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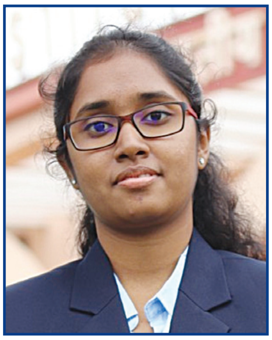
# ENHANCING PRODUCT QUALITY AND EFFICIENCY IN MOLDED FIBER FOOD PACKAGING THROUGH AI-DRIVEN STIFFNESS PREDICTION PROGRAM





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**Abstract:**

The increased demand for molded fiber products as alternatives to plastic packaging has led to production challenges. Issues such as scaling manufacturing processes, addressing equipment limitations, and maintaining consistent product quality need to be resolved. Optimizing chemical consumption is crucial for cost reduction and waste minimization. This paper focuses on a study based on the implementation of our stiffness prediction program and explores in detail how it can improve product quality in the molded fiber products industry.

**Keywords: Stiffness Prediction, Molded Fiber Products, Artificial Intelligence, Chemical Consumption**

## INTRODUCTION:

The current decade has witnessed an increase in the production of alternatives to plastic-based packaging products. Particularly augmented by a ban on single-use plastics under Section 15 of the Environment Protection Act (EPA), effective July 1, 2022 [1] this resulted in a steep spike in the demand for sustainable alternatives such as paper packaging, bioplastics, glass, metal, plant-based packaging and Molded Fiber Products (MFP).

The increase in demand resulted in subsequent challenges in production, particularly in the case of MFP. These challenges include the scaling of manufacturing processes, addressing equipment limitations, streamlining supply chain logistics, and ensuring consistent product quality. As the raw material majorly consists of natural fibers, inconsistencies are observed in maintaining the properties, which impact the quality consistency of the products [2].

When compared to plastics, there are limitations in MFP, particularly with water and oil-proofing, and stiffness. The raw material costs may also vary due to sourcing costs, industry demand as well as fluctuations in availability, resulting in higher unit costs and limited scaling opportunities [3].

### Drawbacks of Manual Testing:

Optimizing chemical consumption essentially minimizes costs in molded fiber production, which is carried out by testing the recipe implemented. In the manufacturing industry, quality & recipe testing is carried out manually in a periodic manner, at discrete intervals.

Even though manual product testing is the conventional practice, it has the following drawbacks:

1. Issues in Scalability - Manual testing is time-consuming and labor-intensive due to which the process may not be efficient in accommodating high production volumes. The recent growth in product demand also has resulted in the rise of bottleneck issues.

2. Incomplete Coverage - Due to the testing occurring at discrete intervals, there is a limit to the ability to promptly identify and rectify deviations/abnormalities in process & wet end parameters, impacting product quality consistency and cost-effectiveness.

3. Limited Scope of Testing - Conventional analysis typically focuses on predetermined parameters, which may not encompass the entire range of quality characteristics and performance factors relevant to MFPs, which results in critical aspects or potential defects being overlooked.

4. Incoherent Recipe Alteration - Recipe alterations can be time-consuming, especially when multiple iterations are required due to testing being carried out at discrete periodic intervals instead of in real-time, reducing overall efficiency.

5. User Subjectivity - Variations in the testing process and inconsistencies due to the individual interpretation of different testers can impact the reliability and accuracy of the results.

Improving the efficiency of operations and chemical usage can involve better process control, accurate dosing, and recycling or reusing chemicals where feasible [4]. By implementing these measures, manufacturers can reduce chemical consumption and associated expenses.

### Building Sustainable Production with Artificial Intelligence:

Integrating AI in molded fiber product manufacturing yields numerous benefits for the industry. Conventionally, manual testing is carried out at regular, yet discrete intervals to gauge the process, which results in critical parameter alteration delays. AI enables real-time monitoring and prediction of process KPIs, thereby immediately adjusting the operating parameters and chemical dosage to limit fluctuations. This enhances product quality, minimizes material waste, and reduces production costs.

By analyzing extensive datasets and identifying patterns, AI algorithms can pinpoint opportunities in the long term to optimize operating conditions and minimize chemical consumption without compromising product quality. This optimization not only reduces operational costs but also aligns with sustainability goals, as it decreases the environmental impact associated with chemical usage and waste disposal.

The incorporation of AI-driven process optimization in the Indian pulp and paper industry aligns with the government's focus on sustainable manufacturing practices. With stringent targets to reduce plastic waste and promote eco-friendly alternatives, this proactive measure provides a viable and environmentally friendly packaging solution, supporting sustainability initiatives while driving economic growth [5].

### Our Study:

Through our services, there is an alignment toward achieving both efficiency and sustainability. The application of our solutions solves the critical challenges faced by the molded fiber products industry, driving efficiency and ensuring optimal production with fewer resources.

Our AI-ML-driven industrial equipment, has a particular focus on operational and chemical aspects to drive production rate and product quality, while ensuring optimal resource utilization across several stages in the production process is observed.

A critical property observed is stiffness because it directly affects the structural integrity, strength, and performance of the final products. The goal is to ensure adherence to specifications and performance requirements to maintain product consistency, which can be achieved by implementing a measured Stiffness Prediction Program.

### Methodology:

The study was conducted at one of the leading wood pulp and agro-waste-based MFP manufacturers, producing molded products in the 400 GSM range, over a period of 30 days. The client was facing quality issues affecting their production lines.

The following steps were followed in designing a prediction model for molded fiber products:

### Goal Definition:

The primary objective of the program is to predict the Key Performance Indicator (stiffness) in real-time and optimize the process conditions and usage of strength additive in real time based on the KPI. This meant developing a system that could accurately estimate the stiffness of MFPs based on certain process parameters.

### Data Collection:

Real-time data for critical parameters were collected using sensors such as pH, conductivity, temperature and suspended solids during the manufacturing process. Additionally, enough process and quality data were also collected for the study. This data served as the foundation for the subsequent analysis and modeling stages.

### Data Cleaning:

Pre-processing techniques are applied to prepare data for analysis and modeling. Pre-processing helps in gaining actionable information from raw data. This includes managing missing data, removing outliers, and normalizing or scaling variables to a common range.

### Data Analysis:

The collected dataset was subjected to multivariate analysis, which helped identify the critical parameters like furnish, operational aspects of manufacturing including refining, and the wet-end process, that have a significant impact on product stiffness. By examining the relationships among various parameters, the most relevant factors for predicting stiffness could be determined to be used in modeling.

### Modeling:

Based on the identified relationships, the predictive model for stiffness was constructed based on which, a strength additive dosage prediction model was developed. The models took into account the target stiffness as well as the objective of optimizing chemical consumption. The accuracy of the prediction models was assessed by comparing the predicted values with actual lab values.

The accuracy of the model was determined by studying the difference between the lab stiffness and model-predicted stiffness values (Fig. 1). This study was performed live to demonstrate the accuracy of the model to the customer. The model was then fine-tuned based on the performance to improve its efficiency.

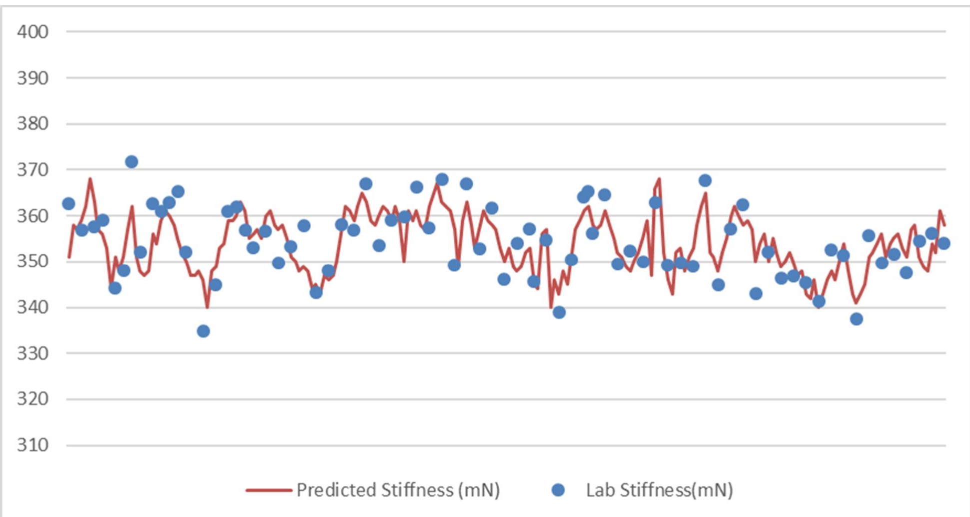


*Fig. 1: Predicted vs Lab Stiffness*

## Results:

The stiffness program, when enabled with AI-ML models, helped to optimize the operating conditions and control chemical addition in real-time, and achieve consistent & desired stiffness properties. Deviations in product quality were also minimized with the AI-ML model [6]. This had the following significant impact on the process.

1. **Improved Reliability and Reduced Error -** By utilizing live process and operational data, the predictive models provided more reliable stiffness values than traditional lab-measured values. Any deviations in the wet-end process starting from the refining or change in additives composition to the process variables were captured in the predictive model to provide accurate stiffness predictions every 30 seconds in comparison to lab-measured values, which do not incorporate any such change in the process.

2. **Consistent Stiffness and Quality -** The AI-ML models allowed for real-time adjustments in operating conditions based on stiffness predictions. This capability resulted in better control over the manufacturing process, leading to minimize deviations in stiffness when compared to target stiffness (Fig. 2). Consistent stiffness properties were achieved, reducing the likelihood of rejected products and enhancing overall product quality.

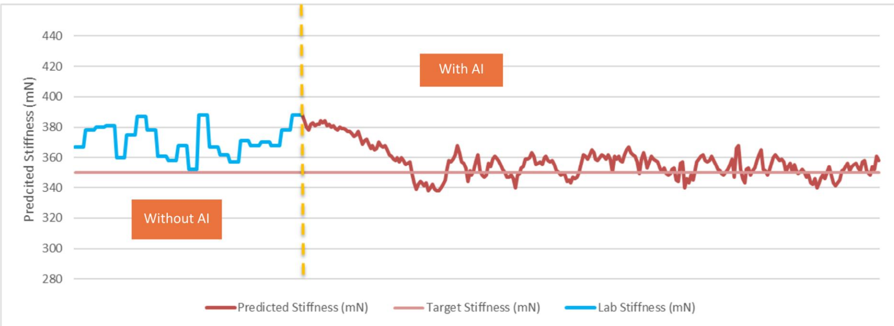


*Fig. 2: Trend for Stiffness Prediction*

3. **Increased Productivity -** The consistent achievement of the target product stiffness through the AI-driven stiffness prediction resulted in fewer rejections during the production process. With reduced rejections, overall productivity improved as fewer resources were wasted on defective products. This efficiency enhancement positively impacted the manufacturing process, allowing for higher throughput and improved operational efficiency.

4. **Optimized Chemical Consumption -** The stiffness program, driven by AI, facilitated the optimization of chemical consumption. By accurately predicting stiffness requirements, the program enabled precise control over chemical addition in real time. As a result, chemical consumption was reduced by **7.8%** without compromising the desired stiffness properties (Fig. 3). This reduction in chemical usage not only had cost-saving implications but also contributed to environmental sustainability.

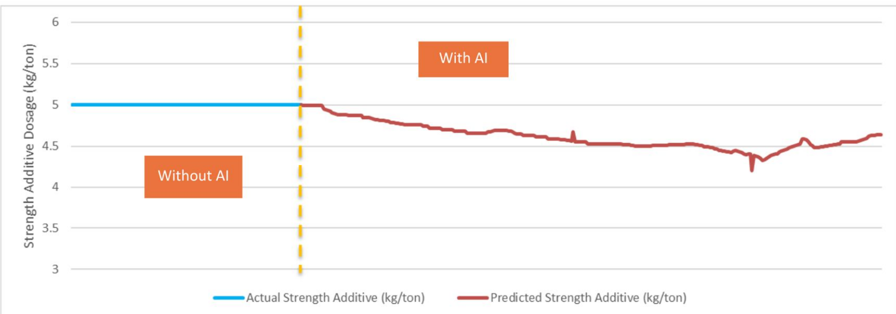


*Fig. 3: Trend for Strength Additive Prediction*

## Conclusions

Artificial Intelligence-based process control has helped drive production rate and product quality. The implementation of the program also resulted in the accumulation of cleaner data due to real-time acquisition. In terms of sustainability, the program not only supported the cost optimization of molded fiber production but also reduced the chemical requirements. These improvements support sustainable manufacturing practices and meet the demand for cost-effective, eco-friendly packaging alternatives, while maintaining quality control and providing increased, real-time dominion over the process.

## Abbreviation:

AI: Artificial Intelligence, KPI: Key Performance Indicator, MFP: Molded Fiber Product, ML: Machine Learning,

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