

An experimentally evaluated magnetic device's efficiency for water-scale reduction on electric heaters



Danijela Dobersek*, Darko Goricanec

University of Maribor, Faculty of Chemistry and Chemical Engineering, Smetanova ul. 17, 2000 Maribor, Slovenia

ARTICLE INFO

Article history:

Received 11 December 2013

Received in revised form

25 July 2014

Accepted 8 September 2014

Available online 27 September 2014

Keywords:

Efficient energy usage

Water-scale

Scale prevention

Magnetic water treatment

Permanent magnet

Electromagnet

ABSTRACT

Water-scale precipitation was observed on electrical heaters within boilers for hot water preparation within households. Different permanent magnetic devices and electromagnetic device were installed on the inlet pipe in the boiler. The system was supplied with tap water of known chemical composition. The magnetic water treatment took place over several days under constant conditions (temperature in the boiler, water composition, etc.) along two parallel lines. The first one was the treated line and the second was for comparison. This paper presents the experimentally confirmed results using different permanent magnets and electromagnets for reducing the amount of precipitated water-scale on heaters for hot water. The impacts of different operational conditions are presented regarding the devices' effectiveness. Scale samples were analysed by X-ray diffraction, where it was discovered that all the samples were in the shapes of aragonite.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Nowadays many efforts regarding the rise in energy savings due to large environmental problems and declining energy sources, which result from inconsiderate usages of natural sources, and wasteful usage of fossil fuel and electricity in the past [1,2]. It was because of this that efforts for more effective energy exploitation began at the end of the 20th century [3].

Many technological processes need raw water, for example for cooling. Raw waters, which are actually ground and underground waters, are in contact with rocky bases from which inorganic salts dissolve. These salts are for example CaCO_3 , MgCO_3 , sulphates, nitrates and chlorides of calcium, and also magnesium. Such water is usually oversaturated with calcium carbonate and this is a dominant component within water-scale [4].

The conditions of over saturation are very often achieved during industrial operations. That is why the water-scale precipitates on heat-transferred surfaces within cold water systems, as well as within high temperature systems.

The scale problem in hard water arises because the solubility of CaCO_3 decreases with increasing temperature. Consequently a large

amount of energy is wasted because precipitated scale is deposited on the heat-transferred surfaces and it has very low thermal conductivity.

The consumption of drinking and industrial water is increasing, and this is another reason why many researchers are searching for new ways of ensuring suitable amounts of water and accordingly think about how to use energy more efficiently. Therefore it is reasonable to search for a solution regarding scale-reduction [5,6,7].

The mineral substances from raw water precipitate on the walls of flowing water supply systems, on washing machine heaters, in boilers and in dishwashers. They form hard linings which cause large technological and economic problems, for example [8,9]: – hindering of water flux in pipes.

- reduction of the working volume in heat-exchangers,
- a more frequent need for maintenance work,
- the premature replacements of devices.

The accumulation of scale deposits is a common and costly problem during several industrial processes. Energy-consumption increases due to scale. For instance with 1 mm scale layers energy consumption is greater by 15% and at 7 mm by 40% [9].

Therefore, different traditional chemical methods are used for scale prevention: either the pre-precipitation of the scale-forming using lime or soda ash, the addition of scale inhibiting reagents, or

* Corresponding author. Tel.: +386 2 2294 479.

E-mail addresses: danijela.dobersek@um.si, danijela.dobersek@gmail.com (D. Dobersek).

Table 1
Water hardness in German degrees [12].

Water classification	Hardness
Very soft water	0–4°n
Soft water	4–8°n
Middle hard water	8–12°n
Pretty hard water	12–18°n
Hard water	18–30°n
Very hard water	>30°n

the replacement of the scale's formation with soluble ions using ion exchange. These methods are effective but they can be very expensive and substantially change the water's chemistry, and therefore have to be avoided for drinking water distribution [10].

Systems for non-chemical water treatment are more frequently being used in efforts towards eliminating water-scale deposits. One such treatment is the magnetic water treatment, which is a long-standing method for water-scale reduction. Magnetic devices in different shapes, from devices for household usage to devices for large capacities throughout industry, have been used for over 50 years [11–13].

The first magnetic device for scale-control was used in the USA. Today, many of these devices are commercially-available and have very different constructions.

Thus, there are devices with electromagnets, and those with permanent magnets. Various studies have shown that the more effective are those devices that provide alternative magnetic fields.

This paper presents the experimental results from several tests on different commercially-available devices for magnetic water treatment. The first experiment was done on a device with permanent magnets that provides a density of alternating magnetic field of around 0.6 Vs/m², the second one was carried out on devices that also had permanent magnets but provide a density of alternating magnetic field of around 0.8 Vs/m². The third experiment was done on a commercially-available electromagnetic device for water-scale reduction, and the fourth one was done to confirm the results from the second experiment.

2. Water-scale

Drinking waters have very different compositions and contents of dissolved substances. In addition to ions of hardness (Ca²⁺, Mg²⁺), waters can contain other cations (Fe²⁺, Na⁺, K⁺) and different amounts of anions (Cl⁻, SO₄²⁻, NO₃⁻, HCO₃⁻) [11].

It is mainly calcium and magnesium ions that influence water-hardness. The more ions that have dissolved from the earth and rocks, the harder the water. Very hard water can be expected from those areas composed of limestone. Water that springs-up within those areas composed of other rocks and small amounts of

disintegrated silicates, is soft just like rainwater. The classification of water depending on hardness is given in Table 1 [12].

Water-hardness within those areas where our experiments were done was very different due to various ground compositions.

Our experiments were carried out on raw tap-water that was rather hard and had total water hardness of around 14°n.

The most frequent component of water scale is calcium carbonate, which precipitates in three different forms [14,15]:

- Calcite (Fig. 1a),
- Aragonite (Fig. 1b),
- Vaterite (Fig. 1c).

The more thermodynamically stable one, calcite crystals, has rhombohedra crystal structures. The density of calcite is 2.7 g/cm³ and its thermal conductivity 2.72 W/mK at 100 °C [16]. Rhombohedra crystals have large connecting areas and that is why the linings are more compact.

On the other hand, there are needles of aragonite crystals with smaller contact areas and less compact linings.

Vaterite crystals with hexagonal structures rarely occur and have densities of 2.6 g/cm³ [16].

Other bivalent ions that are in water usually precipitate in smaller quantities and indirectly effect the precipitation of calcium carbonate.

In water processes that are usually supplied with tap-water containing different ions, the nucleation is important as the first step of the crystallisation. The crystallisation mostly occurs on surfaces of dispersed particles and especially on the walls of pipelines and heating equipment.

The compositions and structures of the precipitated scales also depend on the material on which the nucleation started.

Which crystal shapes are precipitated depends on the waters' compositions. The more important threshold inhibitors for water-scale precipitations are definitely Mg²⁺ and Zn²⁺ ions.

2.1. The effect of Mg²⁺ ions

The inhibiting of CaCO₃ crystallisation by magnesium ions has been studied by a number of investigators.

A. Gutjahr et al. reported the efficient inhibition by aragonite during calcite transformation in the presence of Mg²⁺ ions even at very low concentrations. The experiments were done on pure solutions, where Mg²⁺ ions were added at different concentrations. The results showed that the calcite growth was inhibited at concentrations greater than 10⁻³ mol/l [18].

Kiatmura reported that magnesium ions suppress the transformation of vaterite by inhibiting the growth of the calcite. Magnesium ion is selectively included within calcite and causes an increase in the attained concentration and a remarkable change in the morphology of the calcite, especially in 0.05 mol/l solution. The

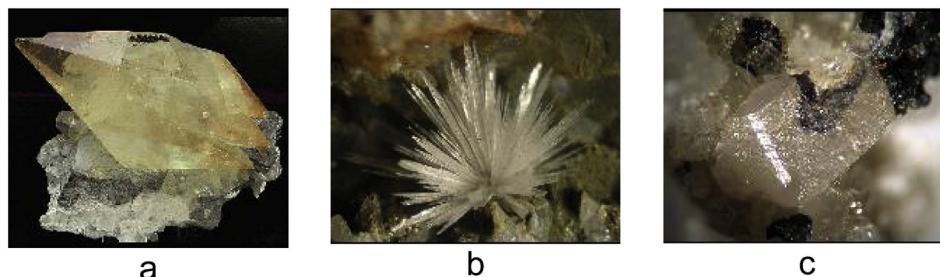


Fig. 1. The crystals of calcite (a), aragonite (b), vaterite (c) [14,15].

Download English Version:

<https://daneshyari.com/en/article/8076348>

Download Persian Version:

<https://daneshyari.com/article/8076348>

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