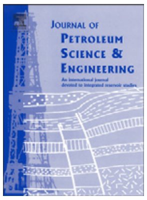
Journal of Petroleum Science and Engineering 81 (2012) 1–6

Contents lists available at SciVerse ScienceDirect

Journal of Petroleum Science and Engineering

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



Study on the composition of mineral scales in oil wells

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ARTICLE INFO

Article history:
Received 29 June 2010
Accepted 4 December 2011
Available online 21 December 2011

Keywords:
mineral scales
TG/DTA
FT-IR
XRD

ABSTRACT

The formation of mineral scales is one of the most common problems in oil wells around the world and despite great technological developments by engineers, this problem remains without an effective solution. The aim of this work was to investigate a methodological procedure that characterizes the composition of mineral scaling that occurs in wells from oilfields, assuming that the proper identification of these mineral scales is decisive for proper use of available technology resources in support of the oil industry. For this proposal we select the following thermal analytic techniques: thermogravimetric analysis (TG), derivative thermogravimetric analysis (DTG), and differential thermal analysis (DTA). These techniques are widely used for the characterization of mineral rocks, including those samples with complex chemical compositions. In order to complement the thermal analysis we used Fourier transform infrared spectroscopy (FT-IR) and X-ray diffraction (XRD). The samples employed in this work were collected from oil wells in the state of Sergipe, Brazil. Nowadays, Sergipe is the third largest producer of oil in this country.

1. Introduction

The presence of mineral scaling is very common in oil fields around the world (Dyer and Graham, 2002; Salman et al., 2007). Scales are a serious issue because it grows on the inner surface of tubing of oil wells, increasing the roughness of this surface and reducing the inner diameter of the tube, which may lead to oil flow reduction and a significant decrease in productivity. García et al. (2005) defined scales as a hard adherent on a surface originating from deposited mineral that precipitates from brines. These authors affirmed that the amount and location of the scales depend on various factors such as the degree of supersaturation, kinetics, pH, composition of the solution, temperature, and pressure in the system (reservoir and well).

The formation of the scales is explained, in general, by two factors: the first is related to the breakdown of thermodynamic equilibrium in the formation water of the reservoir that occurs at the moment of creation of the well and/or the mixing of incompatible waters. This disequilibrium promotes a modification in the temperature and pressure of the system, which can interfere with the pH and the degree of supersaturation of the solution and consequently its kinetics in different positions of the oil wells and tanks, inducing the deposition of solid phases which can lead to the scaling process. This set of factors gives the materials formed a high degree of complexity which makes the determination of their composition difficult.

Generally, the growth of the mineral scales can be explained by two factors, which are presented below. The breakdown of thermodynamic equilibrium of the natural formation water state occurs at the moment of well creation and/or mixing of incompatible waters, which takes place when the injection of water in the oil reservoir is necessary for the well to continue production. With the creation of the well, modifications in temperature and pressure of the reservoir occur which influence the pH, degree of saturation and consequently the reaction kinetics of the formation water along the tubing well and reservoir, causing the deposition of the solid phases and starting the growth of the scales.

The second factor to be mentioned is the mixing of incompatible waters, which is the main cause of the sulfate formation. It is known that incompatible waters are those waters that interact chemically. For example, when the injection of water rich in sulfates (SO_2^{-2}) is mixed with formation water that is rich in Ba^{2+}, Ca^{2+}, and Sr^{2+}, precipitation of barite ($BaSO_4$), celestite ($SrSO_4$), and/or anhydrite ($CaSO_4$) can occur from this combination (Sorbie and Mackay, 2000; García et al., 2005).

Consequently, it can be said that scales originate from the supersaturated solutions wherein the more unstable atoms tend to join, resulting in a seed crystal, a process denominated as homogeneous nucleation. If this seed crystal anchors in a surface, this occurrence is called heterogeneous nucleation. The instability of the thermodynamic conditions may favor the growth of different crystals at the same time,

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doi:10.1016/j.petrol.2011.12.007

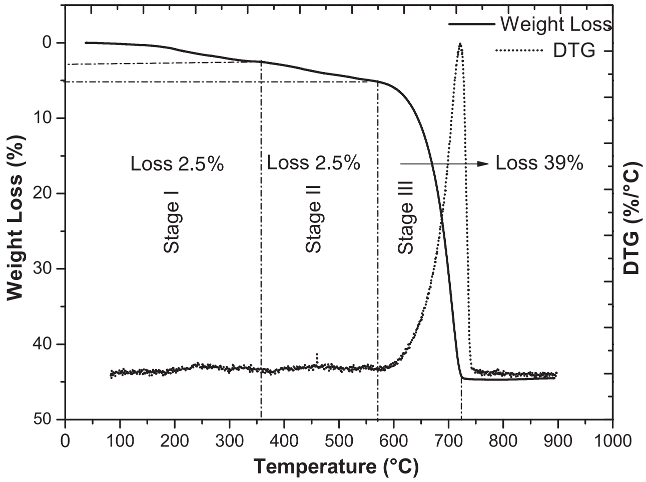

Fig. 1. TG of sample RT.

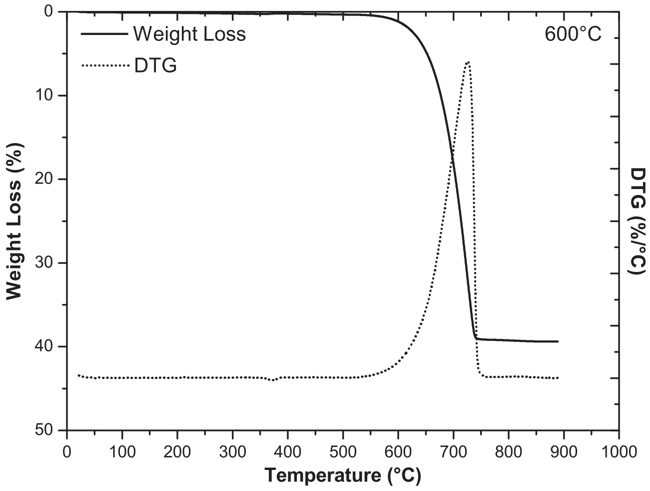

Fig. 2. TG of sample 600 °C.

which provides the materials with a high degree of complexity in their composition. Thermal analysis techniques are very reliable for investigation of materials with such characteristics since the weight loss, endothermic, and exothermic events of minerals are well known.

Recently, the technologies used for the production of the chemicals that make it possible to prevent or combat mineral scaling are well developed. There are also studies that involve computer simulations allowing thermodynamic modeling of the disturbances that occur in the oil reservoir, and these simulations may assist in the choice of procedures for reducing scales in young oilfields. The combination of these actions is a powerful weapon against the scale processes. However, these actions are not sufficient to solve the problem completely. The present work was developed with the aim of proposing a methodological procedure for characterization of the composition of mineral scales that occur in oilfield wells, because knowledge of this composition is decisive for the use of all available technological potential on behalf of the oil industry. For this, thermal analysis techniques were selected: thermogravimetric analysis (TG), derivative thermogravimetric analysis (DTG), and differential thermal analysis (DTA). The motivation for using these techniques was that they are often employed for characterization of mineral rocks and chemical samples of complex compositions. Complementing the thermal techniques, Fourier transform infrared (FT-IR) and X-ray diffraction (XRD) were used in the characterization. The samples employed in this work were collected from oil wells located in the state of Sergipe, Brazil, which is at present the third largest producer of oil in this country.

2. Materials and methods

Mineral scale samples used in this work were collected from oil wells of oilfields in the state of Sergipe, Brazil. The samples were ground in a zirconia balls mill for 5 min to ensure homogeneity.

Thermal analysis measurements were carried out using a TA SDT 2960 instrument and simultaneous TG/DTA system. The experimental conditions were: continuous heating from room temperature to 900 °C at a heating rate of 10 °C/min; a dynamic air (100 mL/min) nitrogen atmosphere; a platinum crucible; and a sample mass of approximately 6 mg.

Table 1
Data of the weight losses of the RT sample.

Stage	Temperature range (°C)	Weight loss (%)	Reaction
	37–900	44	Whole analysis
I	200–400	2.5	Release of bound water
II	400–600	2.5	Dehydration of hydrated phases
III	600–750	39	Release of CO_2

A PerkinElmer instrument was used to obtain the BX FTIRspectra and the samples were performed with KBr. The spectra were traced in a range of 4000 to 400 cm^{-1}, and the band intensities were expressed in transmittance percentages.

XRD measurements for powdered samples were performed with a RIGAKU RINT 2000/PC instrument, using Cu Kα radiation and step-scan mode with acquisition of 5 s/step, in the 2θ range between 10 °C and 80 °C.

The quantitative and qualitative analysis of X ray diffraction data were carried out by the Rietveld Method (RM) with the DBWS program from graphic interface free DBWSTools version 2.23 (Bleicher et al., 2000).

3. Results

3.1. TG/DTG

In Fig. 1, TG and DTG curves of the room temperature sample (RT) are simultaneously traced. From the analysis of the DTG curves three temperature ranges could be determined where weight loss occurs. These ranges are denominated as Stages I, II and III. From the weight loss curve each weight loss was determined. Stages I and II together represented a loss of around 5%, and 39% in Stage III, thus 56% of the sample weight remained.

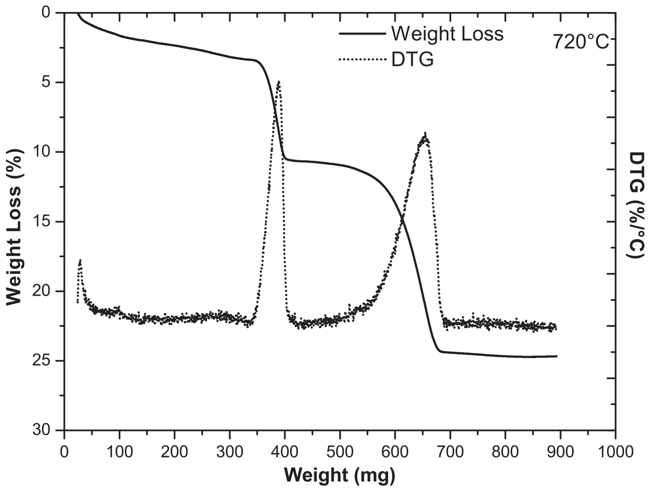

Fig. 3. TG of sample 720 °C.