

Machine-direction control tuning seminar features lab on an actual pilot paper machine

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Reliability of equipment and demands of the marketplace have forced field service personnel to improve their process control system maintenance skills. The field engineer of the 1960s and 1970s focused on system up-time and hardware reliability. During the 1980s, field engineers focused primarily on the utilization and optimization of control loops.

The senior field engineer of the 1990s will find an additional shift in job requirements and focus. To obtain maximum system utilization and results for clients, the senior field engineer must have excellent technical, communication, and professional skills.

To this end, ABB Process Automation has developed a Senior Field Engineer (SFE) Certification Program to ensure that service personnel attain the skills necessary to successfully maintain and operate today's advanced process automation systems.

The developmental activities for the SFE Certification Program take a number of forms from structured field assignments with specific objectives and formal self-study courses to formal classroom training courses. While classroom training provides the basic theory of process control, it does not provide "hands-on" experience. Because this course allows students to put theory into practice, they learn more and retain information longer.

Pilot paper machine used for lab assignment

Typically, training labs for this type of course are conducted on software simulators. These simulators are effective but fall short of the actual experience of tuning complex control strategies on a paper machine.

Our senior field engineer candidates work on an actual paper machine located in the pilot plant of Western Michigan University's Department of Paper Science and Engineering. These labs focus primarily on the tuning and optimization of machine-direction control strategies such as basis weight, moisture, and drystock flow controls.

The pilot paper machine, which is capable of speeds up to 140 ft/min (0.71 m/s), is a 24-in. (0.61 m) fourdrinier with a main dryer, size press, and after dryer. An Accuray measurement and control system provides automatic

control of key paper quality characteristics. This system features AccuRay basis weight and Hemiplus moisture sensors mounted in a customized Accuray Microscan measurement platform. Machine-direction (MD) controls include basis weight, moisture, and drystock flow.

Objectives

Field engineers attending these seminars are called upon to examine process issues that impact the performance of machine-direction loops. Therefore, one key objective of the program is to provide an adequate overview of the process from the machine chest to the dryer section. This three-day course is designed to give the student a foundation to build upon; it is not intended to make them expert papermakers.

This course is based on the notion that "process" topics are just as important as specific tuning procedures, regardless of the technology platform that the system is based upon. This process knowledge represents the basic tools needed to be a successful senior field engineer.

Organization

The seminar is organized into two days of classroom work followed by a "lab" day at the Western Michigan pilot paper machine. During the first classroom session, the student reinforces his or her basic knowledge of the process and the control system's design.

The following topics are covered in the first session:

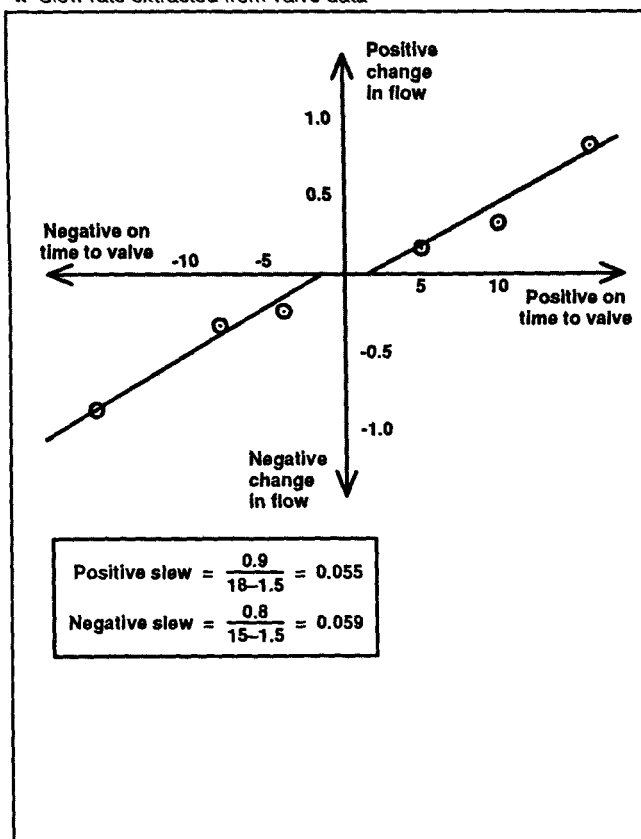
1. The importance of bone-dry weight
2. The coupling that exists between bone-dry upsets and moisture upsets
3. The process, with emphasis on areas that have an impact upon machine-direction weight or moisture control
4. Basic algorithms for basis weight, moisture, and drystock controls.

The importance of bone-dry weight

The paper sheet is presented to the students as being made from bone-dry fiber (calculated from basis-weight sensor measurements) and water (measured by the moisture sensor). It is stressed that the control system or process troubleshooter must be able to categorize upsets in terms

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1. Slew rate extracted from valve data



II. Student data describing stock valve characteristics

On time to valve	Thick stock flow, gal/min	Change in stock flow
Test 1 start	16.55	...
+4	16.80	+0.25
+4	16.94	+0.14
+4	17.04	+0.10
+4	17.29	+0.25
+4	17.45	+0.16
+8	17.88	+0.43
+8	18.20	+0.32
+8	18.53	+0.33
Test 2 start	15.45	...
-16	14.74	-0.71
-16	13.90	-0.84
-16	12.99	-0.91
Test 3 start	13.70	...
+16	14.36	+0.66
+16	15.50	+1.14
+16	16.36	+0.86
+16	17.00	+0.64
Test 4 start	17.02	...
-4	16.78	-0.24
-4	16.55	-0.23
-16	15.33	-1.22
-16	14.58	-0.75
Test 5 start	15.45	...
-8	15.12	-0.33
-8	14.81	-0.31
-8	14.46	-0.35
-8	14.13	-0.33

of "fiber" or "water."

An example is given in which a machine operator reports that "weight" is not on target at the end of an automatic grade change. By categorizing the problem into either "fiber" or "water," one can determine which portion of the automatic grade change control algorithms to troubleshoot. This lesson teaches the field engineer how to find the right solution more quickly.

In addition, the topic of sensor accuracy as it affects control performance is discussed. Although senior field engineers may be familiar with sensor accuracy, the link to MD control performance may be a new concept.

Table I demonstrates how an inaccurate moisture sensor can cause erroneous readings in bone-dry weight.

The coupling between bone-dry and moisture upsets

Moisture upsets are categorized into those that are related to the removal of water or those related to temporary upsets in bone-dry weight. By understanding the coupling, the student will not only be able to better understand how the system decouples the effect, but also how the decoupling parameters are calculated. Additionally, the student will better relate to the concept of improving moisture control through better bone-dry weight control.

The process

The first process topic discussed is that of thick-stock consistency measurement and control. The field engineers attending the seminar are called upon to tune drystock flow control—a feedforward strategy that reduces reel bone-dry upsets caused by consistency upsets. Adequate

1. Example data used to demonstrate the link between sensor accuracy and MD control performance

	Initial conditions	Slope accurate	Slope too small	Slope too large
Basis weight	50.00	50.53	50.53	50.53
Moisture (actual)	5.00	6.00	6.00	6.00
Moisture (reading)	5.00	6.00	5.70	6.30
Bone-dry (actual)	47.50	47.50	47.50	47.50
Bone-dry (reading)	47.50	47.50	47.65	47.35
Bone-dry (error)	0.00	0.00	+0.15	-0.15

coverage of tuning issues is important because students need to understand the typical instrumentation used to measure consistency and the requirements for calibration within the process control system.

The next process area discussed is the stuff box. Since the field engineer will be required to tune the thick-stock-flow direct digital control (DDC) loop, it is important to understand the potential for interaction with either stuff box level control or a stock line pressure control (if no stuff box exists).

In the headbox area, the class discusses the effects of gross slide adjustments and steam-flow adjustments on the average bone-dry weight at the dry end.

The process overview ends by presenting a mass balance view of the machine. This topic leads to a simple formula for calculating bone-dry weight if stock flow, consistency, and machine speed are known.

Basic algorithms

During this section, the specific algorithms for control of basis weight and moisture are presented. A specific technique used during this portion of the seminar is to maximize the practical view of the algorithms and minimize the focus on long-winded derivations that can complicate the issue.

Some typical quiz and review questions asked at the end of the day are:

- Discuss the effect of stuff box level PID loop tuning on the Accuray system basis-weight control loop.
- Given an initial set of conditions, calculate the effect of a given consistency upset on bone-dry weight. What size thick-stock flow change would be required to return weight to target?
- Describe a method for calibrating the thick-stock consistency transmitted at your site.

Day two in the classroom covers important topics specifically needed for tuning machine-direction weight and moisture loops. The topics include:

- Stock flow control-loop tuning
- Compensation for nonlinear valve characteristics
- Testing the stock flow loop
- Conducting bump tests for model reference weight control
- Conducting bump tests for drystock flow control
- Tuning basis weight and moisture control loops
- Tuning drystock flow control loops.

During the second day, students are given actual mill data and must derive basis-weight valve characteristics from bump test data. Additionally, model reference bump test data is analyzed to determine wet-end dead-time and time-constant data for the basis-weight loop.

Lab assignment

On the third day, students attend the lab at Western Michigan's pilot paper machine. After the initial startup of the pilot plant, students will be asked to complete several tasks that are prerequisites to the actual tuning effort for basis-weight control.

Students are asked to comment on the accuracy of the key instrument signals such as stock flow, consistency, and machine speed, based upon their new "mass balance view" of the paper machine. They are also asked to determine the transportation distance from slice to reel.

The major tasks for the lab day are:

- Determining basis-weight valve characteristics
- Tuning the closed-loop stock flow
- Determining model reference parameters for weight control
- Tuning basis-weight control.

During the first portion of the lab, students conduct open-loop response tests on the machine's stock valve. One of the class members logs the valve's test data while

another enters various "on times" to the actuator. Using the same data, each student works independently to determine valve characteristics such as backlash, dead time, minimum on time, and amount of stock flow change per pulse.

Table II and Fig. 1 show actual student data used to obtain thick-stock valve characteristics. The key parameter determined in this part of the lab is the valve "slew rate." This value predicts the amount of stock flow change per computer pulse. Although there is no penalty for making off-spec paper on the pilot plant, the stock valve response tests do offer an opportunity to discuss some guidelines for conducting bump tests at a client's facility.

The first guideline relates to effective communication. The test plan must be clearly explained to machine operators, "over-communication" being the rule of thumb. Secondly, it is pointed out that many machine response tests can be conducted during startups, after sheet breaks (and prior to re-thread), or prior to or following a machine grade change.

After the new tuning parameters are installed, each student tests the stock loop by making set-point changes.

The afternoon session is devoted to tuning the actual weight control loop. Students conduct single-point response tests by making step changes to thick-stock flow and observing the subsequent bone-dry weight response. Using the resulting data, each student determines the wet-end time-constant and dead time. These are the key parameters for the system's first-order error model that tracks corrections made to the paper machine actuators.

Once all parameters are obtained, the students place machine-direction basis-weight control into automatic and conduct several performance tests. During this period, students can try a wide range of tuning parameters and note the resulting improvement or degradation of loop performance.

Some common trials are:

- Operating weight control with a hard dead-band or reduced gain band that is too narrow
- Operating weight control with an incorrect setting of integral gain
- Performance with incorrect parameters for the first-order model.

The biggest advantage to using the pilot plant is the student's ability to try different tuning combinations without worrying about producing off-quality product.

Also, it is easy to answer process related questions by actually trying the effect on the machine. For example, in one class a student had a difficult time visualizing the effect of a headbox flow adjustment and the transient "spike" that will occur in machine-direction bone-dry weight. The pilot plant machine tender was more than pleased to produce such an upset for all to observe.

Follow-up report project

An additional feature of the MD tuning seminar is the follow-up assignment used to demonstrate proficiency in machine-direction control tuning skills. The assignment is outlined below:

1. Choose paper machine from field engineer's regular sites.
2. Discuss project with customer contact.
3. Conduct complete set of process bump tests.
4. Analyze data to obtain tuning parameters.
5. Retune machine-direction weight or moisture control.
6. Randomly collect end-of-reel data to document performance improvements.
7. Write a performance or results report for the customer.

The benefit of writing the performance report is to provide the student with a means to sharpen communication and report writing skills.

Summary and conclusions

Follow-up assignments for students who have attended the machine-direction control seminar indicate increased understanding and retention of the material covered during this three-day session.

The pilot-plant-based control seminar was developed as one of many field experiences used in ABB Process Automation's Senior Field Engineer Certification Program. In the long run, the real beneficiaries of this program will be the field engineer's customers, who will benefit from an increased level of service.□

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