Control Parameter Optimization Service for Paper Machine Quality Control Systems, QCS Tune-up Engineering, for Ideal Paper Manufacturing Plant

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The paper industry is being forced to reduce manufacturing costs in response to market conditions, and so paper companies are restructuring their production systems to boost profitability, save labor, and ensure stable operations and efficient maintenance. Paper machines are essential for paper manufacturing, and their stable operation to meet various product specifications is a major challenge. To meet these market demands, Yokogawa has developed the QCS Tune-up Engineering control parameter optimization service for paper machine quality control systems (QCS). This article introduces applications of the QCS Tune-up Engineering service in which cost has been reduced and quality improved by diagnosing the process control of QCS.

INTRODUCTION

Recently, in the pulp and paper industries in Japan, production facilities are being consolidated by scrapping and building paper manufacturing equipment accompanied with reengineering of manufacturing systems. As a result, there is growing demand for high-mix, low-volume production. For paper machines, this means that the control parameters of quality control systems (QCS) must be optimized to a variety of production conditions. This article highlights the importance of control parameter optimization for the paper-making process and also introduces Yokogawa’s QCS Tune-up Engineering service with an example of improving the controllability by applying this service.

CHALLENGES IN PAPER MACHINE CONTROL

Usually, control parameters of paper machines are fixed to the same values as optimized when a QCS is first introduced using a typical product, even when producing other similar grades. Recently, many paper machines are operated in a high-mix, low-volume condition because of the consolidation of equipment and diverse products to satisfy the requests of end users. Furthermore, stable operation of the paper machine is often disturbed by the feed preparation process and/or by auxiliary systems. Stable control of this process and equipment is another important reason why control parameters must be optimized. The control parameters need to be monitored and optimized every 1 to 2 years to meet these challenges and thus control product quality, reduce feed costs and curb emissions.

PAPER-MAKING PROCESS AND PAPER MACHINE QCS

In the paper-making process, many qualities of the product are controlled, as paper is used for a wide variety of purposes, and the controlled qualities vary from product to product. In the paper-making process, usually physical properties (such as basis weight, i.e. weight per square meter, caliper and color) and chemical properties (such as moisture and ash) are measured on-line and controlled in a certain range depending on the paper product. Because the paper-making process is the final stage of the whole paper manufacturing process, the results of control in this process have a significant impact on the final product quality. Accordingly, optimizing control parameters of each control component such as machine direction (MD) control, cross direction (CD) control and grade change control depending on the paper product will greatly help stabilize the operation and thus improve the profits. Figure 1 shows an overview of the paper-making process and typical control components of the QCS. 10

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Diagnosis (examining the operation based on gathered information and setting the target for improvement)

Training on techniques for tuning control parameters optimally

Improvement proposal (providing solutions for each identified issue with its benefits of improvement)

Optimum tuning of control parameters and their evaluation (tuning of parameters and verifying the effects of the results)

THE QCS TUNE-UP ENGINEERING

The QCS Tune-up Engineering service diagnoses the customer’s paper-making process and control states, and optimizes the control parameters to reduce the cost, raise the productivity and improve the product quality. The QCS Tune-up Engineering provides the following services of the QCS for a paper machine and a coating machine.

- Diagnosis (examining the operation based on gathered information and setting the target for improvement)
- Improvement proposal (providing solutions for each identified issue with its benefits of improvement)
- Optimum tuning of control parameters and their evaluation (tuning of parameters and verifying the effects of the results)
- Training on techniques for tuning control parameters optimally

The following sections describe the detailed procedures of these services.

Diagnosis

Control performances on stability, convergence and tracking ability are obtained from the trends and reports on each of the QCS components, machine direction control, cross direction control and automatic grade change control. The obtained control performance of each component is evaluated by certain criteria and summarized as a diagnosis report. Paper machine conditions are also reported correlated with QCS data. Figure 2 shows an example of the diagnosis report including the status quo of each control component and the diagnosis results.

In collaboration with the customer, items to be improved and their targets are determined at this stage based on the diagnosis analysis.

Figure 1 Paper-making process and control components of the QCS

Figure 2 Examples of the diagnosis report

Improvement Proposal

The diagnosis report is analyzed and optimum tuning of control parameters of each control component is proposed for improving the control performance in terms of stability, convergence and tracking ability. If necessary, modification of the paper-making process equipment is also proposed. Figure 3 shows a part of the improvement proposal.

Figure 3 An example of the improvement proposal

Each improvement proposal is ranked according to the financial effects with a value estimated using the dedicated improvement effect calculation tool for the QCS Tune-up Engineering service as shown in Figure 4.

Figure 4 Estimation of improvement effects by the dedicated calculation tool
Optimum Tuning of Control Parameters and Evaluation of Results

Optimum tuning of each control component is carried out one by one according to the priority of the ranking to improve the control performance. The result of the improvement in controllability is evaluated using the control index calculated based on the standard deviation, together with the financial effects calculated by the dedicated tool. Figure 5 shows an example of the control loop performance before and after the tuning and the evaluation results in the report.

![Figure 5](image_url)

(6-1) Control stability

Under the predefined conditions (no change in the set point value or automatic operation), the stability was confirmed by the standard deviation $\sigma$ (using time machine direction, LMD, i.e. standard deviation for long-time represented by standard deviation of normal distribution) for each control component.

Evaluation criteria

The targets are as follows:

- $\sigma < 10\%$ of the set point value
- $\sigma < 10\%$ of the set point value
- $\sigma < 10\%$ of the set point value
- $\sigma < 10\%$ of the set point value
- $\sigma < 10\%$ of the set point value

Result

<table>
<thead>
<tr>
<th>Control component</th>
<th>Before tuning (σ in metric units)</th>
<th>After tuning (σ in metric units)</th>
</tr>
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<tbody>
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<td></td>
<td></td>
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</table>

Figure 5 An example of the evaluation report

Training on Optimum Tuning Techniques of Control Parameters

The optimum tuning technique for stability, convergence and tracking ability of each control component is explained to the personnel responsible for maintenance and operation of QCS. The control functions of the QCS and the control theory are also explained so that the personnel can maintain the QCS by themselves.

Examples of improvement by QCS tune-up engineering

The following sections provide examples of the QCS Tune-up Engineering implemented by Yokogawa.

Improvement in stability of basis weight control in machine direction

This is an example where the control of basis weight in the machine direction often became unstable, resulting in defective products that caused losses of approximately ten million yen a year. We investigated the cause of the problem and proposed measures to solve the problem.

Setting targets

We began the service by setting the improvement target of zero defects.

Diagnosis

Based on information obtained by the site survey concerning the trend, process piping and control state, we found that the system became unstable due to the following causes.

- The fluctuation in MD appeared to be caused by fluctuation of the fiber concentration of feed stock (pulp) at the stock inlet of the paper machine.
- The fluctuation of the fiber concentration of the stock was caused by poor control of the stock inlet concentration control panel.
- The control gain of the MD basis weight controller was too large, causing oscillation throughout the process.

Improvement proposal

Through these analyses, we concluded that the following measures would be effective, and proposed them.

- Conducting optimum tuning of the control parameters for the stock inlet concentration control panel.
- Conducting optimum tuning of the control parameters for the basis weight in MD.
- Introducing more input signals such as concentration, liquid level, flow rate and pressure to the QCS to facilitate cause analysis for future poor control.
- Replacing the stock inlet control valve by a higher-precision one and installing a flow meter.

Identifying causes is like finding a way out of a labyrinth. The only available data were those in the recorders on the local control panel. Despite this difficult situation, we were able to quickly analyze the cause and solve the problem, thanks to our broad experience with similar services for paper and pulp processes.

Optimum tuning of control parameters and result evaluation

The optimum tuning of control parameters including fine tuning of control loops led to stable operation and contributed to reduced product loss, higher product quality and lower costs at the same time.

Figures 6 and 7 show trends of the control variables before the optimum tuning of the control parameters and after implementation of the service in this example.
Variables trends after optimization of control parameters

The middle part of Figure 6 and the bottom part of Figure 7 show the trends of basis weight in the absolute dry (bone-dry) condition. It is clear that the control state was significantly stabilized by the improvement measures. The fluctuation range ±0.5 g/m² before the improvement (*1 in Figure 6) has decreased to ±0.3 g/m² (*2 in Figure 7), indicating that a 40% improvement effect was achieved.

Improvement in Stability of Control of Moisture Content in the Cross Direction

The next example of applying the service is the handling of a claim about spotted (uneven parts) products. This seemed to be caused by poor control of moisture content in the cross direction.

- Setting targets
  We began the service by setting the target; we decided to keep the 2σ of moisture content variation in the cross direction within 10% of the control setting. We set the 2σ of the control profile as the index for controllability.

- Diagnosis
  The site survey revealed that the poor control was a result of the following events.
  - The average output to steam flow was lowered to reduce the production cost (reducing steam used).
  - Lower average output caused poorer controllability.
  - The position correspondence table that relates each manipulated variable and CD moisture content was not set properly.
  - The CD basis weight and CD thickness were well controlled.

- Improvement proposal
  On the basis of this cause analysis, we proposed and implemented optimum tuning of the moisture content control in CD.
  - We conducted a mapping test to correct the position correspondence table.
  - We conducted a step response test using the machine automatic step generator function to identify the process dynamics (gain, time constant and dead time).

Optimum tuning of control parameters and result evaluation

The most critical points in the process of optimum tuning of control parameters are the timing of the test and the magnitude of the step to the actual machine. Since the tests are conducted under normal operating conditions, they must not interrupt the production. Therefore, extensive field experience is required to judge and respond properly to the process behavior in the case of poor operation. In this example, the optimum tuning was achieved through collaboration between Yokogawa’s experienced service engineers and the customer.

Figure 8 shows the product photos before and after the improvement. It is clear that the optimum tuning of control parameters improved the controllability of CD basis weight and, as a result, eliminated spots appearing on the products. Thus, it reduced defective products and thereby decreased the production loss.

CONCLUSION

This article outlined QCS Tune-up Engineering for the paper-making process and examples. For paper manufacturing using paper machines, it is necessary to establish the control scheme for high-mix, low-volume product production. Control parameters are the key component of optimizing the operation, and so Yokogawa is requested to perform QCS Tune-up Engineering for many customers. This service also has a good reputation as a training tool to transfer the optimization techniques for tuning control parameters to younger generations.

As a partner of customers, Yokogawa will keep improving and expanding its services to contribute to optimum operation of equipment in the paper-making industry.

REFERENCE