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BEST PRACTICES IN THE PROCESS OPTIMIZATION OF PAPER MACHINES

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Abstract: ***Optimizing the Paper Machine has been a challenge to the Paper industry for many years. Paper making is an intricate process with many inter-connected systems and is usually affected by various unknown disturbances from different parts of these connected systems, resulting in quality and runability issues. Optimal process conditions would potentially increase the plant operating efficiency by around 20% resulting in the improvement of bottom line of the organization and lesser environmental impact.***

Optimization services have evolved significantly over the last decade, (i) with advancements in big data analytics, (ii) availability of hardware and software tools and (iii) increased interoperability within control systems making data collection much easier.

In the last few years, Optimization programs have become extremely structured, with clear timelines and pre-defined KPIs that help track the success of the program and an engineered approach.

This Paper outlines some of the best practices in process optimization that can create positive impact on the performance of the Paper Machine. The Paper also discusses the simple, yet effective ways to improve the performance of Machine. Common issues in the Paper Machine s and some real-world examples on the various practices followed to overcome the issues were discussed, which may enable the reader to relate some of their current issues and find potential solutions.

1. INTRODUCTION

In any Paper plant, the purpose of automation system is to maintain the product quality, production rate, reduce start-up time, and increase speed of operation with human safety. Control system whether it is a Programmable Logic Controller (PLC) or a Distributed Control System (DCS) or Quality Control System (QCS) is required for the same purpose. We know that the field instruments, DCS, QCS, QMS, Drives and Camera Systems are pumping large volumes of data which is incredible, but author noticed that the utilization of those data is questionable. The control, process and mechanical performances decay with time and the machine performance declines. Hence it becomes imperative to have some arrangement to monitor the performance of the machine with existing large volumes of data.

Paper Machine optimization is a combination of data analytics and process engineering activities that leverages the power of big data analytics and the expertise of Paper maker to:

- Identify
- Classify
- Simulate
- Monitor the Paper Machine performances.

2. STEPS IN PROCESS OPTIMIZATION

Optimization process have evolved significantly over the last decade,

- With advancements in big data analytics,
- Availability of hardware and software tools for various data collection and
- Increased interoperability within control systems making data collection much easier.

The Optimization process involves experienced process engineers performing the following activities

- Benchmarking the Paper Machine and defining KPIs to measure the performance with respect to international baselines.
- Establishing an optimization calendar to define which systems will be optimized when, based on the current requirements of the plant management
- Identifying the various sub-systems in the Paper making and potential sources of disturbances within each sub-system
- Data collection, analysis and visualization to establish the potential links between the various sources of disturbances and the actual disturbances
- Addressing the source of disturbances
- Continuous monitoring maintains the Paper Machine performance at the optimum levels

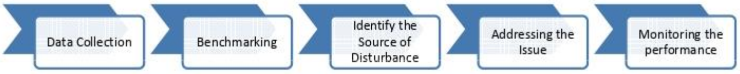


Figure 1 – Steps in Process Optimization

3. PROBLEM STATEMENT

Paper Machine s across the globe face the following few frequent issues

- Machine instability during speed /grade change/ sheet breaks
- Product quality issues arising from
  a. Consistency disturbances
  b. Chemical disturbances
  c. Unstable Broke System
  d. Process equipment disturbances, etc.
- Disturbances arising from process instrumentation issues/signal inconsistencies etc.,

Process optimization steps and the implementation of the best practices in the optimization steps will effectively address the above-mentioned issues.

4. BEST PRACTICES IN PROCESS OPTIMIZATION

Industrial Research shows that industries rely on data analytics for decision making for only 6%. But the author experienced that the Paper industry understands the value of data analytics and intend to be predictive and proactive. The author believes that the next generation might move towards the structured data analysis and big data analytics.

Points to be considered while implementing the process optimization in every mill are listed below

- Realize there is no silver bullet: Building an analytics culture using next-generation analytics and putting the ecosystem together takes time. It is important not to ignore the basic data collection and analysis part.
- Utilize available (existing) data and Consider more advanced analytical tools
- Take Training Seriously: Industries need to think about the skills process engineers require for data management, as well as the skills to deal with mill data. With statisticians and other quants in short supply, thinking on training will become an important part of industries next-generation strategy.
- Act on data: Improvement plan needs to be taken care by available resources.
- Finally remember to monitor the success: It's important to analyze in continues basis where action is taking place on a periodic basis to make sure that machine performance is still sustained.

Figure 2 – Implemenation of Process Optimization

5. CASE STUDY – REAL WORLD EXAMPLE

The Paper explains the issues, the methodology adopted by the author to identify the issue, the solution/recommendation provided to improve the performance and the end state in one 400 TPD Paper Machine in Asia. The name and location of the Paper Machine., are masked in line with the confidentiality requirements. This well documented set of use cases would provide the readers an insight into the power of optimization services.

The case-in-point here can be your typical machine which is more likely to be operating at sub-optimal conditions. The start point is to engage and benchmark the current performance with best-in-class standards defined by TAPPI and then setting targets as part of the optimization calendar.

Table 1: Results of Case Study

Performance Indices	Benchmark	Before	After	% Imp
Weight 2 Sigma	<0.2	0.799	0.24	70%
Moisture 2 Sigma	<0.16	0.604	0.18	70%
Ash 2 Sigma	<0.2	0.8262	0.10	87%
Loop Tuning Index	<15.0	79	26	68%
Stability Index	<0.3	2.6	0.68	78%
Response Index	<4.5	22	4.5	79%
Grade Change Time		>12 Mins	<6 Mins	>50%

Table above shows the benchmark, the before and after values of the KPI across major variables. Some of the best practices followed in the above process optimization exercise is presented below

6. DEFINE OPTIMIZATION STRATEGY

Paper Machine systems have super large volumes of data and are one of the best bets for use of Big data solutions with possibilities to identify extremely high number of improvement areas. However, it is very important to prioritize areas of improvement that will give the best ROI given the limited resources available for the management to deploy. The first step in this process is defining various data collection sources → and classify them to various disturbance groups to enable easy prioritization. So, it is recommended to have data collection setup in every machine. The following examples showcases the strategy of the data collections for process, control and equipment analysis.

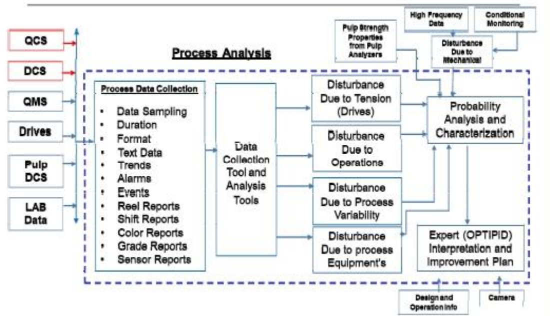


Figure 3 – Overview of Data Collection

7. DON'T ASSUME PROCESS VARIATION AS SIGNAL VARIATION

In signal processing, data compression or Quantization is the process of encoding information using fewer bits than the original representation. The process of reducing the size of a data file is often referred to as data compression. Normally loops with limited noise have large filters on either the analog input or the transmitter itself. Usually the result of dead bands or compression and time updates if MV does not change by more than x amount.

Compression is useful because it reduces resources required to store and transmit data. Often this is the way mill historians save data. The problem comes in the reconstruction of the points. Interpolation of the points results in non-smooth trends. Compressed or Filtered data really can't use for process analysis and control the loop as well.

So, the first step is to prepare the below chart before doing the Paper Machine process analysis.

	Area	Stock Flow	Stock Consistency	Weight	Moisture
Transmitter	Type				
	Installation				
	Calibration				
	Filter				
Signal Conditioning	Decimal Points				
	Filter				
	Dead Band				
Valve	Size				
	Type				
	Precision				
	Positioner				
Control	Tuning				
	Execution Rate				
	Dead Time				
	Delay				
Process	Disturbance				
	Design				
	Oscillations				

Figure 4 – Step by step approach

Filtered Data reduces process visibility

The below trend shows one of consistency loop. The left-hand side the straight line shows how badly filtered the data were. For the process analysis, the straight lines won't tell us anything. The right-hand side showing the real process signal which must be controlled with the help of control system

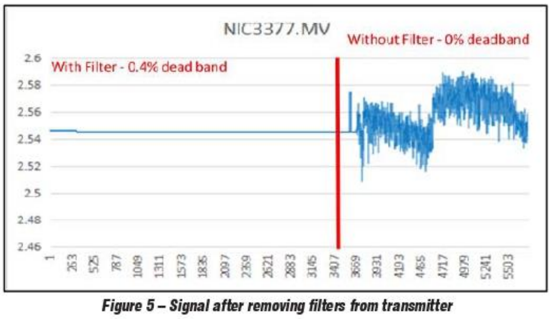


Figure 5 – Signal after removing filters from transmitter

Filtered Data increases the process variability

The below trend is one of level loop which clearly visible after removing the filter the process stability improves >50%. And also reduces the variations in valve operations which will save valve life too.

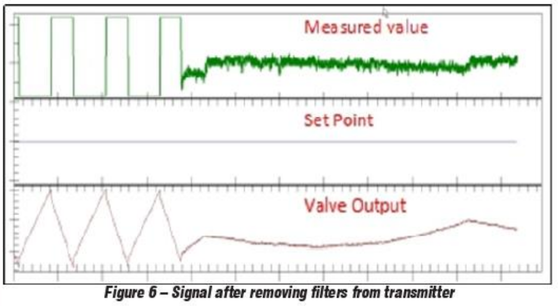
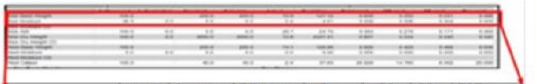


Figure 6 – Signal after removing filters from transmitter

8. USE OF QCS REEL REPORT

QCS Reel Report data has been available for over 30 years. But utilizing those reports are less impressive. Reel Report data collection and interpretation gives tremendous insights into the steady-state as well as historical variability performance of a Paper Machine. Understanding the statistics behind these numbers will greatly improve process troubleshooting and variability bench marking.



	Actual	Set point	Efficiency	MDL	MDS	CD	TOT
Size Basis Weight	72.9	73.0	100	0.253	0.498	0.24	0.609
Size Moisture	4.6	5.0	100	0.06	0.05	0.04	0.09

Figure 7 – Standard reel report from leading QCS supplier

What should we look from the Reel Report?

MDL: MDL or MD Sprd is Machine Direction Long Term variation which is equivalent to the variability in the scan average for a reel. If MDL is abnormally high, then the problem is typically with the QCS tuning, Stock or steam approach systems and Chemicals.

CD: CD or CD Sprd is Cross Direction variation which is equivalent to the variability in the average reel profile. If CD is abnormally high, then the problem is typically associated with: CD actuators, the headbox not operating with in design specification, headbox consistency problems, the CD controls are not properly set up for that grade, dirty wires, or felt problems.

MDS or RES: MDS or RES Sprd represents the Machine Direction Short Term or Residual variations that get averaged out in the scan average and profile average during a reel. If MDS is abnormally high, then the problem is typically found in machine equipment's like fan pump, screening, mixing, Centricleaning, machine clothing, and rotating elements.

TOT: Total or TOT Sprd is the variability of entire reel.

What can we analyze from the reel report?

Can we use reel reports to analyze various problems?

Yes, we can use the reel reports to analyze the below or more purposes.

- Machine performance on Variability at different frequency
- Machine performance on different grades
- Machine performance at different speeds
- Machine performance vs. Time
- Machine performance vs different fabrics

What is the frequency Spectrum?

Reel Report data can be used for analyze frequency content of each variability

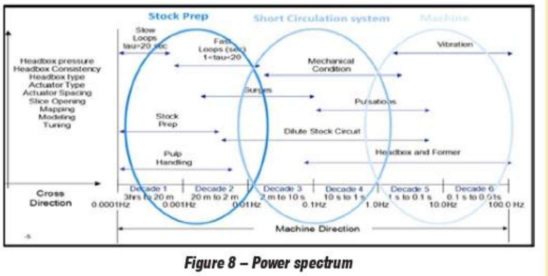


Figure 8 – Power spectrum

area. Comparing the reel data frequency bands with process information can help in the identification of machine direction variability sources. The following process spectrum chart shows common variability sources and the frequency bands they are associated with.

Example of reel report analysis

Normally, one month of reel report data has been stored in the QCS. Every automation supplier will have a tool to collect those data. The below charts are showing the reel report information.

Table 2: Total variability as % of process

Description	Goal	Machine_xxxx
Reel Weight	<1.7	1.86
Reel BD Weight	<1.5	1.76
Reel Moisture	10.0	11.45
Reel Caliper	<1.0	1.68
Size Weight	<1.7	2.42
Size BD Weight	<1.5	2.04
Size Moisture	<10.0	24.55

Total variability is further distributed into three components like MDL / MD Spred, CD / CD Spred, and MDS / RES. The rule of thumb or target is as shown in the goal column in the below chart in yellow.

Table 3: Variability distribution

TYPE	Goal	Reel Weight	Reel BD Weight	Reel Moisture	Reel Caliper	Size Weight	Size BD Weight	Size Moisture	Size Ash
MDS	<70	73.38	79.45	26.65	54.62	50.4	65.2	12.95	82.22
MDL	<10	7.11	6.17	8.28	32.7	5.29	5.17	5.47	7.79
CD	<20	19.51	14.37	65.07	12.68	44.31	29.74	81.58	9.98

Once we derive the above numbers, then the Paper maker can understand the source of product variabilities.

Also, the Reel reports can help Paper maker to analyze the following

- Machine performance at different frequencies
  - **MDS/RES** (Short MD variation)
  - **MDL/ MD Spread** (Long MD variation)
  - **CD / CD Spread** (Cross direction variation)
  - **TOT** (Total variation in the sheet)
- Machine performance on different grades
- Machine performance at different speeds
- Machine performance vs. time
- Machine performance at different equipment's (Wire / press fabrics, vacuum rolls, calendar rolls etc.)

9. USE OF ALARM & EVENT

Alarms are the notifications used to inform operators of process activity: Alarms represent warnings of process conditions that could cause problems, and require an operator response.

Events represent normal system status messages, and do not require an operator response. A typical event is triggered when a certain system condition takes place, such as an operator logging.

Alarm-flooded

Operators often find alarm systems difficult to manage following a trip or critical issue. The stress of the situation makes matters even worse. A good performance indication for proper alarm management is the number of alarms in the first few minutes following a trip or critical situation. It was observed that 80% of alarms are low priority. If it has no consequence or doesn't matter, why have an alarm?

Alarm Setup and Utilization

Providing accurate detection, recording and storing of events and leveraging accurate time stamps, system solutions enable you to analyze when change of states occurred in your process and the precise order of occurrence is very important for any industry.

1. Set appropriate limits

Figure 9– Object for alarm setting

2. Define clear procedures for managing alarms Non-alarms that provide useful information for the operators are called notifications or user alerts. They are not alarms, and during an abnormal operating condition or emergency, they can be silenced and ignored.

3. Make alarms manageable

(i) The objective of an alarm philosophy is to control daily alarms and to reduce the size and frequency of alarm floods.

(ii) When the system performs effectively, the operator workload is not burdened by the alarm system, and we can consider alarms to be within normal operations.

(iii) Provide tools for managing alarms, enforcing the philosophy and maintaining the system.

10. DON'T IGNORE CONSISTENCY

Consistency Control is one of the important in wet end to improve machine stability and agility. Nevertheless, it is the same time one of the most poorly implemented and maintained in Paper Machine loops on many machines based on the experience of author and the data collected across the globe.

Little Variation, Big Impact

Considering mass balance equation for this system shows that variations in stock flow and consistency directly impact the weight and moisture. During the normal machine run, Paper makers usually ignore these fractional changes of stock consistency and stock flow variations. But Our experience and data analysis show that fractional changes in stock consistency and speed directly impact the weight.

$$\text{Bone Dry Weight} = \frac{\text{Stock Flow} * \text{Stock Consistency} * \text{FPR} * \text{Unit Conversion}}{\text{Wire Speed} * \text{Slice Width} * 100}$$

When we troubleshoot weight variation, we ignore the FPR and Speed variations. However, for this discussion, we assume that both FPR and Speed are constant.

The fractional changes of consistency have very important and dramatic interpretations.

For example, Stock Consistency = 3.5% , Weight = 60 gsm

If the consistency variation +- 0.1% (that is 3.4 to 3.6), this would result in a change in weight of +- 1.72 gsm (that means 58.2 to 61.8). This source weight variation may not be able to find in any historical or process trending data. Few examples

Dilution Water Pressure:

If the dilution water pressure is not constant, then the dilution water flow will not be constant and the consistency will definitely vary as shown in below picture. The red and green color trends are dilution water which was varying heavily which created huge variation in consistency (+_1.5%). After stabilizing the dilution flow, it was noticed that the consistency variation has come down >50% (+- 0.2%)

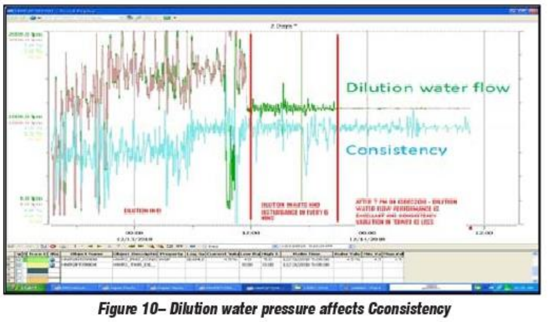


Figure 10– Dilution water pressure affects Cconsistency

Dilution Water valve operational limitations:

The below figures show that the Valve is hitting above 80%. During higher demand, the controller is trying to "windup" or push the Valve beyond the valve's hardware limitations. If the setpoint is such that the output is close to 20 or 80, this does not provide sufficient control range. Adjusting the setpoint may allow for better control performance because valve will be in range. It is always better to prevent disturbances than attempt to compensate for them after the fact. Often, this requires simple attention from the operation team and maintenance of the basic instrumentation in the stock preparation area. Unfortunately, this part of the plant often receives low priority.

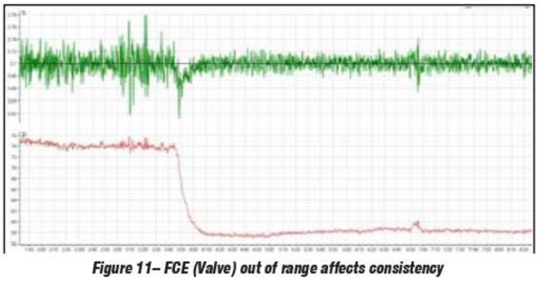


Figure 11– FCE (Valve) out of range affects consistency

11. PROCESS ANALYSIS AND FINE TUNING THE SYSTEM

The Process analysis and DCS/QCS tuning will greatly help to improve the machine stability and agility as well. The below figures are showing the improvements which was helped to achieve the benefits int that machine.

Loop Stability Improvement

The below figure is showing the excellent improvement in mixing chest level after tuning the PID.

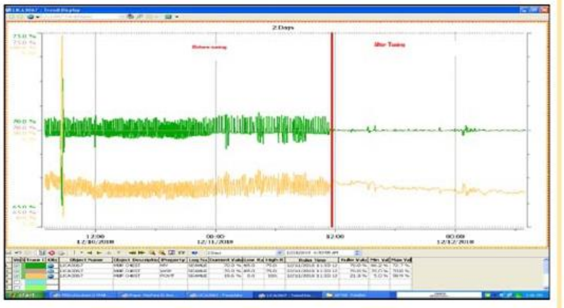


Figure 12– Loop tuning improves chest level stability

Loop Agility (Time to target) Improvement

The below figure is showing the excellent improvement in Clay flow time to target (Means settling time after the change was 500s and now 50s) after tuning the loop.

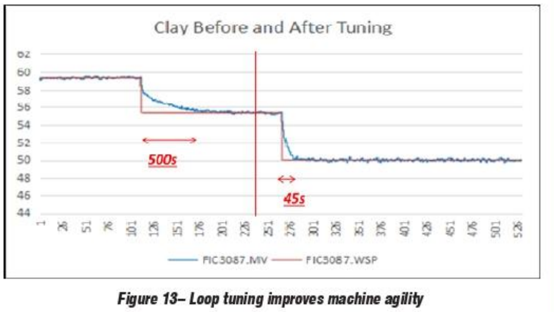


Figure 13– Loop tuning improves machine agility

Logical Issue

The below figure is showing the excellent improvement in steam condensate take level after changing the set point as shown below. Further deep dive reveals that there was some unwanted process logic was placed which was removed later.

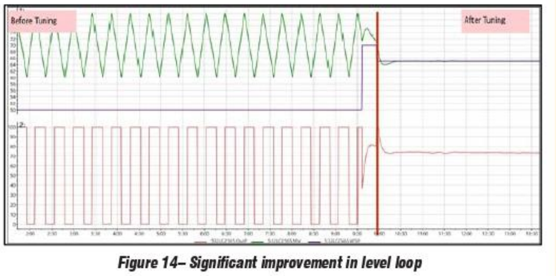


Figure 14– Significant improvement in level loop

Chemical (Process) Issue

The below figure is showing the tremendous improvement in stock flow after changing some chemical addition point which was creating stock flow signal spikes.

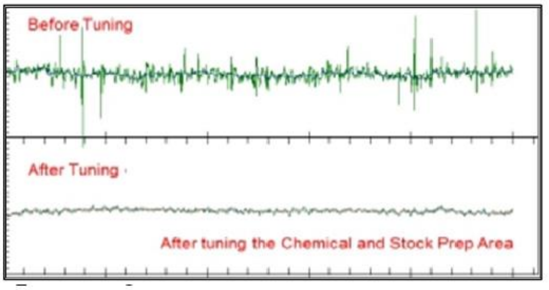


Figure 15– Chemical issue improves stock flow stability

Operational Issue

The below figure is showing reduction in basis weight 2 sigma for about 50% after changing the set point of primary screen reject tank level. Further deep dive reveals that there was some design issue related with primary reject tank and it was solved by the customer later. This process analysis and improvement activity accolades huge appreciation from customer.

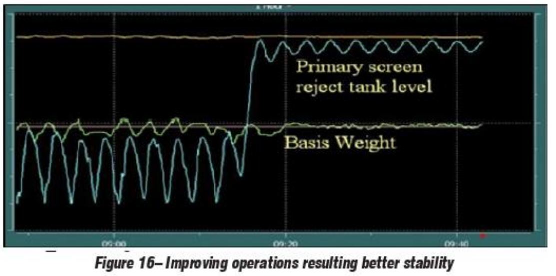


Figure 16– Improving operations resulting better stability

Product Stability Improved by Optimization

After the improvement activities, the weight 2 sigma has been reduced by more than 70% as shown below trend is showing 10 hrs. of data)

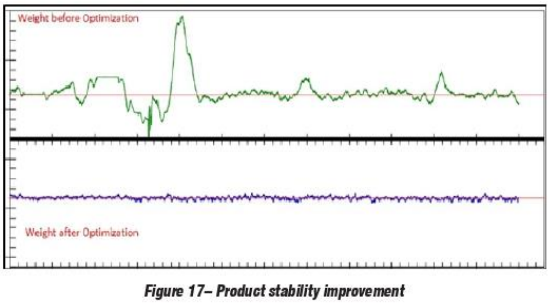


Figure 17– Product stability improvement

Sheet Break Detection

During the improvement activities, it was observed few sheet break sources as shown below which shows the power of data collection and analysis tools. The below case, rush/drag variation noticed before break

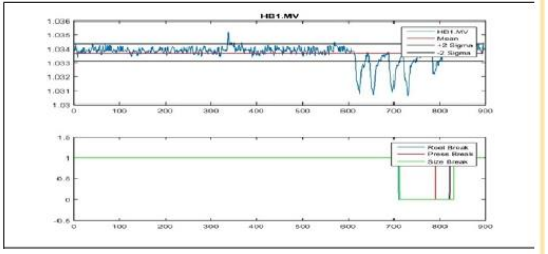


Figure 18– Sheet break detection thru data collection

12. Conclusions:

Following best practices in the process optimization will not only result in a better quality and a more efficient Paper Machine, but also provide the operators a better understanding of the process. Informed operators have a systematic approach to improving efficiency and quality through better process control.

Overall performance will be improved after optimization of Paper Machine that would result in the following:

- Increased production
- Improved sheet quality
- Reduced rejects and broke
- Reduced sheet breaks
- Provide the potential for target shifts
- Reduced grade change times.
- Faster sheet break recovery times
- Reduced energy
- Reduced chemicals etc.

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