

# Development of a rinsing-efficiency sensor to reduce washing water use and energy consumption in dyeing plants

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**Abstract**—This paper presents the field application and performance evaluation of a multi-functional composite sensor that consists of colorimetry and pH sensors for energy savings in the rinsing process of dyeing. The duration of the rinsing process varies with the residual dye concentration on the fabric; however, current practice often relies on operator experience, so a systematic and quantitative decision tool is required. The study constructs a rinsing-rate model based on measurements from the composite sensor. The study also presents a method that reduces rinsing time and washing water consumption, and validates the method in a production dyeing plant. Experimental results show a significant reduction in rinsing time; light-shade conditions achieve clear energy savings, whereas deep-shade conditions require further investigation.

**Keywords**—Dyeing, Rinsing process, Water consumption, Colorimeter, pH, Energy savings

## I. INTRODUCTION

The rinsing process removes dye that has not been fixed to the fabric after the dyeing process and uses a large amount of washing water to cleanse the dyed fabric. The dyeing process requires substantial electrical and thermal energy, whereas the rinsing process requires a large volume of washing water. Although many dyeing machines provide automated functions for the rinsing process, on-site operations still rely largely on manual control because operators often avoid automatic control and the workforce has aged. As a result, systematic and quantitative indicators to determine rinsing completion are essentially absent. Figure 1 shows two references: the left panel shows an on-site visual inspection of the dye solution to judge the degree of rinsing, and the right panel shows the color of the fabric targeted for dyeing.

This paper applies a multi-functional composite sensor that consists of colorimetry and pH sensors to the rinsing process, presents criteria to determine rinsing completion, and analyzes a production-plant case that reduced the input of washing water.

## II. CONFIGURATION OF THE RINSING-EFFICIENCY SENSOR

This section presents the configuration of a composite sensor for the rinsing process in dyeing plants to reduce energy use and

process time. Prior work [1, 2] developed a multi-functional composite sensor that comprised pH, conductivity, and colorimetry sensors to reduce energy use and process time in dyeing processes, and the work was validated in a production dyeing plant. The present study judged the relevance of conductivity in the rinsing process to be low, so the composite sensor that consists of colorimetry and pH sensors was adopted. Figure 2 presents the configuration.



Figure 1. Assessment of rinsing completion of dyed fabrics by visual inspection

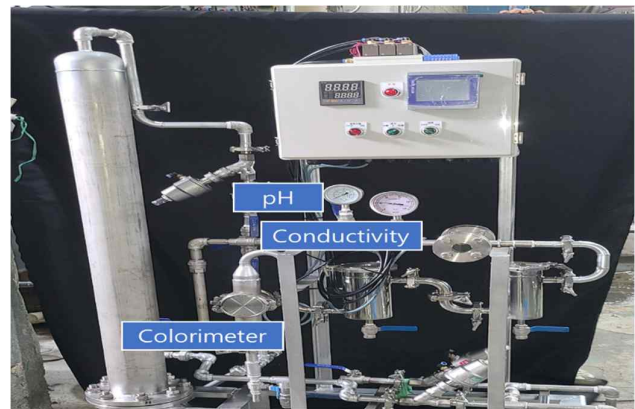


Figure 2. Composite sensor system for dyeing and rinsing process

In the field dyeing plant, the rinsing process was carried out for polyester and nylon fabrics, and no fabric-dependent peculiarities of the composite sensor that consists of colorimetry and pH sensors were observed. Measurements

confirmed variations in the dye concentration and bath pH during the rinsing process.



Figure 3. Magnetic water level meter. The left panel represents the state after washing water supply, while the right panel represents the state before dyeing wastewater effluent discharge.

Figure 3. Magnetic water level meter. The meter was installed to enable on-site confirmation of washing water supply and discharge during the rinsing process. A magnetically coupled float tracks the liquid level and drives an external indicator that shows level changes. The meter provides the timing of supply and discharge events as a reference signal, so the events can be aligned with signals from the composite sensor that consists of colorimetry and pH sensors for verification and interpretation.

### III. ANALYSIS OF THE THE RINSING-EFFICIENCY SENSOR

This section presents field measurements and analysis from the rinsing process obtained with a composite sensor that consists of colorimetry and pH sensors. Figures 3 and 4 compare the decision points for rinsing completion between dark and light shades. The colorimetry sensor operated over 400–2000 in manufacturer-specific units, and the measurable concentration range proved limited. For a single fabric run, a rinsing-rate calculation model was established; the model uses the difference between the colorimetry value at the highest bath concentration after dye addition and the value at rinsing completion. Rinsing completion generally fell within 400–600. Nylon and polyester dyeing typically proceed at pH 3.0–4.0, and pH 6.0–8.0 was expected after the supply of washing water. Light-shade cases reached pH 6.0–8.0, whereas dark-shade cases remained acidic even after the supply of washing water.



Figure 4. Composite sensor that consists of colorimetry and pH sensors: rinsing-process results for dark-shade dyeing.

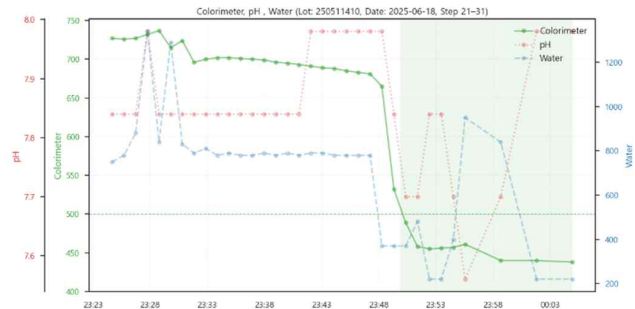


Figure 5. Composite sensor that consists of colorimetry and pH sensors: rinsing-process results for light-shade dyeing.

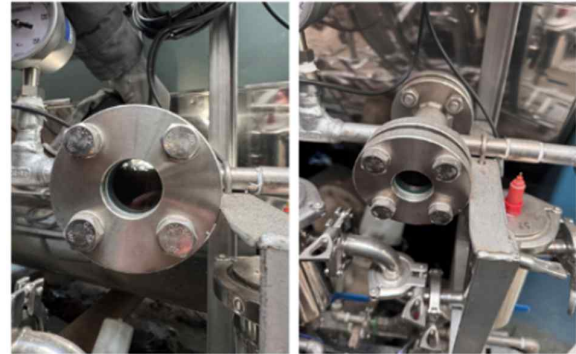


Figure 6. Sight glass piping for monitoring dye solution conditions

### IV. RESULT

This study verified in a production dyeing plant the feasibility of reducing washing water use and process time with a rinsing-process composite sensor that consists of colorimetry and pH sensors. Light-shade cases showed a significant reduction in rinsing time and input energy. Dark-shade conditions require additional experiments in the rinsing process. Figure 6 introduces the application of an image-based concentration-estimation method, in addition to the colorimetry sensor, to the rinsing process. A subsequent paper will analyze the accuracy of the sensors with respect to concentration levels in the rinsing process.

### ACKNOWLEDGMENT

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### REFERENCES

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