112 Determining the effect of Electronic Anti Fouling system on the scaling behaviour by inline technique

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ABSTRACT

Scaling represents a serious problem to many industries. Scaling in pipes leads to an increased pressure drop and often to complete blockage. On heat exchangers it reduces the heat transfer. It may also lead to unstable operation which could result in unscheduled shutdown and loss of revenue. One of the most common types of scaling is due to calcium carbonate. Calcium carbonate scaling occurs when Ca^{++} and CO_3^{--} ions in water react to form an insoluble solid.

This research is thus focused on understanding the behaviour of calcium carbonate scaling in the presence and absence of Electronic antifouling. The novelty of this work is that an inline in-situ monitoring technique is utilised to obtain real time data of the calcium carbonate deposition on a surface. The calcium carbonate crystals are obtained by a standard precipitation process and the formation and deposition of the crystals is monitored using inline technique known as FBRM (Focused Beam Reflectance Measurement). The experimental work has been designed to understand the effect of Electronic Anti fouling (EAF) on precipitation and scaling of calcium carbonate at given calcium ion concentration and solution temperature. The scaling is characterised by measuring the rate of number of crystals deposited on a surface of the FBRM which, unlike mass as used by previous workers, makes this method unique.

Keywords: Electronic antifouling, online, calcium carbonate, precipitation, deposit.

1 INTRODUCTION

Scaling is defined as the hard, adherent deposit that precipitates out of solution and deposit on surface. The problem of scaling causes loss of production or process time, it causes deterioration at equipment and equipment failure, increased energy consumption and loss of turnover. The methods by which scale can be treated can be chemical or physical. The chemical method has been shown to be very effective however can cause environmental pollution through the disposal of treated water. The physical methods such as magnetic treatments have attracted much attention for over 100 years. However their efficiency is still a controversial question as shown by a recent review by (Baker and Judd, 1996)

Scale formation is the precipitation of sparingly soluble salts, most commonly calcium carbonate which form an insoluble deposit on surfaces. (Donaldson, 1988) suggest that magnetic treatment can not only reduce the scaling potential of the water but also cause the existing scale to dissolve over an extended period of time.

(Hasson and Bramson, 1985) recorded no change in either the rate of scale deposition or the deposit tendency after test duration from 15 to 35 hours and concluded that Antiscale Magnetic Treatment (AMT) was ineffective at the very high levels of supersaturation employed. The effect of magnetic field on the scaling rate is studied by

Various authors, (Ellingsen and Kristiansen, 1979) studied effect of field strength on scaling rate. The authors found the precipitation rate to increase with increasing magnetic flux.

Apart from inducing direct magnetic flux the application of induced magnetic flux by means of solenoid type equipment has been reported. Electronic anti-fouling is a green method of scale mitigation because; it does not use chemicals and removes the option of treatment of process water before disposal. The principle behind the technology involves using a time varying electronic current in a solenoid wrapped around a pipe to create an induced electromagnetic field inside the scale producing solution. From the law of physics, moving magnets or changing magnetic fields, can produce electrical field as a result and induced molecular agitation of the charged ions in the solution, as exemplified in a solenoid (Cho et al, 1997). The present paper shows the influence of EAF on precipitation and scale kinetics of calcium carbonate. The measurements were carried out online technique known as FBRM (Focussed beam reflectance method).

2 EXPERIMENT SETUP AND PROCEDURE

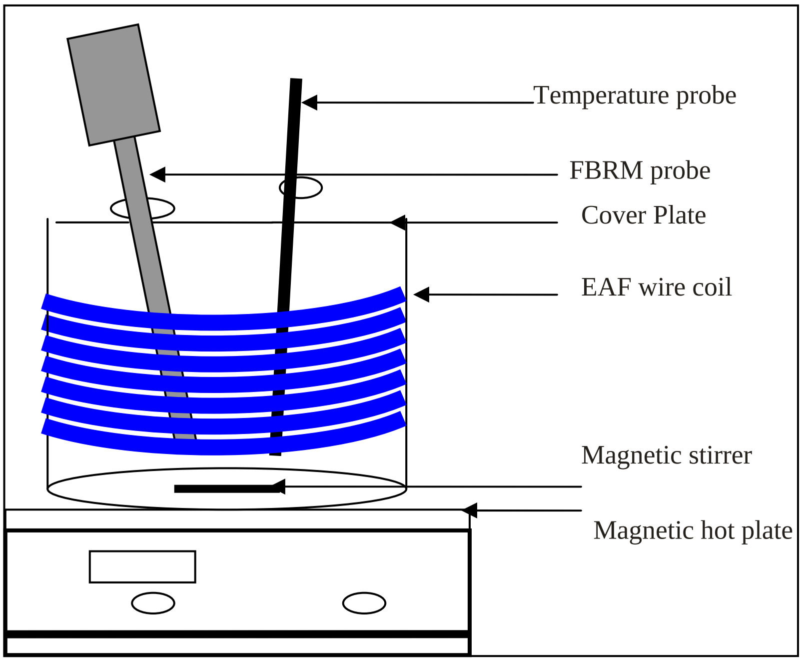

Figure 1: Experimental setup for EAF technique to inhibit scaling of calcium carbonate.

The experimental procedure is as follows: Firstly, solutions required for precipitation of calcium carbonate were prepared. The sources of calcium ions and carbonate ions were *(*$CaCl_2 \cdot 2H_2O$*)* and *(*$NaHCO_3$*)*. One Litre solution of each chemical was prepared using distilled water. The two solutions poured into the 3L beaker placed on a hot plate as shown in Fig. 1 and set at the required solution temperature, at this moment the FBRM and temperature measurements were started simultaneously. The numbers of particles within the solution were recorded after every two seconds by FBRM (Mettler Toledo). Mixing was brought about by a magnetic stirrer at a speed sufficient to give good mixing in order to keep all the crystals in suspension without settling. The experiments were conducted at 0.02 mol/liter calcium ion concentration at 25^{o}C temperature. This experiment without the use of EAF is termed as blank experiment.

The Electronic anti fouling experiments involved the use of the device that generated a 300mA current at 50-500Hz frequency all other conditions such as mixing, solution temperature and calcium ion concentration were similar to that of the blank experiments.

3. RESULTS

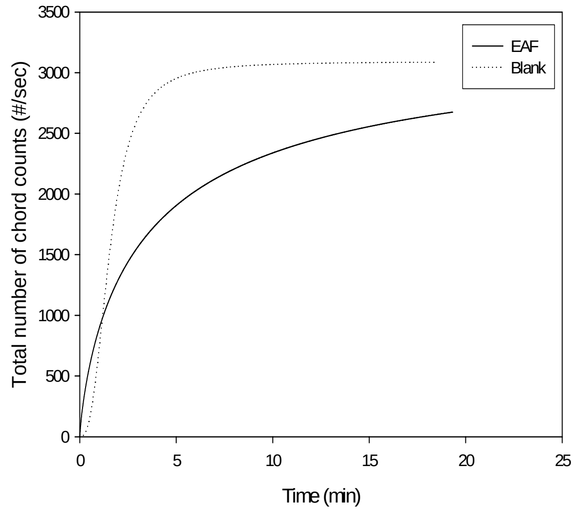

Figure 2: Effect of EAF at 0.02 mol/litre calcium ion concentration and 25^{o}C temperature.

Figure 2 shows typical plot for the total number of chord counts vs. time measured by FBRM probe as a result of calcium carbonate precipitation. The data shown is a result of smoothing the raw data obtain from FBRM; the methodology to obtain the smoothed data is reported earlier in (W.N Nasser et al., 2008). The number of chord counts increases with time for Blank experiment at 0.02 mol/L calcium ion concentration. Similar trend is observed in presence of EAF. But the total number of chord counts in presence of EAF is found to be less than in Blank condition. However when the experiments were repeated the difference in number of chord counts between blank and EAF condition is not found to be significant. This can be seen in Figure 3. The total number on the ordinate is at 15 minutes of the process. The vertical bars indicate the average values of the numbers measured for five experiments. The average values shows that Blank condition contains slightly higher number of chord counts as compared to EAF, the error bars were calculated as the ratio of standard deviation to root of number of measurements. The error bars for each condition overlap each other; hence any significant difference in the numbers could not be concluded.

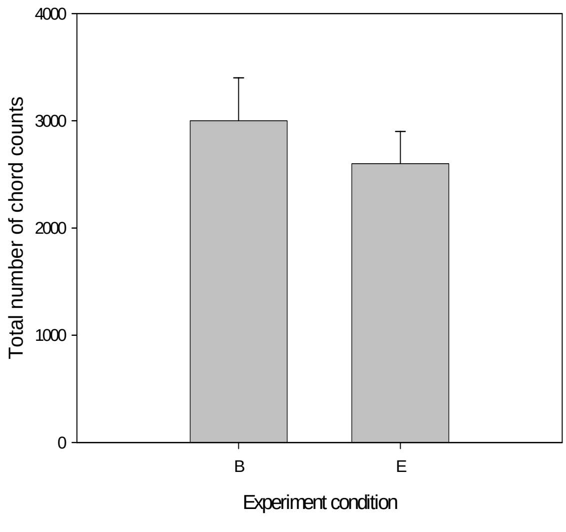

Figure 3: Effect of EAF on total number of chord counts at 0.02 mol/liter calcium ion concentration and 25^{o}C temperature.

3.1 Effect of EAF on scaling rate

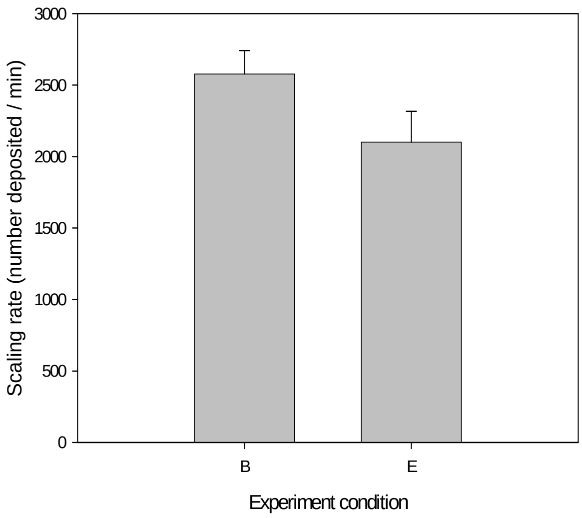

Figure 4: Effect of EAF on scaling rate at 0.02 mol/liter calcium ion concentration and 25^{o}C temperature.

In the present work the scaling rate is calculated from measured data online by using FBRM. The detail procedure to calculate online scale rate is shown in (W.N. Nasser et al., 2008). Figure 4 shows the online scaling rate obtained from FBRM in terms of number of deposits per minute. The experiment was performed at 0.02 mol/litre calcium ion concentration and at 25^{o}C solution temperature. The values on the ordinate are the average obtained from five experiments. The difference in average shows significant difference in the scaling rate between blank and EAF condition. This shows that in presence of EAF there is less scaling rate of calcium carbonate. This result is in agreement with the literature.

4. DISCUSSION AND CONCLUSION

The present results shows that there is little difference in the total number of chord counts measured under EAF and blank condition. While the difference in scaling rate as measured by FBRM in terms of number of deposition of crystals in terms of chord per unit time is considerable. The effect of EAF on the scaling rate is in agreement with the literature which shows considerable evidence of effect of magnetic field or EAF (Cho and Fan, 1997) on scaling rate. The literature shows scaling decreases in presence of EAF. According to (Cho et al., 1997) the pulsing current creates a magnetic field inside the system wrapped around the wire, the magnetic field varies with time, the magnetic field induces an electrical field, and this result in a solenoid induced molecular agitation, which increases the frequency of collision between calcium and bicarbonate ions, the dissolved ions are converted to insoluble crystals. Hence favours precipitation in the solution. This does explains reduction in the scale formation.

EAF has an effect on the scaling process more than precipation process. This could be investigated further by looking at the morpholgy of crystals in the presence and absence of EAF at different conditons.The number of crystals is not been measured directly in this type of application. Hence the effect of EAF on the number of crystals which in present case the number of chords is not very clear. The present results does not show conclusive the effect of EAF on the number of chord counts measured.

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