

Controlling of Magnesium Carbonate Scale Deposition on the Piping System with Laminar Flow and in The Presence of Alumina

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1 Controlling of Magnesium Carbonate Scale Deposition on the Piping System with Laminar Flow and in The Presence of Alumina

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Abstract. The scale of magnesium carbonate deposited on the pipe wall was investigated in the present study. In the experimental work, the scale-forming solution was prepared by mixing equimolar solutions of $MgCl_2$ and Na_2CO_3 . The alumina was selected to inhibit the crystal growth. The scale growth was continuously observed by measuring the conductivity of the solution coming out of the pipe. The formed scale was then evaluated using SEM/EDX analysis. The result showed that the scale has a plate like morphology and the crystalline phase of the scale was found to be mostly calcite. The presence of alumina seemed to change the morphology of the crystals. The results with an influence of 20 ppm alumina were able to extend 100% induction time and crust mass that formed down drastically to 40% and were able to change the morphology of crystals.

INTRODUCTION

Magnesium carbonate ($MgCO_3$) is a mineral of calcium carbonate, which is slightly soluble in water and ground water. It can be formed in certain industrial applications, namely, in the evaporator and cooling power plants. The presence of this mineral can make significant problem because it can precipitate and clog the pipe. Principally, the formation of magnesium carbonate scale is influenced by many factors such as the concentration of solution, pH value, temperature, pressures, and ionic strength [1].

In general, magnesium carbonate can be precipitated from the saline water upon heating and there are three polymorphs namely calcite, valerate, and aragonite. Aragonite and valerate are the most stable phase in lower temperatures, while calcite is commonly formed at higher temperatures [2]. The scaling formation is actually the crystallization phenomenon. Bulk crystallization arises when crystal particles are formed in the bulk phase through homogeneous crystallization and deposit on membrane surfaces as sediments/particles to form a cake layer that leads to flux decline [3]. In addition, supersaturated scale forming conditions leads to scale growth and agglomeration [4]. This is due to the random collision of ions with particles and secondary crystallization occurs on the surface of these foreign bodies present in the bulk phase [5].

Further, formation of magnesium carbonate scale was determined by flow rate [6]. In laminar flow, the higher flow rates lead the more magnesium carbonate scale mass to be deposited indicating that the increasing fluid flow raises the volume flow rates [2]. A previous study by Gourdon [7] have shown that the scale formation can be found in fully laminar and turbulent flow. In full laminar flow, the crystal growth of deposit is found at a slow rate, while in fully turbulent the deposit was increasingly grown with the increasing mass flow rate [8]. In general, the scale growth rate does not follow linear with time, as higher velocity can sometimes lead to reduce scale deposition [6]. Moreover, crystallization due to the lateral growth of the scale deposit on the membrane surface may result in flux declining and surface blockage [3].

A method to prevent the formation of the $MgCO_3$ scale in the pipe is to use chemical inhibitors, which can control the crystal growth, and change morphology [9]. The presence of inhibitors into a solution may continuously

control the process of nucleation and crystal growth occurring on the surface of a growing crystal. The use of tailor-made additives may help to examine the variety of processes regarding to crystal nucleation and growth, interaction with growth environment and crystal polymorphism.

This paper presents a study on the $MgCO_3$ scale formation on pipe with laminar flow. The variable processes investigated were: temperature (30, 40, 50, 60°C) and the concentration of citric acid additives (5 ppm; 10 ppm; 20 ppm). The scale deposits were then characterized by SEM/EDX for morphology and chemical elemental analysis.

MATERIALS AND METHOD

Materials and equipment

The powder precursor used for the preparation of the crystal forming solution were $MgCl_2$ and Na_2CO_3 with the analytical grade. The Alumina (Al_2O_3) with analytical grade was added in the solution in an amount of 5 ppm, 10 ppm, and 20 ppm. The $MgCO_3$ forming scale was grown using the pilot-scale equipment shown in Figure 1.

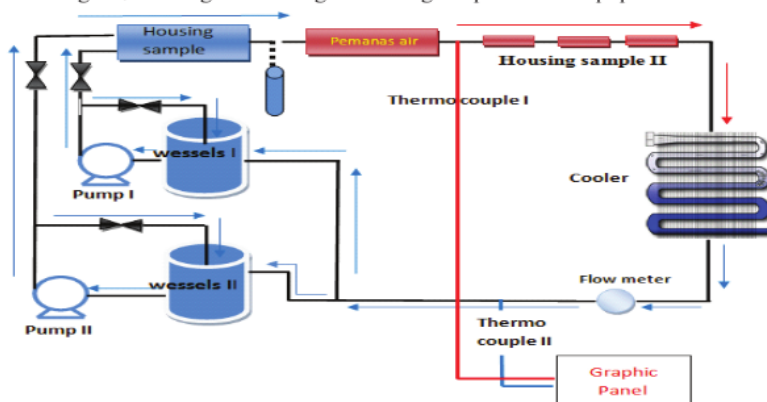


FIGURE 1: Experimental setup used in the $MgCO_3$ Precipitation

Experimental method of the scale formation

For the crystallization experiment, five liters of equimolar $MgCl_2$ and Na_2CO_3 were prepared in the glass beaker. This experiment was performed in the same method which was proposed by Muryanto et al (2014), by dissolving the $MgCl_2$ and Na_2CO_3 powder with the Mg^{2+} concentration of 3000 ppm. The solutions at predetermined concentrations were separately placed in the two vessels and equilibrated until the designated temperature was reached. Subsequently, the amount of alumina additive was dissolved in to a vessel containing five liters of solution $MgCl_2$, then stirred at 200 rpm until it was well mixed.

The conductivity of the liquor exiting the test pipe section was continuously checked for up to 2 hours. The scale deposited on the surface of the coupons was carefully removed and stored in vials for subsequent characterization.

Characterization of precipitates

The characterization of the precipitating scales was conducted by scanning electron microscopy (SEM-analysis), equipped with EDX for morphology and chemical elemental analysis and XRD for phase identification analysis. For the SEM observation, the powder crystals were mounted on a circular metallic precipitate holder and finally sputtered with gold.

The XRPD data collection for phase identification was performed using Cu-K monochromated radiation in a conventional Bragg-Brentano (BB) θ - 2θ focusing geometry (D5005 SHIMATZU). The scan parameters (5-85 O 2, 0.020 steps, 15 s/step) were recorded. A PC-based search-match program, the MATCH Software was employed for identifying possible crystalline phases of precipitates.

RESULTS AND DISCUSSION

Effect of temperature on the mass scale produced

The mass scale deposited in pipes during the experiment was given in Figure 2. The figure shows that the increasing temperature increased the scale deposition rate.

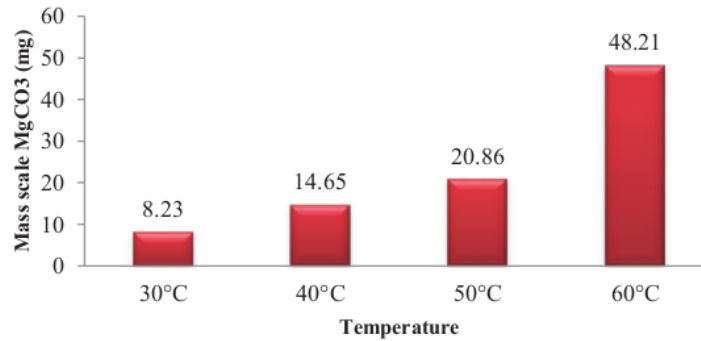


FIGURE 2. Effect of temperature on the resulting mass scale in pipes

The temperatures (30, 40, 50, 60°C) have strong effect on increasing the mass scales of MgCO₃. The mass scales of MgCO₃ were produced 8.23 mg, 14.65 mg, 20.86 mg and 48.21 mg at temperature 30°C, 40°C, 50°C and 60°C, respectively. The results were in agreement with the previous finding indicating that the increasing temperature led to the increasing mass flow rate of scale [10].

The influence of alumina (Al₂O₃) additive in the formation of MgCO₃ scale.

The experimental result of alumina addition to the mass of scale produced is presented in Figure 3. Testing variable concentrations of citric acid (5 ppm, 10 ppm, 20 ppm) showed a proportional decrease in the mass scales with increasing additive concentration.

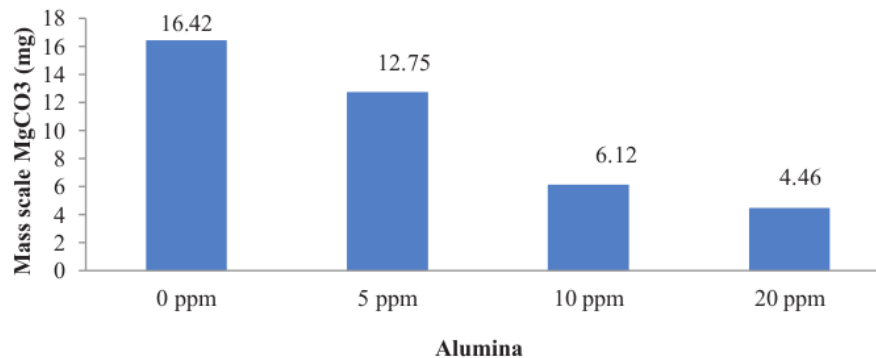


FIGURE 3. Effect of the citric acid on the mass scale produced

The mass scales obtained in the presence of 20 ppm alumina was 4.46 mg of MgCO₃. Similarly provided 6.12 mg of mass scale was found in the presence of 10 ppm alumina. The increasing mass scale (12.75 mg) was also produced at 5 ppm alumina. Clearly the alumina additive may be used to improve the scale produced.

Determination of induction time during the precipitation of magnesium carbonate.

The addition of alumina (5 ppm, 10 ppm, 20 ppm) resulted in the increase of induction time of crystallization (Fig. 4).

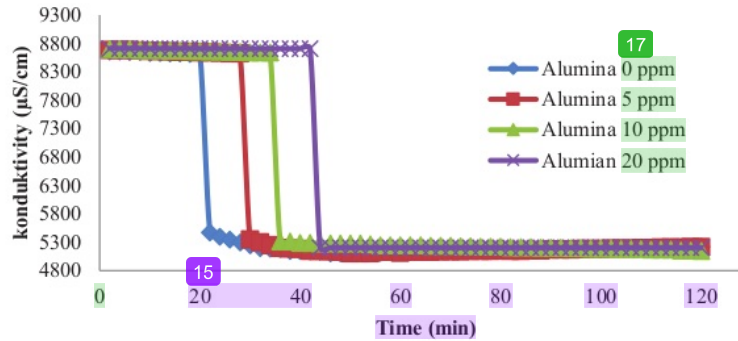


FIGURE 4. Induction time measured on the $MgCO_3$ precipitation

The induction time was observed in the $MgCO_3$ system almost doubled in the presence of 5 ppm alumina (28 min), tripled with 10 ppm (34 min). Moreover, the presence of 20 ppm alumina (42 min) led to an induction time four times greater than that for in the absence of alumina system (20 min).

Microstructure of magnesium carbonate precipitates

The addition of alumina also affected the changes of crystal morphology as shown Figure 5. The presence of alumina additive 5 ppm; 10 ppm; 20 ppm, resulted in the type of crystal morphology was from a prismatic to a round shaped crystal which valerate transformed to magnesite [4]. Thus, the alumina may be potentially effective to control the morphology of the crystal magnesium carbonate and the grain size.

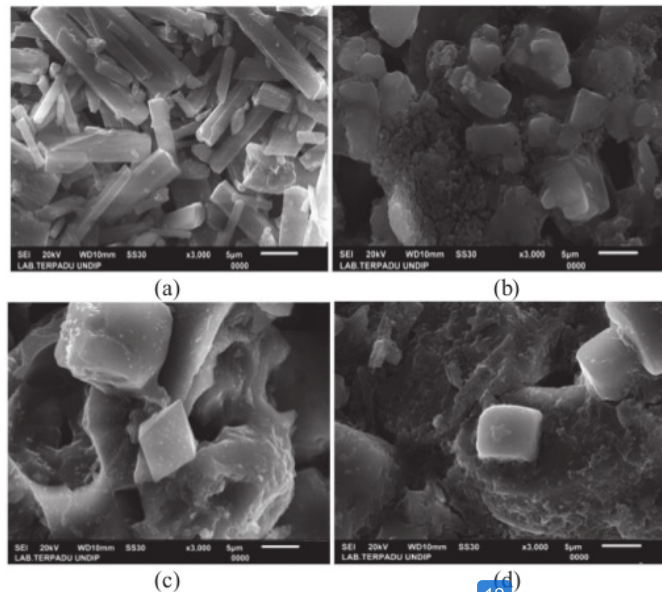


FIGURE 5. Morphology of the $MgCO_3$ scale with the Alumina (a: 0 ppm, b: 5 ppm c: 10 ppm d. 20 ppm).

EDX data of the experiment at a rate of 30 ml/min in the absence and presence of additives alumina 5%, 10%, 20% are presented in Figure 6. The SEM/EDX analysis provided elements of Mg, C and O composed of the calcium carbonate. From the data, calcite is shown as the most stable, while vaterite is the metastable, and most likely to transform into calcite at subsequent temperature [2]. Moreover, calcite was clearly precipitated in the presence of alumina.

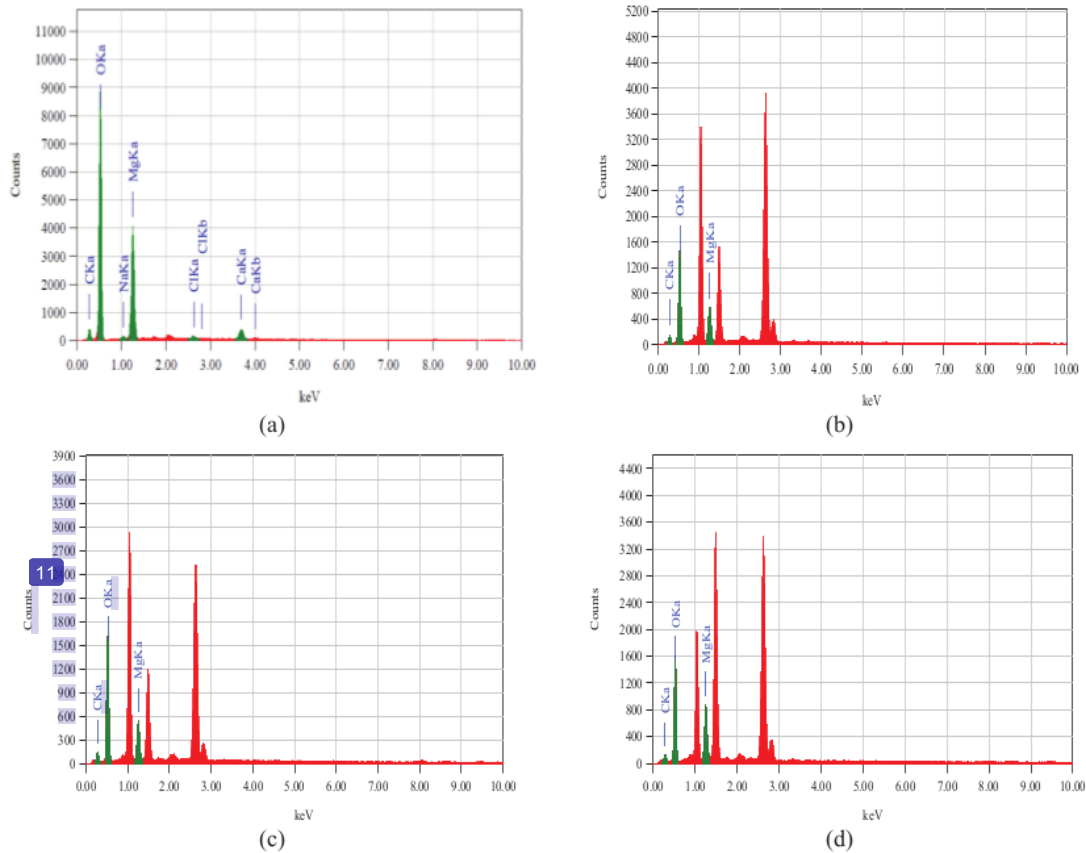


FIGURE 6. EDX of samples obtained from the scale synthesis, (a) alumina 0 ppm, (b) alumina 5 ppm, (c) alumina 10 ppm, (d) alumina 20 ppm

CONCLUSIONS

It was found that in all the experiments, the conductivity decreased abruptly after a certain induction period. The higher temperature produced, the more mass of the scale obtained indicating that the increasing temperature promoted the scale formation. SEM observation of the scale shown crystals with plate-like morphology obtained without additives. This crystal changed to the round shaped morphology in the presence of additive. The crystalline phase of the scale was found to be mostly calcite as shown by the XRD. The addition of alumina seemed to change the crystal morphology, which shows the possibility of alumina adsorption occurred on the surface of the crystal.

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