New Control concept for Optimizing Chemical Pulping Fiberlines and Bleach Plants

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Fiberline
Objectives & Requirements

- Produce pulp fulfilling the customer specifications
- Produce at lowest possible cost and load on environment
- Accurate control of the delignification process – kappa number
- Lignin (kappa number) measurement is essential in cooking, oxygen delignification and the early bleaching stages
- Lignin occurs both in fibers and in filtrate
- Other properties like chemical residual, pH, temperature etc.
Selective Lignin Removal Efficiency

Kappa after Cooking

Brightness after Cooking

Cooking  O₂-Delign.  1-Stage  2-Stage  3-Stage  4-Stage

Final Brightness
Kappa No = 6.7 times lignin content %

Bleached Pulp Kappa

Delignification
Lignin Removal

Brightening
Selective Lignin Oxidation

Cost Increase
Kappa Measurement Methods

Tappi & SCAN laboratory methods
- Sample handling
- Titration with KMnO4

Automatic kappa analyzers
- Sample handling
- Lignin is measured by absorption of UV-light
- UV-light generated by a bulky light bulb sensitive to vibrations and temperature
- LED based UV-technology has allowed for single point measurement
Traditional Process Control
Kappa + Conductivity

O2 Delignified Pulp

Unbleached Fibers

Fiber Bound Lignin

Kappa Analyzer

Black Liquor

Inorganic Compounds Na⁺ Salts

Conductivity
Consumption reported as:

- 1 kg Cl\(_2\) per 1 kg black liquor measured as sodium sulfate
- 2 kg of Cl\(_2\) of carry-over as lignin
- 0.5 kg equivalent Cl\(_2\) per kg of total dissolved solids
How Can WE Directly Measure Dissolved Lignin??

O2 Delignified Pulp

Unbleached Fibers

Black Liquor

Fiber Bound Lignin

Kappa Analyzer

Dissolved Lignin

???????
Measuring Lignin

- **Degree of delignification** – (Kappa Number): the only pulp parameter measured on-line.
- **Control process conditions**
  - Temperature, pH, OH⁻, ClO₂
- **Kraft SW cooking K=30, example:**
  - Wood 27% lignin (o.w.)
  - Pulp ~5% lignin (o.p.), i.e. ~2.5% o.w.
  - ⇒ 90% delignification
Black Liquor Carry Over

- Organics and inorganics
  - Dissolved lignin (DL) claimed determining washing efficiency
  - DL consumes bleaching chemicals
- Total Bleach Load = Fiber Kappa + Filtrate Kappa
- Lignin has strong absorption in UV (-VIS)
DLT: A New Sensor for Measuring Carry Over

- O2 Delignified Pulp
- Unbleached Fibers
- Black Liquor
- Fiber Bound Lignin
- Dissolved Lignin
- Kappa Analyzer
- DLT
Filtrate Kappa Measurement
Principle: UV Absorbance

- Lignin has strong absorption in UV (-VIS)
- Wavelength not critical
  - Lignin dominant in UV-VIS
- Output directly proportional to DL
- DL quantified as Filtrate Kappa (or COD)
  - Per ml filtrate
  - Can be recalculated to “gram fiber basis” (knowing the consistency)
Fiber Lignin vs. Filtrate Lignin

- Result show that filtrate kappa (dissolved lignin) is 10-50% of the total lignin entering the bleach plant.

- The variability in filtrate kappa (COD) is significantly higher than the fiber kappa variability.

- Filtrate lignin consumes as much chemicals as the fiber lignin.
Fiber Kappa vs. Filtrate Kappa
Measuring the complete Lignin

Smarter eyes for fiberline process
Applications for Dissolved Lignin Measurement

1. Sulfite & continuous digester recirculation
2. Pre O₂ Delig
3. Brown Stock washing
4. Do feed
5. Board machine head box
6. Waste water
Example of Conductivity Correlations: Samples taken prior to O$_2$ Delig

**Conductivity Vs. COD**

\[ y = 8.419x - 3.3738 \]
\[ R^2 = 0.4096 \]

**Conductivity Vs. Filtrate Kappa**

\[ R^2 = 0.4625 \]
Conductivity = Organics + Inorganics

Assumption:
Organic to inorganic ratio is constant

- Impacts on Conductivity
  - Kappa out of digester
  - Liquor-to-Wood ratio
  - White liquor charge
  - Wood age and other disturbances
Case 1: Brown Stock Washing

- Sulfite dissolving pulp, large Kappa range
- Belt washer, multi-stage, 2% Cs
- Used as key control variable in Advanced Process Control
  - COD specification, grade dependent
  - Controls DF
  - DS to recovery
Case 2: Feed to Bleach Background and Trend

- Bleached SW Kraft pulp
- Before wash press before $D_0$ stage, 4.5% Cs
- To monitor washing performance upstream

![Filtrate Kappa (per mL) vs. time (days)](graph.png)

- DLT signal
- Laboratory samples
Case 2: Feed To Bleach Correlations

- Large variability
- Excellent correlation with Filtrate Kappa number and COD
- Filtrate Kappa = 1 per ml corresponds to ~21 Kappa units on fiber basis, i.e. “per gram fiber” (4.5% Cs)
Case 2: Feed to Bleach after Wash Press

- Filtrate Kappa = 0.16 (1/ml)
- Corresponds to 1.6 Kappa units on fiber basis at 9% Cs
- Average Fiber Kappa = 13.0
- Bleach Load = 14.6
- Filtrate Kappa ~11% of total Bleach Load...
Case 2: Feed To Bleach After Wash Press

- ...but 1/3 of total Kappa variability:

- To be investigated:
  - ClO$_2$ consumption of Dissolved Lignin (calibrate sensor to ClO$_2$ demand)
So, Is Conductivity Good Enough?

There is a flaw in using conductivity as an indicator of carryover.

- Conductivity is based on the measurement of the ionic sodium species in the liquor, inorganic phase.
- Conductivity does not directly measure the organic phase, the dissolved lignin.
- It is assumed that the inorganic/organic phase remains constant so a relationship can be built between the conductivity and dissolved lignin.
Comparing Dissolved Lignin vs. Conductivity

Dissolved Lignin Transmitter Predicting COD

\[ R^2 = 0.9225 \]

Conductivity Vs. COD

\[ y = 8.419x - 3.3738 \]

\[ R^2 = 0.4096 \]
Comparing Dissolved Lignin vs. Filtrate Kappa

Dissolved Lignin Transmitter Predicting Filtrate Kappa

Filtrate Kappa per gram

Dissolved Lignin Transmitter (UV Absorption)

Filtrate Kappa Vs. Conductivity

Filtrate Kappa

Conductivity S/m

$R^2 = 0.9659$

$R^2 = 0.4625$
What does a Poor Correlation Cost Mills?

- The weak correlation is shown to be slightly over 0.40 for COD versus conductivity.
- The industry has long accepted the relationship of carry over expressed as 1 Kg COD will consume 1 to 1.5 Kg of chlorine dioxide\(^3\).
- The economic impact using this relationship on a 1000 ton per day mill results in a 2 month payback for new sensor vs. conductivity.
Fiberline – Control Solution

Cooking optimization
Fiber Kappa

O₂ optimization
Fiber + filtrate kappa

BSW optimization
Dissolved lignin

Bleach Load Transmitter – Total Kappa, Brightness
Single Point Kappa Analyser – Fiber Kappa
Dissolved Lignin Transmitter – Filtrate Kappa
pH Measurement
Brightness Transmitter
Residual Transmitter

Unbleached HD Tower

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Fiberline – Control Solution

BLT: Bleach Load Transmitter – Total Kappa, Brightness
SPK: Single Point Kappa Analyser – Fiber Kappa
DLT: Dissolved Lignin Transmitter – Filtrate Kappa

pH Measurement
Br: Brightness Transmitter
Res: Residual Transmitter

Unbleached HD Tower

D0-stage control
Total kappa

D1-stage control
Brightness + residual ClO₂

Storage Tower
Conclusions

- New technologies for lignin measurement now allow
  - Cooking – stabilize operation to maximize yield
  - Optimize oxygen delignification to lower bleach cost
  - Optimize BSW to lower evaporation cost
  - Reduce bleach plant chemical consumption by utilizing the new total bleach load concept
  - Smarter eye to the process allows for further tuning of the entire fiberline
Thank You for Your Attention!