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# Decreasing the Fouling of Heat Exchanger Plates using Air Bubbles

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**Abstract.** The heat transfer performance of heat exchanger plate decreases as time goes by. The main reason for this phenomenon is the fouling of the heat exchanger plates. To remove the fouling, we have usually cleaned the plate of heat exchanger using chemicals or polishing brush or cloth with hand after stopping the equipment and disassembling the heat exchanger. However, to clean the plate using these methods, the heat exchanger equipment needs to be stopped and disjointed. In addition, it must be re-jointed after cleaning. Especially, the concern of environmental pollution happens in case of using chemicals. Therefore, we need to develop an automatic fouling removal equipment which can continuously keep high heat transfer efficiency and solve the problem of environmental pollution. So, in this paper, we developed and tested the equipment which can clean the fouling on heat exchanger plates automatically per constant period and interval using air bubbles. The total heat transfer coefficient decreased with a slower tendency when using air bubbles compared to the existing methods. There was 10% higher heat transfer effect air bubbles every 10 minutes for 2 hours to remove the fouling ingredients on the heat transfer surface area concerned to the case without air bubbles after 192 hours.

## Introduction

Fouling is the deposit that disturbs heat transfer on the heat exchanger surface. As a result the heat transfer performance of heat exchanger plate decreases as time goes by. The main reason for this phenomenon is caused by the fouling of the heat exchanger plate. To remove the fouling, we have usually cleaned the plate of heat exchangers using chemicals or polishing by brush or cloth with hand after stopping the equipment and disassembling the heat exchanger [1][2].

However, to clean the plate using these methods, the equipment needs to be stopped and disjoined heat exchanger. And we need to re-joint after cleaning. Especially, the concern of environmental pollution happens in case of chemicals. Therefore, there is a need to change the manual processing or problem of environmental pollution by a method that can continuously keep high electric heat efficiency [3]. Now, a device that washes by passing sponge balls in tube is supplied. However, a device that can wash automatically the heat exchanger plates is not developed. This research moved the method that can solve the mentioned problems and remove the pollution.

## Experimental setup

The device for this research can be divided into 2 parts that consist of a hot water and a cold water part. The plate material of the heat exchanger is STS 304, its size is width 816 mm and length 325 mm. An air bubble generation device is mixed with compressed air and cooling water. Fouling is removed due to pressure change at turbulence of the air bubbles and the air separation [4].

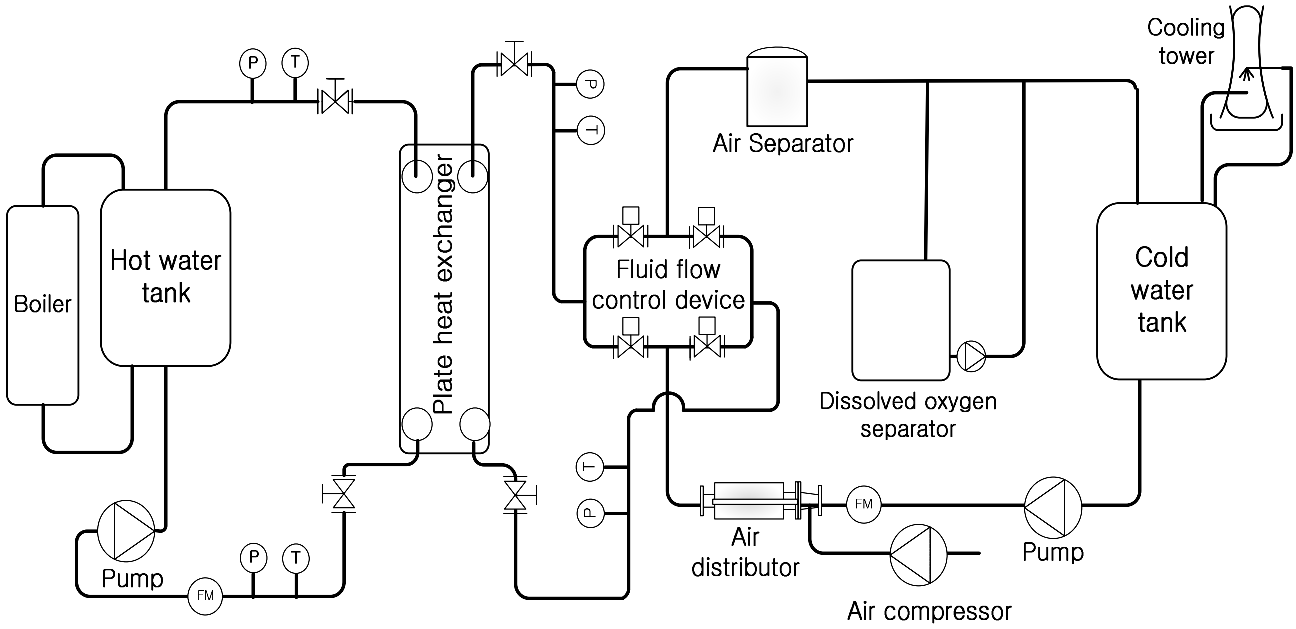


Fig. 1 Schematic diagram of experimental apparatus.

Figure 1 shows the schematic diagram of the experimental apparatus, and Fig. 2 presents a photograph of the heat exchanger plate.

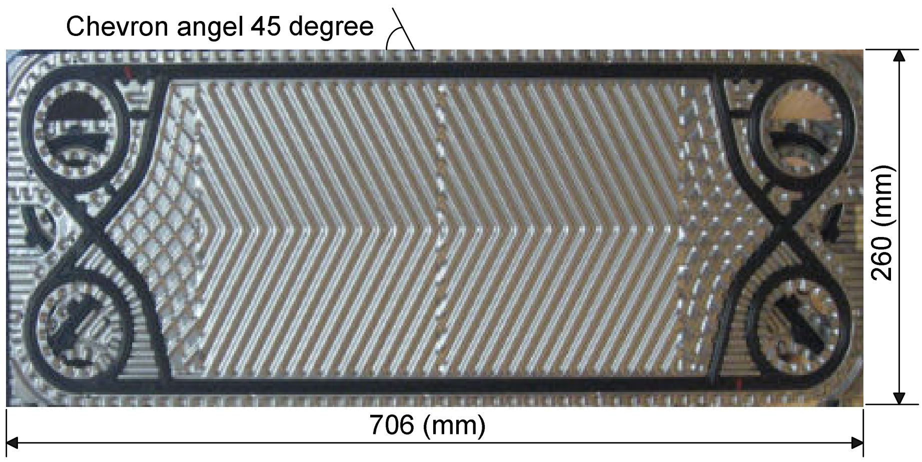


Fig. 2 Photograph of the heat exchanger plate.

## Experimental conditions and method

Hot water is supplied continuously by two boilers with a temperature of 65℃, the temperature of the cold water is kept by a cooling tower which is installed in the loop. Furthermore, the chilled water velocity through the heat exchanger plate varied between 1.0 m/s and 1.25 m/s due to grasp creation of capacity and fouling of the heat exchanger plate according to the water velocity. A K-type thermocouple was installed on the piping to measure the temperature at the inlet and outlet of the cold water and hot water.

The basic heat exchange experiment was performed and the equipment generating air bubbles was installed to erase fouling of the heat exchange plate. The data with air bubbles were compared to the data without bubbles. The experimental conditions are shown in Table 1.

The heat transfers between the cold and hot water in the heat exchanger plates. Beside out the capacity Q and total heat transfer coefficient can be written as

$$U = \frac{Q}{A \Delta T_{LMTD}} . \quad (1)$$

Table 1 Test range of experiment.

| Parameter | Value |
|---|---|
| Starting temperature [℃] | Cold side: 25, Hot side: 65 |
| Cooling water velocity [m/s] | 1.0, 1.25 |
| Air distributer nozzle size [mm] | 1.0 |
| Air bubble | Every 10 minutes per 2 hours |

**Water analyses and pH**

The structure analysis of fouling which was generated on the surface of the heat exchanger plates was performed after a basic experiment. Table 2 shows analysis results of chilled water in this study. Furthermore, Table 3 shows the water analysis results of the Nakdong River in downstream.

Table 2 Componential analysis data of chilled water.

| | Ca hardness | Mg hardness | Total hardness | Alkalinity | Chloride |
|---|---|---|---|---|---|
| (mg/l) | 210.2 | 76.1 | 286.3 | 38.0 | 154.6 |

Table 3 Water analysis data of Nakdong River.

| | Ca hardness | Mg hardness | Total hardness | Alkalinity | Chloride |
|---|---|---|---|---|---|
| (mg/l) | 62 | 12 | 74 | 78 | 34 |

The total hardness shows the value of conversed content of caution metals such as Ca++ or Mg++ which are dissolved in the water [5].

The experimental device used chilled water and it recognized the variation of Calcium and Magnesium hardness, Alkalinity and Chloride according to a periodic variation of 12 hours. Measured value with respect to time increased constantly. The hardness value 286 mg/l as the sum of Calcium and Magnesium shows a three times higher value than that of the Nakdong River water analysis.

After 6 days, the value showed about two times of the original value compared to the value before operating the device. Table 4 shows the variation of the ingredients measurement in chilled water with time.

Table 4 Water analysis data with time.

| Time (hour) | Ca Hardness (mg/l) | Mg Hardness (mg/l) | Total Hardness (mg/l) | Alkalinity (mg/l) | Chloride (mg/l) |
|---|---|---|---|---|---|
| 0 | 210.21 | 76.076 | 286.286 | 38 | 154.562 |
| 12 | 246.246 | 95.095 | 341.341 | 72 | 192.848 |
| 24 | 275.3 | 98.07 | 373.37 | 84 | 202.774 |
| 36 | 276.236 | 109.159 | 385.395 | 94 | 218.372 |
| 48 | 286.286 | 126.126 | 412.412 | 100 | 233.97 |
| 60 | 312.312 | 118.118 | 430.43 | 100 | 243.896 |
| 72 | 316.316 | 134.134 | 450.45 | 106 | 249.568 |
| 84 | 322.322 | 148.148 | 470.47 | 108 | 257.367 |
| 96 | 330.33 | 132.132 | 462.462 | 112 | 262.33 |
| 108 | 338.338 | 141.141 | 479.479 | 116 | 266.584 |
| 120 | 342.342 | 146.146 | 488.488 | 112 | 278.637 |
| 132 | 354.354 | 142.142 | 496.496 | 124 | 285.018 |
| 144 | 362.362 | 153.153 | 515.515 | 126 | 289.272 |
| 156 | 386.386 | 151.151 | 537.537 | 130 | 297.78 |
| 168 | 389.388 | 153.248 | 542.636 | 133 | 299.95 |
| 180 | 392.249 | 153.912 | 546.161 | 135 | 301.01 |

The pH values show a slightly increasing tendency according to change by time from 7.4 to 7.6. Figure 3 shows variations of cooling water pH and total hardness with time. It indicates that there was rarely change of pH value of cooling water from 48 to 84 hours. However, it showed an increasing tendency again after hardening 96 hours, and the differences in change of pH value after 144 hours lower than the anteriority, from 96 hours to 144 hours.

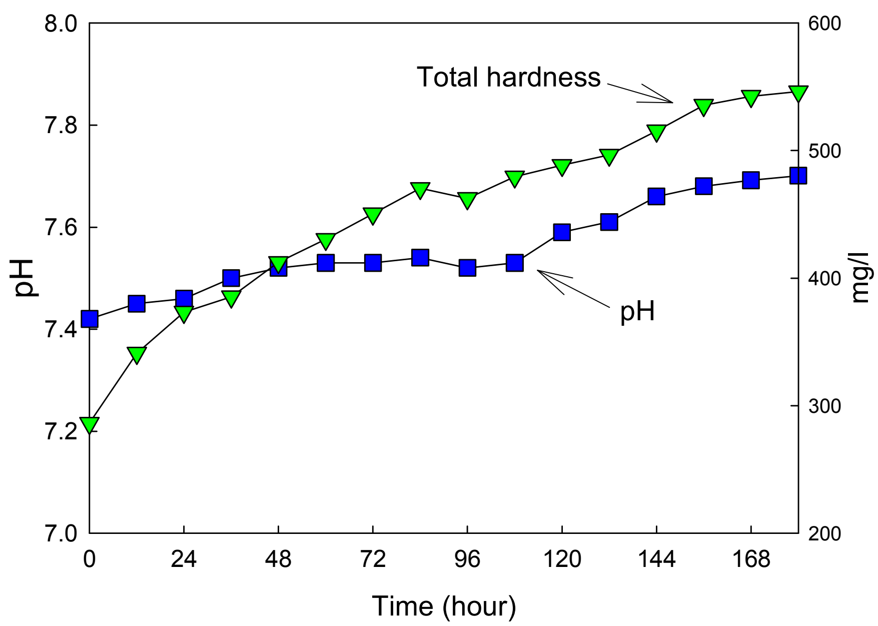

Fig. 3 Variations of cooling water pH and total hardness with time.

**Heat transfer coefficient and dissolved Oxygen**

Figure 4 shows the overall heat transfer coefficient with respect to the change of cooling water velocity from 1.0 m/s to 1.25 m/s. As time passes, in case of both is 1.0m/s and 1.25m/s, the overall heat transfer coefficient shows gradually a decreasing tendency. It is indicated that increasing the cooling water flow velocity is essential to reduce foul ring creation of the heat exchange plate in light of the above results [6]. Comparing the flow velocity of 1.0 m/s and 1.25 m/s, the overall heat transfer coefficient with a flow velocity of 1.25 m/s was about 22% higher than that with a flow velocity of 1.0m/s. It is comprehensible that flow velocity of 1.0 m/s brings a heat transfer loss of 22% compared to a flow velocity of 1.25 m/s.

Figure 5 shows variations of overall heat transfer coefficient between washing cooling water with and without air bubbles. The values are calculated with respect to time. There is no difference in the overall heat transfer coefficient until 72 hours elapse when the washing cooling water increase air bubble every 10 minutes for approx. 2 hours to remove the fouling ingredient on the surface of heat transfer area. However, it was relatively effective increase air bubbles into the cooling water in regards to the overall heat transfer coefficient. It shows 2% and 5% higher value after 96 hours and 114 hours. Moreover, it is indicated that there was a heat transfer effect of approx. 10% compared to the case without air bubbles after 192 hours.

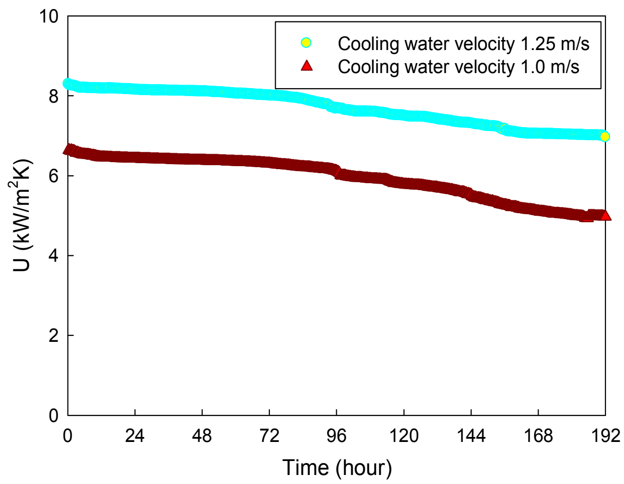


Fig. 4 Overall heat transfer coefficient for different cooling water velocities.

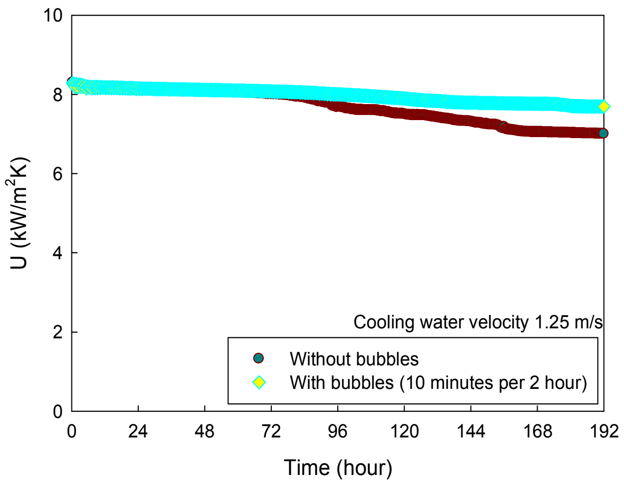


Fig. 5 Overall heat transfer coefficient for the case with bubble and without bubble.

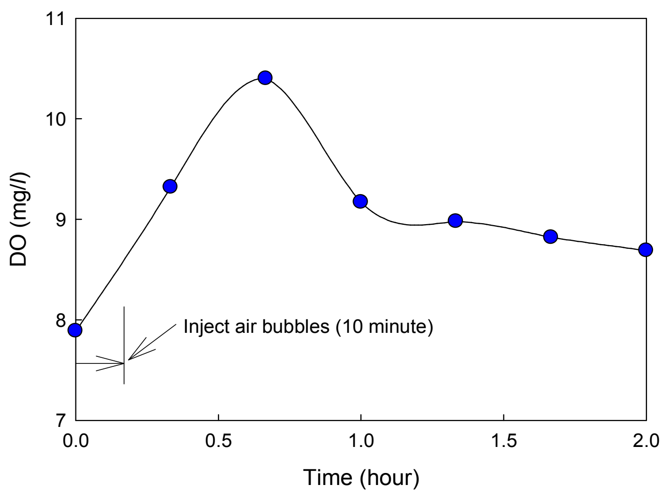


Fig. 6 Variations of cooling water DO with time.

Figure 6 shows removing ability of DO (Dissolved Oxygen) when air-bubble was injected for 10minutes per 2 hours with the unit of separating air bubble. After 40 minutes from injecting air bubbles, DO value increase from initial value 7.89 ppm to 10.4 ppm. However, after 2 hours, DO value decrease to 8.69 ppm due to the influence of the unit of separating air bubbles. In case that the unit of removing DO and air bubble operated, it was confirmed the result which is reducing the value of DO approx. 70% than the initial DO value. And it is judged that this study will be contributed to not only the heat exchanger plates but also suppress corrosion of pipes, due to DO is removed.

## Conclusions

Experiments were conducted to observe the effect of air bubbles in heat exchangers to prevent pollution. The summary is as follows.

The overall heat transfer coefficient with a cooling water velocity of 1.25 m/s showed lower than for a velocity of 1.0 m/s. In addition, the heat transfer effect was increased as flow velocity increased. The flow velocity of 1.25 m/s brings heat transfer gain of approx. 22% compared to a flow velocity of 0.75m/s.

It shows that there was a 10% higher heat transfer effect by making air bubbles every 10 minutes around 2 hours to remove fouling ingredient on the surface of the heat transfer area compared to the case without bubbles of after 192 hours.

In case that the units of removing DO and air bubble operated, it was confirmed the result which is reducing the value of DO approx. 70% than the initial DO value.

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