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Pulp Viscosity Variation Reduction through AIML Model

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Abstract:

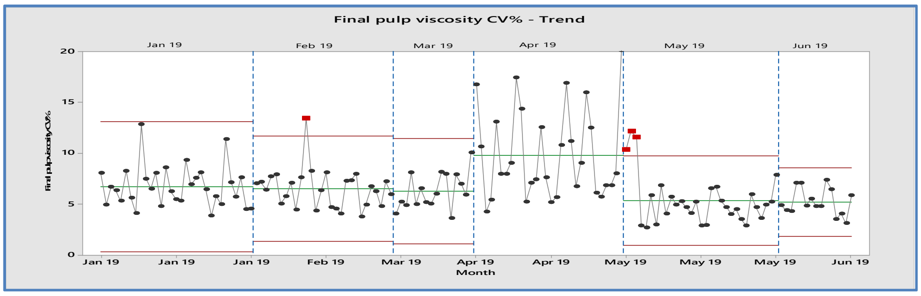
In the current competitive business scenario, it has become more customer driven segment which requires continuous improvement in pulp quality keeping in phase with latest pulp technology. Meeting customer growing expectations and demand with old technology and aged equipment is a challenge. The variation in pulp quality will affect fiber quality lead to customer complaints and losing customers. Replacing existing equipment without expansion is cost prohibitive and not viable.

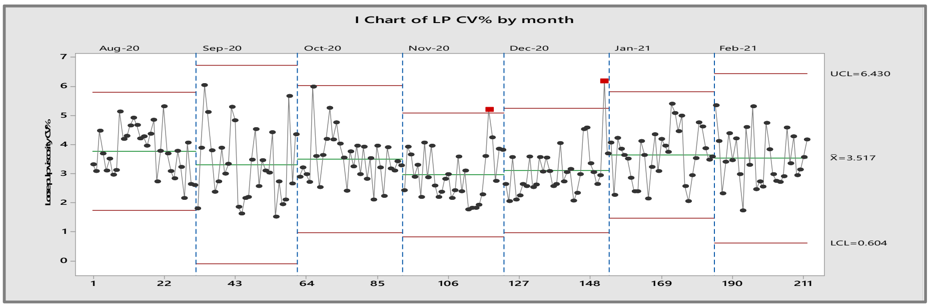
One of the critical parameters is pulp viscosity. Variation in pulp viscosity which affects fibre quality in terms of ball fall variation, filtration delay and variation in machine splinter.

Key words : *Viscosity, Algorithm, AIML model, Statistical tool, Cv%, Hypo dosage*

Introduction

Mill practices 5 stage bleach process to achieve desired pulp quality. Bleaching sequence is Do-Eop-H-E2p-D1, where sodium hypo chlorite solution is used to control the viscosity. Final pulp viscosity CV% variation was 4.92 % (Baseline FY20) with range of 3.0 – 6.0 % variation on day-to-day variation.





CV%	Min.	Max.	Avg.
FY20	3.29	16.1	4.92

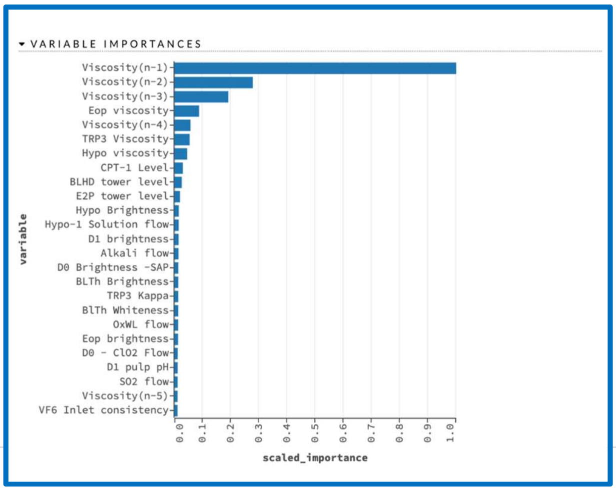
Approach and Root Cause Analysis:

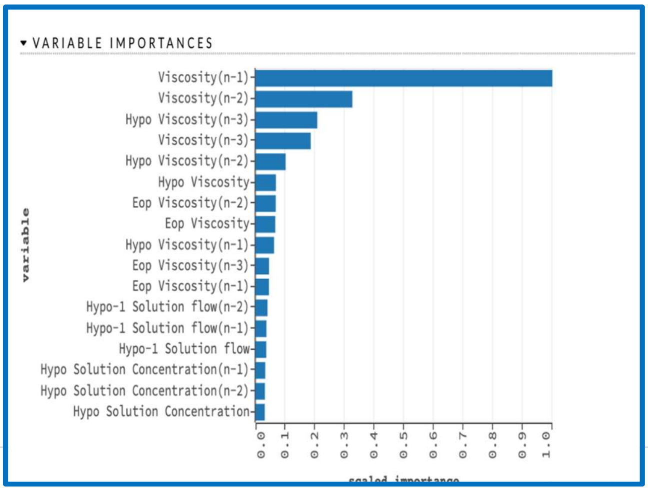
In Indian context, raw material (Eucalyptus wood) is procured from unorganized sector (Farmers). The preferred Eucalyptus age (maturity period) is > 5.0 years similar to bench mark units of global best in class mills like SAPPI, South Africa. However, farmers in India, harvest Eucalyptus trees at 2-3 years age as per there financial need.

The immature harvested wood will have poor debarking which induces variation in chips quality, viscosity, brightness and pentosans. Kraft pulping process depends on nature of wood, quality of chips, the cooking recipe, pulping equipment and bleaching sequence process.

Process involves > 80 operating variables, it is very difficult to control on manual base on raw material quality. It is important to understand which of these factors are individually or in combination is leading to variation in RG Pulp viscosity. Harihar unit doesn't have state of the art online measurement and control system unlike state-of-the-art benchmark best in class mills.

These raw material and equipment issues poses highly challenging operational issues in maintaining minimum pulp viscosity and brightness.





Inhouse development of algorithm for Hypo viscosity control has started in Jul-2021 to minimize pulp viscosity variation.

All causes of viscosity variation selected and corelation analysis done through MINITAB. 25 Parameters analysed and narrowed down to 04 No parameters which are contribution more to viscosity variation. Various algorithm models deployed using MINITAB and tested offline to ascertain effectiveness in comparison to manual control.

Statistical Algorithm Model – 1 (Simple Regression)

Hypo Dosage = 2.19 * (Target Hypo Brightness – Target Eop Brightness) + Avg. (Last 3 hr Hypo Dosage) * Ln (Eop Viscosity (n-2) / Hypo Viscosity Target)

Statistical Algorithm Model – 2 (10-point Regression)

Hypo Dosage = A * (Target Hypo Brightness – Actual Eop Brightness) + B * Ln (Eop Viscosity (n-2) / Target Hypo Viscosity)

Statistical Algorithm Model – 3 (6-point Regression)

Hypo Dosage = A * 5 + (B * Actual Eop viscosity) - Target Hypo Viscosity – (sum of deviation from last 3 hr hypo dosage / 3)

Statistical Algorithm Model – 4 (Multivariate)

Hypo Dosage = (A + (B * Actual Eop viscosity) +C * Ln (Actual Eop Viscosity / Actual Hypo Viscosity) + D * Exp (Hypo pH) + E * Ln (Actual Eop Viscosity / Target Hypo Viscosity)) / (Hypo Concentration * Pulp Rate)

Based on various model deployment experience team developed 5th model which works on last 10 hours rolling data of pre and post hypo stage viscosity, brightness and dosage.

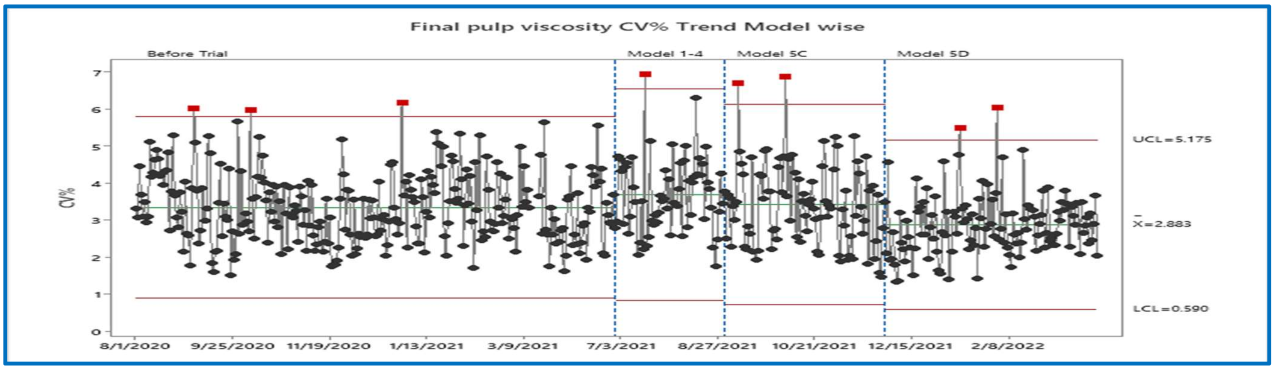
Statistical Algorithm Model – 5C

Hypo Dosage = If (Hypo dosage < Min Hypo dosage, last hypo dosage) + If (Target Hypo Brightness – Eop Brightness (n-1) > 10, Hypo dosage is zero)

Statistical Algorithm Model – 5D

Hypo Dosage = If (Hypo dosage < Min Hypo dosage, last hypo dosage) + If (Target Hypo Brightness – Eop Brightness (n-1) > 10, Hypo dosage is min 10)

Improvement observed from model to model



- Models were developed using excel sheet and needs timely input, any human error is misleading the model.
- Artificial Intelligence and Machine Learning (AI/ML) model collaborative project under taken with AI/ML developer to develop dynamic algorithm to control hypo pulp viscosity to minimize the final loose pulp viscosity variation.
- AI/ML team developed the variable importance plot of each parameter for viscosity variation.
- Based on the degree of importance last two hours pre & post hypo stage viscosity and final pulp viscosity targe. Model output observed for one month in offline and after ascertaining reliable suggested hypo dosage deployed for plant scale.

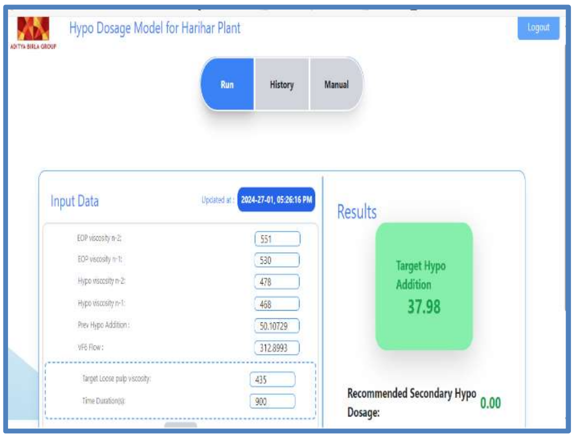
AI/ML Model

Hypo Dosage = 24.63 – 0.0074 * Eop Viscosity (n-2) + 0.0183 * Eop Viscosity (n-1) – 0.0276 * Hypo Viscosity (n-2) – 0.0412 * Hypo Viscosity (n-1)

AI/ML Algorithm Model

Hypo Dosage = - 24.23 – 0.208 * Eop viscosity (n-2) + 0.263 * Eop Viscosity (n-1) + 0.802 * Hypo Addition (n-1) + 0.1 * ((Hypo Viscosity (n-2) – Hypo viscosity Target) + (Hypo Viscosity (n-1) – Hypo viscosity Target))

- With encouraging results, continuous improvement and eliminating the human interruption, developed software by integrating with SAP data and PI historian. The software pulls dynamic data from SAP/PI and from previous AI/ML model, suggest auto hypo values which minimized the variation to great extent.
- Presently every 15 min data get refreshed automatically and suggest the hypo dosage addition.
- History report can be generated in Excel, Doc and pdf format.



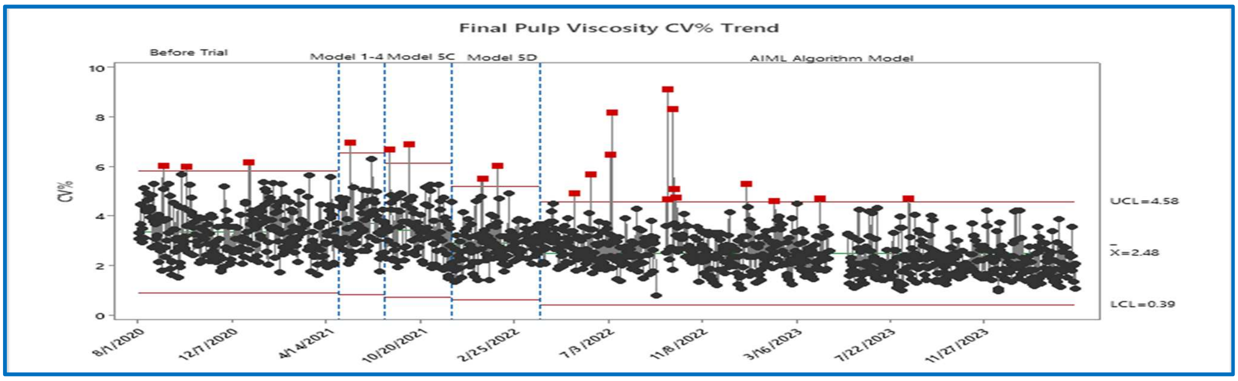
Key learnings:

- In Hypo stage, biggest variable driving the delta in viscosity is inlet viscosity (EOP viscosity) Hypo addition (flow rate and concentration) are important drivers but have a time lag effect. They impact n, n+1, n+2 hours.
- Combining time series modeling with AI modeling with solving partial dependence equations also led us to the insight that delta hypo addition has to be controlled by observing variation in Hypo viscosity and EOP viscosity.
- RG pulp viscosity comes after 3-4 hours of lag and is an impact of all previous additions - hence changing hypo flow rate from latest RG pulp viscosity will lead to process imbalance

- Hypo addition in secondary doesn't help: It doesn't lead to a significant improvement in viscosity but adds to volatility of the process.
- Viscosity in post hypo stage is seen to follow a curve of natural decay - with inlet viscosity in hypo stage (the Hypo outlet viscosity) the most important driver. Delta viscosity in post hypo stage as % of hypo inlet - is seen to be around 10% with minimal

Results and Discussions:

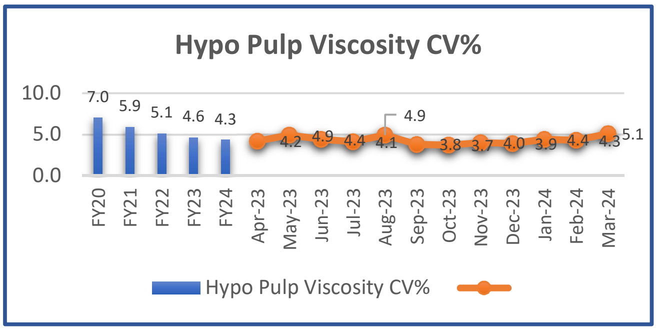
Benefit for the Pulp plant: Final pulp viscosity CV% reduction trend model to model:

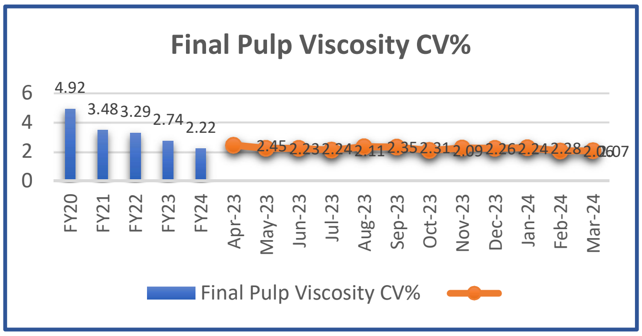


Results achieved with inhouse statistical algorithm generated using MINITAB and with collaborative R&D project with PFIC & AI/ML developer (Invested Rs. 24.0 lacs) are as under:

Year	FY20	FY21	FY22	FY23	FY24
CV%	Before	In-house Model		AIML Model	
	4.92	3.48	3.29	2.74	2.22

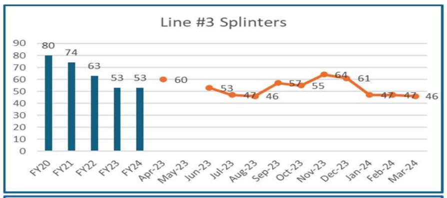
Hypo pulp viscosity CV% reduced from 7.0 % to 4.3 % and Final pulp viscosity CV% reduced from 4.9 % to 2.2 %.

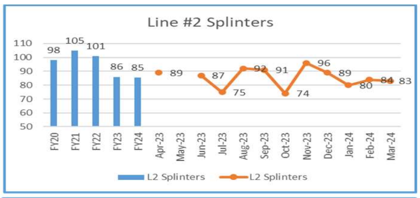


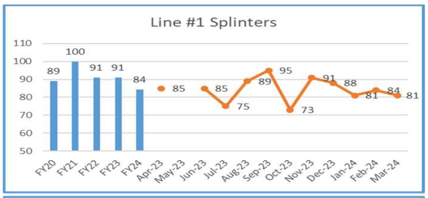


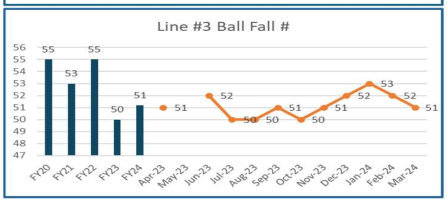
Benefit for the customer (Fibre Plant):

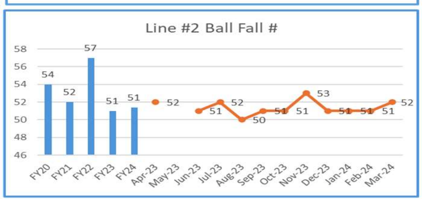
1. Reduced Ball Fall variation.
2. Reduction in Filtration delay.
3. Reduction in Machine splinter.
4. Improved sustainable plant operations

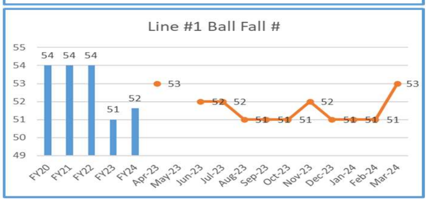












Conclusion:

Despite the complexity of the problem, with continuous improvement in statistical algorithm model and further converting the learnings using AI/ML model significantly reduced the pulp viscosity variation.