

# FLOCK SENSOR FOR WASTEWATER TREATMENT PLANT

*H. Tsutada, T. Hirai and T. Usami*

Sensing Systems Department, Industrial Electronics and Systems Laboratory,  
MITSUBISHI Electric Corporation, 8-1-1 Tsukaguchi-honmachi, Amagasaki, Japan

*Abstract: This paper proposes a new image sensor that can evaluate wastewater quality and automatically determine the amount of chemicals to be added in the wastewater treatment process. The sensor can stabilize the wastewater quality and reduce the operator man-hours and chemicals used.*

*Keywords: Water Treatment, Sensor, Image Processing*

## 1 INTRODUCTION

In wastewater treatment plants, chemicals are added to wastewater to make 'flock' to remove pollutants and to make the water clear. As there are variable amounts of wastewater and pollutants, a skilled operator has to go to the plant to check and adjust the amount of chemicals every hour.

Accordingly this paper proposes a 'flock sensor' that measures the sedimentation time of the flock and water turbidity from on-line images, and determines the amount of chemicals to be added automatically. We also present the test results of the flock sensor in a real wastewater treatment plant.

## 2 APPLICATION PLANT

Figure 1 shows the target wastewater treatment plant. The water undergoing the wastewater treatment is mainly used for washing products after metal plating. The wastewater is stored in the raw water tank before being transferred to the coagulation tank where coagulants (organic polymer coagulant) and PAC (poly aluminium chloride) are added. The sedimentation rate of the flock is influenced by the amount of coagulants, and turbidity of the solution is influenced by the amount of PAC. The solution is then transferred to the sedimentation tank, where the pollutants are settled as flock and skimmed off the surface.

Until now, a skilled operator has had to go to the coagulation tank to check the sedimentation rate of the flock and the turbidity of the solution, and adjust the stroke of the coagulants pump and the PAC pump. The flock sensor measures the sedimentation time of the flock and the turbidity from the solution in the coagulation tank, calculates the amount of chemicals and controls the stroke of the chemicals pump. This chemical control system uses FOUNDATION fieldbus devices to achieve field-distributed control [1].

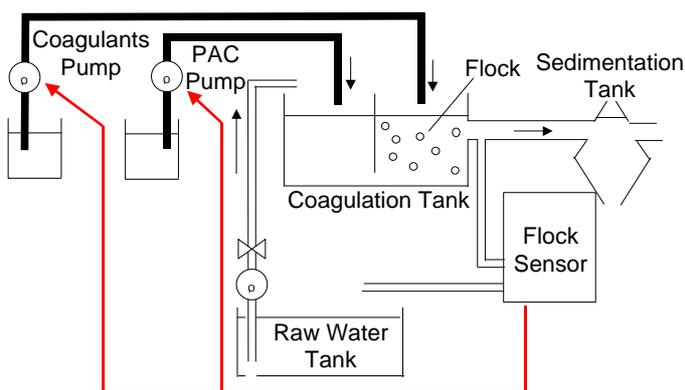


Figure 1. The wastewater treatment plant.

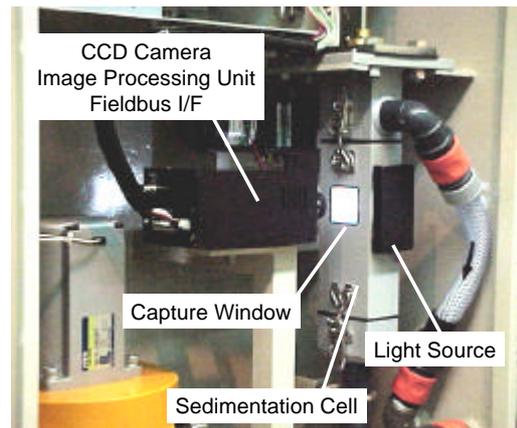


Figure 2. View of the flock sensor.

## 3 FLOCK SENSOR

### 3.1 Measurement Principle

Figure 2 is a view of the flock sensor. Wastewater containing flocks is sampled in the sedimentation cell by the sampling pump and is lit by the light source which is attached to the cell. The sampled water in the cell is captured from the capture window by the CCD camera every 5 seconds. Figure 3 is a sample of an acquired image. The white background board is attached to the opposite side of the

capture window in the cell and it is used for calculating the water turbidity and calibrating the sensor. The sampled water is changed every 6 minutes. The camera unit in the center of Figure 2 has a CCD camera, an image processing unit and a FOUNDATION fieldbus I/F built in. This unit controls the sequence of the sensor, measures the water quality, calculates the amount of chemicals to be added and sends the manipulated variables to the pumps.

### 3.2 Calculation of measurement parameters

First, we describe the method of calculating the flock sedimentation time. The acquired image is binarized by an appropriate threshold, and the flock area is defined as sum of white pixels in the flock measurement area of the binary image (Figure 4). The time characteristics of the flock area are given in Figure 5. Well coagulated flock sinks faster than bad-coagulated flock, so the flock sedimentation time is defined as the time taken until the flock area becomes less than 20% of the entire image area, and the time period for well coagulated flock is smaller than that for badly coagulated flock.

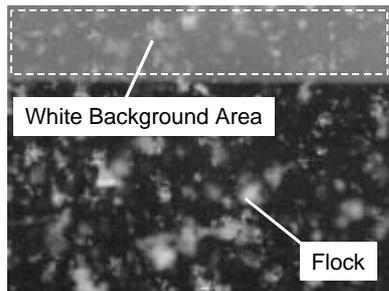


Figure 3. Original image.

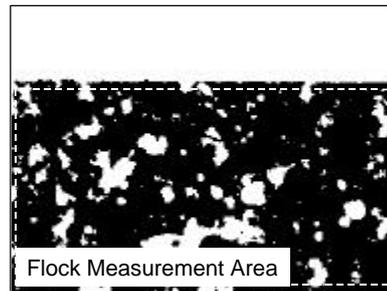


Figure 4. Binary image.

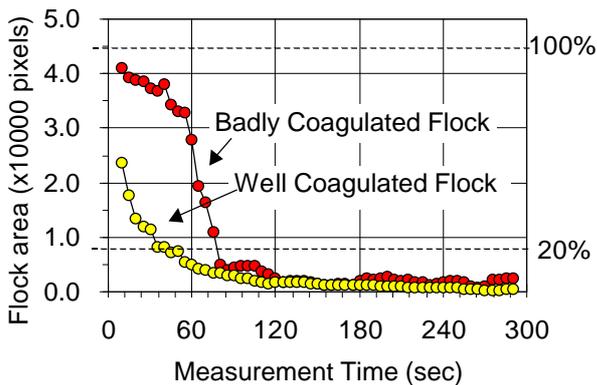


Figure 5. Time characteristics of flock area.

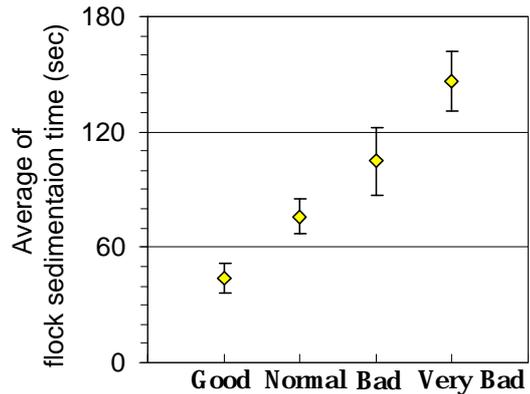


Figure 6. Measurement results of flock sedimentation time.

The measurement results of the flock sedimentation time are given in Figure 6. The x-axis in Figure 6 indicates the subjective score of coagulation rate of the flock, classified into four levels (good, normal, bad and very bad) by a skilled operator. The y-axis in Figure 6 indicates the average and standard deviation of the measured flock sedimentation time. It shows that the measured value is related to the subjective score, so the measured flock sedimentation time can be used as an index of the sedimentation rate of the flock.

Next, we describe the method of calculating the water turbidity. The image intensity of the white background after the flock has sunk completely is defined as C1, the image intensity of the background of pure water (= 0 degrees of turbidity) for calibration is defined as C2, and that of the standard water (= 50 degrees of turbidity) for calibration is defined as C3. The water turbidity T is calculated by Equation (1) if the black level of the CCD camera is zero.

$$T \text{ (degrees)} = 50 / (C3-C2) * (C1-C2) \tag{1}$$

The dispersal of light occurs due to particles that make the water turbid if lit. The intensity of the dispersal of light is linear with the number of the particles, so if the amount of pollutants in the sampled water is increased, the water turbidity is increased and the image intensity of the white background is increased by the dispersal of light because of the particles in the water.

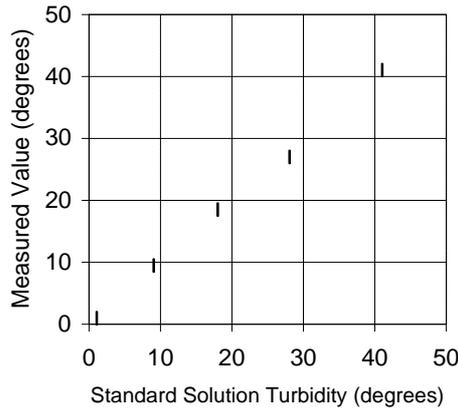


Figure 7. Measurement results of turbidity.

The relationship between the measured value of turbidity and the standard solution turbidity is given in Figure 7. It shows that the output value of the flock sensor is linear with the turbidity from 0 to 50 degrees.

### 3.3 Calculation of manipulated variables

In this system, the amount of injected coagulants is controlled in order to make the measured sedimentation time the same as the target sedimentation time. Since the flock sedimentation time is influenced by the amount of coagulants injected, the amount of coagulants injected has to be increased if the measured time is larger than the target time. Also the amount of PAC injected is controlled in order to make the measured turbidity the same as the target turbidity. Since the water turbidity is influenced by the amount of PAC, the amount of PAC has to be increased if the measured turbidity is smaller than the target turbidity.

The control block diagram for calculating the amount of chemicals is given in Figure 8. In Figure 8, SV is the target value, PV is the measured value of the flock sensor, KV is the chemical injection rate, Flow is the flow rate of raw water, and MV' is the amount of chemicals injected. As the variance in the measured values is large, and the time delay of the target plant is also large, we use a sample-hold proportional-integral (PI) control with a gap for this system.

The chemical injection rate is calculated from the error ( $=SV-PV$ ) by PI calculation, and the amount of chemical injected is acquired by multiplying the injection rate by the flow rate of the raw water. In order to avoid an unusual amount of chemicals being added, the maximum and minimum amounts of chemicals are also defined.

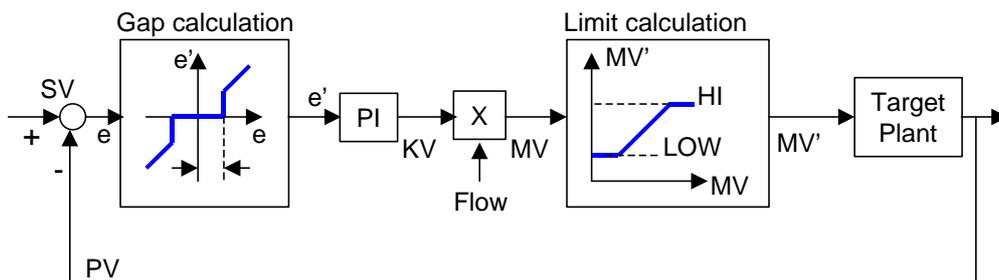


Figure 8. Control block diagram for calculating amount of chemicals.

## 4 TEST RESULTS

We have tested the flock sensor in the real wastewater treatment plant shown in Figure 1. A timechart of the measured sedimentation time for one day is given in Figure 9. In Figure 9, "Without control" is when the amount of coagulants injected is fixed to a constant value by an operator all day, and "Controlled" is when the amount of coagulants injected is controlled to make the measured sedimentation time the same as the target sedimentation time, which is set to 80 seconds. The timechart of the measured turbidity on one day is given in Figure 10. In Figure 10, "Without control" is when the amount of PAC injected is fixed to a constant value by an operator all day, and "Controlled" is when the amount of PAC injected is controlled to make the measured turbidity same as the target

turbidity, which is set to 10 degrees.

Figures 9 and 10 show that the sedimentation time and the turbidity are well controlled to the target value. The standard deviation of the measured flock sedimentation time for one day is 32 seconds for manual control by an operator, and 10 seconds for automatic control by the sensor. The average sedimentation time for one day is 86 seconds for the target flock sedimentation time of 80 seconds with automatic control. The standard deviation of the measured turbidity on one day is 4.3 degrees for manual control by an operator, and 0.4 degrees for automatic control by the sensor. The average turbidity on one day is 10.5 degrees for the target transparency of 10 degrees with automatic control. Thus, the sensor can stabilize the water quality well.

The wastewater in the target plant is always transferred to the raw water tank every morning and quality of the wastewater is always bad in the morning. So, the sedimentation time and the turbidity have tended to be bad every morning when the amount of coagulants injected has the same value all day. However, Figures 9 and 10 show that this control system can stabilize the water quality all day.

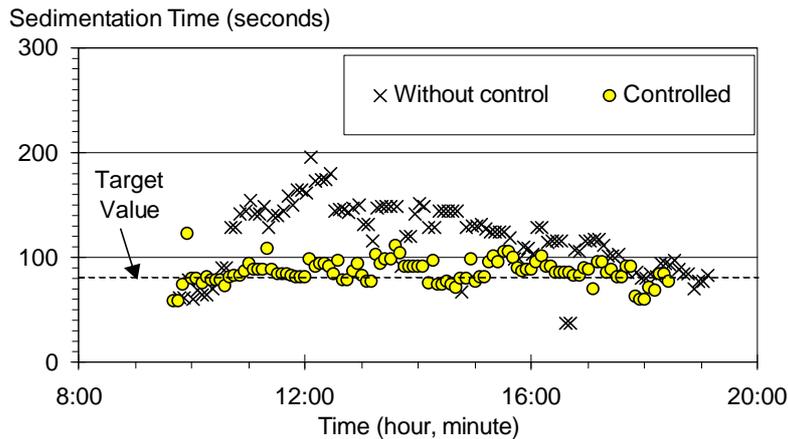


Figure 9. Effect of control: sedimentation time.

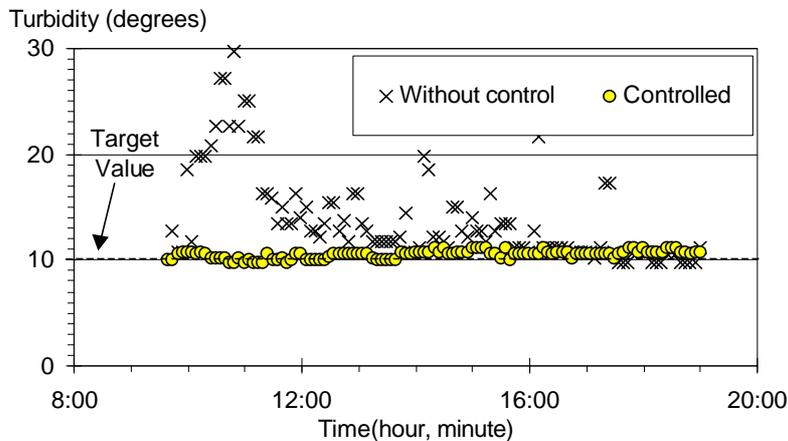


Figure 10. Effect of control: turbidity.

## 5 CONCLUSION

Based on the test results, it is clear that the flock sensor and this system have realized numerous benefits. These include, (1) stabilizing the water quality through continuous control, (2) reducing the operator man-hours, and (3) the amount of chemicals used will be decreased by the appropriate control of the sensor.

## REFERENCES

[1] T.Ishii, F.Sasaki, T.Hirai, T.Hirai, Y.Nakayama, Development and Application of Fieldbus System (in Japanese), Instrumentation and Control Engineering 41 (12) (1998) 14-19

**AUTHORS:** Hiroyuki Tsutada, Takahide Hirai and Teruo Usami: Sensing Systems Dept., Industrial Electronics and Systems Laboratory, MITSUBISHI Electric Corporation, 8-1-1, Tsukaguchi-honmachi, Amagasaki, Hyogo, Japan, Phone +81-6-6497-7739, Fax +81-6-6497-7728, E-mail: tsutada@sen.sdl.melco.co.jp