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

S. Maharaj[1,3], J. Wesley-Smith[2] and T. Bush[3]

[1]*School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban, 4041*
[2]*Electron Microscope Unit, University of KwaZulu-Natal, Durban, 4041*
[3]*CSIR, Forestry and Forest Products Research Centre, P.O. Box 17001, Congella, 4013*

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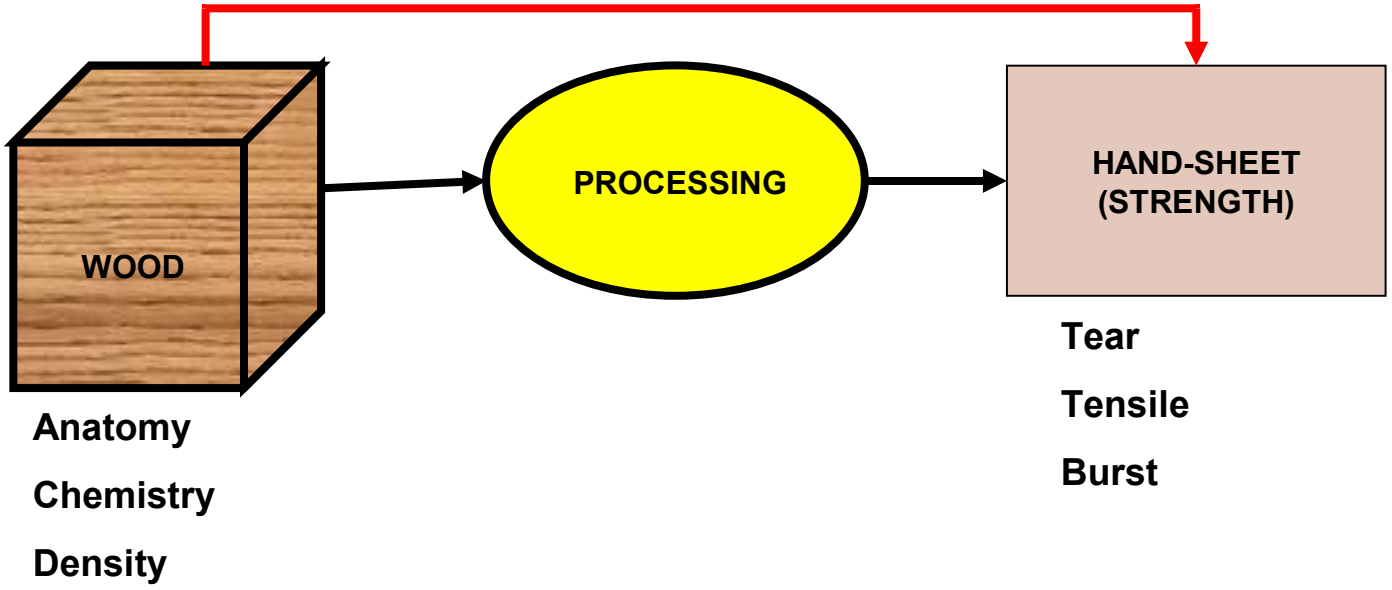
Background



Variation in pulp mills

- Need to predict quality of end-product

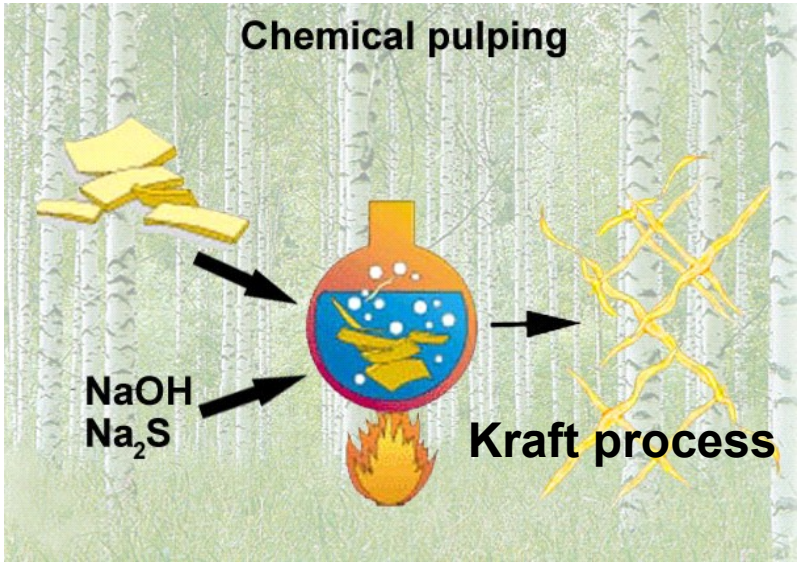
Processing

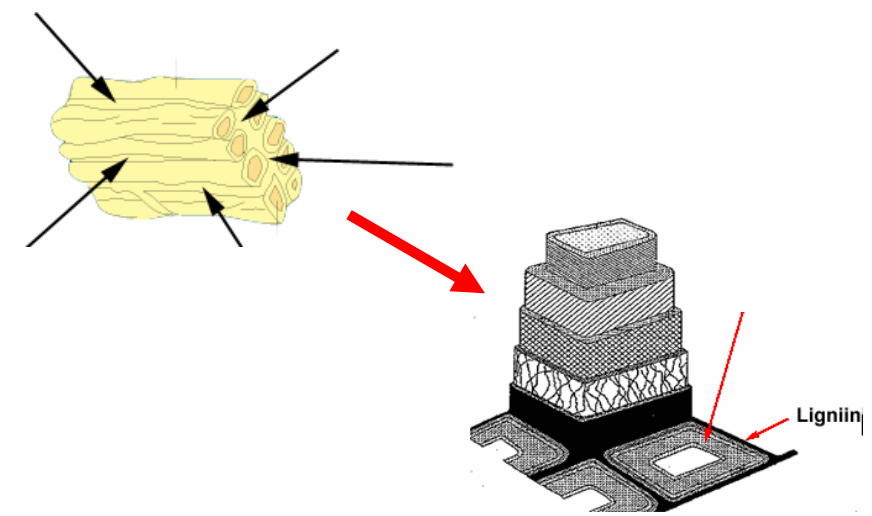
Logs

Wood chips

Pulp fibres

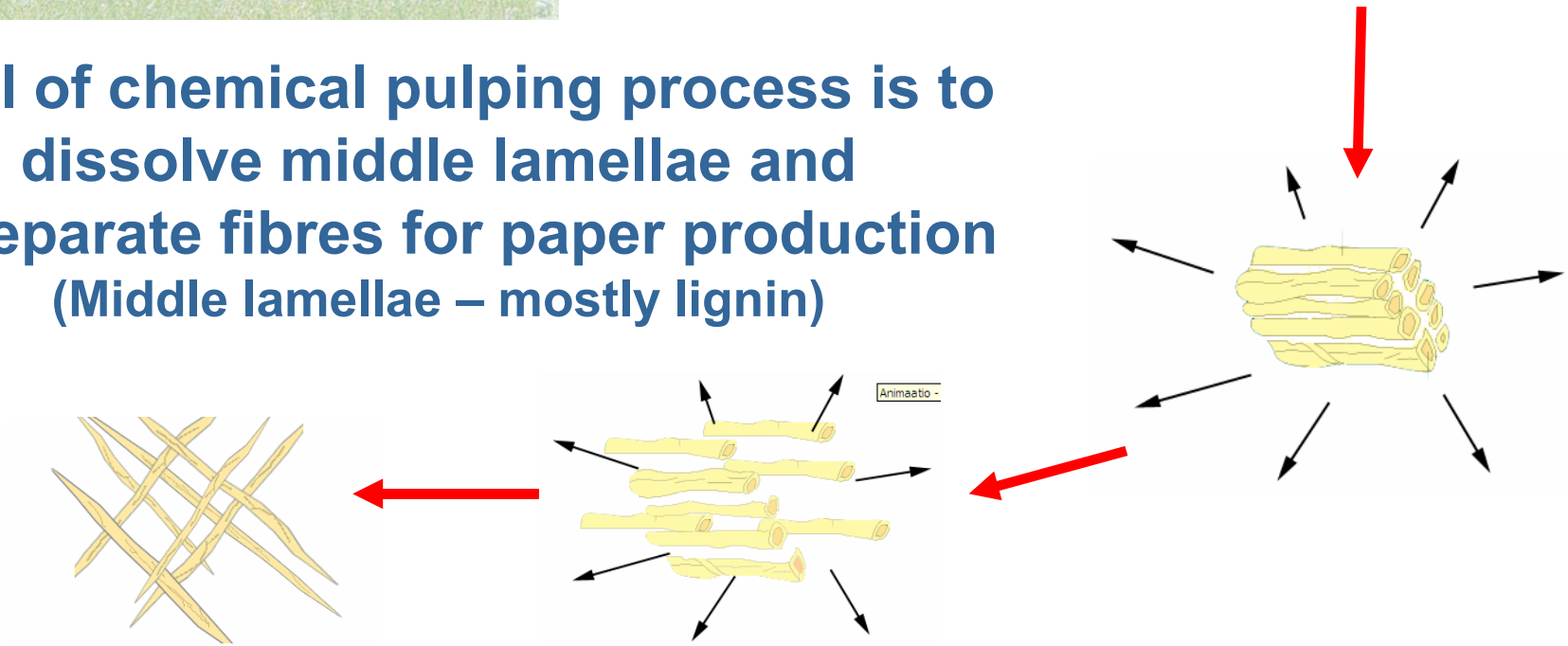
Chemical pulping





Goal of chemical pulping process is to dissolve middle lamellae and to separate fibres for paper production

(Middle lamellae – mostly lignin)



Processing

Logs

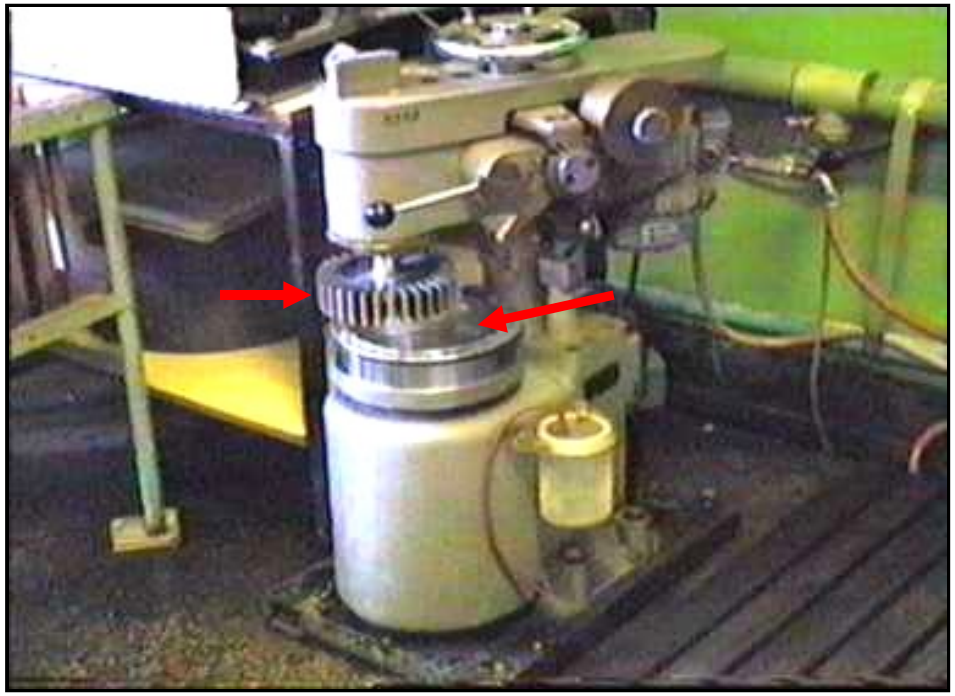
Wood chips

Pulp fibres

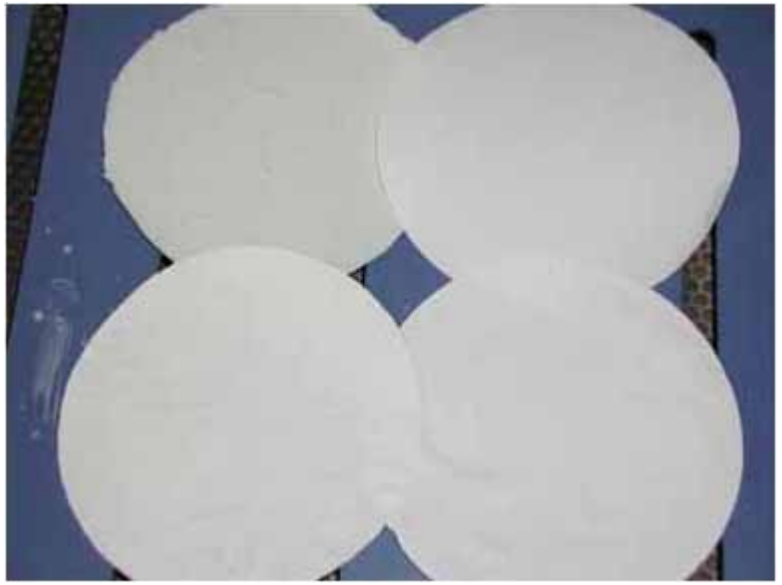
Refining

Refining (beating)

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

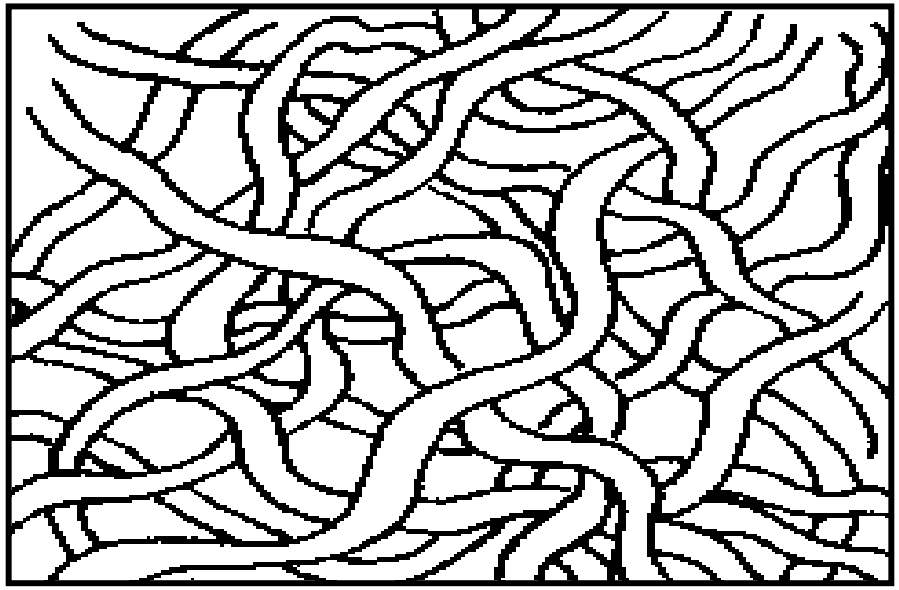


Hand-sheets



Some important concepts…

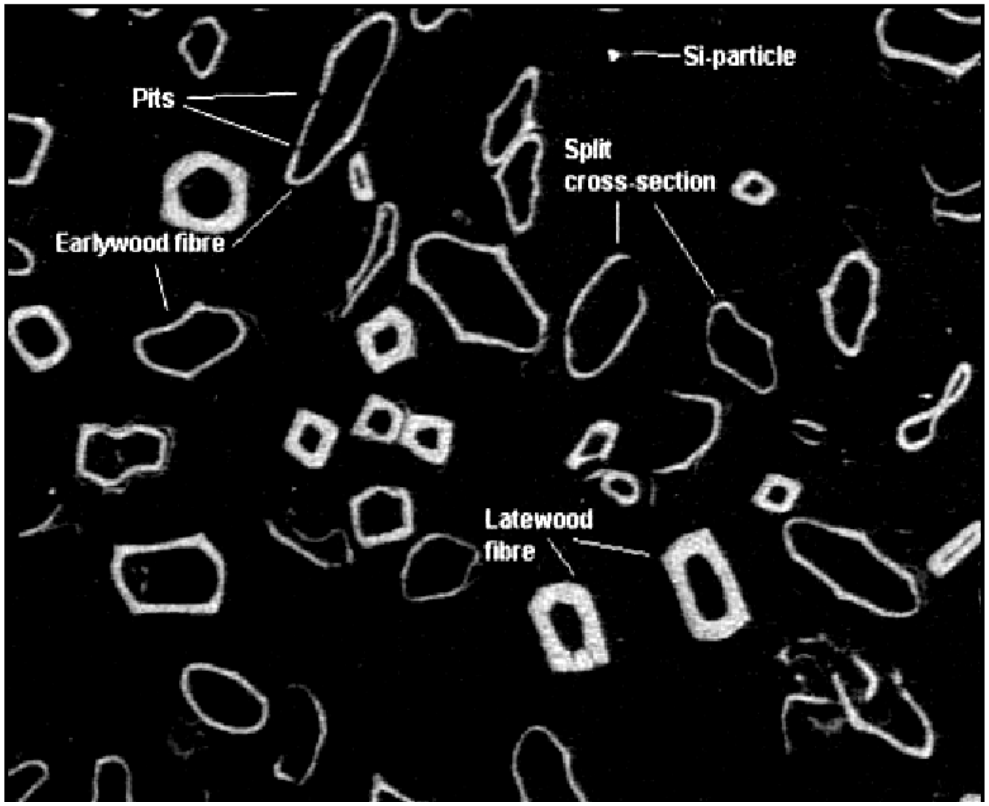
- Paper *vs.* hand-sheets
  - Orientation of fibres:
    - Aligned → paper
    - Random → hand-sheet

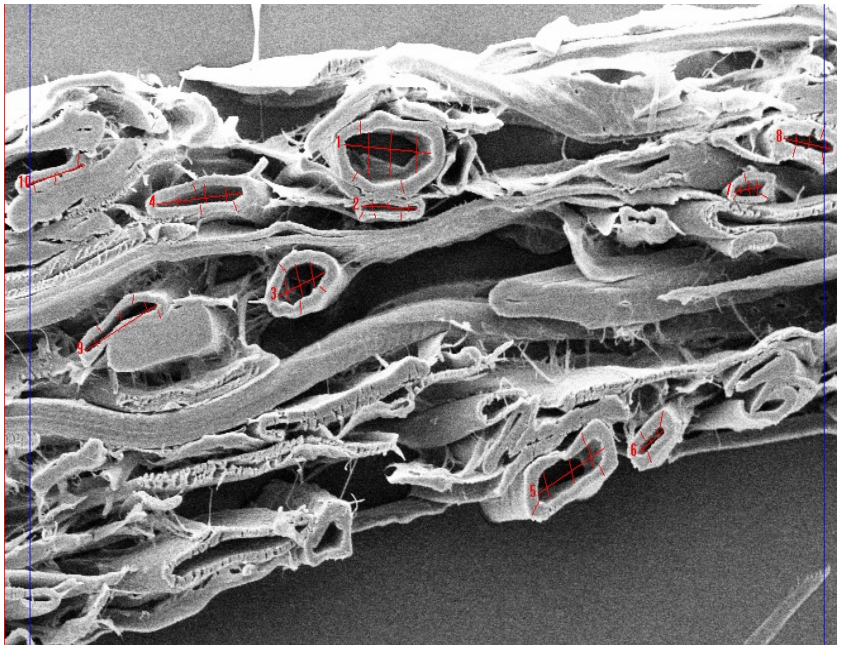


Some important concepts…

- Collapsibility and inter-fibre bonding

Light Microscopy





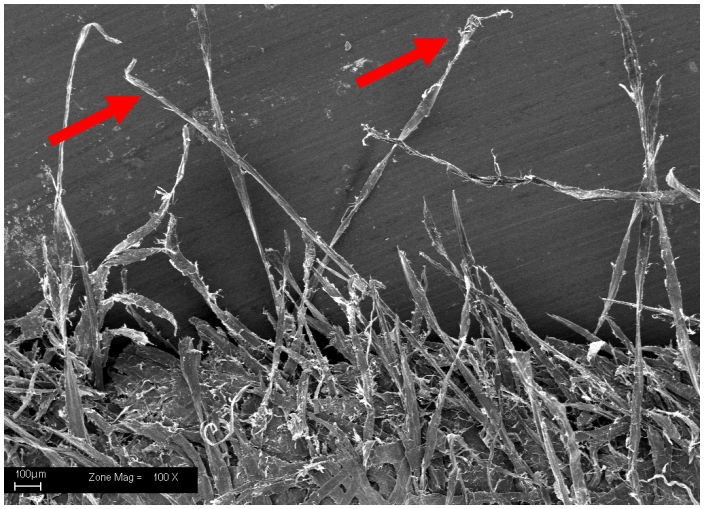
SEM

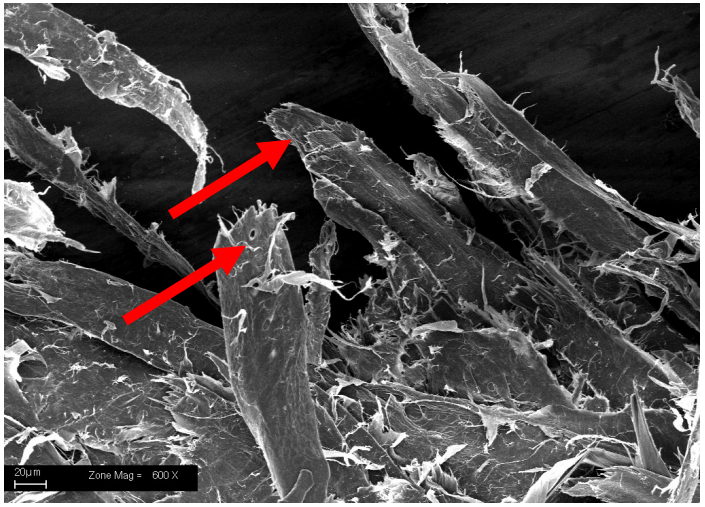
Some important concepts…

- Tear
  - Fibre level: pull-out *vs.* breaking/rupture

    •Fibre pull-out: greater energy = higher tear strength

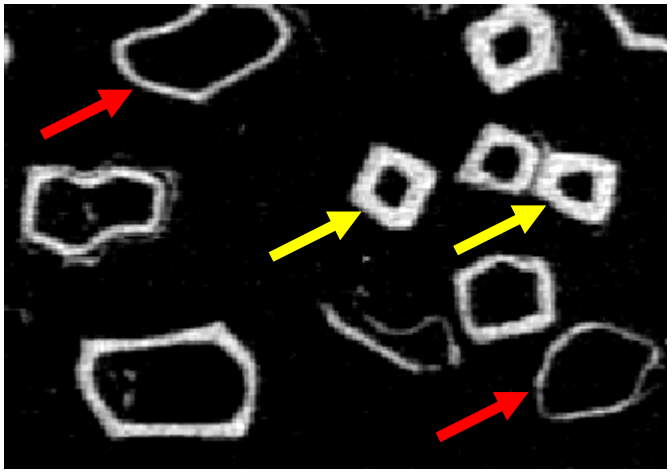
    •Fibre breakage / rupture: less energy = lower tear strength





Some important concepts…

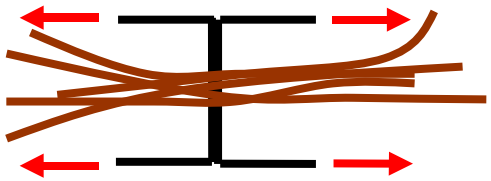
- Tear
  - Fibre level: pull-out *vs.* breaking/rupture
    - Fibre pull-out: greater energy = higher tear strength
    - Fibre breakage/rupture: less energy = lower tear strength
  - Cell wall thickness
    - Resistance to tear



Objectives

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

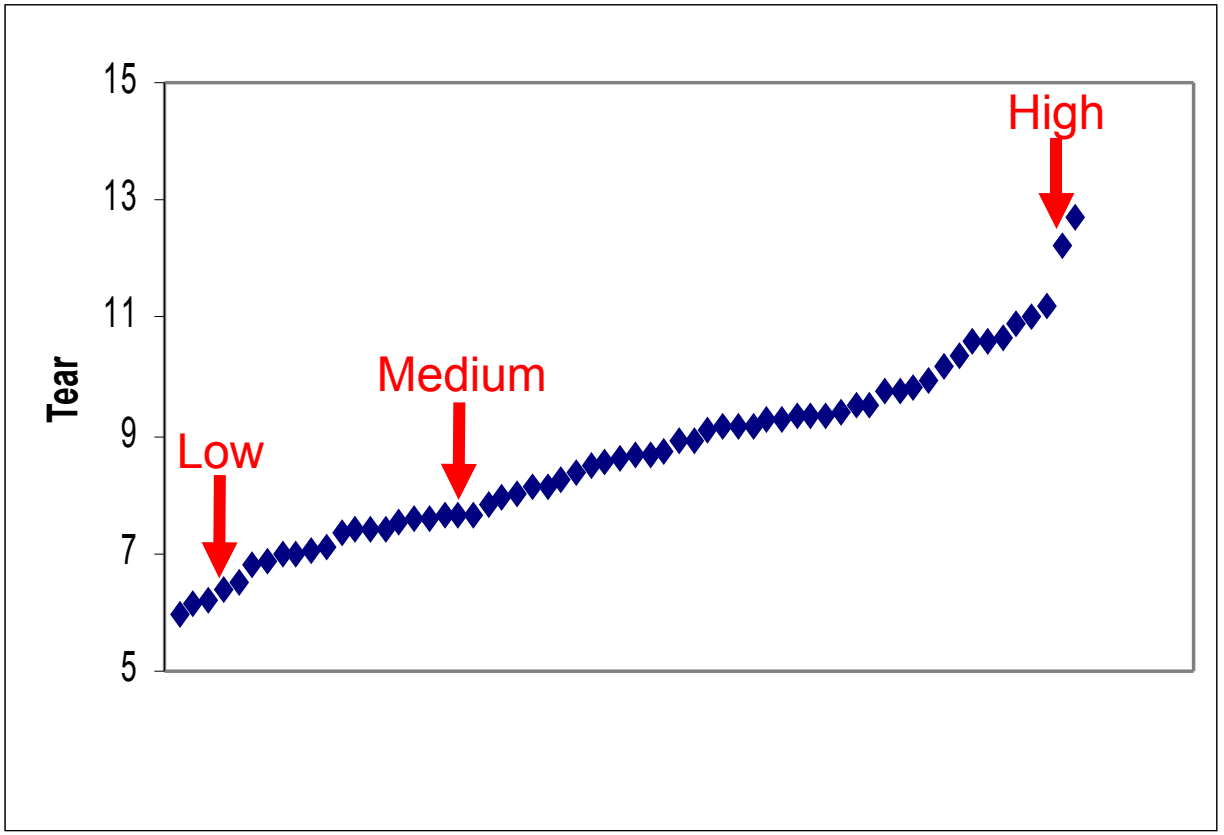
- Measure properties of pulped fibres that previously were not considered in depth
  - At individual fibre level: e.g. zero-span strength



  - At hand-sheet level: e.g. inter-fibre bonding (porosity), fibre pull-out / breakage

Material used

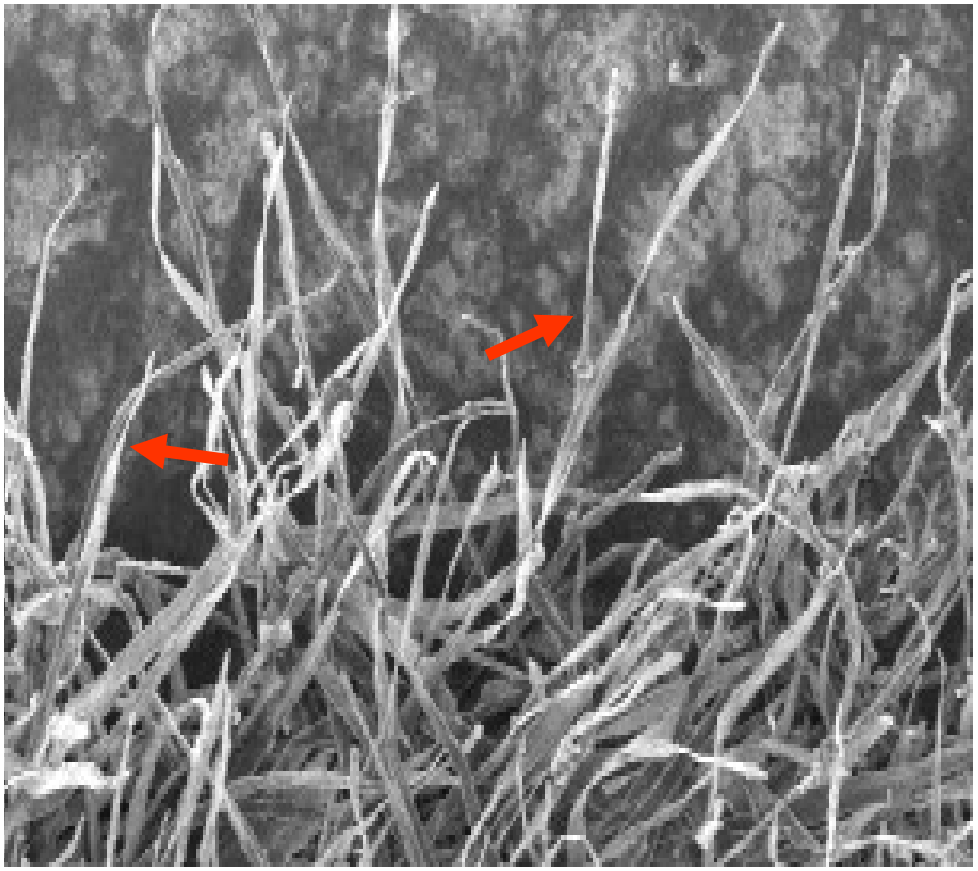
- Unbeaten *Eucalyptus nitens* pulp samples with varying levels of tear strength

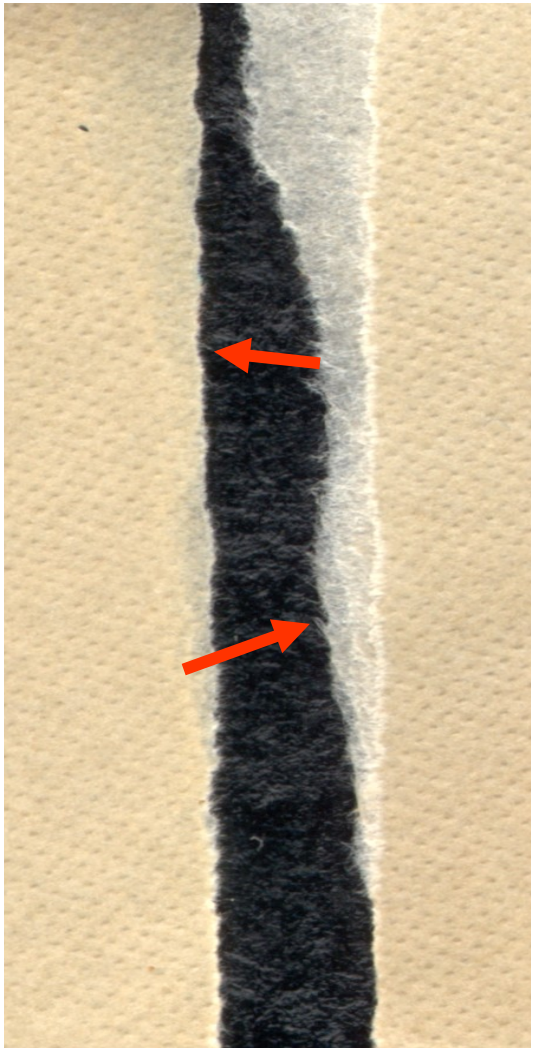


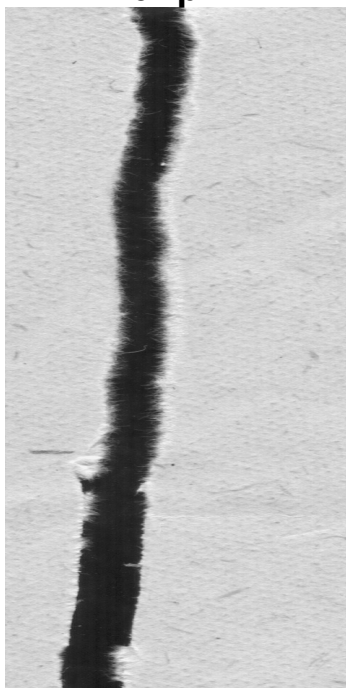
Assessing failure surfaces

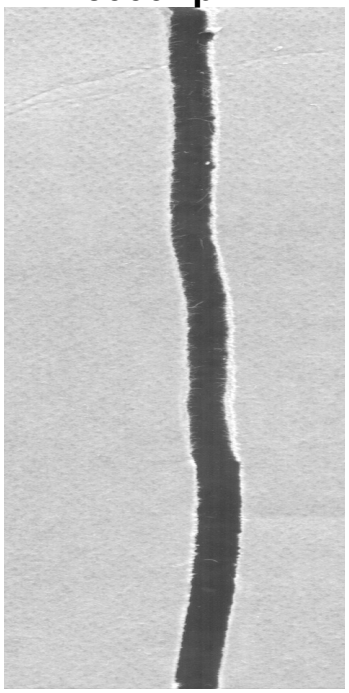
Two methods are being investigated

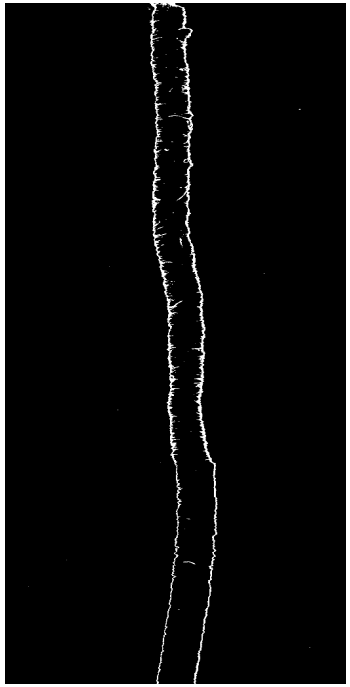
- Flat-bed scanner method
- SEM





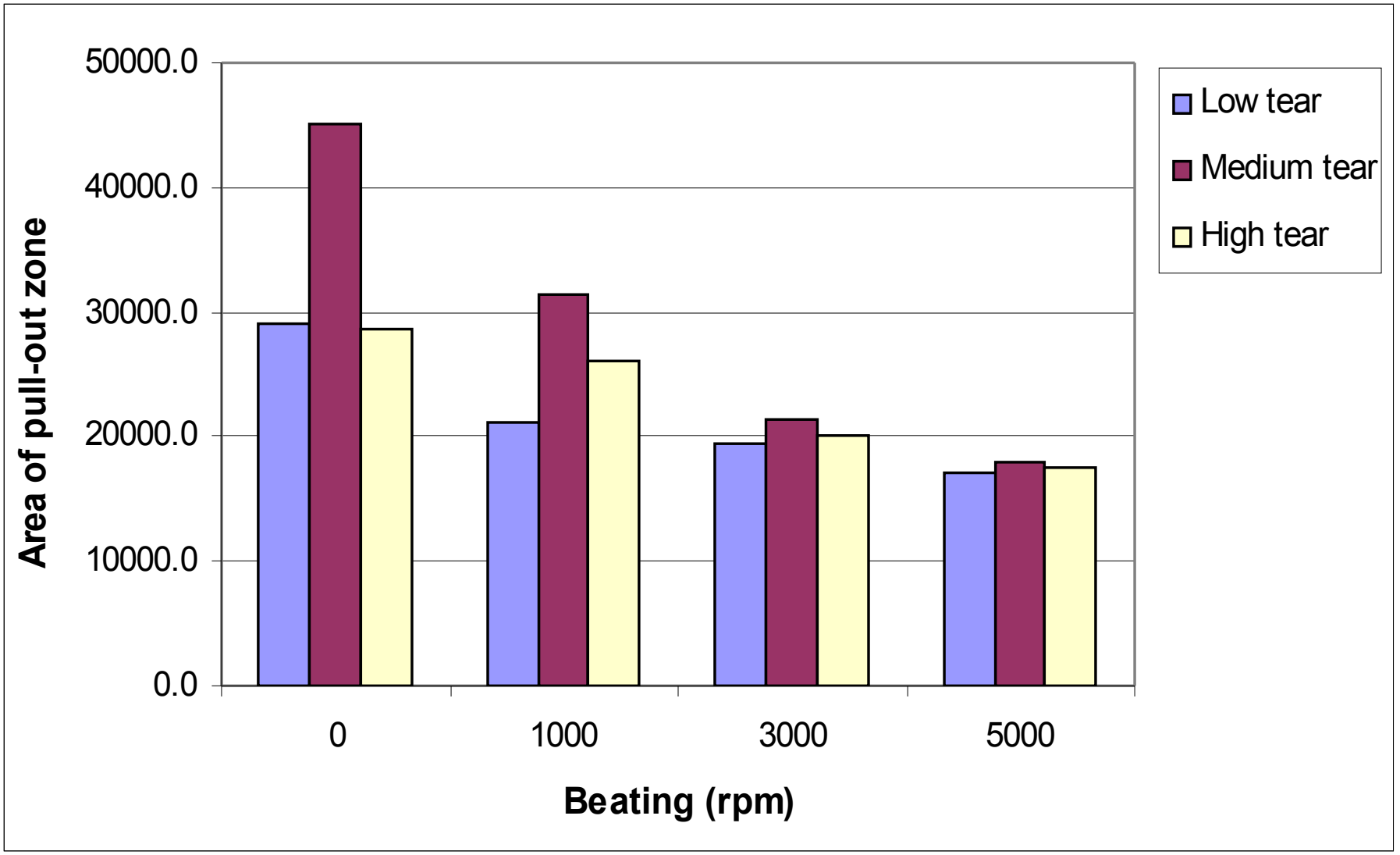






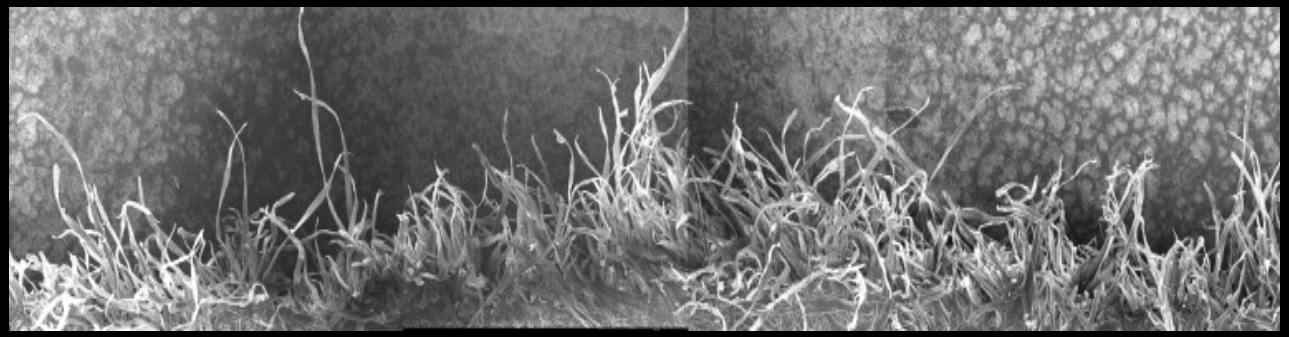
- Flat-bed scanner method
  - The failed / torn surfaces were scanned
  - Image analysis
    - Segmentation
    - Quantification

Results: Flat-bed scanner method



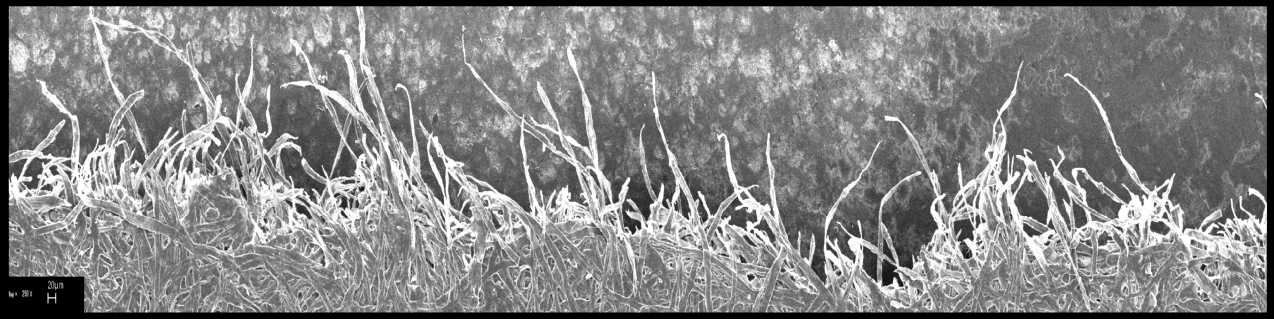
SEM

0 rpm



High level of fibre pull-out visible

3000 rpm

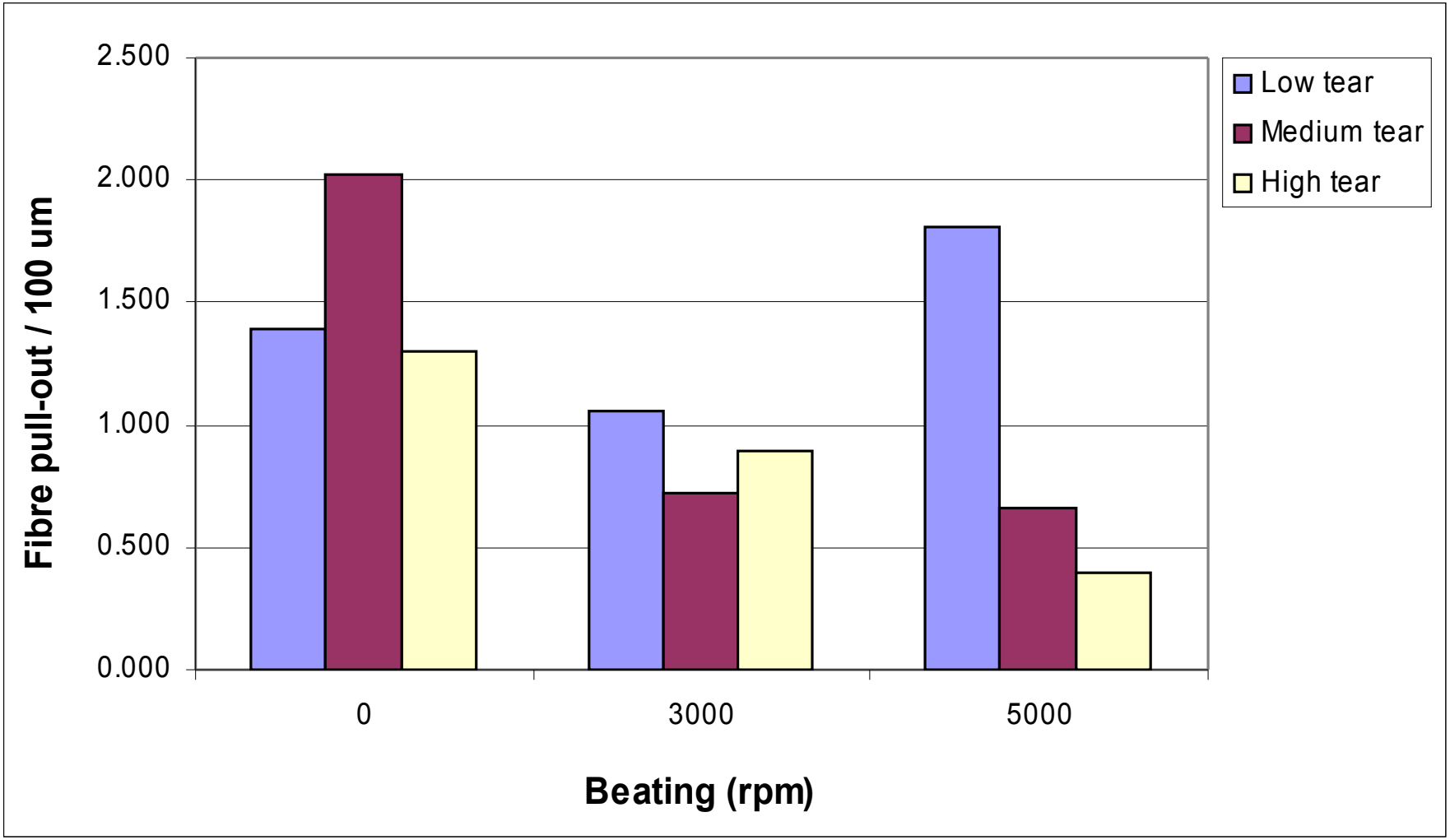


Medium level of fibre pull-out visible

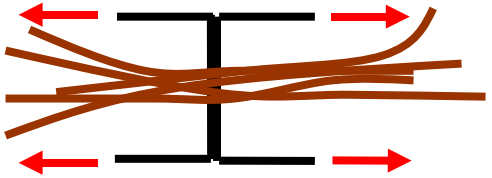
5000 rpm

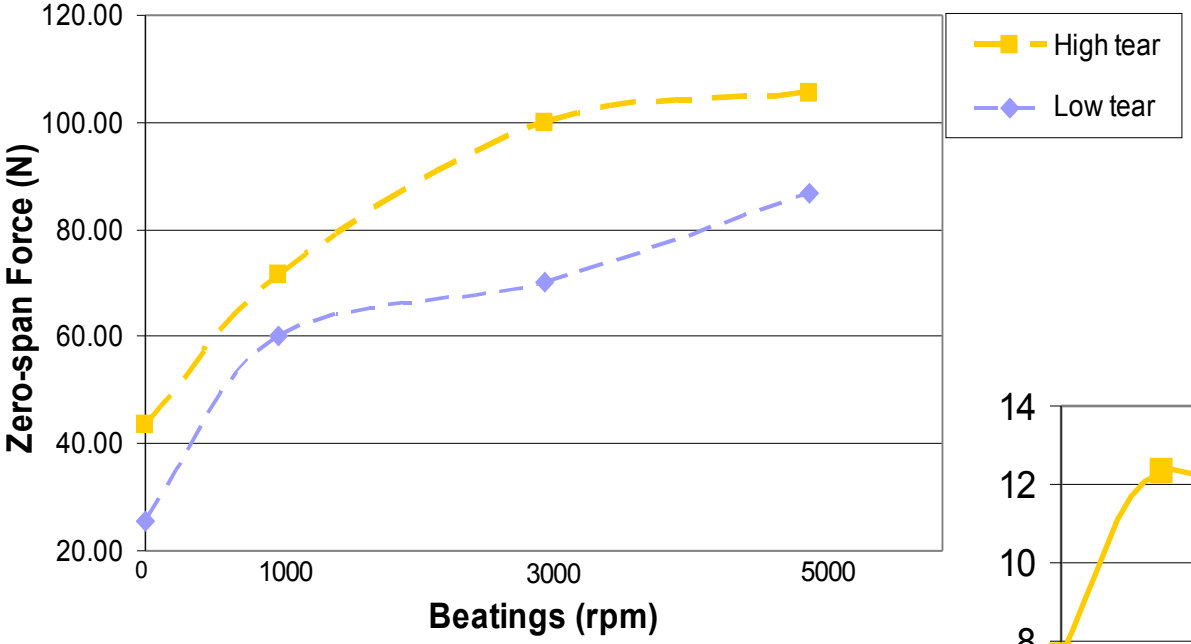
Low level of fibre pull-out visible

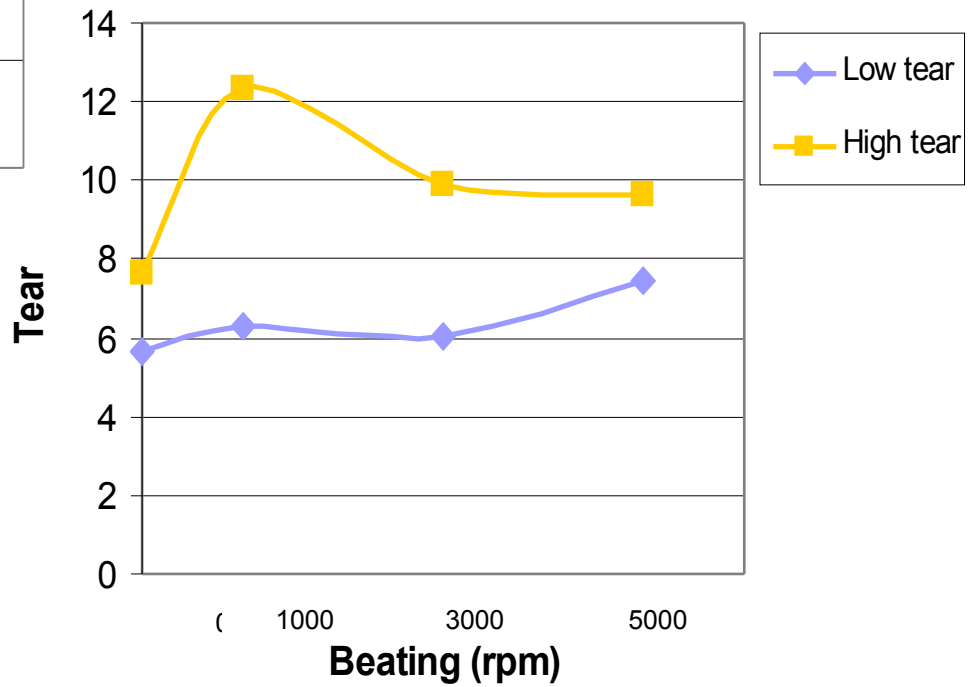
Results: SEM


2.500
2.000
1.500
1.000
0.500
0.000
Fibre pull-out / 100 um
0
3000
5000
Beating (rpm)
Low tear
Medium tear
High tear

Zero-span tensile measurements

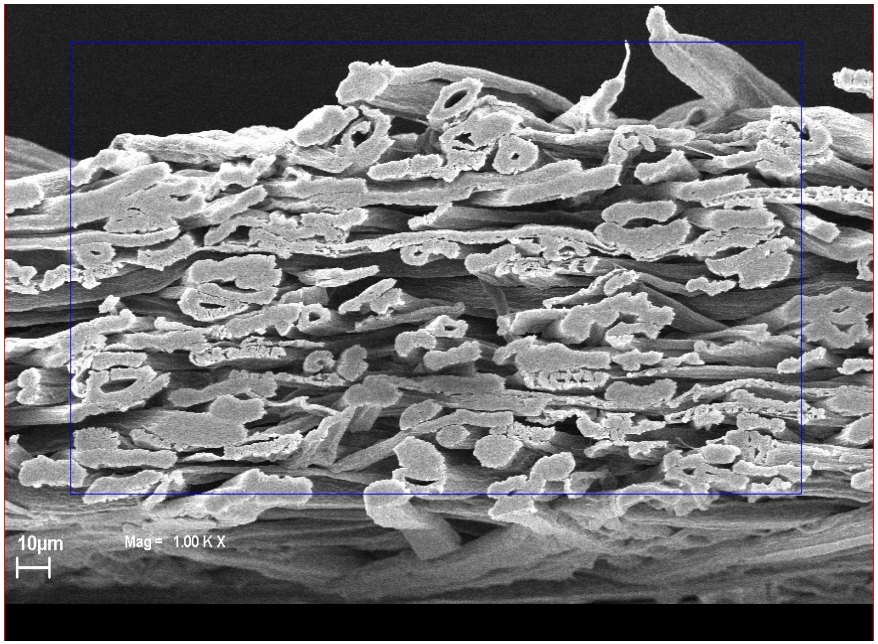


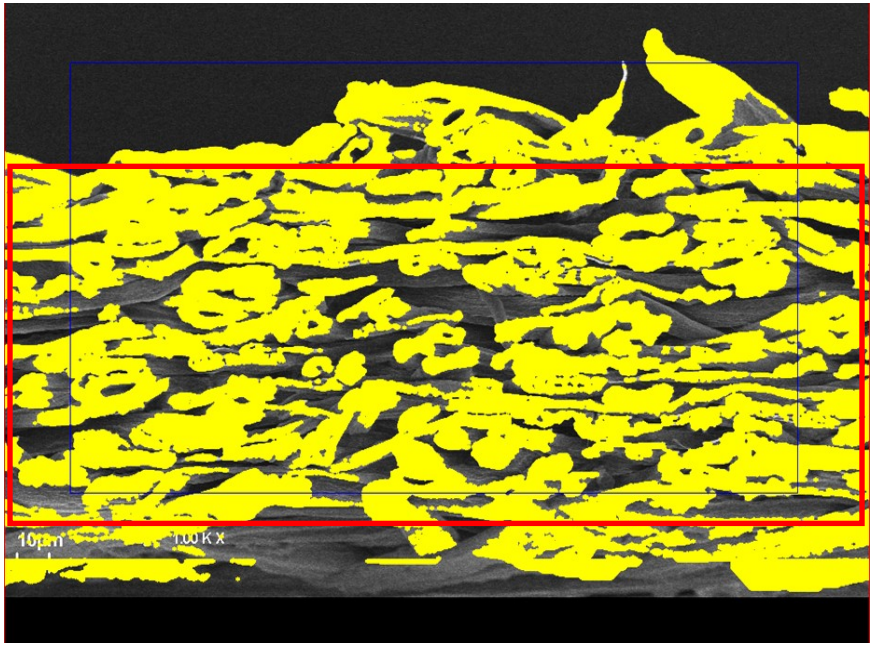




Porosity

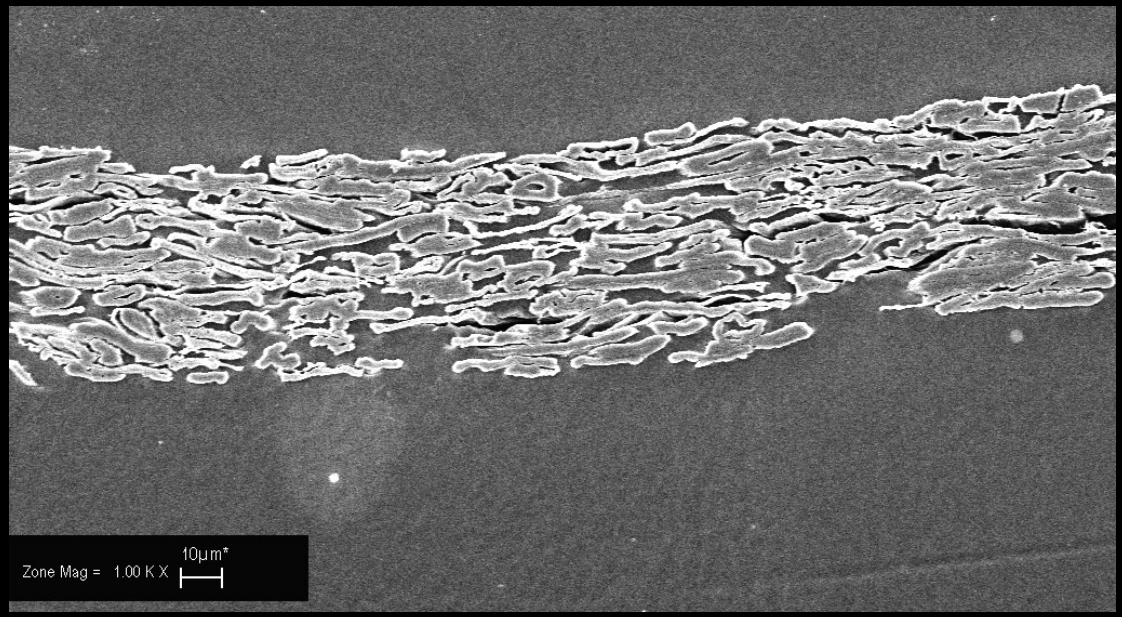
- Compactness of the fibres in the hand-sheet
- Measuring voids within the structure



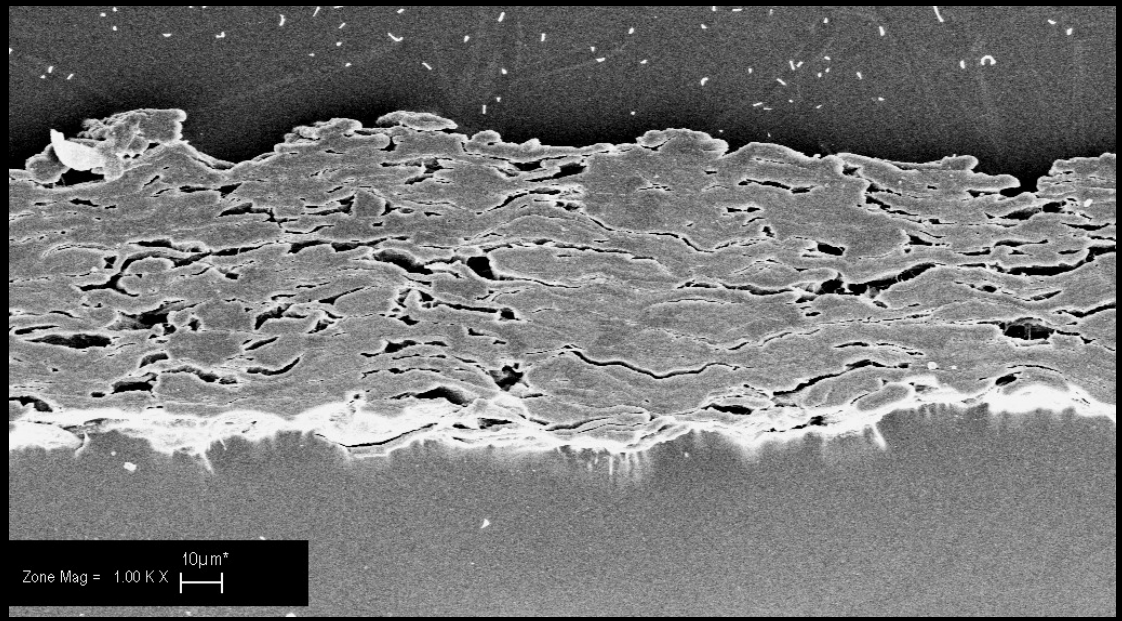


POROSITY

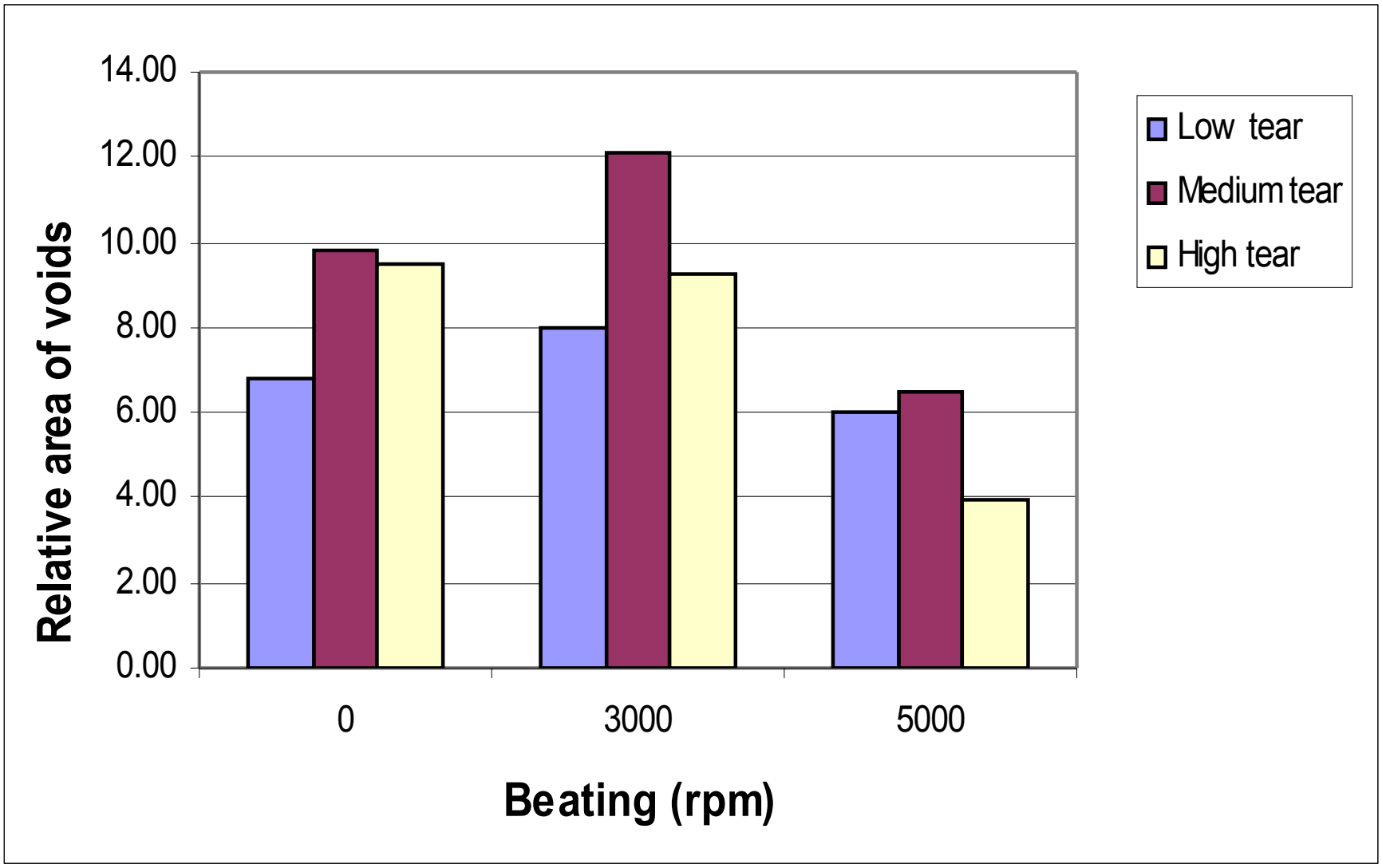
0 rpm



5000 rpm



Results: Porosity



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

Acknowledgements

- *Eucalyptus* Co-operative
  - CSIR, Mondi and Sappi

- UKZN

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Thank you

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