-PDF file card number of 01-076-0213 for barite and resulted that all peaks were matched with the pure barite (Figure 4). The alteration of crystal plane texture shows in the Miller indices that the peak intensity of a plane of (2 0 0) increased when the experiment as vibration frequency in 4.00 Hz. The peak intensity of a plane (2 1 1) shows increase when the experiment vibrated at 4.00 and 8.00 Hz. The peak intensity of a plane (1 1 3) shows increase either for the experiment of 4.00 and 8.00 Hz.

4. Conclusion

Experiment to investigate the influence various vibration frequencies has been successfully conducted and resulted new information about the barite scaling process in vibrated piping system and in the presence additive citric acid. The increase vibration frequency leads scale formation in larger otherwise the use citric acid can decrease the scale. Crystal phases identified as barite for all experiments, but the dimension were altered as the influence of vibration and additive which it has been analysis through Miller indices.

5. Acknowledgments

The authors acknowledge financial support by PhD research program from Universitas Pembangunan Nasional Veteran Jawa Timur.

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Table captions

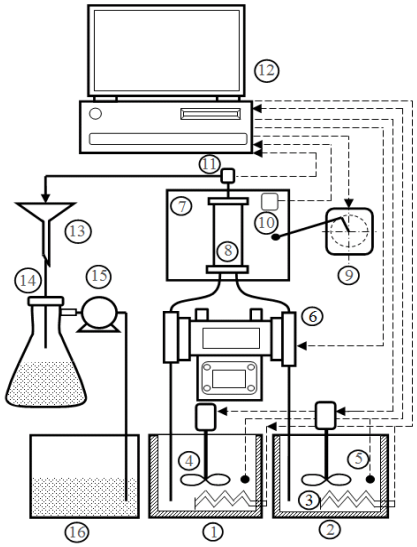
Table 1. Scale mass deposition obtained from the experimentations

Table 1. Karaman et al.

Number Exp.	Vib. Freq (Hz)	Citric acid (ppm)	Scale mass (gr/hr)
1	0	0	0.1389
2	4	0	0.1421
3	8	0	0.1687
4	8	5	0.1531
5	8	10	0.1462

Figure captions

Figure 1. The experimental rig for barium sulphate scaling.
Figure 2. Graph of conductivity over time.
Figure 3. Characterized by SEM analysis a) shows the morphology of blank-unvibrated crystal; b) shows blank-vibrated crystal; c) shows citric acid-vibrated crystal
Figure 4. Peak intensity of plane of barite by XRD analysis



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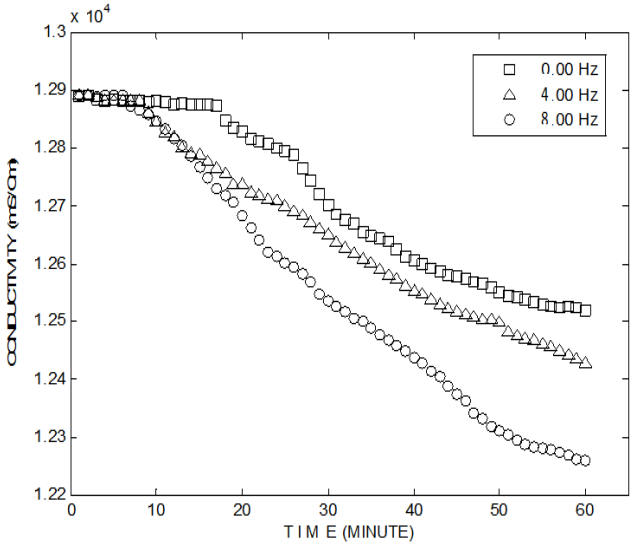

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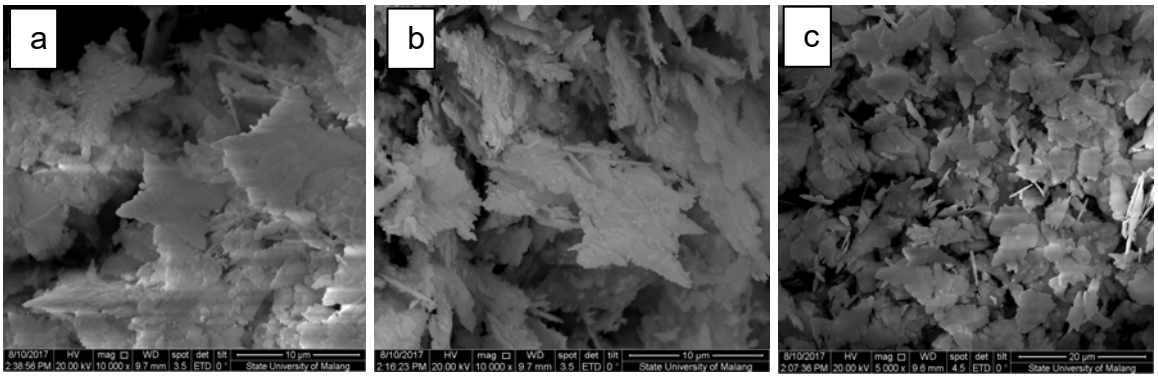

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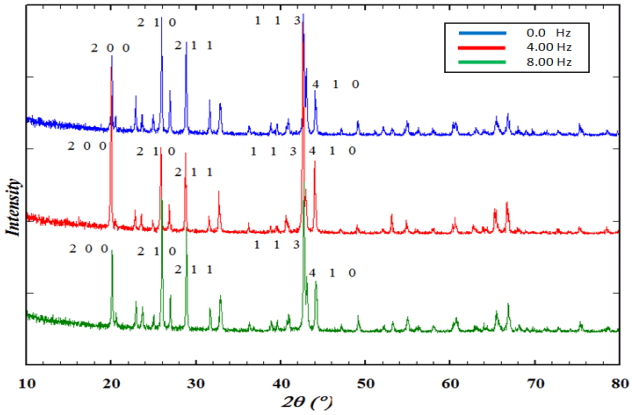

Figure 4. Karaman et al