A Comparative Evaluation of Hardwood Kraft Pulp Bleaching Sequences
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Sequences

• (DC)(EPO)DED
• D(EPO)DED
• (D/Z)(EPO)DED
• OD(EPO)D

• OD(EPO)DD
• OD(EPO)DP
• OD(EPO)DZ
• O(Z/D)(EPO)DP
Furnish and Conditions

- Southern U.S. hardwood kraft
- Brownstock kappa 13
- Oxygen delignified kappa 9.3
- Black liquor (10 kg BLS/t) in first stage and filtrate carryover in other stages (10% from D₀, 20% from other stages)
- Kappa factor 0.20
- Consistency 3.5% for D₀, (D/C), (D/Z) and (Z/D), 32% for final Z, 10% all others
Delignification Partial Sequences
Delignification Partial Sequences

- (DC)(EPO)
- D(EPO)
- DW(EPO)
- WDW(EPO)

- (D/Z)(EPO)
- OD$_3$(EPO)
- OD$_4$(EPO)
- O(Z/D)(EPO)

W = Perfect wash
Kappa After S(EPO) and OS(EPO)
Initial Brightening
Final Brightening
$D_2$ Bright. vs Total ClO$_2$ After (EPO)
Hydrogen Peroxide and Ozone as Final Brightening Stages
Brightening After OD(EPO)D

![Graph showing brightness increase with chemical charge]

- Brightness along the y-axis
- Chemical Charge, % o.d. pulp along the x-axis
- Different markers for Chlorine Dioxide, Peroxide, Ozone

The graph illustrates the increase in brightness with the addition of chemical charge for different treatments:
- Chlorine Dioxide
- Peroxide
- Ozone
Total ClO₂ Requirement
Total ClO$_2$ Requirement, %
Bleached Pulp Properties
Brightness Loss After 1h @ 105ºC
Bleached Pulp Viscosity, mPa·s
Viscosity vs %ClO₂ and pH in D₁ of OD₀(EPO)D₁
Effluent Properties
Untreated AOX, kg/admt

OBS.  PRED.

O(Z/D)(EPO)DP
OD(EPO)D
(D/Z)(EPO)DED
D(EPO)DED
(DC)(EPO)DED
Untreated COD, kg/admt
Summary and Conclusions
Delignification Stages

- (DC)(EPO) gives much lower kappa no. than D(EPO)
- (D/Z)(EPO) gives the same kappa no. as D(EPO) [1 kg O$_3$ = 1.7 kg ClO$_2$]
- O(Z/D)(EPO) gives the same kappa no. as OD(EPO) [1 kg O$_3$ = 1.7 kg ClO$_2$]
- After OD(EPO), the kappa no. is lower when the D stage exit pH is 4 than when it is 3
Initial Brightening ($D_1$) Stage

- At a given charge of ClO$_2$ in $D_1$, pulp that had been O$_2$ delignified was brighter.
- Bleaching to a given high brightness in 3 stages needs much less ClO$_2$ after O$_2$ delignification.
- Critical ClO$_2$ ratio $\sim$0.2 ($\sim$0.1 after O$_2$ delig.)
- Moderate filtrate carryover into or beyond the $D_0$ stage had little or no effect on $D_1$ brightness.
- Substitution of Cl$_2$ or O$_3$ for part of the ClO$_2$ in $D_0$ has little effect on $D_1$ bleachability.
Final Brightening (89-90 Bright.)

- In the final stage, S, of the OD(EPO)DS sequence, \( \text{H}_2\text{O}_2 \) and \( \text{ClO}_2 \) were equally effective on a weight basis, \( \text{O}_3 \) less effective.

- Low charges of \( \text{H}_2\text{O}_2 \) were less effective in the O(D/Z)(EPO)DP sequence than in the OD(EPO)DP sequence, but the former sequence was capable of reaching higher brightness at high \( \text{H}_2\text{O}_2 \) charges.
Full Sequence

- Total ClO$_2$ requirement, in ascending order, is
  - OD(EPO)DP [1.1%]
  - O(Z/D)(EPO)DP [1.35%]
  - (DC)(EPO)DED = (D/Z)(EPO)DED = OD(EPO)DD [1.9%]
  - D(EPO)DED [2.4%]
  - OD(EPO)D [2.5%]
Bleached Pulp Properties

- Brightness reversion was similar for all sequences except better for sequences ending in P and poorer for the one ending in Z.
- Viscosity appears to be adversely affected by exclusion of carryover and inclusion of an ozone stage.
- The OD(EPO)D sequence has the potential to give low viscosity because of the high ClO$_2$ charge needed in the final stage when KF 0.2
Effluent Properties

- AOX generation levels agreed with predictions of a pre-existing empirical model, ranging from 0.24 to 0.74 kg/admt for the ECF sequences studied.
- COD values ranged from 27 kg/admt for OD(EPO)D to 61 kg/admt for O(Z/D)(EPO)DP.
Chemical Costs

• All 5-stage sequences had similar chemical cost

• $O_2$ - delignified pulp can be bleached in 3 stages at the same cost as a 5-stage sequence on brownstock

• Addition of another D stage to OD(EPO)D reduces chemical costs by 20%; addition of a P stage gives similar savings but 1 point lower brightness

• Partial replacement of $\text{ClO}_2$ with $O_3$ in $D_0$ increased chemical costs at high brightness
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