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IMPROVE SUSTAINABILITY OF PAPER MILLS THROUGH PROCESS OPTIMIZATION


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Abstract:

Increased focus on environment and resource makes it imperative for paper mills to adopt sustainable production methods to conserve the raw materials and reduce the energy consumption. While Green manufacturing processes and equipment's are being developed to address these issues, exiting paper mills have to deal with the limits of operating plants to achieve the goal of sustainable manufacture of paper. Implementation of process optimization is one of the strategies that can be deployed to achieve the goal of sustainable production of paper. Optimization of paper machine operations conserves valuable resources and reduces the impact on the environment. It involves the usage of advanced process control and data analytics tools to reduce the wastage, energy and chemicals consumption.

This paper explains the methodology and techniques used for optimization of paper machine operations with emphasis on product quality variations, grade change, sheet breaks and wet end operations. Application of model predictive control strategies, control loop performance monitoring and tuning and data analytics are discussed with plant case studies. The process optimization projects are delivered as service to reduce the implementation costs with an attractive return on the investment.

1. Introduction:

Climate change concerns are forcing the process industries around the world to evaluate their production processes to reduce the environmental impact. In this regard, Paper mills are searching for ways to reduce the consumption of raw materials and utilities and also minimize the emissions to reduce the impact on the environment. While it is possible for greenfield paper mills to adopt newer process technologies to address the issues of environment, it is not so in the case of brownfield mills. Existing Paper mills have to operate within the limitation of the process and equipment to meet the production targets. These mills have to adopt operation strategies to meet the goals of sustainability and environment protection.

Process optimization is one of the strategies that can be applied to reduce the cost of the operating the mill and at the same time achieve the objective of reduced consumption of raw material, energy and chemicals. Modifying the existing mills to incorporate the new green process technologies involve considerable capital expenditure whereas process optimization can be implemented at a much lower cost with attractive return on the investment (ROI). Paper making is a complex multivariable process affected by various unknown disturbances resulting in runnability and quality issues. Optimization of paper machine involves collection of real-time data and application of sophisticated data analytics and optimization algorithms to improve the performance. Most of the current paper mills use computer based Distributed Control System (DCS) and Quality Control System (QCS) with interoperability features making it easy to collect the data and perform the required analysis and optimization of the operating conditions to meet the sustainability goals and reduce the operating costs.

2 Methodology

Paper Machines across the globe face the following few frequent issues

- Machine instability during speed /grade change/ sheet breaks
- Product quality issues arising from
  - o Stock preparation disturbances
  - o Chemical disturbances

  - o Unstable Broke System
  - o Process equipment issues, etc.

- Disturbances arising from process instrumentation issues/ signal inconsistencies etc.,

These issues lead to generation of more off-grade product, more energy and chemicals consumption which in turn affect the environment. Process optimization steps and the implementation of the best optimization practices will effectively address the above-mentioned issues. Paper Machine optimization is a combination of data analytics and process engineering and involves 4 steps as shown in Figure 1

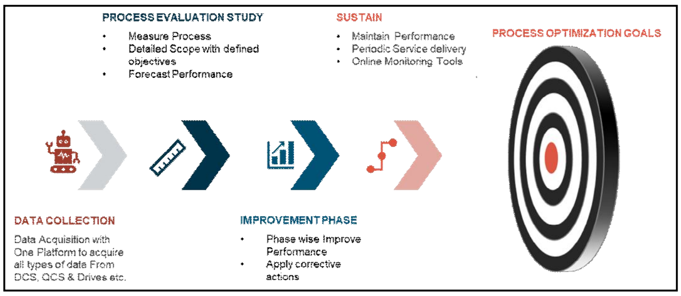

Figure 1 – Steps in process optimization

Data Collection Phase: The first step in process optimization is the data collection. There are many methods and tools available in the market to collect all the plant data. Process optimization system consists of a computer connected to an integrated process automation system consisting of DCS, QCS, Drives and other analyzers and field instruments as shown Figure 2. This system is provided with the software tools for automatic data logging, advanced data analytics using AI (Artificial Intelligence /ML (Machine Learning), Multivariable Predictive Control and optimization.

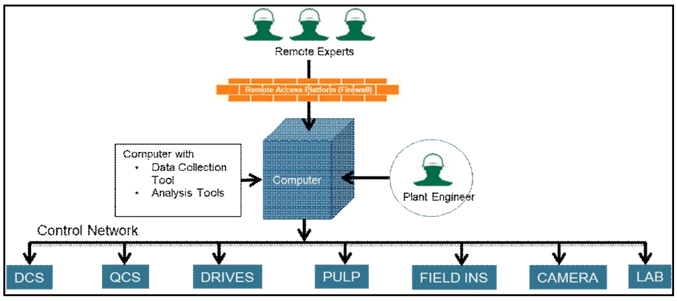

Figure 2 – Data Collection Phase

Process evaluation Study: Next step in process optimization is evaluation of the current performance of the mill and identify the scope for improvement. It involves collecting data from DCS, QCS, Drives, laboratory, conditional monitoring, camera system etc. and analyze it using the advanced data analytics tools to identify performance issues. Real-time data of all the control loops is collected and analyzed using advanced data analytics tool to diagnose the performance issues such as control valve stickiness, high noise in process measurements, oscillatory disturbances and PID tuning. Process interactions are also assessed to identify the need for implementing MVPC algorithms. Key performance indices are calculated to measure the performance of the machine with respect to Machine Direction (MD) variability, QCS response, stock approach stability and Cross Direction (CD) performance capability. Paper Machine performance is compared with industry benchmark and corrective actions are identified to reduce the operating costs and improve the product quality, machine runnability and broke reduction by reducing the time to target parameter in every control loop from DCS & QCS.

Outcome of this phase is a detailed plan of implementing the optimization solutions required to improve the performance.

Typical action plan includes

- o Level 1 control loops tuning from DCS,
- o Level 2 control tuning (MD and CD) from QCS
- o Level 3 (Speed, Auto Grade Change, Shade Change, Ply loading, etc.) tuning
- o fixing instrumentation issues,
- o identifying/fixing the equipment issues,
- o identifying/fixing process design issues,
- o identifying the optimized operating parameters,
- o improving operating procedures,
- o implementing APC algorithms etc.

Improvement Program Phase: Based on process evaluation study recommendations, corrective actions such as fixing the filed instrumentation issues, process issues, equipment issues and maintenance of the control valves identified with stickiness and tuning of the identified PID control loops are implemented. Tuning of the MD and CD control loops is also carried out to improve the grade transition times and reduce MD and CD profile variations.

Depending upon the outcome of the process evaluation study, the optimization solutions such as APC systems for

(i) Wet End section to control Reel Ash content and White-Water Consistency (WWC)

(ii) Refiner Energy Optimization.

Other advanced solutions that are usually implemented include application of advanced data analytics to carry out Sheet Break Analysis. Sheet Break analyzer collects data from different sources such as process control systems, drives and quality management systems. Advanced data mining and

Machine Learning algorithms analyze the correlation among hundreds of process variables to identify the root cause of the sheet break within a minute of occurrence and provide the operators with alerts and notifications to help them to take the required corrective actions. It helps in improving the safety as operators enter the dryer to extract the paper less frequently due to reduced sheet breaks.

Sustain Phase - On-Line Monitoring Tools: Once the process optimization solutions and services are implemented, performance of the paper machine improves. However due to process changes and wear and tear of the equipment, performance of the machine gradually deteriorates. To sustain the improved performance on a long-term basis, an on-line performance monitoring and diagnosis system is deployed in the paper mill. This system is connected with the DCS, QCS and Drives systems and collects the data continuously and periodically analyzes the data to identify the performance issues and suggests remedial measures to be taken to ensure the high performance of the paper machine. It helps in making the mill more sustainable by reducing the energy usage, raw material and water footprint while improving the fiber recovery

3 Results and Discussion

3.1 Control Loop Performance and Tuning

Several Paper Mills implemented tuning of the DCS/QCS control loops and achieved improved machine stability as well as reduce the operating costs. Analysis of the normal operating data indicates that only about 30% of the control loops performing satisfactorily while the remaining 70% of the loops were diagnosed with issues such as control loop tuning, manual operation, output saturation, control valve stickiness, oscillations in measured variables and signal noise issues. Advanced data analytics software tools are used to analyze the process data and diagnose the performance issues. Correction of these issues result in reduced off-grade products, improved startup and grade transition times, reduced variability in paper quality and increased thruput. All these improvements contribute to more sustainable operations and reduced environmental impact due to reduced off-spec product and improved conversion of raw material to final product.

Control loops performance analysis of around 250 of control loops in one paper mill in South India indicated that 7 loops were identified with tuning issues, six loops with valve stiction, seventeen loops with oscillatory variations, eight loops with valve sizing and leaking problem and ten loops with signal conditioning issues.

Short fiber Chest level control loop was diagnosed with signal conditioning issue and after correction the transmitter, DCS filters, large step variations in the measured value were removed resulting in much less variation in the process value and control valve oscillation which leads improved valve life as shown in Figure 3.

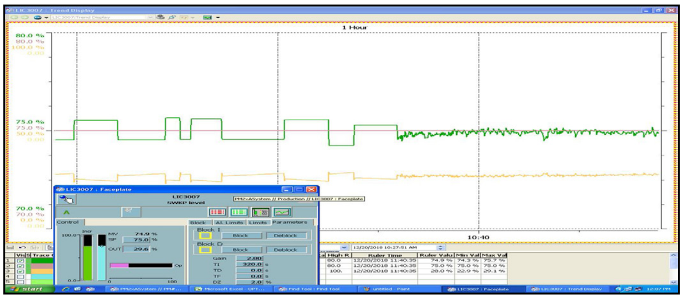

Figure 3 – Improvement after signal issues solved

Tuning of the PID tuning parameters of the mixing chest level control loop has resulted in drastic improvement in the stability of wet end as shown in Figure 4. This helped in reducing the variation in the product quality.

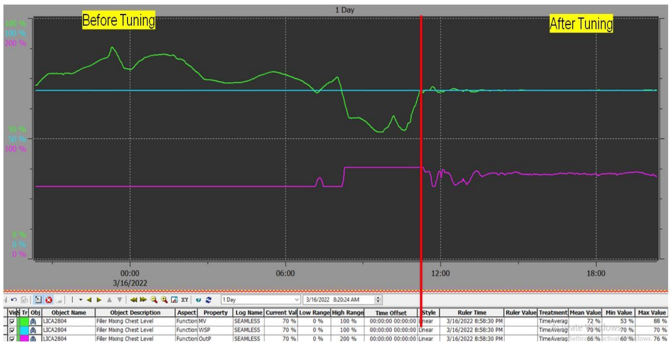

Figure 4 – Mixing chest level variation reduced by 90%

Another loop tuning of the chemical flow control has resulted in drastic reduction in the response times during setpoint changes as shown in Figure 5. This helped in reducing the variation in the Ash content in the paper produced

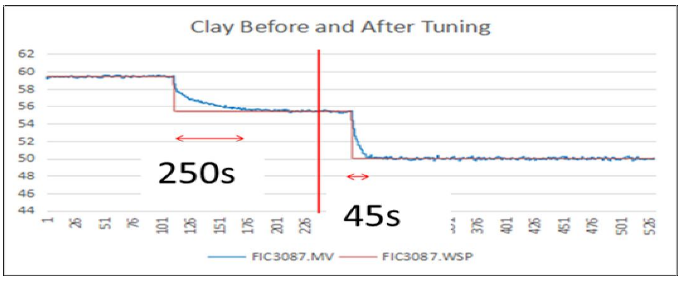

Figure 5 – Chemical flow time to target improvement

Deployment of control loop performance monitoring and tuning services in South African customer has

- Reduced amount of reject paper during startup and speed changes by 18%
- Reduced grade change time by 24%
- Reduced sheet break recovery time by 40%

This improves the performance in the mill contributing to the goal of sustainable operations in the mill and also the cost reduction.

3.2 Refiner Optimization

Refining is the most energy intensive process in a paper mill. It is common practice to apply specific energy control along with consistency control of stock entering the refiners. With the availability of fast, accurate and reliable on-line freeness analyzers, it is possible to apply APC for optimization of energy in Refiners.

The first step in the implementation of APC in Refiner is to tune and stabilize the Refiner feed pressure, refiner feed chest level, refiner outlet thick stock flow, and refiner feed consistency control loops. A Refiner Energy Curve (REC), which describes the relation between the refiner specific energy (SPE) and pulp properties such as tear, tensile, burst, fiber length, and freeness, is developed using historical plant data or through step tests. The REC enables the inference as well as prediction of the pulp properties at different power levels. The on-line Freeness measurement is fed to the APC algorithm which calculates optimum setpoint of the Specific Energy Controller which accordingly manipulates the power such that the freeness is closer to the desired target value.

Figure 6 shows that the SPE reduction from 175 to 105 kwh/t of paper after implementing the APC in the Refiner in a paper mill in Indonesia.

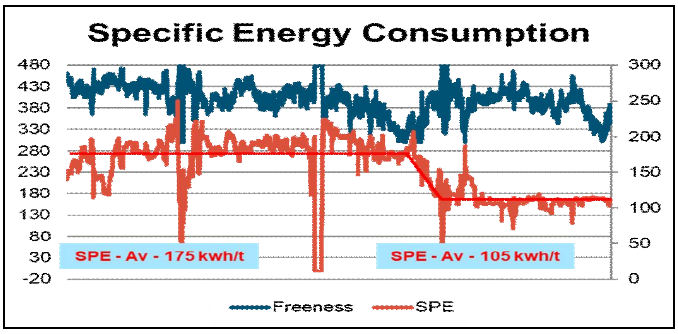

Figure 6 – SPE reduction after apc switch on

For a paper mill of 500 TPD, the energy savings from Refiner optimization are expected to be around 35,000 kWh per day (105 million kWh per year assuming 300 operating days of the mill). As per US EIA [1] 1.0 kg of CO2 emissions per kWh, the implementation of Refiner Optimization will lead to reduction of about 105000 tons of CO2 emissions per year.

3.3 Wet End Optimization

A South East Asian paper mill implemented APC for Wet End operations with very good results.

Step tests were carried out and dynamic process models were developed between Filler/RA/Silica/Bentonite flows and Reel Ash and White-Water Consistency (WWC). These models were used to predict the future values of Reel Ash and WWC and optimum values of the Chemicals dosage rates were calculated to keep the Reel Ash and WWC close to the target values. Reduction in the variations in WWC before and after implementing the APC solution can be observed in the figure below.

APC obtained the following results

- 67% reduction in variation of WWC
- 10% reduction in clay dosage
- 20% reduction in retention chemicals dosage
- 23% reduction in Sheet breaks due to wet end disturbances
- 27% reduction in grade change time and improved shade control due to faster ash settling time

Related trends are shown in the Figure 7:

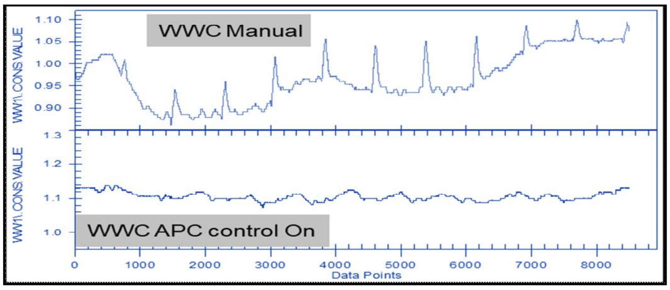

Figure 7 – WWC variability reduced by 60% after apc

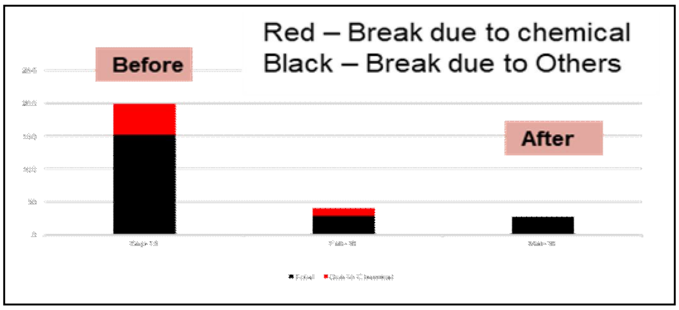

Figure 8 – Statistics for break reduction after APC

It was observed that sheet breaks due to chemicals were reduced to zero after implementation of APC as shown above Figure 8.

Thus, Wet End Optimization leads to sustainable operations due to lower consumption of chemicals and sheet breaks leading to lower environment pollution. Assuming 20% reduction in chemicals consumption after APC implementation, the quantity of chemicals in the mill effluents would have reduced by 20% TSS for a 500 TPD paper mill.

3.4 Grade Change

Auto Grade Change (AGC) Tuning has reduced the grade change time by more than 50% in a Paper Mill in New Zealand.

The results of grade change tuning are shown in Figure 9. Quick transition in weight accompanied by moisture settling time of around 9 minutes was achieved. Before tuning, it was observed that the weight was settling in time but the moisture took very long time around 18 mins.

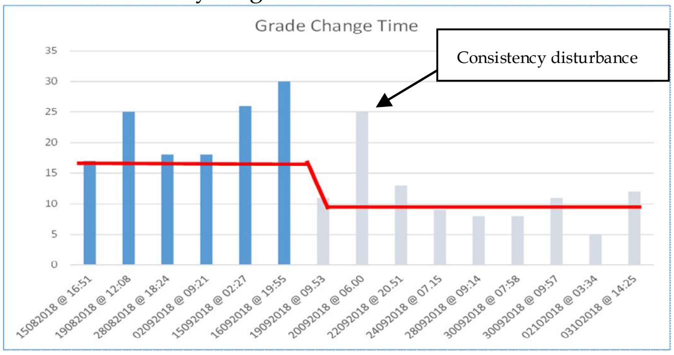

Figure 9 – Grade change time reduction after agc tuning

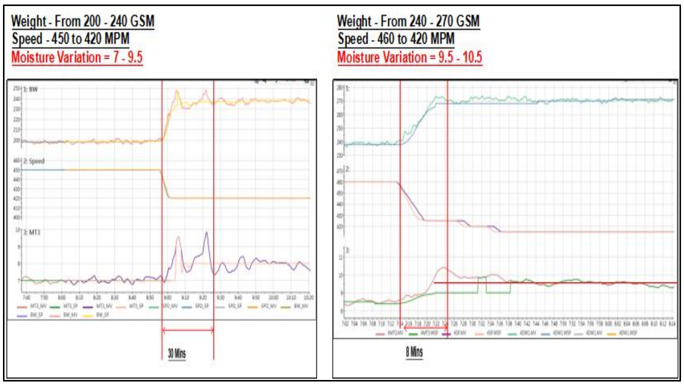

Figure 10 – AGC before and after improvement

Thus, AGC optimization leads to sustainable operations due to lower off spec product/broke. One of the Indonesian Pulp Sheet machines (2000 TPD capacity) achieved 50% reduction in the grade change time as shown in Figure 10 and this has resulted in additional production of 500 Tons per month without using additional raw material and chemicals.

3.5 Sheet Break Analysis

Paper machine runnability is often evaluated by the number of web breaks in proportion to production speed. To attain good runnability, the paper must run well (with a low number of web breaks) in each sub-process along the entire paper machine line.

Process data was collected around 399 sheet break events for 6 months and was further classified into 182 Size press breaks and 217 Reel breaks and analyzed. Analysis of the data indicated following major reasons for the instability of the Paper Machine and sheet breaks:

1. Wet end variability due to stock chemistry changes
2. Chemical variability
3. Headbox variability
4. Vacuum variability

After the implementing the corrective actions, the average sheet break time has come down from 3842 mins to 1488 mins (approx..60% reduction). The below Figure-11 shows that the break time reduction over the one-year period which resulted in 0.8% reduction in off-spec production and improved sheet break recovery time by approx.50%.

For a 500 TPD paper mill, this would be equivalent to savings of 30000 trees per year assuming that 25 trees are required to produce 1 ton pf paper.

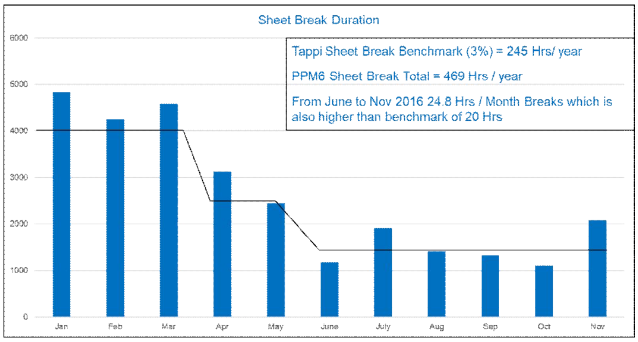

Figure 11 – Sheet break reduction - one year

4 CONCLUSION

Process Optimization helps existing paper mills towards meeting the goals of green manufacturing and sustainable production of paper. It involves application of MVPC, Data Analytics and Control Loop Performance monitoring and tuning to various aspects of paper machine such as sheets breaks, grade transition, refiner optimization and wet end operations. It helps in reducing the operating costs and also meets the objectives of sustainable production of paper with environmental conservation. Several real-life examples indicate that implementation of process optimization in paper mill contributes considerably to savings of raw materials, energy and chemicals.

5 REFERENCE

[1] https://www.eia.gov/tools/faqs/faq.php?id=74&t=11 dated 02/14/2023