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Optimizing Cost and Quality in Kraft Paper Production: A guide towards process optimization and sustaining the economic benefits

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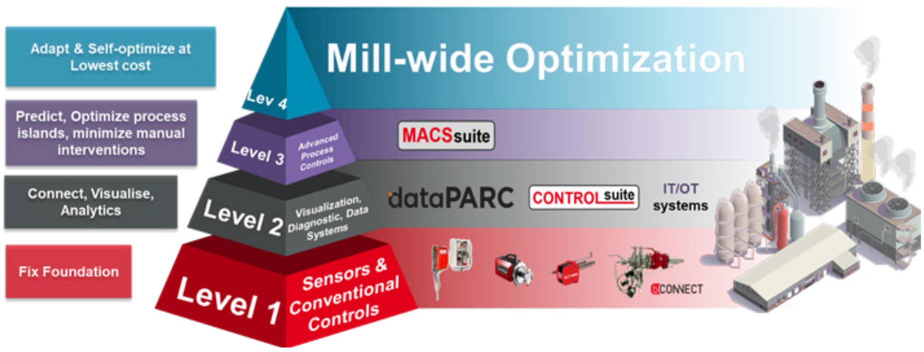
Abstract:

For most paper grades produced today, the economic situation requires to transform paper-making processes towards real-time stabilizing of final paper properties at target level and in parallel, minimizing production cost. However, there are several aspects to a successful optimization of a paper production line which are often overlooked, one of which is the completeness and healthiness of underlying measurements and conventional controls. We will also cover the requirements for sustaining the benefits of optimization projects in a paper mill after these have been implemented, such as personnel development and the recommended setup for project management & maintenance. We will present a couple of case studies to illustrate what is possible today.

Keywords: _Advanced Process Control, Fiber mass flow Audit -FiberMAX, Chemical Charge Audit - ChemMAX, Morphology strength Prediction._

PROVEN ROADMAP TO PROCESS OPTIMIZATION



Level 1: Foundation Process Measurement

At this foundational level, the focus is on implementing essential process measurements that are representative, accurate, reliable, fast, and smart. These measurements are crucial for any type of control, whether it be manual, regulatory, or advanced. They form the basis for the next level of smart monitoring.

Key Foundation Measurements:

- **Consistency:** Ensures uniformity in the pulp mixture.
- **Flow:** Monitors the rate of material movement through the system.
- **Pressure:** Maintains the necessary force within the system to ensure proper operation.
- **Temperature:** Controls the heat levels to optimize reactions and processes.

Specialty Measurements:

- **Freeness:** Measures the drainage rate of pulp, indicating fiber quality.
- **Ash/Filler %:** Determines the amount of inorganic material in the paper.
- **Brightness and color:** Assesses the visual quality of the paper.
- **ERIC (Effective Residual Ink Concentration):** Measures the amount of ink remaining in recycled paper.

- **Fluorescence:** Detects optical brightening agents.
- **Morphology:** Analyzes fiber shape and structure.
- **Colloidal charge:** Measures the charge of particles in the pulp, affecting retention and drainage.
- **Entrained air:** Monitors air bubbles within the pulp, which can affect paper quality.
- **Kappa number:** Indicates the lignin content in pulp.
- **Residuals:** Measures remaining chemicals after processing.

Level 2: Smart Monitoring

At this level, all process data, including the foundational measurements, are utilized by process control systems to drive the process as close to its designed state as possible. While BTG does not provide Distributed Control Systems (DCS), we offer tools to support and maximize the performance of regulatory controls. Also offers suite of solutions to integrate, histories, visualize and analyze the real time process data.

Tools for Smart Monitoring:

- Data management systems (dataPARC): Collects and organizes process data for analysis and decision-making.
- Loop monitoring & control support (ControlSuite): Enhances the performance of control loops, providing operational intelligence to maintain optimal process conditions.

Level 3: Advanced Process Control (APC)

In complex processes with multiple manipulated and control variables, and further complicated by long process delays in tanks and towers, regulatory controls alone are not effective. Advanced Process Control (APC) is a proven solution for these complicated processes, such as bleaching.

Benefits of APC:

- **Improved process stability:** Maintains consistent operation despite process variability.
- **Enhanced efficiency:** Optimizes the use of resources and reduces waste.
- **Cost savings:** Demonstrates significant savings in various mills by improving process performance.

Level 4: Full Optimization

At this highest level, all unit operations are fully optimized, and the demand/supply between unit operations is completely balanced. The goal is to achieve the minimum possible overall mill-wide cost at all times.

Requirements for full optimization:

- **Integration of all levels:** Ensures that foundational measurements, smart monitoring, and advanced process control are all optimized.
- **Balanced operations:** Maintains equilibrium between different unit operations to prevent bottlenecks and inefficiencies.
- **Continuous improvement:** Regularly updates and refine processes to adapt to changing conditions and new technologies.

By following these levels of optimization, pulp and paper manufacturers can achieve significant improvements in efficiency, cost-effectiveness, and sustainability. Each level builds upon the previous one, creating a comprehensive approach to process optimization.

DEVELOPING AN OPTIMIZATION JOURNEY

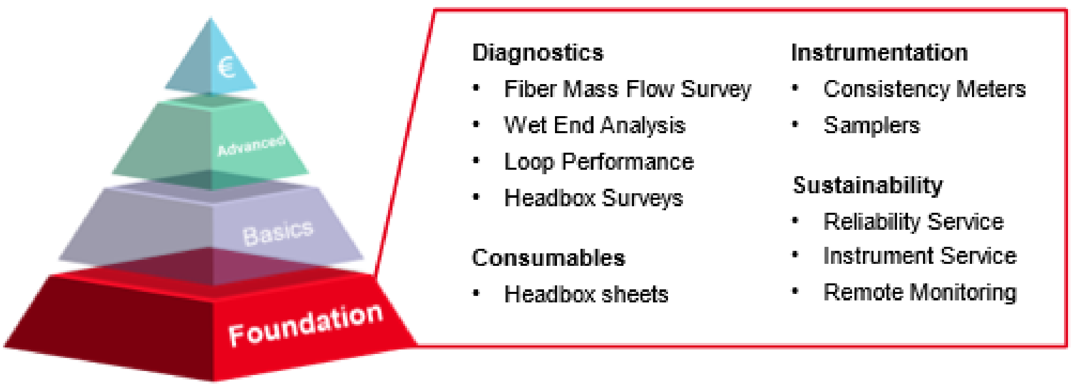
An optimization journey pyramid illustrates how the different components of state-of-the-art process control are relying on each other. It also can be used to explain the journey of process optimization and continuous improvement. To build the pyramid, we need to build it from the ground up. The strong foundation containing well-performing measurements and loops are required to build up and further improve to reach upper level like advanced control and business optimization.

Foundation Layer - Measurements & Loops

Delving into our optimization journey starting with the foundational layer, the primary goal is to ensure that all measurements and control loops are functioning optimally. This layer includes several critical products and solutions.

First, we have **Diagnosis**, which involves conducting a thorough survey to understand the current state of your existing system. This step is crucial for identifying areas that need improvement. Next, we consider **consumables** such as headbox sheets, which play a vital role in the papermaking process.

Consistency sensors and samplers are essential components at this level, providing accurate and reliable measurements that form the cornerstone of effective process control. Additionally, sustainability measures, including **reliability services, instrument services, and remote monitoring, are integral to maintaining** the health of the foundation layer. These services ensure that the foundational elements are consistently performing at their best, supporting the overall optimization efforts.

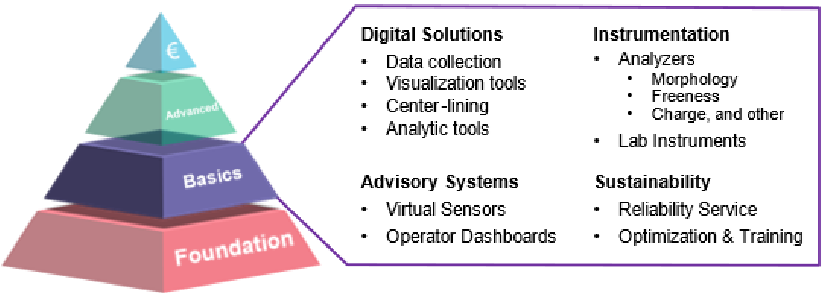


Visualization & Analytics Layer

Once the measurements and control loops in the foundation layer are well-established, we move on to the basics layer, which focuses on "visualization and analytics." This layer encompasses digital solutions that facilitate data collection, visualization, center-lining, and analytics. These tools are essential for transforming raw data into actionable insights, enabling better decision-making and process optimization.

Our portfolio of analyzers and lab instruments is integral to this level, as their application provides higher-level process insights that are crucial for fine-tuning operations. Additionally, advisory systems such as virtual sensors and operator dashboards play a significant role in this layer, offering real-time data and predictive analytics to enhance process control and efficiency.

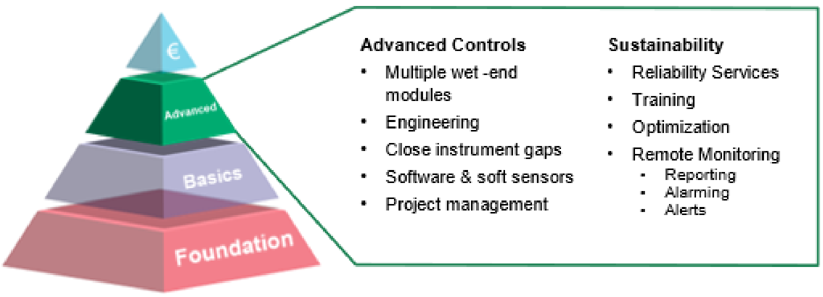
Sustainability remains a core component across all layers to ensure reliable outcomes throughout the optimization journey. In this basics layer, sustainability efforts focus on reliability services, process optimization, and comprehensive training programs. These initiatives are designed to maintain consistent performance and support continuous improvement, ensuring that the benefits of optimization are sustained over the long term.



Advance Process Control Layer

Next, we arrive at the Advanced level, which encompasses sophisticated process control solutions along with essential supporting services and systems. This level includes a comprehensive suite of advanced control modules specifically designed for paper machines, covering all necessary aspects for successful implementation. These aspects range from engineering and closing instrument gaps to software development, soft sensors, and even project management. Each of these components is crucial for delivering effective and efficient advanced control solutions.

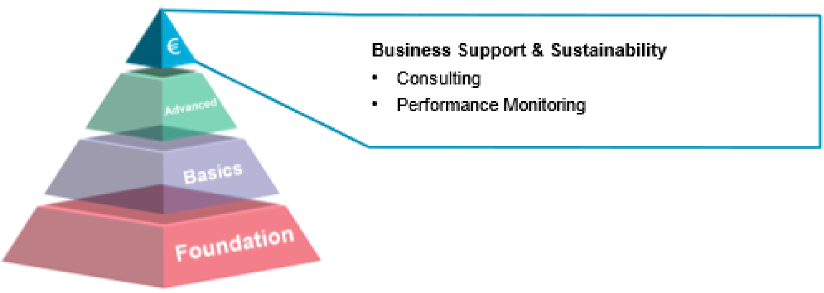
Moreover, sustainability remains a key focus at this level. This includes ongoing optimization, remote monitoring, and various reliability services. These functions are vital to ensure that the advanced controls continue to deliver the economic benefits they were designed for, maintaining their effectiveness and contributing to overall process efficiency and cost savings. By integrating these advanced solutions and sustainability measures, we can achieve a higher level of process control and optimization, ultimately enhancing the performance and profitability of the papermaking process.



Business Optimization Layer

Finally, we reach the pinnacle of the optimization pyramid, referred to as "business optimization." This layer represents the overarching strategy where we address high-level cost and benefit optimization for an entire paper mill or even across the entire customer organization. At this stage, the focus shifts to a broader perspective, encompassing strategic planning and project consulting to help our long-term customers achieve their business objectives.

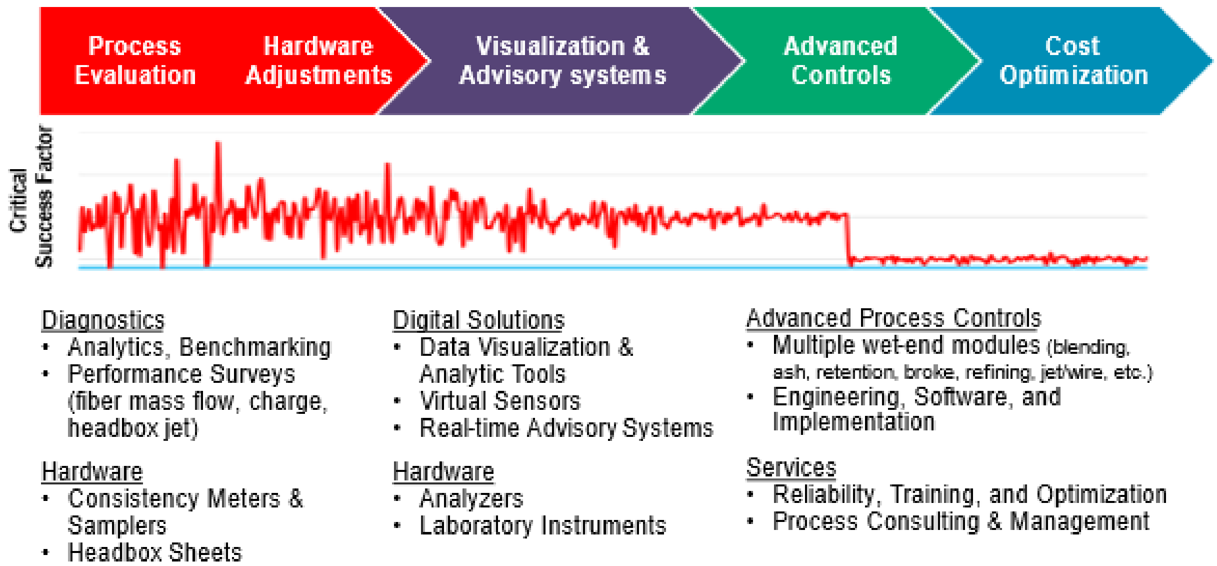
We provide comprehensive consulting support for various projects and strategic initiatives, ensuring that our customers can make informed decisions that drive efficiency and profitability. Additionally, enterprise-wide performance monitoring functions play a crucial role at this level. These functions offer valuable insights and data analytics that support customer goals, enabling them to monitor and optimize performance across their entire operation. By integrating these high-level strategies and tools, we help our customers achieve sustainable business optimization, ensuring long-term success and competitive advantage in the market.



Outcomes and Benefits from Process Optimization

In summary, progressing through the pyramid levels represents a comprehensive journey of wet-end optimization, aimed at reducing process variability at each stage. The journey typically begins with analytics, benchmarking, and diagnostic surveys to assess the current state of the process. This initial step often leads to the upgrading of transmitters, samplers, and related instrument services, as well as the implementation of headbox sheets. These foundational improvements pave the way for higher-level solutions, including advanced visualization and advisory systems, digital solutions, and enhanced hardware.

As the journey continues, the focus shifts to advanced controls, fostering long-term cooperation with customers. Throughout this process, services are essential at every step to ensure continuous improvement and optimization. Importantly, savings can be realized from the very first step, demonstrating the value of each stage in the optimization journey.



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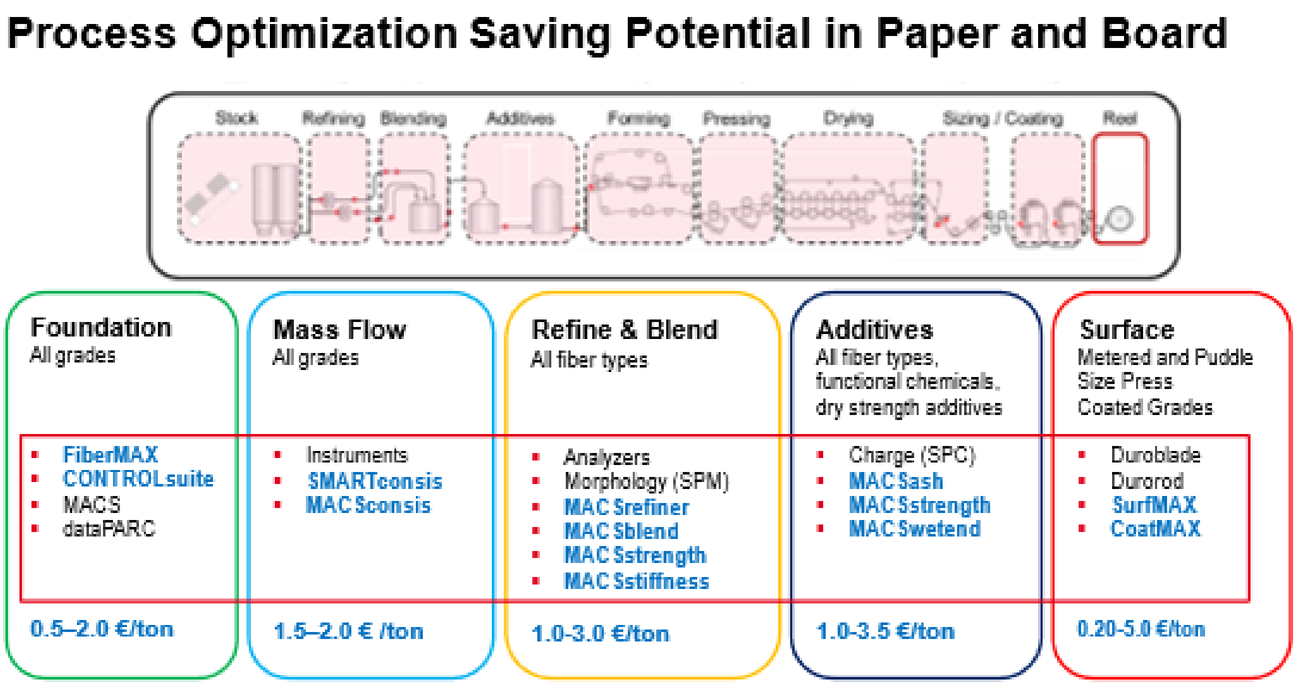
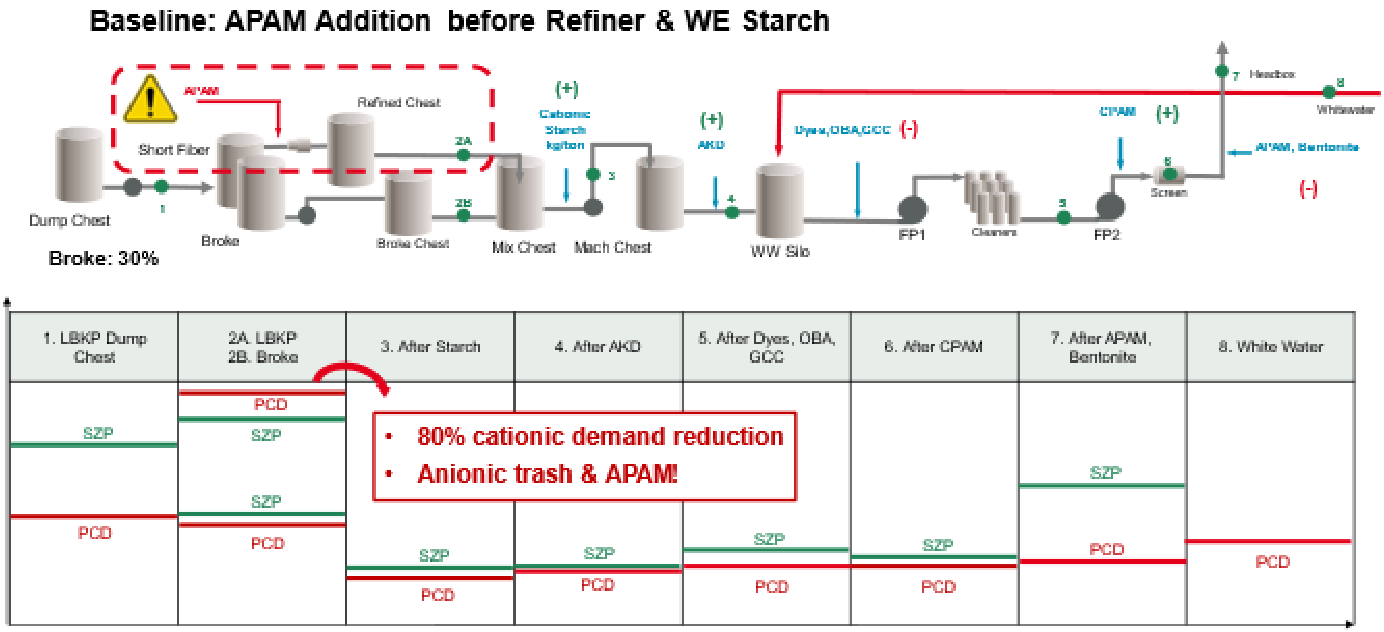


Process Evaluation Case Study: Charge Mapping & Chemical Optimization

Challenge: Customer had issue with high Cationic Starch Dosage, Deposit issues in the wet end, and poor machine runnability

Scope: BTG conducted charge mapping survey onsite (with BTG lab instruments PCD-05 and SZP-10)

Result: BTG was able to identify incorrect chemical addition points. Customer saved 1.2 €/ton through optimization of APAM and Cationic Starch usage alone; overall savings due to better runnability were much larger



A charge mapping survey was conducted to evaluate the effectiveness of the chemicals used in the production process. Both free charge and fiber charge were measured for lab samples taken at identified points. The results showed a significant charge reduction before and after the addition of starch: PCD (Particle Charge Detector) readings decreased by 81%, and SZP (Streaming Zeta Potential) fiber charge readings decreased by 71%. This indicated a strong presence of anionic trash in the system. APAM, an anionic polymer used for strength development, was added before refining, during broke addition, and before cationic starch addition. However, this sequence was non-typical and suspected to be inefficient.

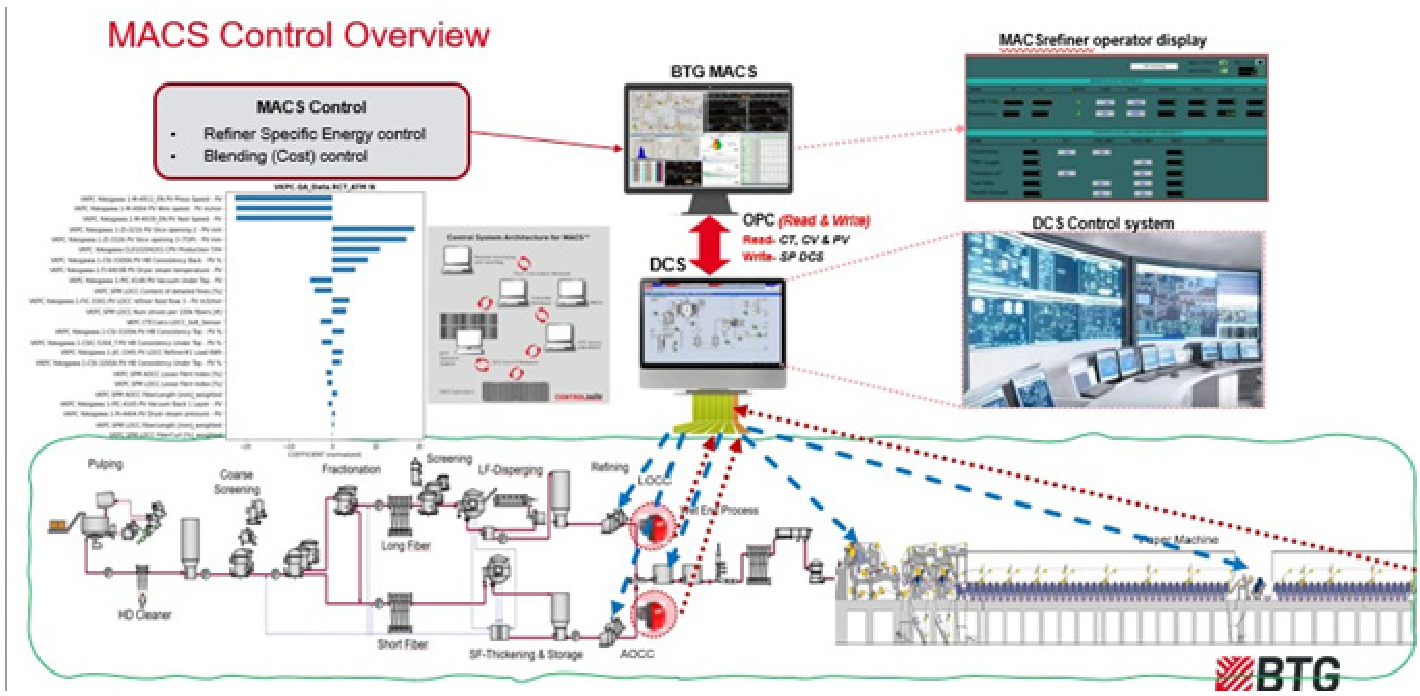
Recommendation: Based on the charge mapping results, it is recommended to stop the addition of APAM before the Double Disc Refiner (DDR). The charge mapping indicated that APAM contributed more to increasing the soluble charge rather than being retained on the fiber. This increase in soluble charge could potentially interfere with the effectiveness of the cationic starch addition at the mixing chest outlet, thereby reducing the overall efficiency of the process.

Cost Optimization Case Study: Refiner Specific Energy and Furnish Blending optimization

Challenge: Model & Predict the Final Paper Strength properties based on Refining parameters. To optimize the Furnish blending between Local OCC & Imported OCC while maintaining the Strength Quality.

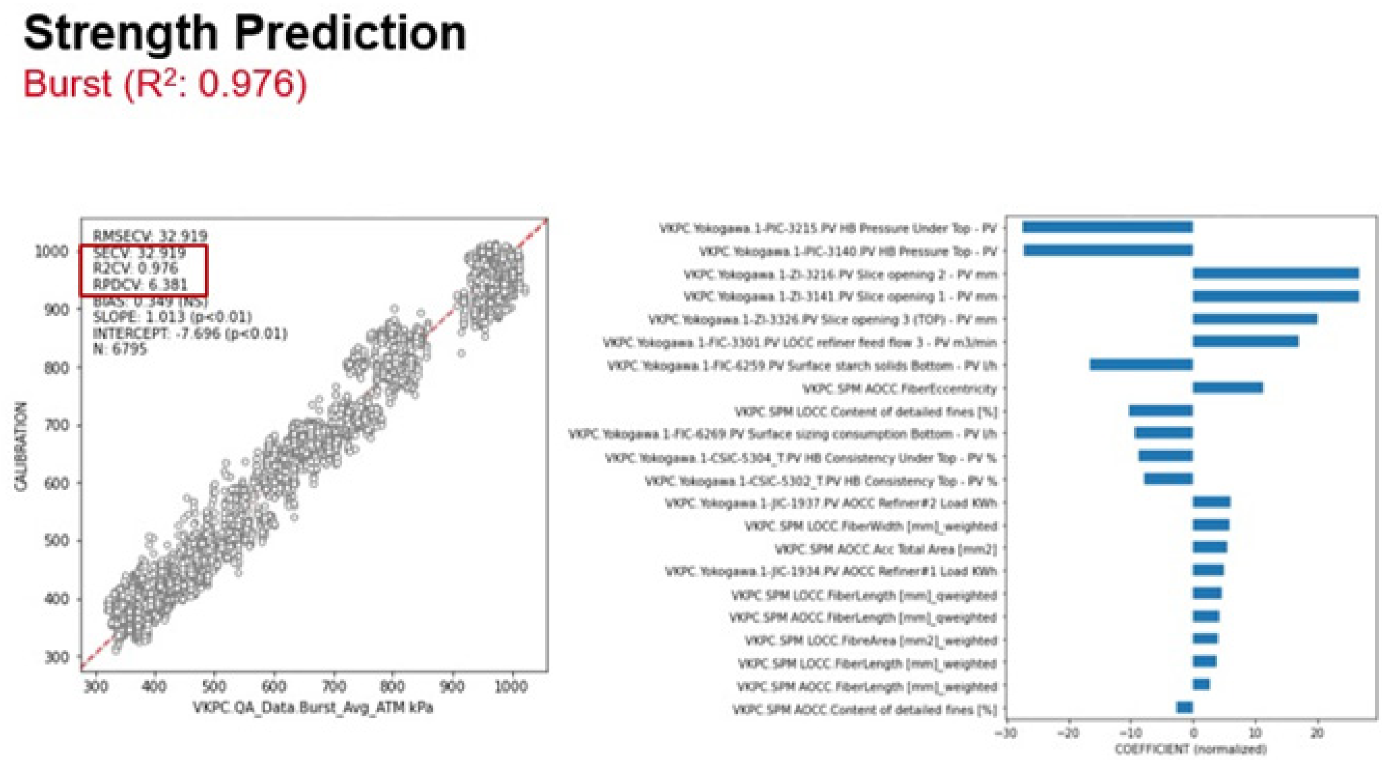
Scope: Measurement of Fiber Morphology, Modeling the Final Paper Strength property RCT& Burst. Adjusting the Furnish blend ratio to maintain the strength and other critical quality measures.

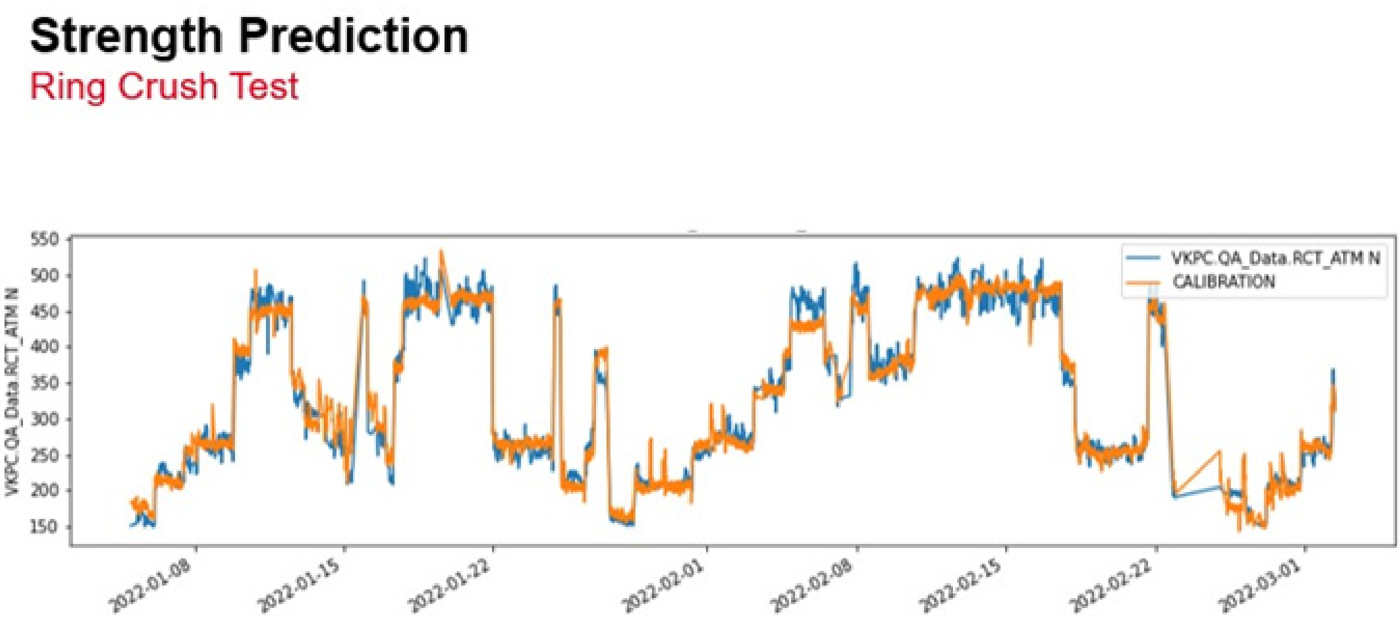
Result: Reduced Refiner Specific Energy by 5%. Reduced imported OCC cost by 1-3%.



The unique control solution is a model predictive controller (MPC) that allows for both off-line development and testing of controller models in addition to the actual on-line control of the process. The key objectives of the Refiner control solution are to optimize specific energy , reduce quality variability and improve process stability.

Advanced control predicts the CSF at the Refiner outlet on real time basis & manipulates the Refiner Specific energy to the Refiner loop. Also, Morphology signals are used to create soft sensors for the Burst and RCT to constantly predicts the strength properties.





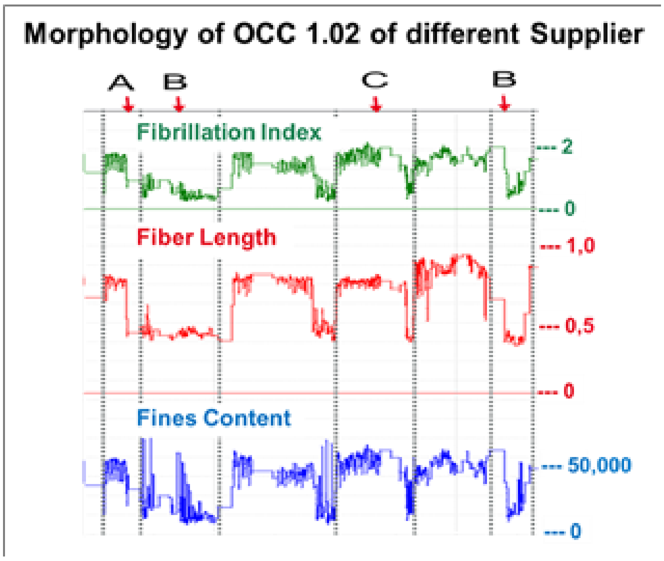
The feed forward disturbance variables are included in the Advanced Process controller to provide predictive disturbance rejection. The controller utilizes two model matrices: the projection matrix and the control matrix. The projection matrix predicts the future process response based on historical setpoint or output changes. The controller calculates the optimal set of manipulated variable setpoints or output changes to improve the predicted future response based on the control matrix. Engineers determine the process model matrices specific to the process from analysis of the process response test (i.e., bump tests) results. By independently isolating the Manipulated Variables and performing a series of experiments the models are defined. The controller is usually configured with a control horizon that is typically 3 to 4 times the longest process time constant plus the largest process delay. An example of the controller expressions can be summarized by the quadratic optimization:

Process Optimization in Stock Preparation and Mixing

In the initial stages of stock preparation, it is crucial to monitor changes in the old corrugated containers (OCC) very early. This early detection allows for timely adjustments to various parameters to ensure optimal performance.

Key adjustments include:

- Recipe: Modifying the composition of the stock to achieve the desired properties.
- Refining: Adjusting the refining process to control fiber characteristics.
- Paper Machine (PM) Settings: Tweaking the settings of the paper machine to accommodate changes in the stock.
- Grade: Altering the grade of the paper being produced to meet specific requirements.
- Feed Forward Control: Implementing either manual or automatic feed forward control to proactively manage the process.



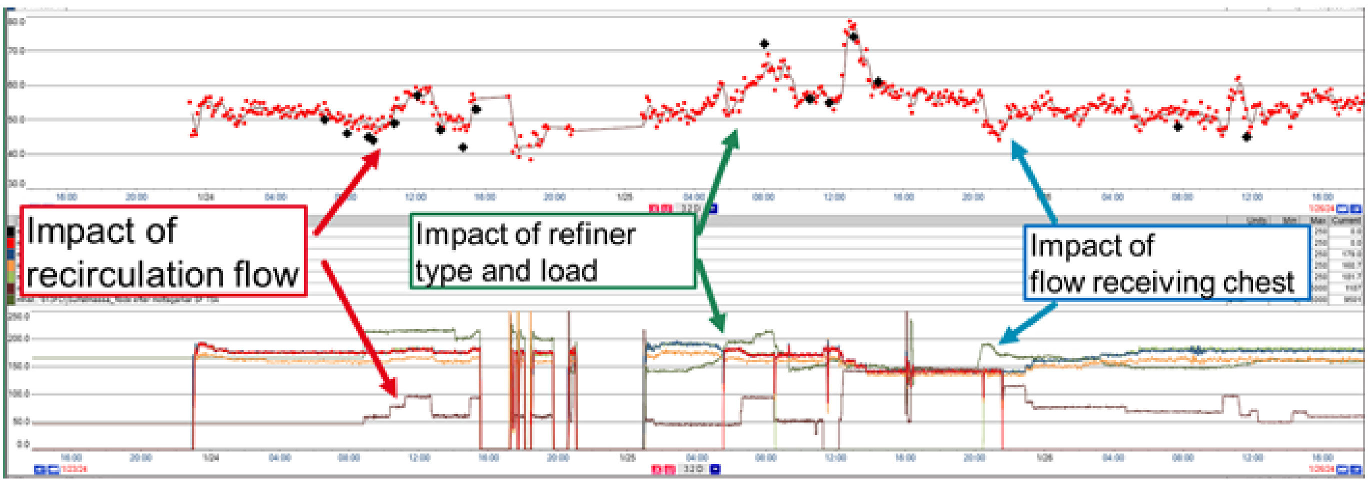
Once the stock has been mixed, the focus shifts to the total fiber fingerprint of the paper web. This stage involves several critical control and treatment processes:

- Feedback Control: Using feedback mechanisms to adjust the process based on real-time data.
- Fiber Treatment: Applying specific treatments to the fibers to enhance their performance.
- Fiber Blend Recipe: Fine-tuning the blend of different fibers to achieve the desired paper qualities.
- Feed Forward Control: Continuing the use of feed forward control to maintain process stability.
- Additives: Incorporating various additives to improve paper properties.
- PM Settings: Further adjusting the paper machine settings as needed.

These steps provide a solid foundation for ongoing process optimization, such as through the use of MACSrefiner tools, ensuring continuous improvement and efficiency in paper production.

Project results

Early in the project, a sheet quality and refiner energy baseline was established and a structured methodology for computing specific energy improvement. The evaluation tool includes data collection frequency, data filters, and any formulas that are needed to evaluate the improvement from baseline. The solution was implemented in the summer of 2020 and its performance evaluated shortly thereafter. Figure below shows a trend of specific energy controls dashboard.



How to sustain the Process optimization benefits

Based on discussions with multiple OEMs and producers, the rapid decline and deactivation of Optimisation program and Advanced controls are very typical, including the paper industry. This is the elephant in the room that no one likes to talk about. About half of Advanced controls get turned off within 24 months after start-up.

Why does performance optimization and APCs often decline?

People

- Operators don't like it – Insufficient buy-in, lack of training, frustration, workarounds

- No clear ownership of overall APC systems after start-up – Coordination between different departments lacking
- Personnel Turnover – Global issue, insufficient training, lack of transition management
- Lack of Expert Support – Limited availability after initial start, both mill & supplier

Training

- Insufficient Training – Not all stakeholders are trained; only passive training methods are used; rarely refresher training is offered
- Retention of Information is best with active and hands-on training; knowledge/skill level drops off significantly in the weeks and up to 80% of it is lost if not used
- Refresher Training is required to maintain skills

Budgets

- No Clear Ownership of overall APC systems after start-up – Support expenses are "hot potatoes" for different departments
- Maintenance – APC-related Work Orders don't get sufficient priority, due to limited resources, separate budgets, etc.
- Lack of Service Contracts – APC-related Components are not properly serviced, separate budgets.
- "Penny-wise and Dollar-foolish" – Department cost reduction versus overall performance value

Lack of Support after Start-up

- Support from Corporate Engineering, OEMs and relevant suppliers drop off significantly after start-up
- Moves from "capital" support to "maintenance / expense" support

Technical

- Relevant Components – Drifting, Availability, Calibration, etc.
- Process Changes occur and the APC is not adjusted properly.
- Conventional Control Loops in APC area not operating properly
- Drive Controls – Insufficiently tuned and/or not coordinated with APC

What can be done to sustain Optimization results long-term?

To ensure that optimization results are maintained over the long term, several key strategies and practices should be implemented:

- Establish a Mill Champion for Process Optimization: Designate a dedicated individual or team responsible for overseeing Advanced Process Controls (APCs). This champion will ensure that APCs are consistently monitored, maintained, and optimized.
- Involve the Operators: Engage operators in the optimization process. Their hands-on experience and insights are invaluable for identifying issues and opportunities for improvement. Regular training and involvement in decision-making processes can enhance their commitment and understanding of APCs.
- Optimize Conventional Process Controls: Before implementing advanced controls, ensure that conventional process controls are fully optimized. This provides a solid foundation for more sophisticated control strategies and helps in achieving better overall performance.
- Develop APC-Specific Knowledge: Invest in training programs to build APC-specific knowledge among operators and support staff. This includes understanding the principles of APCs, troubleshooting common issues, and leveraging APCs for process improvements.
- Preventative Maintenance Program: Treat APCs as critical assets by establishing a preventative maintenance program. Regular maintenance checks and updates can prevent issues before they arise, ensuring that APCs continue to function effectively. Remember, "an ounce of prevention is worth a pound of cure."
- Cross-Departmental Support: Adjust the organizational setup to facilitate cross-departmental support for APCs. Collaboration between different departments can lead to more comprehensive and effective optimization strategies.
- Monitor APC Performance: Understand the tell-tale signs of APCs in trouble and establish respective alerts. Regular performance reviews and adjustments are crucial for maintaining the effectiveness of APCs. Implementing a system for continuous monitoring and feedback can help in identifying and addressing issues promptly.

By implementing these strategies, mills can sustain the benefits of optimization efforts, ensuring long-term efficiency, cost savings, and process stability.

Conclusions:

In conclusion, optimizing paper production processes not only involves real-time stabilization of final paper properties and cost minimization but also requires attention to often overlooked aspects such as the integrity of measurements and controls. Sustaining the benefits of these optimization projects demands continuous personnel development and effective project management and maintenance strategies. The presented case studies demonstrate the potential advancements achievable in today's paper mills.