

Prevention of Scale Deposits in a Water Pipe by Physical Treatment

Senshin UMEKI, Takuya KATO, Haruki SHIMABUKURO,
Noboru YOSHIKAWA and Shoji TANIGUCHI

Graduate School of Environmental Studies, Tohoku University,
6-6-02 Aza-Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan
FAX: 81-22-795-7302, E-mail: FY03033@kankyo.tohoku.ac.jp

Scale deposits are formed on a wall in a water pipe, while it has been used for many years. The scale causes some troubles in various industrial fields. Traditionally, chemicals have been applied to the scale deposits to solve the problem. But these chemical treatments have many problems from the economical or the environmental point of view. Therefore, we attempt physical water treatment in place of the chemical one. Physical water treatment with magnetic fields has been utilized since about 50 years ago. Although its scale prevention effects have been reported, their mechanism is not necessarily elucidated clearly, so far. According to the reports of the fundamental researches and the commercial devices, it has been confirmed that a fluctuating magnetic field is effective for the scale prevention. So we also focused attention on the effect of scale prevention in a water pipe by weakly fluctuating magnetic field. The effect of scale prevention is confirmed by the field researches. Moreover, change in the zeta potential of non-magnetic colloid particles by imposition of weak fluctuating magnetic field is observed in our experiments. Therefore, we suppose the effect of scale prevention by fluctuating magnetic field is related to the change in the surface potential of the microparticles in the water solution.

Keywords: magnetic treatment, water, zeta potential, colloid, scale

1. INTRODUCTION

Certain dissolved constituents tend to deposit as a scale on the inner surface of a water pipe. Although some chemicals have been used for prevention of the deposition, it is not preferable both from the economical and environmental point of view. Therefore, we attempt physical water treatment in place of the chemical water treatment.

Physical water treatment with magnetic fields has been utilized since about 50 years ago [1]. Although its effects for scale prevention have been reported [2, 3], their mechanism is not necessarily elucidated clearly, so far.

We investigated the problems in detail from both the fundamental researches and the commercial devices.

Over the past few decades, a considerable number of studies have been conducted on the effects of magnetic field to aqueous solutions. According to the previous studies, it has been reported that when fluctuating magnetic fields were used, that effects appeared remarkably [3-6]. Among them, there are some reports that the effect of magnetic fields to aqueous solutions arises even if a weak magnetic field of several hundreds μT or less in strength was imposed [5, 6]. As a result of the fundamental researches, it has been confirmed that a fluctuating magnetic field is more effective than static one.

The effect of scale prevention is also confirmed in our field researches. And as given in the fundamental researches, we found the tendency that fluctuating magnetic field is effective. The purpose of this study is to elucidate the mechanism of scale prevention by fluctuating magnetic field water treatment.

We focus our attention to a scale prevention device "Scale Watcher" by using a fluctuating magnetic field. Fig. 1 shows a schematic drawing of scale prevention by "Scale Watcher". (Produced by SKA Co, Ltd. Tokyo, Japan)

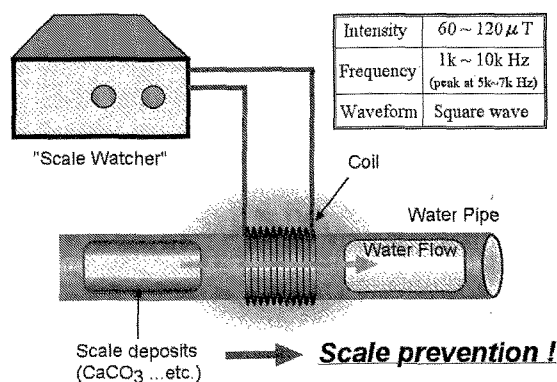


Fig. 1 Schematic drawing of scale prevention with fluctuating magnetic field treatment device "Scale Watcher".

Concerning this device, it is pointed out that the prevention effect is related with the surface potential of particles in aqueous solution [7]. Hence, we investigated the surface potential of non-magnetic micro particles in aqueous solution by imposition of weak fluctuating magnetic field with various conditions.

2. EXPERIMENT

2.1 Zeta potential measurement

Electrolytes employed in the experiment was 10mM KCl aqueous solution. The solution was prepared by dissolving electrolytes in pure water (Daiwa Pharmaceutical Co., Ltd., *AQUA PURIFICATE*: $8M\Omega\cdot\text{cm}$). The colloidal particles used were TiO_2 particles (Ishihara Sangyo Co, Ltd.) with diameters of 100-200 nm. Colloidal solutions were prepared by dispersing particles into the electrolyte solution. A pH value of the solution was 5.5 (25°C) at the start point of the measurement.

Figure 2 shows the schematic diagram of the experimental set up. First the sample colloidal solution was set into the sample cylinder, and the zeta potential without magnetic treatment was measured several times. An apparatus of laser Doppler electrophoresis (Ohtsuka Electric Ltd. ELS-800) was utilized to evaluate the zeta potential. The measurement temperature was controlled at $25 \pm 0.1^\circ\text{C}$.

Then the solution in the cylinder was treated with weak fluctuating magnetic field in a state of rest. The conditions for the treatment were as follows; temperature: 24°C , treatment time: 1 min. In order to impose a controlled fluctuating magnetic field, the "Scale Watcher" and the "Function generator" (NF Co., Ltd., WF1944A) connected with a hand made coil were used to generate the field. The magnetic flux density was $60\sim 150\mu\text{T}$ at the center of the coil with a square waveform. Using function generator, we selected the frequency of the fluctuating magnetic field at 7kHz and 50Hz. Immediately after the treatment, zeta potential was also measured.

2.2 Observations of the precipitates

Since, the main component of the scale deposits is CaCO_3 , we need to measure the zeta potential on CaCO_3 particles in aqueous solution. However, the measurement of the zeta potential on CaCO_3 is difficult, because equi-sized colloidal particles are difficult to produce, but it is easy to coagulate in aqueous solution. Therefore we attempted another experiment in order to investigate the surface potential of CaCO_3 in aqueous solution.

Figure 3 illustrates the experimental flow. A suspension of CaCO_3 particles in 10mM KCl solution

was used as a sample. First, we dripped non-treated sample on a slide glass. Then the sample was treated with fluctuating magnetic field as well as the previous experiment. After the treatment, it was dripped on a slide glass, and then left to evaporate.

After they dried fully, we observed the precipitates with an optical microscope.

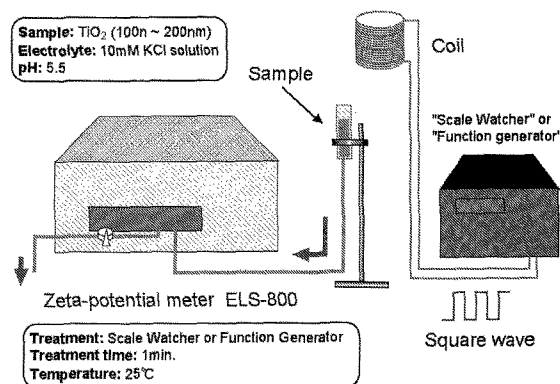


Fig. 2 Schematic diagram of experimental set up for zeta potential measurement.

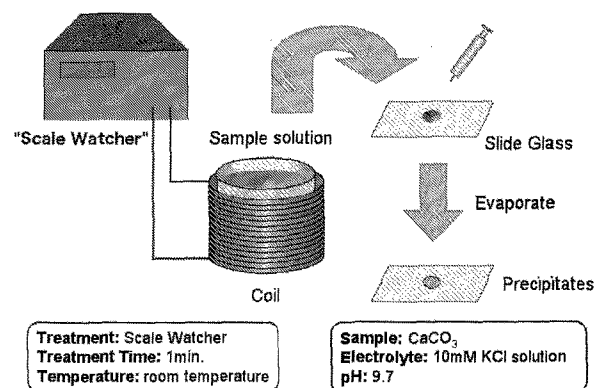


Fig. 3 Experimental flow of observations of the CaCO_3 precipitates.

3. RESULTS AND DISCUSSIONS

3.1 Zeta potential

Figure 4 summarizes the results of the zeta potential measurements. The graph shows the zeta potential values obtained for the non-treated and the treated specimens at different frequency.

In the case of "Scale Watcher" treatment and the magnetic field treatment at 7kHz, the zeta potential shifted to minus direction noticeably. However, the values changed much less by the 50Hz treatment.

The surface potential of a metal oxide in aqueous solution is determined by pH of the solution and by specific adsorption of anions [8]. In order to examine the pH effect, we tried to measure the change in pH of

the solution by the treatment. However, change was not observed at any treatments. Therefore, the change of zeta potential values in this study is pointed out to be related with the specific adsorption of anions. Generally, anions in aqueous solution tend to adsorb on a solid/liquid interface, more than cations [9].

Since the colloid particles (TiO_2) are non-magnetic materials, interaction between the magnetic field and the particles can be neglected. And there might be much small interaction between the water and the magnetic field. Therefore, these effects were presumed to be caused by the induced electric field due to the change in the magnetic field ($\text{rot } E = -dB/dt$), rather than direct influence of the imposed magnetic field. The mechanism presumed is as follows: Vibration of either colloid particles or ions is excited in a specific frequency range of the induced electric field, where association probability between colloid particles and ions is increased. This resulted in promotion of the specific adsorption of the anions on the colloid particles.

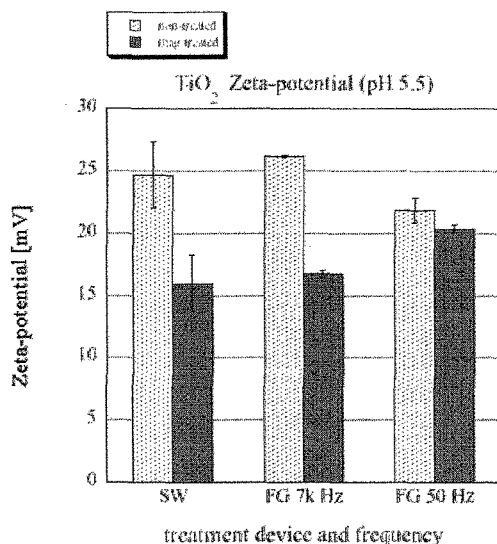


Fig. 4 Change in zeta potential of non-treatment and fluctuating magnetic field treatment at specific frequency. "SW" means "Scale Watcher" using. "FG" means a "Function generator" using.

3.2 Microscopic observations

Figure 5 is photomicrographs of CaCO_3 and KCl precipitates; (a) is non-treated solution, and (b) is the solution with the magnetic treatment. They illustrate boundary lines of the water drop. This photo shows that accumulation of precipitates in the boundary is suppressed by the treatment. Generally, interface of water/air has minus charge. On the contrary, CaCO_3 particles in aqueous solution have plus charge.

Therefore, the particles are drifted to the boundary line of the drop. After the treatment, the surface potential of the particles shifted to minus side, then the particles drifted to opposite direction. This result is consistent with the previous one (3.1).

Figure 6 is photomicrographs of CaCO_3 precipitates in pure water. (a) is non-treated, and (b) is treated. In this case, no change was observed by imposition of the fluctuating magnetic field. This is presumed as follows: There are only a few anions in the solution. So the specific adsorption of anions cannot be expected to occur easily.

We carried out the same experiment by using KF instead of KCl. No change was observed by imposition of the fluctuating magnetic field even in this case. Generally, the F^- ions in aqueous solution do not adsorb [9]. This result has suggested that the consideration is valid.

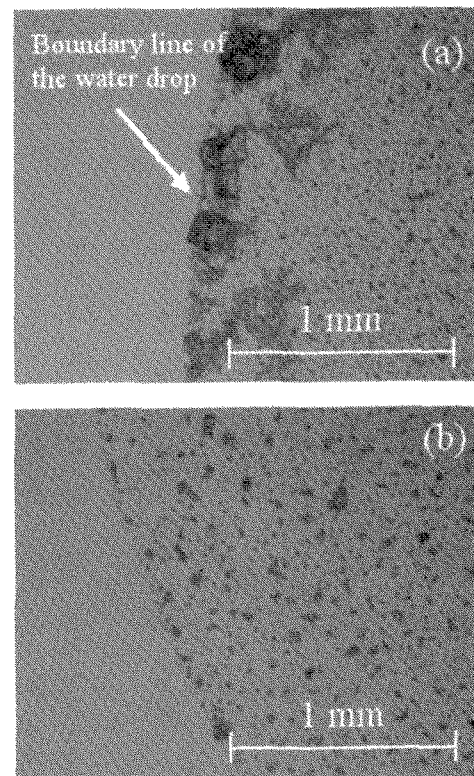


Fig. 5 Photomicrographs ($\times 50$) of CaCO_3 particles in 10mM KCl aqueous solution. (a) non-treated. (b) after having magnetic field treatment by "Scale Watcher".

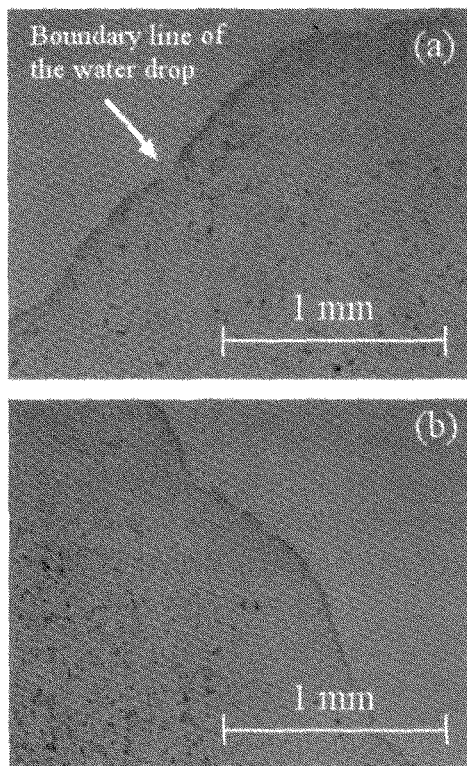


Fig. 6 Photomicrographs ($\times 50$) of CaCO₃ particles in pure water. (a) non-treated. (b) after having magnetic field treatment by "Scale Watcher".

4. CONCLUSION

From the experimental results, we investigated the mechanism of scale prevention by fluctuating magnetic field treatment. The results are as follows: Normally, a surface of inner wall of a water pipe has minus charge and surface of scale particles in water has plus charge. So the particles are attracted by the water pipe and are attached to it. After the treatment, surface potential of the particles shifts to minus side, then repulsive force is formed between the particles and the wall.

This effect arises by imposition of the fluctuating magnetic field at the special frequency. It is considered to be due to the specific adsorption of anions on the particles' surface by the effect of induction electric field instead of the magnetic field itself.

5. ACKNOWLEDGMENTS

This work was supported by 21st century COE Program, Tohoku University International COE of Flow Dynamics. The authors greatly acknowledge the technical supports of the zeta potential measurement by Prof. C. Inoue (Chida Lab., Tohoku Univ.). We also thank Dr. I. Mogi (IMR, Tohoku Univ.) for

helpful discussion. And we wish to thank Mr. H. Otani and Mr. T. Fujino (SKA Co., Ltd.) for suggesting our experiments.

6. REFERENCE

1. S. S. Dushikin and V. N. Ievstratov: Khmiya, Moscow (1986)
2. K. Yamaoka, S. Sugimoto, T. Kimura, R. Akiyama and R. Kobayashi, *Jpn. Goetherm: Energy Assoc.* **25** (1988) 31.
3. C. Gabrielli, R. Jaouhari, G. Maurin and M. Keddam: *Wat. Res.* **35** (2001) 3249.
4. J. Oshitani, R. Uehara and K. Higashitani: *J. Colloid Interface Sci.* **209** (1999) 374.
5. K. Mohri and M. Fukushima: *IEEE Trans. Magn.* **38** [5] (2002) 3353.
6. K. J. Kronenberg: *IEEE Trans. Magn.* **21** (1985) 2059.
7. H. Otani and I. Muraoka: *J. JSPME* **11** [2] (2002) 31.
8. Kitahara, K. Hurusawa, M. Ozaki and H. Ohshima: *Zeta Potential* (Sicentist-sya, Tokyo, 1995) 94.
9. Y. F. Maa and S. H. Chen: *J. Colloid Interface Sci.* **115** [2] (1987) 437.

(Received January 15, 2006; Accepted March 30, 2006)