ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 37, E1, 2025, p. 180-183

Prediction of real-time stiffness and moisture % in Paper through AI

Akhilesh Kumar*
Deputy Manager
(Instrumentation)

Sunandan Mallick*
Asst Manager
(Instrumentation)

** JKPaper Ltd, (Unit J K paper mills), Jaykaypur, Dist-Rayagada, Odisha. India.*

Abstract:

The pulp and paper industry are undergoing a major transformation by leveraging Artificial Intelligence (AI) and data-driven decision-making to optimize manufacturing efficiency, reduce resource consumption, and enhance product quality. This paper explores the integration of AI in critical areas such as reel moisture optimization, and process automation as part of the Digital Initiative at PM6. By implementing real-time AI-driven recommendations, manufacturers have achieved significant reductions in steam and cost, improved moisture control, and enhanced operational efficiency.

AI-powered solutions utilize machine learning, statistical methodologies, and predictive analytics to refine production processes. These technologies facilitate precise process control, enabling dynamic adjustments based on real-time and historical data. In pulp bleaching, AI minimizes chemical overuse while maintaining optimal brightness levels, ensuring consistent product quality and reducing environmental impact. Additionally, AI-driven predictive maintenance improves equipment reliability, reduces downtime, and extends asset lifespan.

Advanced data visualization tools further support decision-making by tracking key performance indicators (KPIs), identifying inefficiencies, and optimizing raw material usage. Case studies from leading industry implementations highlight the benefits of AI in improving productivity, reducing defect rates, and lowering operational costs. The adoption of AI not only enhances process automation and sustainability but also addresses key challenges such as data integration, system scalability, and workforce adaptation.

This paper outlines AI's transformative potential in the pulp and paper industry, presenting methodologies, results, and future trends. By integrating AI-driven control systems with real-time analytics and cloud-based platforms, the industry can drive innovation, achieve sustainable growth, and remain competitive in an evolving market.

Keywords: *Artificial Intelligence (AI), Machine Learning, Predictive Analytics, Process Optimization, Reel Moisture Control, Pulp Bleaching, Data-Driven Decision-Making Sustainability, Quality Control, Digital Transformation, Industry 4.0.*

Introduction

Efficiency and process optimization are critical to remain competitive in the pulp and paper industry. The JKPM PM6 Digital Initiative integrates AI to automate reel moisture control and improve operational efficiency. Traditionally, reel moisture control relied on manual adjustments and periodic lab measurements, leading to inconsistencies and inefficiencies. The introduction of AI and machine learning (ML) models offers a proactive approach to real-time process monitoring and decision-making.

Additionally, this paper aims to build a soft sensor for predicting the Stiffness MD of paper in Paper Machine PM6 to ensure compliance with quality standards. The model focuses on:

- Addressing variations in MD stiffness impacting product quality.
- Utilizing ML for process optimization to minimize downtime and reduce costs.
- Providing predictive recommendations for moisture optimization to maintain stiffness MD without compromising quality.

By leveraging real-time data and predictive models, the initiative minimizes manual interventions and aligns with Industry 4.0 objectives. This document details the data collection process, AI model development, real-time integration, and the impact of AI-driven recommendations on improving reel moisture and reducing steam consumption. Furthermore, this initiative aligns with sustainability goals by optimizing energy consumption and minimizing waste in the manufacturing process.

AI and Papermaking:

AI is revolutionizing the papermaking industry by improving reel moisture control, leading to better product quality, energy efficiency, and cost savings. Here's how AI contributes to this transformation:

1. Real-time Moisture Prediction

- AI models analyse historical and real-time data from sensors installed in the paper machine.
- Predictive algorithms forecast moisture levels, allowing proactive adjustments before deviations occur.
- This reduces the risk of over-drying or under-drying, ensuring optimal paper quality.

2. Automated Process Adjustments

- AI-driven systems provide actionable recommendations to optimize drying rates, steam flow, and chemical dosing.
- These adjustments help maintain uniform moisture levels across the paper sheet.
- Operators receive real-time alerts and suggestions, reducing the need for manual interventions.

3. Improved Product Consistency

- Traditional methods often lead to variations in paper quality due to inconsistent manual controls.
- AI ensures uniform moisture distribution, minimizing defects like curling, wrinkling, or brittleness.
- This results in a more reliable and high-quality final product.

4. Energy Efficiency and Sustainability

- AI optimizes steam and fuel consumption in drying sections, significantly reducing energy waste.
- Smart process control minimizes unnecessary heating, lowering greenhouse gas emissions.
- Sustainable manufacturing practices become more achievable with AI-driven efficiency improvements.

5. Cost Reduction and Resource Optimization

- AI-driven moisture control helps reduce pulp consumption by maintaining precise water content.
- Optimized drying operations lower energy costs associated with steam and electricity use.
- Reduced raw material and energy waste translate into substantial financial savings for manufacturers.

6. Enhanced Process Visibility and Monitoring

- AI-powered dashboards provide operators with real-time insights into moisture trends, drying efficiency, and system performance.
- Data visualization tools help in identifying inefficiencies and making informed process improvements.
- Continuous monitoring enables quick detection of deviations, preventing potential production issues.

7. Faster Decision-Making and Automation

- AI eliminates delays caused by manual analysis and guesswork, enabling quicker adjustments to process parameters.
- Automated controls enhance production speed without compromising quality.
- AI-driven systems learn from past trends, continuously improving moisture control strategies over time.

METHODOLOGY:

1. Data Collection and Cleaning

The AI model was trained using six months of minute-wise process data from PM6. Data was extracted from Distributed Control System (DCS) logs and lab reports, capturing key process variables such as:

- Paper grade
- Steam consumption
- Machine speed
- Environmental conditions
- Reel moisture levels
- Stiffness MD values

To ensure accurate modelling, data cleaning techniques were applied to remove outliers and inconsistencies. Standard statistical techniques, including z-score analysis and variance filtering, were used for preprocessing. Missing data points were handled through interpolation techniques, ensuring a consistent and reliable dataset for training.

2. Feature Engineering

Feature selection was crucial to improving model accuracy. The following techniques were employed:

- Correlation Analysis: Identified key variables influencing reel moisture.
- Principal Component Analysis (PCA): Reduced dimensionality and retained essential features.
- Lagged Variables: Incorporated historical data points to enhance prediction robustness.
- Time Series Analysis: Modelled variations in moisture levels over different operating conditions.

3. Model Development

Multiple ML algorithms were tested, including:

- Linear Regression
- Random Forest Regression
- Partial Least Squares (PLS) Regression

A predictive model was developed using minute-wise PM6 DCS data and manual quality data recorded from logbook measurements. The dataset included process and quality parameters collected over a defined time window. For certain parameters a time lag was introduced. To ensure effective model training (picture-2), the dataset was divided sequentially into modelling and out-of-sample data in a ratio to improve model accuracy.

A regression-based predictive model was chosen since the output variables were continuous. The model was built using the Partial Least Squares (PLS) regression technique, which is a linear approach. Model performance was evaluated based on R-square and accuracy metrics (picture-1).

Model Name	Accuracy	R2
Linear Regression	86.14%	58.90%
GBM	83.26%	50.36%
XG Boost	85.55%	54.43%
Partial Least Squares	86.33%	60.28%
Random Forest	86.27%	59.25%

Picture-1

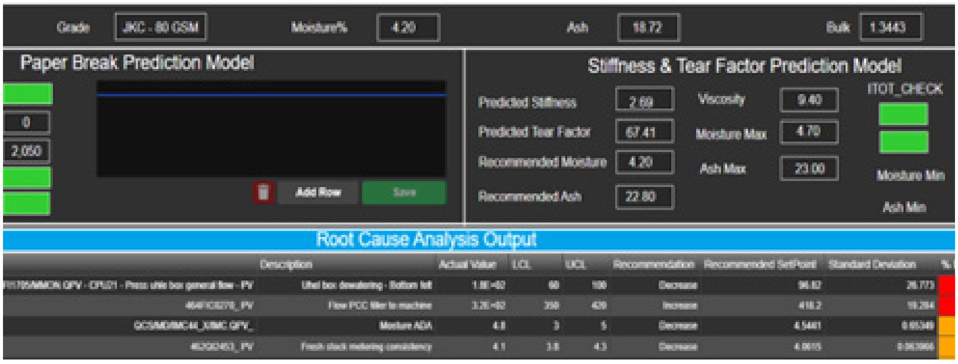
```
print(out_sample_data['Paper Break'].value_counts())
from sklearn.metrics import confusion_matrix
### metrics on Out of sample set
print('Metrics on Out of sample')
out_sample_data_x = out_sample_data[xcols].copy()
out_sample_data_y = out_sample_data[ycols].copy()
```

Picture-2

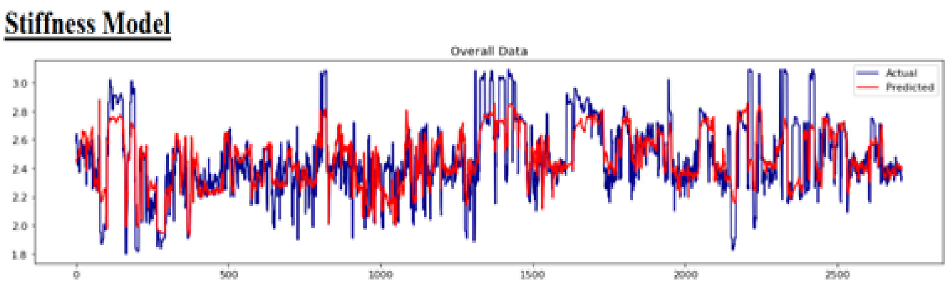
4. Real-Time Integration

The AI model was deployed on an IT/OT platform, allowing real-time monitoring and recommendations. The workflow included:

- Data Collection and Input: Continuous data flow from sensors and DCS to the AI model.
- Prediction and Optimization: AI predicts moisture levels and suggests adjustments.
- Operator Interface: Recommendations displayed via an interactive dashboard (Picture-3).
- Closed-Loop Control: Automatic feedback to the DCS system for seamless adjustments.
- Cloud Integration: Ensuring secure data storage and remote monitoring capabilities.



Picture-3



Picture-4

5. Optimization Logic

The AI model dynamically optimizes moisture levels based on:

- Predicted Stiffness MD
- Bulk properties
- Real-time environmental conditions
- Historical trends
- Adaptive Learning Mechanisms

A closed-loop mechanism was established to refine predictions over time, ensuring continuous learning and adaptation. This approach ensures the system evolves based on changing operational conditions(Picture-4).

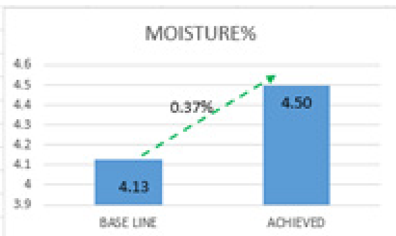
Results:

1. Moisture Optimization

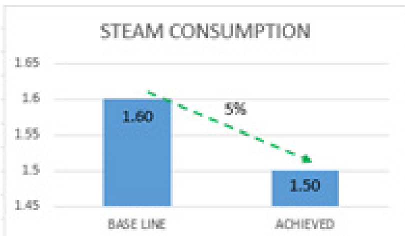
- Baseline moisture: 4.13%
- Target moisture: 4.50%
- Achieved improvement: 0.37% increase in moisture levels (Picture-5).

2. Steam Consumption Reduction

- Baseline steam consumption: 1.60 T/T of paper
- Target steam consumption: 1.52 T/T of paper
- Achieved reduction: 5% reduction in steam usage (Picture-6).



Picture-5



Picture-6

3. Financial Impact

- Annual cost savings: INR 1.71 Cr
- Reduction in pulp consumption: 502 tons per year
- Increase in paper production: 1199 tons per year

Future Scope:

1. Ai-Driven Sizer Profile Optimization

As part of Phase 2 of our Digital Initiative, we are implementing AI-driven sizer profile optimization. Optimizing the sizer profile is critical for achieving precision in dimensions, stiffness, and bulk properties. Traditional methods of tuning the sizer profiler rely on manual adjustments, trial-and-error approaches, and operator expertise. However, with advancements in AI and ML, we are now automating and optimizing this process to enhance precision and efficiency.

AI-driven solutions will predict key material properties based on the configuration of the sizer profiler knob, eliminating human errors and reducing the time required for tuning. By leveraging vast amounts of historical and real-time data, AI will dynamically adjust the sizer profiler to optimize stiffness and bulk properties. This transition will lead to:

- Increased Accuracy: AI-driven models will ensure precise control over individual point stiffness and bulk properties.
- Process Efficiency: Automated adjustments will reduce reliance on manual tuning and trial-and-error approaches.
- Enhanced Consistency: AI-driven solutions will ensure uniformity across production batches, reducing variability.
- Reduced Waste: Optimized configurations will minimize raw material usage, leading to cost savings.

As we progress with Phase 2, our focus will be on integrating this AI-driven system with real-time monitoring and predictive maintenance to further enhance operational efficiency. This initiative will redefine quality control standards in industrial manufacturing.

2. Enhanced Model Tuning

- Retune models every six months or when significant process changes occur.
- Integrate real-time anomaly detection to further improve accuracy.
- Leverage AI explainability tools to enhance operator trust in AI recommendations.

3. Expanded Applications

- Extend AI-driven solutions to ash content prediction and speed sizer moisture profile optimization.
- Implement AI-based paper break prediction to minimize downtime.
- Develop digital initiatives to simulate process changes before implementation.

4. Automation

- Fully integrate AI-driven recommendations into DCS for automated moisture control.
- Develop an AI-powered smart alarm system for real-time issue resolution.
- Implement predictive maintenance models to reduce unplanned downtime.

Conclusion:

The JKPM PM6 Digital Initiative demonstrates the transformative potential of AI in paper manufacturing. By leveraging real-time data and predictive modelling, significant improvements in reel moisture optimization, steam consumption reduction, and production efficiency were achieved.

Key takeaways:

- AI-driven models enhance process control and sustainability.
- Real-time recommendations reduce manual interventions and costs.
- Closed-loop feedback ensures continuous learning and process improvement.
- Integration with digital technologies can further enhance predictive capabilities.

By aligning with Industry 4.0 objectives, this initiative sets a benchmark for future AI applications in the pulp and paper industry.

References:

1. *JKPM Internal Reports, 2023(Manufacturing/JKPM/03-Reel Moisture).*
2. *"Automation in Papermaking Processes," Industry Insights, 2023.*