Relating wood pulp properties to hand-sheet porosity and mechanical strength

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Background

Variation in pulp mills

• Need to predict quality of end-product
Processing

Logs → Wood chips → Pulp fibres
Goal of chemical pulping process is to dissolve middle lamellae and to separate fibres for paper production (Middle lamellae – mostly lignin)
Refining (beating)

- Mechanical energy imparted to ‘soften’ (collapse) fibres
- PFI mill (laboratory use)
Some important concepts...

• Paper vs. hand-sheets
  – Orientation of fibres:
    • Aligned $\rightarrow$ paper
    • Random $\rightarrow$ hand-sheet
Some important concepts...

- Collapsibility and inter-fibre bonding
Some important concepts…

• Tear
  – Fibre level: pull-out vs. breaking/rupture
    • Fibre pull-out: greater energy = higher tear strength
    • Fibre breakage / rupture: less energy = lower tear strength
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• Tear
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  – Cell wall thickness
    • Resistance to tear
Objectives

• To investigate the response of *Eucalyptus nitens* pulp samples to different levels of beating

• Measure properties of pulped fibres that previously were not considered in depth
  – At individual fibre level: e.g. zero-span strength
  – At hand-sheet level: e.g. inter-fibre bonding (porosity), fibre pull-out / breakage
Material used

- Unbeaten *Eucalyptus nitens* pulp samples with varying levels of tear strength
Assessing failure surfaces

Two methods are being investigated
- Flat-bed scanner method
- SEM
• Flat-bed scanner method

– The failed / torn surfaces were scanned

– Image analysis
  • Segmentation
  • Quantification
Results: Flat-bed scanner method

Area of pull-out zone

Beating (rpm)

Low tear
Medium tear
High tear
3000 rpm

High level of fibre pull-out visible

5000 rpm

Medium level of fibre pull-out visible

0 rpm

Low level of fibre pull-out visible
Results: SEM

- Low tear
- Medium tear
- High tear

![Graph showing fibre pull-out (100 um) vs. beating (rpm)]
Zero-span tensile measurements

Graph showing the relationship between Zero-span Force (N) and Beatings (rpm) for High tear and Low tear materials. The graph includes two subplots: one for Zero-span Force (N) and another for Tear vs. Beating (rpm). The Zero-span Force (N) graph shows a steady increase with increasing beatings, while the Tear graph peaks at around 8,000 rpm before decreasing.
Porosity

- Compactness of the fibres in the hand-sheet
- Measuring voids within the structure
POROSITY

0 rpm

5000 rpm
Results: Porosity

The graph shows the relative area of voids at different levels of beating (rpm). The categories are Low tear, Medium tear, and High tear. The x-axis represents the beating in rpm, while the y-axis represents the relative area of voids. The data indicates a significant increase in porosity with increased beating, especially noticeable at higher RPM values.
Conclusions

• Flat bed scanning method favoured over SEM for measurement of fibre pull out along failure surfaces
  – Fibre pull-out decreases with increased beating for all samples

• Zero span revealed differences between pulps
  – Greater replication required

• Porosity: valuable tool to assess paper structure
  – Link to collapsibility and inter-fibre bonding
Conclusions II

- These techniques, and others soon to be applied / developed (e.g. collapsibility), allow the response of fibres to processing conditions to be better understood
  - Enabling better management of resources entering the pulp mill
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