International Conference on Nanotechnology for Renewable Materials

Microfibrillated Cellulose for Next Generation Sustainable Packaging

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FiberLean® Technologies

TAPPI NANO DIVISION

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Introduction

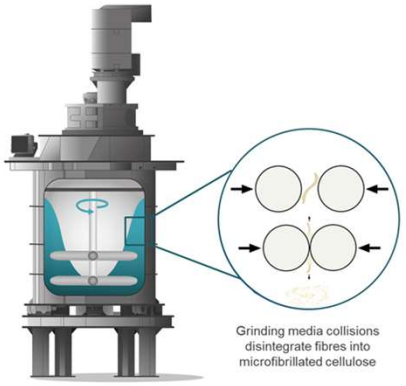
- Microfibrillated Cellulose (MFC) – produced by mechanical treatment of cellulose
- Highly viscous suspension in water
- Typically 1-2% solids content
- Satellite production adjacent to final use location
- Produced using stirred media mills

Product families

- MFC from 100% virgin pulp
- MFC from recycled fibres
- MFC mineral composites

- NB Two of these families have no added minerals. MFC only

Stirred Media Mills



Stirred vessel containing small grinding media beads, which are agitated by an impeller

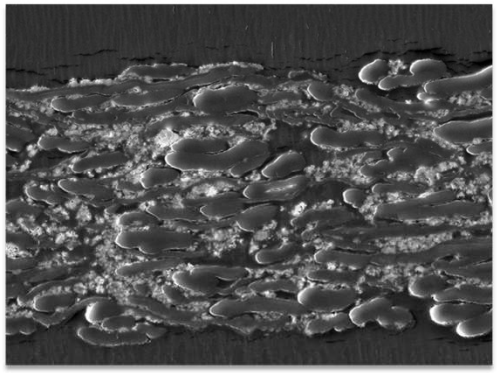
- Grinding media collide with each other, breaking and fibrillating fibres that are caught in the interstices
- High media surface area enhances fibrillation
- Highly tuneable -> highly fibrillated network structure with optimised structure for target application

Advantages

- No close tolerances or precision engineered components
- Robust proven technology
- Continuous single stage process
- Availability > 95%
- Low Capex and Opex
- High throughput
- Small footprint
- Modular easily-scalable design
- No additives or pre-treatments

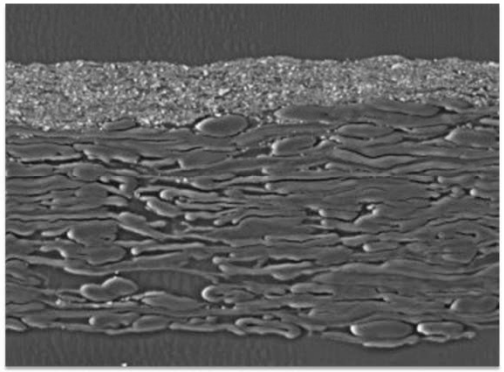
MFC applications in paper and board

In the sheet…
"Internal application"



- MFC is mixed into the pulp stock to provide increased web bonding.

On the sheet…
"Surface application"



- MFC is coated onto the surface to improve barrier properties.
- Or where MFC is used as the sole binder for a mineral coating.

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MFC applications in paper and board

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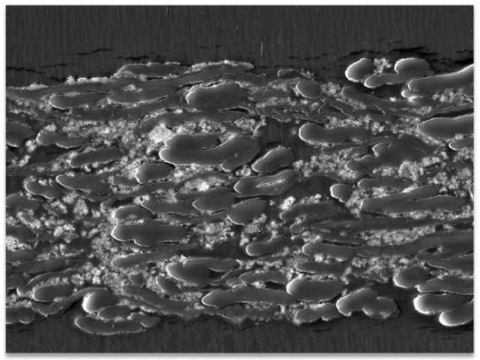

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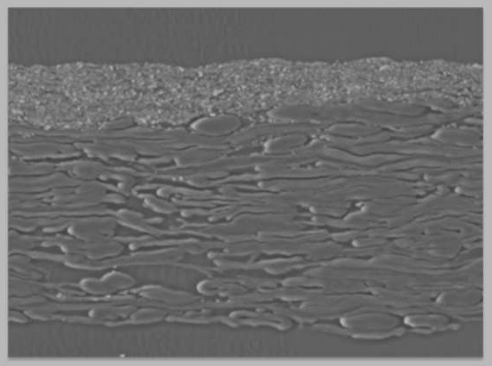

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Add MFC into the base paper furnish "**Internal Application**":

IMPROVE PROPERTIES

- Increase web strength (wet & dry).
- Porosity control & coating hold-out.
- Improve stiffness.
- Improve fold-cracking resistance.
- Improve print quality.

REDUCE RAW MATERIAL COSTS

- Replace fibre with filler.
- Reduce Softwood consumption.
- Light weighting / dematerialization.
- Reduce chemical consumption.
- Reduce starch dependency.

GAIN EFFICIENCY

- Reduce web breaks.
- Improve retention.
- Increase machine speed.
- Reduce steam consumption.
- Reduce refining energy.

IMPROVE SUSTAINABILITY

- Improve quality of recycled feedstocks.
- Use more recycled material.
- MFC is: Recyclable, repulpable, biodegradable and compostable.


Container board


White Top Liner


Coated recycled board


Folding box board


Copy / uncoated paper


Specialty papers


Coated paper


Tissue


3D Moulded Fibre

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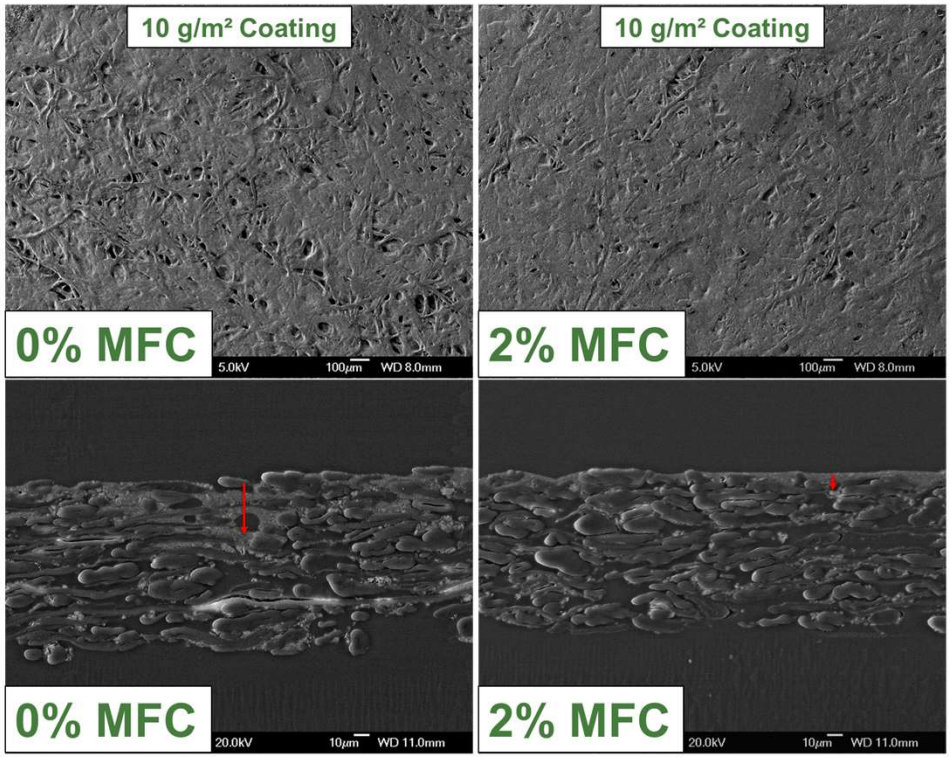
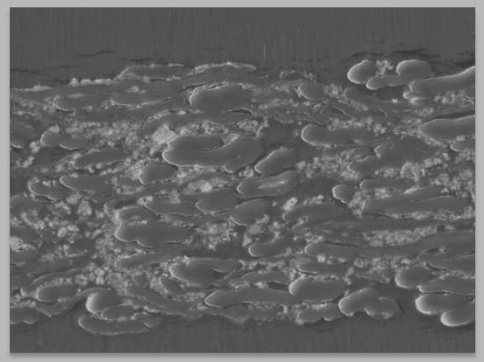


MFC in Base Paper	Base Paper Porosity (Bendtsen, ml/min)	Base Paper Porosity (Gurley, Sec/100 ml)
0%	2633	4
2%	1591	7

- Less coating penetration when using MFC due to smoother and more closed surface structure of the base.
  - Equivalent properties at lower coat weights when using MFC.
    - Typically, for every 1% MFC, coat weight can be reduced by up to 10-15%.
  - Improved properties at equal coat weight (added value).
- **Applications: Graphic, barrier & specialty.**

In the sheet…
"Internal application"



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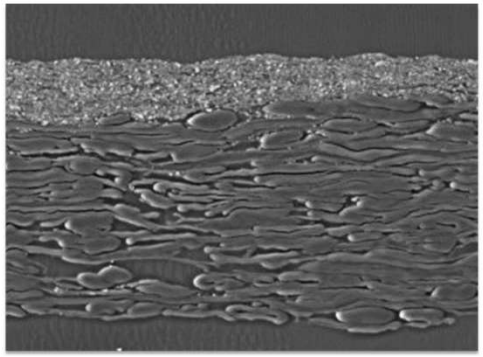

- MFC is coated onto the surface to improve barrier properties.
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MFC applied at the paper machine wet end:

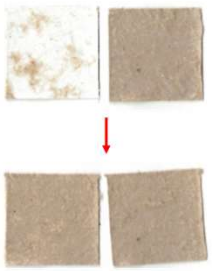
- Drain, press and dry using existing paper machine equipment.
- Low CapEx requirement.
- 2-layer sheet functionality achieved with 1 forming section and no coaters.
- Convert existing production lines to new grades.
- FiberLean are the inventors & patent owners globally of this exciting technology.

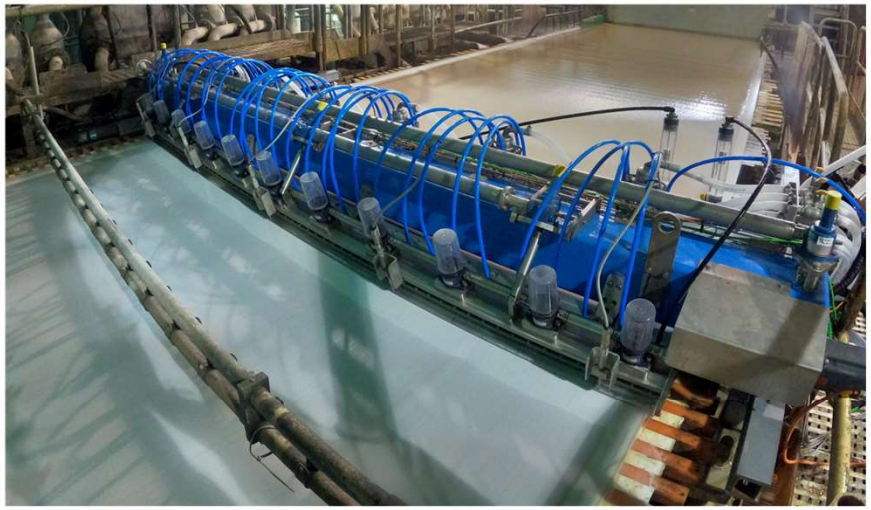
Multiple application uses:

White Top Liner

Barrier

Interlayer Bonding





Commercial-scale application of MFC:

3 m wide paper machine operating at 500 m/min.

3 m wide applicator currently being used for trials

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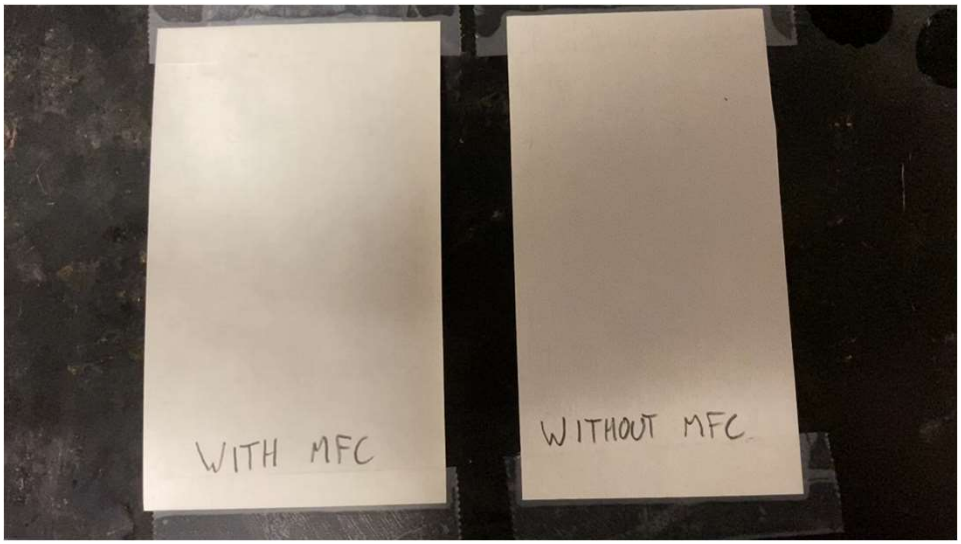
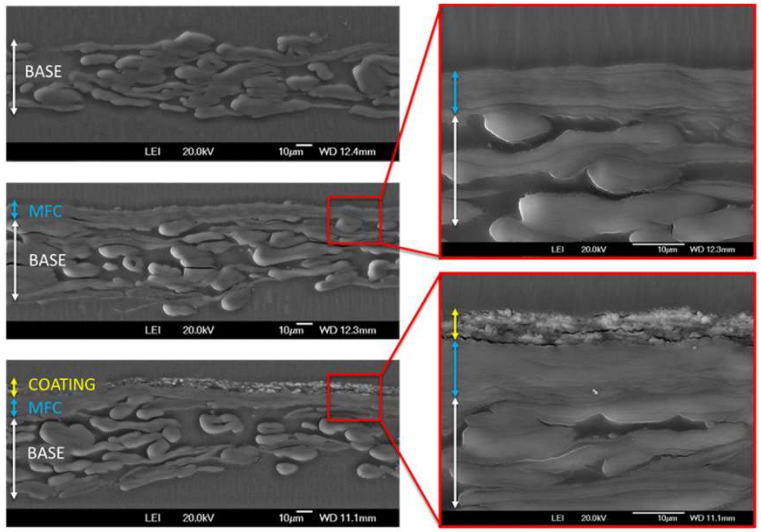
MFC applied *via* wet end coating: many interesting properties for barrier products



KIT 12 oil solution being applied to paper surfaces.



Cross-section Imaging: Scanning Electron Microscopy (SEM)

- ✓ Oil & grease resistance.
- ✓ Oxygen & aroma barrier.
- ✓ Mineral oil barrier.
- ✓ Very smooth & closed surface.
- ✓ Precoated surface for top coatings.
- ✓ High-strength & durable layer.
- ✓ High bio-based content, sustainable packaging.
- × MFC is not a water/moisture barrier.

- MFC remains on the surface, forming a fibril-film.
- The MFC layer has a very closed structure, preventing penetration of oil and permeability of air.
- The surface serves as a substrate (primer) for subsequent coatings (i.e., topcoats to achieve moisture / water barrier).

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Innovation with fibre-based barrier packaging to replace plastics is critical for a more sustainable future

Drivers:

- Consumer awareness
- Single-use plastics directive (SUPD)
- Reduction of petroleum-derived materials use
- PFAS bans
- Demand for sustainability (recyclable, biodegradable and compostable bio-based packaging)
- Natural-themed packaging is on trend

"As governments and brands increasingly look for alternatives to plastic packaging and food service formats, the paper and board sub-segment will assume an increasingly critical role."

Smithers, 2019

'The Future of Functional & Barrier Coatings for Paper & Board to 2024'

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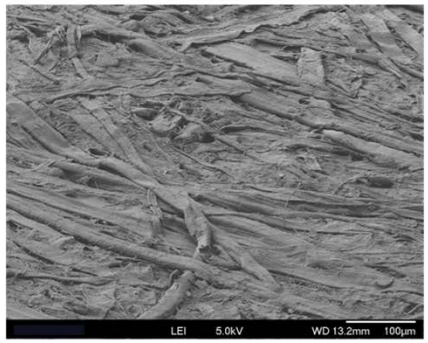
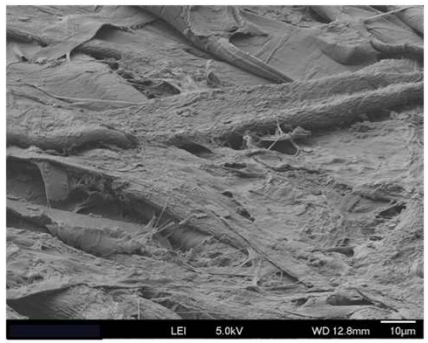
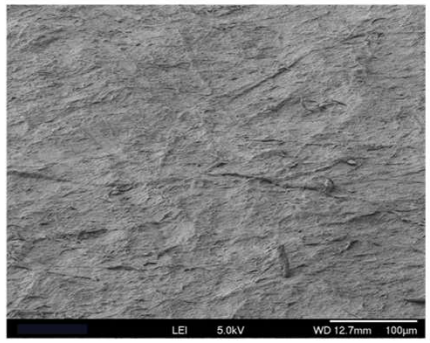
Scanning Electron Microscope (SEM) Imaging of MFC coated papers

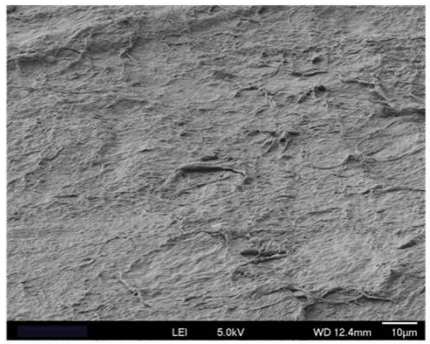
0 g/m² (No coating)



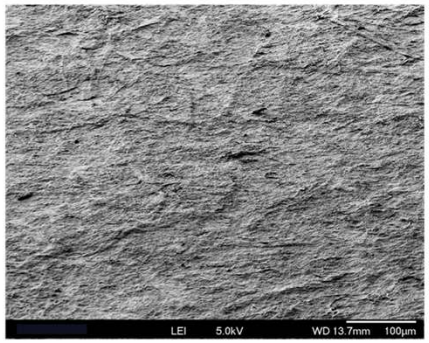


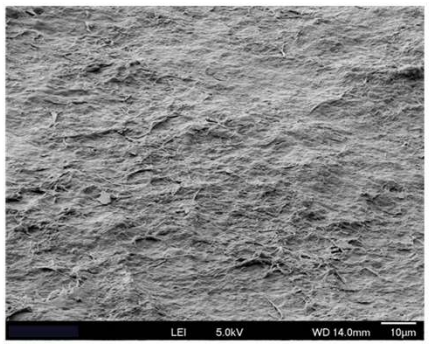
4 g/m² (MFC coating)





12 g/m² (MFC coating)





- The lowest coat weight, 4 g/m² provided substantial changes to the surface topography and structure.
- By 12 g/m², the MFC has formed a film and reached sufficient thickness to achieve high barrier properties.

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Barrier Application Results – MFC applied by wet end coating

Pilot Prototype Paper 1: Oil & Grease / Mineral Oil Barrier

- 50 g/m² Base paper coated with only MFC.
- Between 8 to 12* g/m² MFC applied at the wet end.

Oil & Grease
KIT Rating = 12
23 °C, 50% R.H. (0-12)

Mineral Oils (MOSH & MOAH)
HVTR = < 5
23 °C, 50% R.H. (n-Heptane, g/m² d⁻¹)

Oxygen Barrier
OTR = 40 to 100
23 °C, 50% R.H. (cm³ d⁻¹ m⁻² bar¹)

High Strength & Durability
Fold / cracking endurance

Smooth & Closed Surface
Precoat / primer layer for other top coats

>99% Bio-based
Mono-material packaging

Recyclable
With Paper & Cardboard
PTS-RH Method 021:202

Biodegradable
With no persistence
Certification in progress

*MFC coat weight required depends on substrate roughness/formation and desired properties.

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Barrier Application Results – MFC applied by wet end coating

Pilot Prototype Paper 2: Prototype 1 + Moisture / Water Resistance

- 50 g/m² Base paper coated with 10 g/m² MFC.
- 1-stage coating step of a water-based barrier coating (6 g/m²).

Oil & Grease
KIT Rating = 12
23 °C, 50% R.H. (0-12)

Mineral Oils (MOSH & MOAH)
HVTR = < 5
23 °C, 50% R.H. (n-Heptane, g/m² d⁻¹)

Oxygen Barrier
OTR = 200 to 500
23 °C, 50% R.H. (cm³ d⁻¹ m⁻² bar⁻¹)

High Strength & Durability
Fold / cracking endurance

Water Barrier
COBB 60 = < 0.8
23 °C, 50% R.H. (g/m²)

Functionality added by top coat

Smooth & Closed Surface
Precoat / primer layer from MFC

>90% Bio-based
Packaging complex

Recyclable
Packaging complex

Biodegradable
Packaging complex

Moisture Barrier
MVTR = < 7
23 °C, 50% R.H. (g/m² d⁻¹)

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Barrier Application Results – MFC applied by wet end coating

Pilot Prototype Paper 3: Full Barrier With Improved Oxygen Barrier

- Initial results - Under development.

Oil & Grease
KIT Rating = 12
23 °C, 50% R.H. (0-12)

Mineral Oils (MOSH & MOAH)
HVTR = < 5
23 °C, 50% R.H. (n-Heptane, g/m² d⁻¹)

Oxygen Barrier
OTR = 10 to 30
23 °C, 50% R.H. (cm³ d⁻¹ m⁻² bar¹)

High Strength & Durability
Fold / cracking endurance

Water Barrier
COBB 60 = < 0.8
23 °C, 50% R.H. (g/m²)

Functionality added by top coat

Smooth & Closed Surface
Precoat / primer layer from MFC

>87% Bio-based
Packaging complex

Recyclable
Packaging complex

Biodegradable
Packaging complex

Moisture Barrier
MVTR = < 7
23 °C, 50% R.H. (g/m² d⁻¹)

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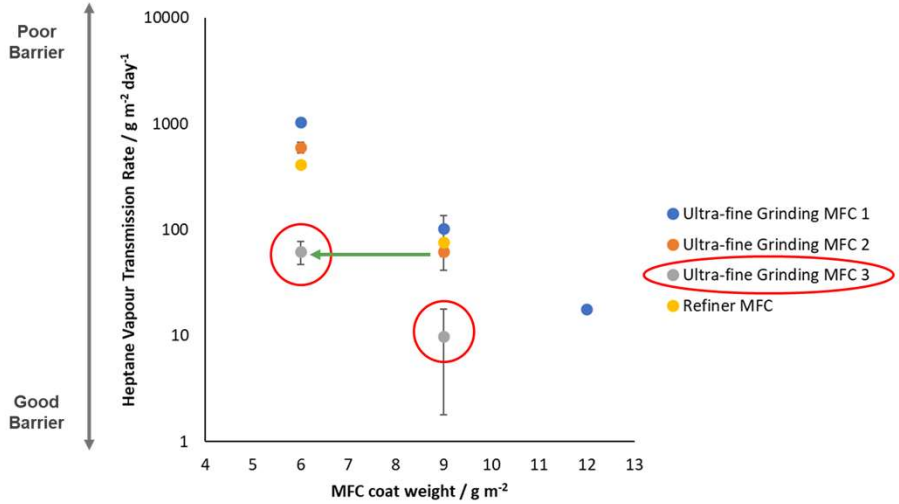
MFC properties are critical for effective application and high-performance

MFC Coat Weight vs. HVTR (23°C, 50% R.H.)
Various MFC samples coated onto paper

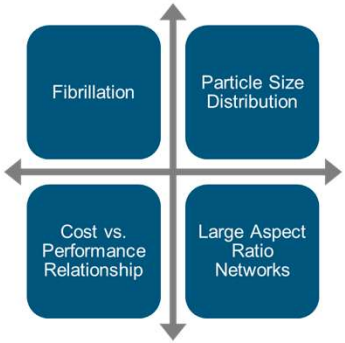


HVTR = Heptane Vapour Transmission Rate; is a barrier / permeation test method to evaluate the transmission rate of a volatile organic compound (n-Heptane), acting as a mineral oil simulant, through paper and plastic packaging materials.

○ = Product recommended for barrier MFC surface application.

✓ **Significantly lower coat weight required or higher performance.**

Tailored MFC Properties for Wet End Coating



- Barrier performance
- Strength / Durability
- Network bridging / film-forming
- Porosity control
- Surface hold-out
- Binding capability
- Viscosity & Drainage

- Avoidance of applicator blockages
- Coating uniformity / formation
- Process throughput to match peak demand
- Dose / Coat weight required
- Cost effectiveness

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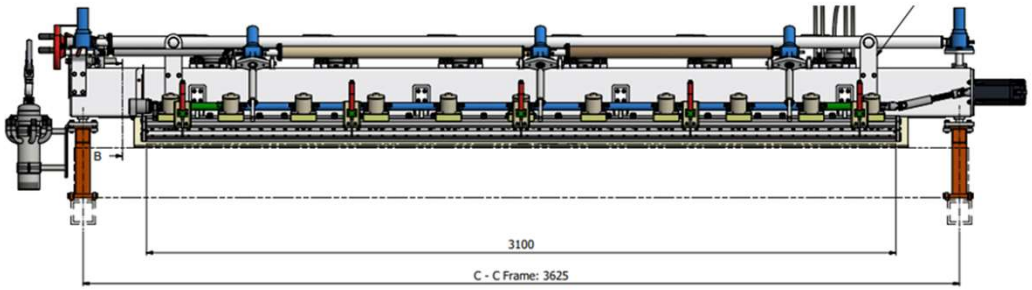
Wet end applicator: Designed for MFC



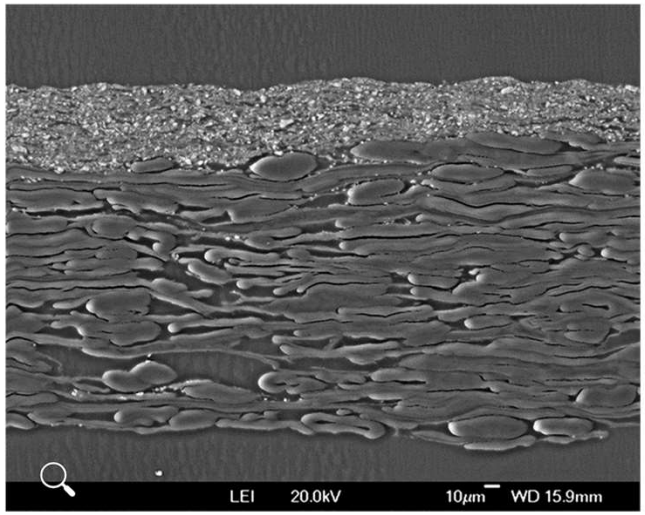
1/10000 sec exposure photographs

Water, 500 m/min

20/80 MFC/$CaCO_3$ 500 m/min

- Designed for application of optimized MFC with jet speed similar to wire speed, i.e., at high-shear conditions. Gradual shear-thinning of MFC through the approach flow system and applicator with maintained laminar flow.
- Easy mounting across paper machine.

Wet end coating of MFC-mineral composites: A new way to convert from brown liner to White Top



- ✓ Low-cost layer comprising mostly minerals, with MFC as the only binder.
- ✓ Absolute minimal white pulp consumption to produce WTL.
- ✓ Smoothness and printing properties.
- ✓ High surface strength and delamination resistance.

- Mineral particles provide a bright, white, printable surface to uniformly cover the dark base.
- MFC binds mineral particles at the surface, ensuring no penetration into the base and high surface strength.

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Summary

- Wet stirred media mills offer a low-cost and high-performance MFC at scale.
- MFC is increasingly more widely established as a key tool in the paper makers toolkit, enabling its users to:
  - Improve properties.
  - Reduce costs.
  - Achieve their sustainability goals.
  - Develop new products.
- Wet-end coating of MFC can be used to achieve new properties on existing paper production lines with minimal investment cost.

Thank you for your attention

FiberLean® Technologies

We are grateful to TAPPI for the opportunity to present this work

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