



ELSEVIER

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Surface inorganic scale formation in oil and gas industry: As adhesion and deposition processes



Mohammad Mohsen Vazirian^{a,*}, Thibaut V.J. Charpentier^a, Mônica de Oliveira Penna^b, Anne Neville^a

^a Institute of Functional Surfaces (IFS), School of Mechanical Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom

^b PETROBRAS - Research and Development Centre (CENPES), 21941-915 - Rio de Janeiro - RJ, Brazil

ARTICLE INFO

Article history:

Received 15 May 2015

Received in revised form

18 October 2015

Accepted 2 November 2015

Available online 4 November 2015

Keywords:

Inorganic scale

Adhesion

Deposition

Hydrodynamic effects

Rotating Cylinder Electrode (RCE)

ABSTRACT

Scale formation on surfaces can normally be divided into two distinct processes: a “deposition process” which refers to the process of heterogeneous nucleation and growth at the asperities of the surface and an “adhesion process” which refers to the sticking of pre-existing crystals, which have nucleated in the bulk solution, and which build up as a layer on the surface. It has been presented in this paper that the surface scale formation rate is more dominantly controlled by the “deposition process” rather than the “adhesion process”. However, the level of agitation could have inverse effects on one process to another. Only a small amount of research has been done to understand the differences of the kinetics of each of these processes. The presented work represents an experimental study of scaling tests to assess the effect of hydrodynamic conditions, using Rotating Cylinder Electrode (RCE), in a complex scaling environment, particularly supersaturated with barium/strontium sulphate and calcium carbonate, on the stainless steel substrate coated with a wide range of different industrial coatings.

In addition, the effect of the surface energy and surface roughness on both processes has been studied. The paper provides data that will assist in the understanding of the controlling parameters in scale formation in different conditions, and also describes what characteristics of the surface can make it a good anti-scale surface for inorganic scale; however, the results have showed that merely one parameter cannot assure a surface as a good antifouling surface.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Scale formation is recognised as one of the major flow assurance problems affecting production in the oil and gas sector. The main problems of scale deposits in oil and gas industries are clogging the wellbore, reducing equipment lifetime, affecting the integrity of components such as subsurface control valve (SSCV), Electrical Submersible Pumps (ESPs) and hydraulic actuators. The economic implications arise from reduced fluid flow and hence lower oil production but also the huge maintenance costs of replacing production lines.

In the oil and gas industry, many oil wells suffer from flow reduction due to scale deposition within the downhole utilities, valve applications, and tubular components especially during the oil recovery operations.

Inorganic scale deposits (e.g. CaCO_3 , BaSO_4 and SrSO_4) can be deposited all along the water paths in the pipeline applications. Oil

industries normally encounter two types of scale formation (Vetter, 1976; Moghadasi et al., 2003b, 2003a; Bader, 2006) as follows:

- (1) *Carbonate scales* (CaCO_3 and FeCO_3) take place where there is a change in temperature and pressure which results in the release of carbon dioxide from aqueous form to gas form from the flowing fluid.
- (2) *Sulphate scales* (BaSO_4 , SrSO_4 , CaSO_4 and $\text{CaSO}_4 \cdot \text{H}_2\text{O}$) come about where there is a mixture of two incompatible brines.

At the early stages of the oil extraction process, due to large differences in temperature and pressure the carbonate scales are the dominant type of scales to form, while in the latest stages of oil extraction the sulphate scales are the dominant types. The reason is that in the Enhanced Oil Recovery (EOR) process seawater, which is abundant and cheap, is pumped down to the reservoir to increase the oil production. Seawater is rich in sulphate ions and reacts with cations (such as Ba^{2+} and Sr^{2+}) in the reservoir and the formation of sulphate scale can result. Although in some cases to prevent sulphate scale problems, de-sulphated seawater is injected into an oilfield, it is not economically efficient (Jordan et al., 2001).

* Corresponding author.

E-mail address: pmmv@leeds.ac.uk (M.M. Vazirian).

Applying surface coatings or changing the physical/chemical nature of a surface can be a potentially good strategy to reduce the formation of scale at surfaces. In developing a surface engineering strategy for scale, it is particularly important to understand the effect of some parameters in reducing scaling such as: surface parameters (e.g. the roughness (Keysar et al., 1994; Cheong et al., 2013; Liu et al., 2011) and the wettability (Cheong et al., 2013; Zhao et al., 2005; Bargir et al., 2009; Förster and Bohnet, 1999; Azimi et al., 2014; Herz et al., 2008a; Rankin and Adamson, 1973a)), kinetics of crystallisation and surface deposition (Crabtree et al., 1999; Kitamura, 2002; Yu et al., 2004; Dyer and Graham, 2002; Peyvandi et al., 2012), and the induction time (Geddert et al., 2011; Geddert et al., 2009; Jaouhari et al., 2000; Gabrielli et al., 2003) for surface scaling which is dependent on the flow regime (Han et al., 2006; Alahmad, 2008; Vazirian and Neville, 2015) and the saturation rate (Merdhah and Yassin, 2009).

Surface deposition and bulk precipitation are interlinked processes. However they have very different kinetics (Eroini et al., 2013). In an oilfield, the type of scale that deposits on the surface would be different from place to place i.e. the mechanism of scale deposition on the surface in the downhole region would be different from that on ground level components due to (a) the difference in water composition and saturation ratio between these two regions, and (b) the formation of crystals and particles in the brine solution while being transported to the ground level valves and pipe components. In so many studies (Wang et al., 2005; Cheong et al., 2008; Quddus, 2002; Quddus and Al-Hadhrami, 2009; Quddus and Allam, 2000; Morizot et al., 1999; Neville and Morizot, 2000), the hydrodynamic effects on the process of scale formation on the surface have been surveyed as one mechanism referred to as “deposition” on the surface. In the presented work, the scale deposits on the surface are divided into two mechanisms: a “deposition process” which refers to the process of heterogeneous nucleation and growth at the asperities of the surface and an “adhesion process” which refers to the sticking of pre-existing crystals which have nucleated in the bulk solution and which build up as a layer on the surface. This paper assesses the effect of hydrodynamics on both processes and the relative scaling tendencies for a range of commercially-available coatings.

2. Experimental methodology

2.1. Substrates

A standard austenitic stainless steel (UNS S31603) is selected as a metallic reference material. The stainless steel samples are coated with 16 different surfaces commercially-available types of coatings which cover a variety of surface roughness and surface energy surfaces with different surface compositions, as shown in Table 1.

2.2. Reagents

The water composition of the tested brine is derived from the real conditions of oil wells provided by Petrobras. As shown in

Table 1
Modified substrate with their corresponding coating code.

Coating type	Coating code	Type details
Glass ceramic	S-1	SiO ₂ -organic components
Paint	P-1-P-5	Epoxies
Fluoropolymer	F-1-F-5	PTFE, ETFE, PFA, FEP
DLC	D-1-D-2	a-C:H
Ceramic	C-1-C-3	TiN, CrN, CrN-Ag

Table 2
Brine composition of the scaling solution.

Brine solution 1		Brine solution 2	
Salt	Mass(g/l)	Salt	Mass(g/l)
Na ₂ SO ₄	1.6604	KCl	9.4228
NaBr	2.6372	CaCl ₂	63.9039
NaHCO ₃	0.1598	MgCl ₂	13.1506
NaCl	228.0267	NaCl	180.8250
NaCH ₃ COO	0.0741	BaCl ₂	0.4772

Table 2, the supersaturated brine used in the study is composed of two complex brines. These were prepared separately by weighing the appropriate quantity of salts and mixing with distilled water, and then mixed with the ratio of 1:1, as follows:

Both brine solutions were filtered by a membrane with pore size of 0.45 μm. Before mixing the two brine solutions, they were heated up to 56 °C and the “brine solution 1” was buffered by CO₂ to pH of 6.7. CO₂ buffering would be continuous during the whole scale tests to maintain the level of pH at a constant level throughout the experiment. The initial saturation ratio, were evaluated using the Multiscale[®] software, data are summarised in Table 3. There is a hydrodynamic tendency for scale formation of calcium carbonate, barium sulphate and strontium sulphate on the surface.

2.3. Surface Characterisation

Prior to any surface scale deposition tests, the surfaces need to be characterised in order to quantify their surface roughness and surface energy. The surface roughness measurements of each substrate are done by a Taylor Hobson surface profiler. Surface roughness refers to the irregularity of the surface texture formed by peaks and valleys, and the quantity of R_a is referred to an arithmetic mean of the absolute departure of the roughness profile from the mean line, as shown for each substrate in Table 4.

Contact angle measurements of each substrate were performed by the sessile drop method which measures the contact angle of a series of liquid probes on solid substrate. The contact angle measurement tests are performed in an open air condition at a room temperature of 20 °C, a relative humidity of approximately 40%. The liquid probes used are ultrapure water (18 MV) and diiodomethane; and their corresponding surface tension components are shown in Table 5.

The dispersive and polar components of surface energy calculations are based on a two component model for solid surface energy referred as Fowkes theory (Fowkes, 1964), as follows:

$$\gamma_i(1 + \cos\theta_i) = 2\left(\sqrt{\gamma_i^d \gamma_s^d} + \sqrt{\gamma_i^p \gamma_s^p}\right) \quad i = 1, 2$$

$$\gamma_s = \gamma_s^d + \gamma_s^p$$

$$\gamma_i = \gamma_i^d + \gamma_i^p \quad i = 1, 2 \quad (1)$$

Where θ_i is contact angle of testing drop, γ_i^d and γ_i^p are dispersion and polar energy of testing drop i , and γ_s^d and γ_s^p are dispersion and

Table 3
Saturation Ratio of different inorganic scales at 56 °C.

Species	Theoretical initial saturation ratio
CaCO ₃	10.1378
BaSO ₄	121.7666
SrCO ₃	3.7794
SrSO ₄	11.7175

Download English Version:

<https://daneshyari.com/en/article/1754634>

Download Persian Version:

<https://daneshyari.com/article/1754634>

[Daneshyari.com](https://daneshyari.com)