PID Tuning and Process Optimization Increased Performance and Efficiency of a Paper Machine

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ABSTRACT

A mill (Canada) produces specialty paper. For many years, one of the mill's older machines had a low efficiency compared to the others; the uptime for this machine was 83% and below the budget.

At the same time the variability [1] for this machine was high, 1.4% for the basis weight and 6 % for the moisture content. The quality needed improvement and the machine broke too often.

They verified the process, the mechanical parts, the electrical components and the operation procedures. The improvements were minimal. Then the process control department proposed to optimize the paper machine using a global approach. This paper describes how they did it and what they obtained.

LOW UPTIME, VARIABLE PRODUCT.

The average uptimes for the previous years are:

- 1997 83.3 %
- 1998 84.3 %
- 1999 83.2 %
- **average of above 83.6 %**

The average variability remained the same month after month for the last three years:

- Basis weight variability 1.4 %
- Humidity variability 6.1 %

After investing 70 thousand dollars in optimization, paper machine's uptime increased by 5%, increasing their bottom line by 1.8 million dollars per year.

A side benefit was a more uniform, higher quality product, with less variability.

In the last four months, the average uptime was:

- November 99 90.1 %
- December 99 83.3 % (Christmas shutdown)
- January 00 88.4 %
- February 00 88.6 %
- March 00 89.4 %
- April 00 90.2 %
- **Average of above 88.3 %**

The average variability for the last six months:

- Basis weight variability 0.71 %
- Humidity variability 2.91 %

This variability is cut by half. The variability of most loops was also cut by half.

HOW THEY DID IT

They trained its staff to analyze and optimize the process. They went through the entire paper machine, and each part of the process was analyzed and repaired or modified, if necessary. They followed the loop optimization steps outlined in a series of 3 articles [1].

They hired a process control consulting company, to train plant staff on the methods. This company also provided support for the more complex problems. Technicians, engineers and supervisors were trained in process control basics, troubleshooting analysis, and efficient use of optimization software. They used loop optimization software [2] to help analyze and troubleshoot the process.

The most important loops where properly tuned once the problems in operation, and equipment were fixed. The loops were tuned to work in harmony to remove interactions and to reduce variability. For example, they synchronized the flow loops in the mixing tank and reduced interaction between level and pressure in the head box. At the same time, the PID parameters and the PV filter were selected to reduce valve effort ensuring valve maintenance would be minimized in the future.

The operation and production people collaborated fully with the instrumentation. At the same time they worked hard to improve the performances for example by installing fast cameras to analyze the origin of breaks on the sheet of paper. They also installed a system to detect holes in the sheet.

Hence the results obtained are not only from the instrumentation effort, but also from the operation, the production and the management.

MANY SMALL CHANGES MADE.

As a result of their analysis work, they made the following interventions:

[1] The variability is the relative value of twice the standard deviation expressed as a percentage of the mean and so allows comparison between different processes.

- Repaired 4 valve positioners, 6 valves;
- Replaced 4 valves;
- Relocated 2 valves ;
- Repaired 1 transmitter ;
- Configured 2 transmitters ;
- Modified 2 control strategies;
- Modified the PID tuning parameters on 42 loops
  - mostly reduced proportional gain, and reduced integral time
  - added derivative on 4 loops;
  - added filtering on 21 loops.
- Modified the process operation
  - pressure in the rejection tank;
  - valve opening for cleaner cyclones;
  - vacuum control in rejection tank.
- Modified the process
  - removed a buffer tank;
  - modified piping arrangement.
- Replaced pieces of equipment:
  - a mixer, manual valves.

QUANTIFYING THE IMPROVEMENTS

To get a solid number on their efforts, they initially collected data on all the important loops of the paper machine. Each variable was analyzed to detect hidden oscillations (using correlation and power spectral density analysis), to determine variability, to verify if tuning parameters were appropriate. Also, interaction was analyzed using cross correlation analysis. Even the amount of valve movement or valve effort was recorded.

The following data was analyzed:

- variability,
- power spectral density,
- valve performance (hysteresis, stiction and process gain).

The overall performance of the paper machine was computed. To reduce the time and the cost, only the most important loops (42 out of 85 loops) were analyzed.

Once the main problems were fixed and the loops were properly tuned, they again collected data on the same loops. The same variables were analyzed.

They compared variability, cycling, valve wear, robustness, and performance of the control loops. They also compared the process stability, product quality, downtime and efficiency.

BIG IMPROVEMENTS FROM SMALL CHANGES

The following average results were found on the most important loops:

- The oscillations of the loops were reduced by a factor of over 200;
- The variability of loops was reduced by a factor of 2, on average;
- Valve movement was reduced by a factor of at least 5 (average for 42 loops);
- The overall variability (basis weight, humidity and dry weight) was reduced by a factor of 2;
- The uptime (efficiency) was increased from 83 % to 87%;
- The time to reach steady state after a grade change was greatly reduced;
- The production people learned a lot from the optimization process and were able to pinpoint problems in process operations;
- Valve maintenance has been reduced since valve movement was greatly reduced.

The following graphics were obtained from the quality monitoring system: basis weight, dry weight and humidity

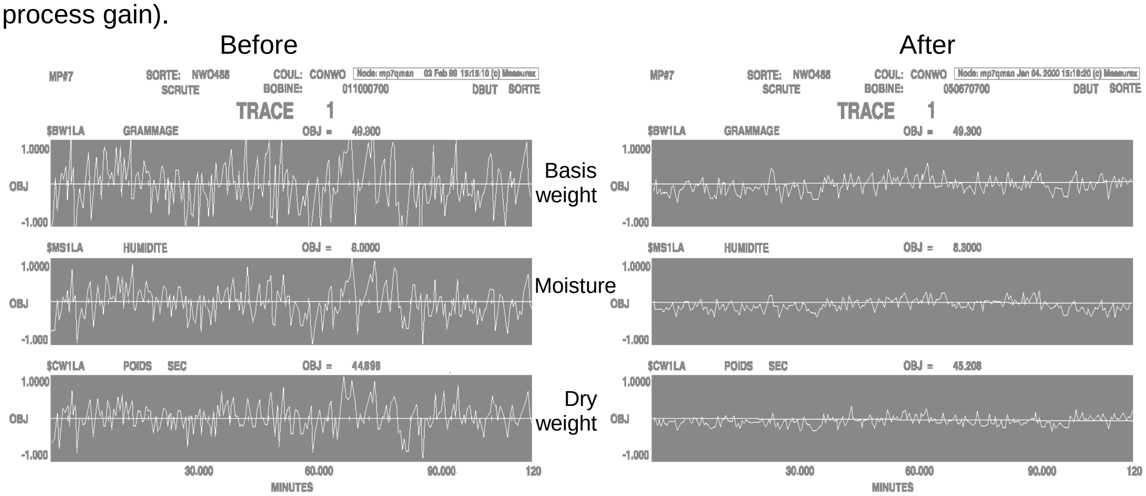


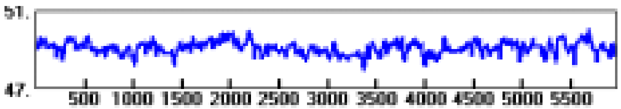
Figure 1

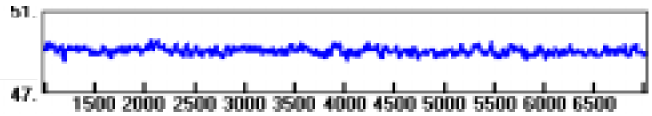
The graphics were generated by the quality monitoring system. Both graphics have the same scales. We observe the variability is greatly reduced. When analyzing them, the hidden oscillations disappeared after the optimization. The results have been the same for months.

The basis weight was analyzed using the software:

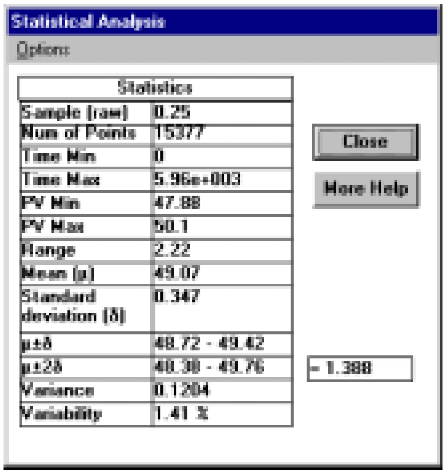
Before | **After**

Time data

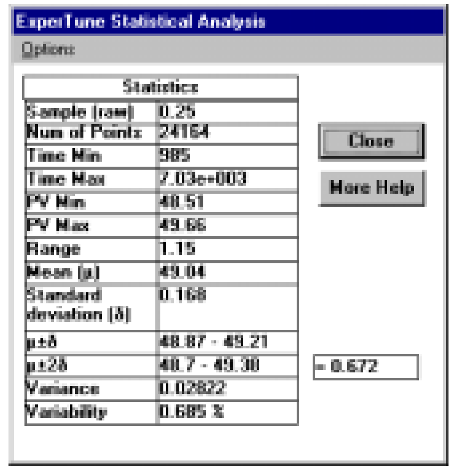




Statistical analysis

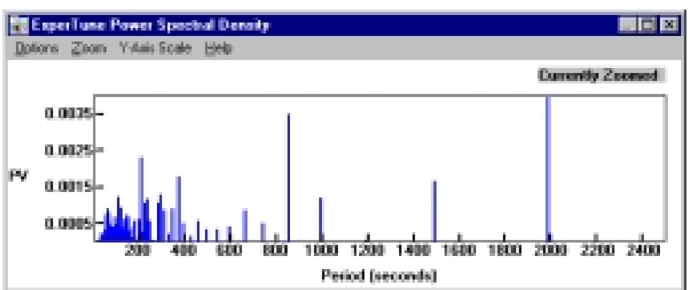


Statistics	
Sample (raw)	0.25
Num of Points	15377
Time Min	0
Time Max	5.96e+003
PV Min	47.88
PV Max	50.1
Range	2.22
Mean (μ)	49.07
Standard deviation (δ)	0.347
μ±δ	48.72 - 49.42
μ±2δ	48.38 - 49.76
Variance	0.1204
Variability	1.41 %



Statistics	
Sample (raw)	0.25
Num of Points	24164
Time Min	985
Time Max	7.03e+003
PV Min	48.51
PV Max	49.66
Range	1.15
Mean (μ)	49.04
Standard deviation (δ)	0.168
μ±δ	48.87 - 49.21
μ±2δ	48.7 - 49.38
Variance	0.02822
Variability	0.685 %

Power spectral density



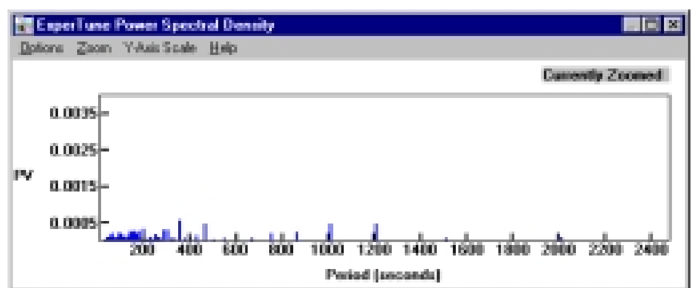


Figure 2

As shown by the power spectral density graphics, the hidden oscillations were greatly reduced. The same results were observed for other loops.

RETURN ON INVESTMENT: BENEFITS VS. COSTS

The computable benefits are:

- Better performance of the paper machine: it starts easily after a grade change and breaks less often;
- Better efficiency of the paper machine;
- Increased production rate;
- They estimate this to be $1 800 000 per year.

The non-computable gains are:

- Better knowledge of the paper machine;
- Better operation of the paper machine;
- People better trained to troubleshoot a paper machine problem;
- Better product quality;
- Replicable expertise for other paper machines
- Smooth operation
- No more abuse of the equipment
- Tools and data in place for predictive maintenance
- Reduced maintenance in the future.

The costs for the entire process are:

- Training and support by TOP Control;

- Purchase of analysis and data acquisition software;
- Labour time for optimization process;
- Maintenance by mill staff;
- Equipment replacement was not included since the equipment would have been replaced eventually.

For a total cost of $68,000.

This gives a return on investment of less than one month. Process optimization is one of the biggest return on investment plants can do today, since the objective is to be sure the actual equipment you already own works at its best.

Preventive maintenance instead of reactive maintenance is another major benefit, since the maintenance people now have the tools and the skills to maintain their gains. They are able to detect and to fix problems before they impact the production. They now use the same techniques on other paper machines and other sections in the mill.

In process optimization, you plan to use the equipment at its best, you do not need new installations with all their procurement costs, engineering, installation and future maintenance cost. In fact the goal is to achieve the maximum performance possible with the actual equipment.

CONCLUSIONS

They save 1.8 million every year for investing $68,000. The return on investment is under one month. A better quality and a more efficient paper machine are not the only benefits; the staff now has a better understanding of the process. It now has a systematic approach to improving efficiency and quality through better process control.

ABOUT THE AUTHOR:

Michel Ruel is a registered professional engineer, university lecturer and author of several publications and books on instrumentation and control[jpg1]. He has 24 years of plant experience including these companies: Monsanto Chemicals, Domtar Paper, Dow Corning and Shell Oil. He is experienced in solving unusual process control problems, troubleshooting and optimizing processes and he is also a pioneer in the implementation of new techniques in process control. Michel Ruel is president of TOP Control Inc.

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2- Expertune software, Hubertus, Wi.