COAGULATION CONTROL USING THE STREAMING CURRENT DETECTOR: PROBLEMS AND A POSSIBLE SOLUTION

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Keywords: potable water treatment, coagulation control, pH control, industrial processes.

Abstract

In water treatment processes, the individual unit operations are complex, highly non-linear and poorly understood. Whilst many models have been developed to improve process understanding these are rarely in a form easily exploited by the control engineer. Attempts to improve the performance of water treatment works through the application of improved control and measurement have had variable success. This paper discusses investigations into the application of feedback control on the clarification process of a large scale pilot plant using a *streaming current detector* (SCD). The application is aimed towards maximising the efficiency of the chemical coagulation process. To achieve this a simple model of the interactions of process operating conditions on the SCD measurements must be made.

1. Introduction

The water industry is probably undergoing its biggest challenge since privatisation in 1992 as the search for cost savings escalates whilst staff numbers continue to fall. One of the suggestions to solve this conundrum is to introduce more automatic control at water treatment works. As part of this strategy, Northumbrian Water, have being undertaken a company wide programme of capital investment in chemical delivery systems. The Broken Scar works near Darlington is one asset that has benefited from this expenditure. This paper presents the findings of an extensive pilot plant study that was initiated to reconsider the role of the streaming current detector (SCD) as the primary sensor in a feedback control system designed to regulate the delivery of the coagulating chemicals.

Automated coagulant control using the SCD has been extensively researched [1,2,3,4] but there has been limited success in implementing the research findings. This is because the sites at which accurate coagulation control is most important are often the most difficult to automate. Treatment works that abstract raw water from rivers can expect large or rapid variations in the raw water quality and current automated systems can become unreliable during these changes. Broken Scar Treatment Works on the River Tees in Northeast England was chosen as the location for this study as the Tees is a notably 'flashy' river prone to extreme variations in water quality that would provide a set of challenging conditions. The aim of the project was the development and practical application of a robust control system, to be used by the plant operators, based on existing but flawed technology, namely the SCD.

The structure of the paper is as follows. Section 2 provides a brief introduction to coagulation control. The next section describes the twin stream pilot plant so essential to the planned comparison trials. The design of the modified strategy and its comparison with the manufactures suggested implementation is the central contribution and appears as Section 4. Section 5 offers some final comments.

2. Description of the Pilot Plant

The test facility used in this research is the twin stream pilot plant (see Figure 1). The unit operations carried out on the pilot plant are chemical dosing, mixing, dissolved air floatation and finally filtration.

The current process operation strategy for coagulation control at Broken Scar is as follows. The process pH is controlled automatically, primarily with the addition of alkali. The target pH for the clarification process is around 6.2. Acid is sometimes required in the summer months when raw water conductivity is high. Coagulant dose is controlled manually, but with flow–proportional dosing. The dose level is determined by a laboratory analysis of the raw water, commonly called a *jar test*, which is performed every one or two days.

The pilot plant is extremely well instrumented as can be seen from the list of measured parameters in Table 1.

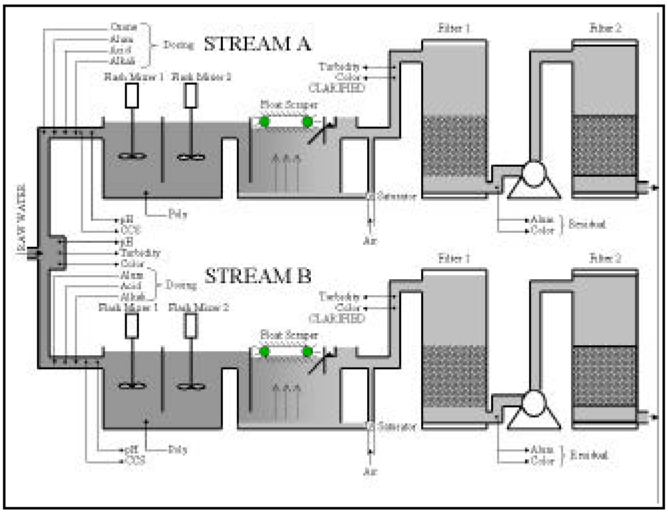

Figure 1 Schematic diagram of the pilot plant at Broken Scar Water Treatment Works.

At present both streams can be independently operated which is useful to compare different control strategies on the saw raw water. The present research work has been carried out to develop and test contrasting control strategies, the main one being that based upon feedback of the SCD measurement. The control signals available for automatic control allow us to vary the flow rate (and hence the dose) of the following chemicals.

- Coagulant (aluminium sulphate)
- Acid (sulphuric acid)
- Alkali (caustic soda)
- Coagulant Aid (polymer)

3. Comparison of the Basic and Modified SCD Algorithms

3.1 SCD Modelling Investigation

The acid and caustic pumps were manipulated to observe the effect of pH on the clarification process efficiency and the output of the SCD. The pH was changed over a range larger than would normally occur in a typical process plant. The time series traces obtained are presented in Figure 2.

The pH can be seen to have a dramatic effect on the SCD. It is clear that this effect will introduce large disturbances to any control system relying on SCD as a feedback signal for coagulant dosing purposes. The pH variations also have a dramatic effect on the clarified colour. It can be seen that at times of high pH (for example values above 7.0) the clarified colour rises significantly, at constant levels of coagulant dose. There is a delay of approximately 20 minutes between the rise in pH and the corresponding rise in clarified water colour. A similar effect is seen with clarified turbidity. Consequently, with appropriate process modelling, future reductions in clarified water quality may be predicted in advance. This would provide valuable information to process operators or to advanced control strategies.

Variable	Units
Raw Flowrate	m^3/day
Raw Colour	Hazen
Raw Turbidity	NTU
Raw pH	–
Raw Conductivity	µS/cm
Raw Temperature	°C
Dosed SCD	–
Dosed pH	–
Settled Colour	Hazen
Settled Turbidity	NTU
Final Coagulant Residual	mg/l
Coagulant Dose	mg/l
Acid Dose	mg/l
Alkali Dose	mg/l

Table 1: Instrumentation Specification for the Pilot Plant

3.2 Modelling the pH changes in the clarification process

The data collected was analysed and the relationship between the process pH and the SCD reading determined. This is portrayed in Figure 4. The process pH can be seen to have a large effect on the SCD reading, even though in these trials the coagulant dose was kept constant. Also, the raw water quality was observed over the same time period and was seen to be relatively stable, indicating no large changes in coagulant demand should be expected. A roughly linear relationship is seen in the scatter diagram, although some spread is observed which indicates that other variables may play a significant part in the relationship.

3.3 Coagulation Control using the SCD Measurement

A typical strategy for coagulation control is shown in Figure 4. As can be seen, both pH and SCD levels are controlled by separate feedback control loops. The disadvantage of this strategy is that both loops are strongly coupled because of the effects of coagulant dose and pH on both the SCD reading and process pH. De-tuning one of the loops can reduce the effects of interaction. This results in more sluggish control and can have a serious affect on process control goals.

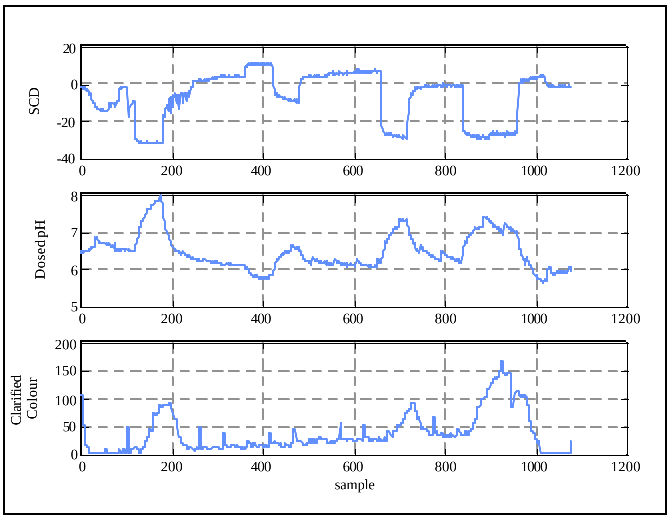

Figure 2 Time series traces for SCD, pH and clarified turbidity.

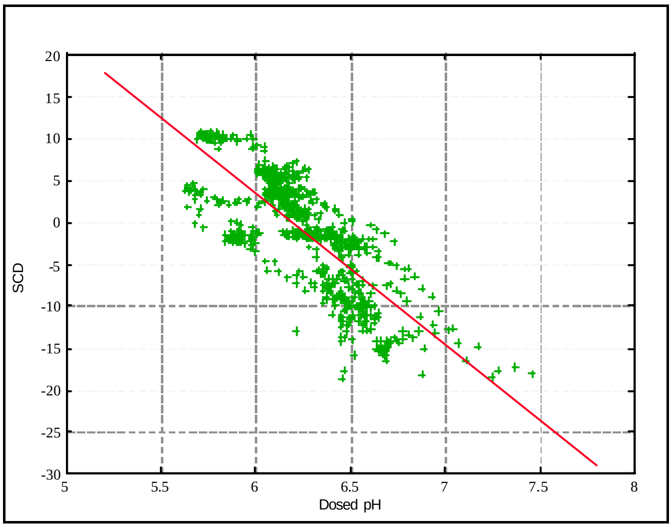

Figure 3 Dosed pH versus SCD measurement.

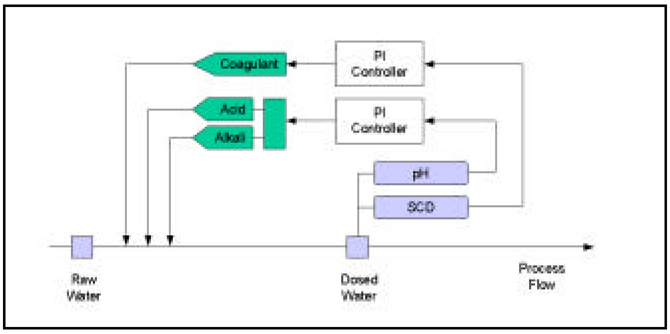

Figure 4 Standard coagulation control using the SCD.

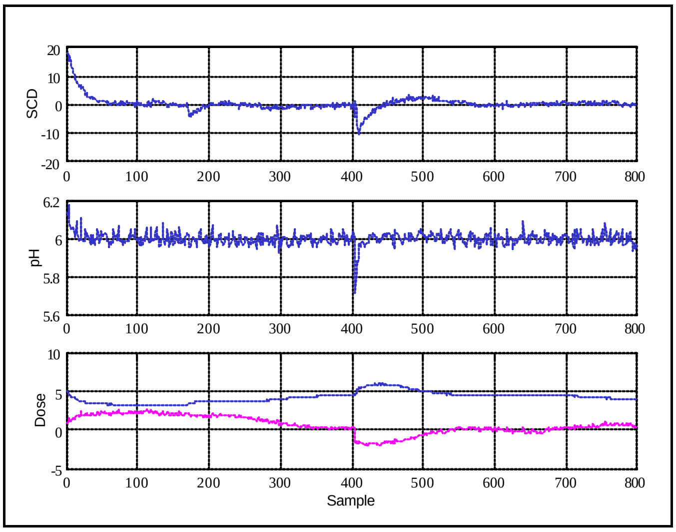

Figure 5 Standard SCD coagulation control strategy.

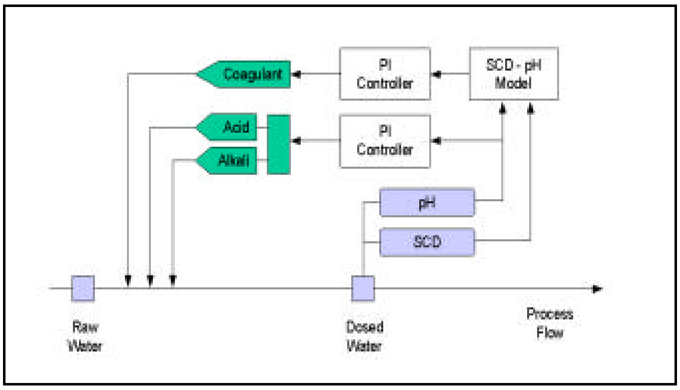

Figure 6 Advanced coagulation control based upon SCD measurement.

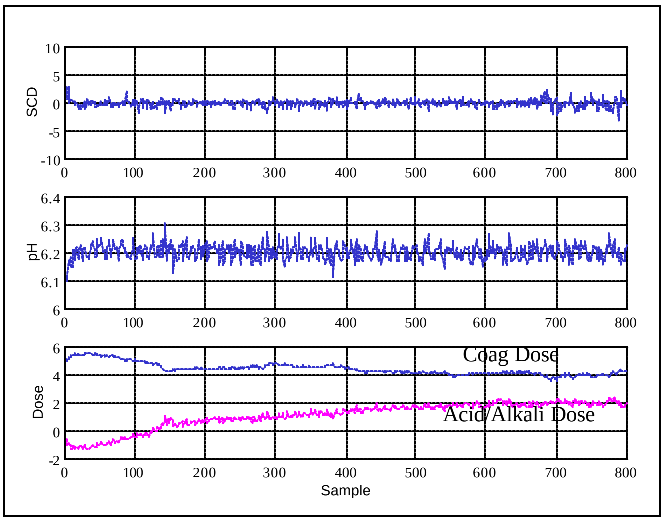

Figure 7 Advanced SCD coagulation control strategy.

The results of applying such a strategy are shown in Figure 5. Here we see the process being fairly well controlled until some disturbance at sample 405 throws the process off its set-points.

On examining the process data, no disturbance in raw water quality could be found to account for this process upset.

3.4 Advanced Coagulation Control using the SCD Measurement

Using the relationship between pH and SCD shown in the previous sub–section, an improved control scheme was developed. The new scheme aims to reduce interactions between the two loops involved in total coagulation control. The control strategy is shown in Figure 6.

This control strategy aims to generate an estimated value of SCD equivalent to that measured assuming that the process pH is at a predetermined optimum value. This almost completely eliminates the effect that process pH has on the SCD measurement, reducing controller interactions and providing a more robust control strategy. The results achieved by using this advanced strategy are shown in Figure 7. The SCD value shown here is the estimated SCD value.

Comparing the results of the standard and advanced SCD control strategies (Figure 5 and Figure 7 respectively) it can be seen that both strategies regulate the SCD signal (and hence the coagulation performance) well. However the advanced strategy appears to be less susceptible to disturbances. The standard strategy has severe interactions between the two control loops, whereas these interactions are removed by de–coupling in the advanced control strategy.

4. Final Comments

The work described in this paper represents a research area of critical importance. The advantages of studying coagulation processes on the pilot plant are numerous. The trials provide much more information than would be possibly collected from an ‘in-service’ treatment works. A wider range of treatment scenarios can be applied to the process, above and beyond the range of ‘normal’ operation. This gives increased understanding of how the process behaves, especially near the thresholds of acceptable treatment performance. The rapid response of the pilot plant process to changing treatment conditions means that effects on treated water can be observed in minutes rather than in hours on the main works. And finally, the twin stream arrangement gave an ideal opportunity to compare different control strategies or investigate the sensitivity of an algorithm to the choice of a particular design parameter. It is hoped to report at the conference the results of applying the modified strategy on the actual treatment loops of the main works at Broken Scar.

5. Acknowledgements

This work was supported through the PRAME funding of the Lyonnaise des Eaux Group. The authors are also grateful for the technical support and co–operation of the staff of Northumbrian Water Ltd.

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