TAPPI ADVANCED COATING SYMPOSIUM

The role of Microfibrillated Cellulose in coated food service packaging

David Skuse
Managing Director
FiberLean Technologies Ltd.

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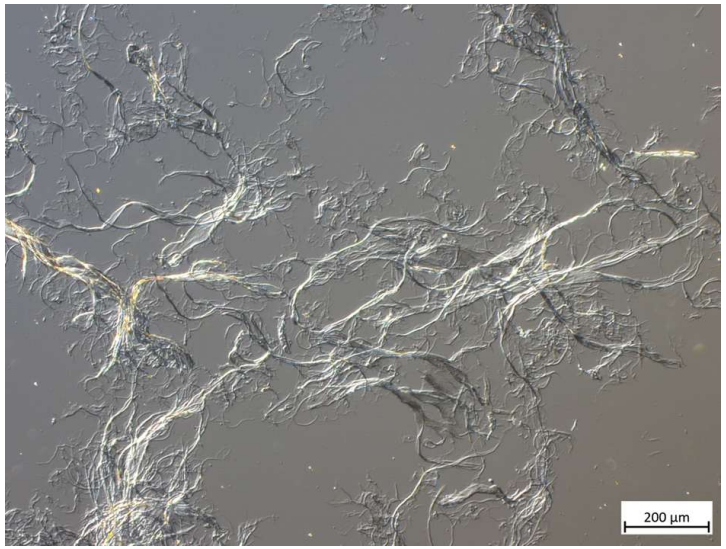
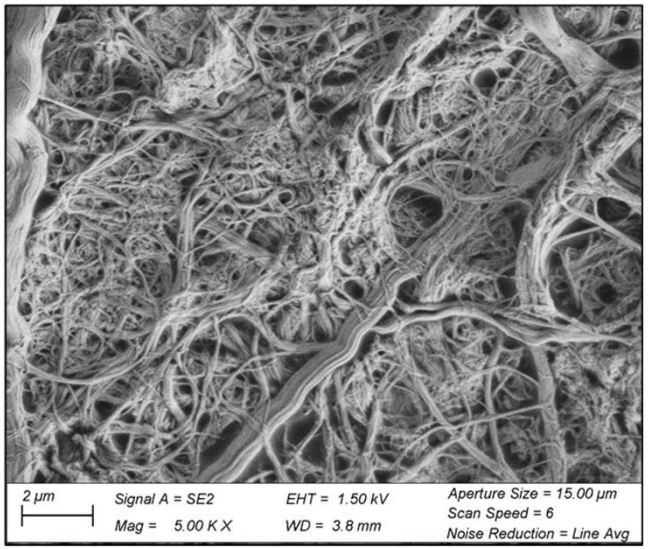
Introduction

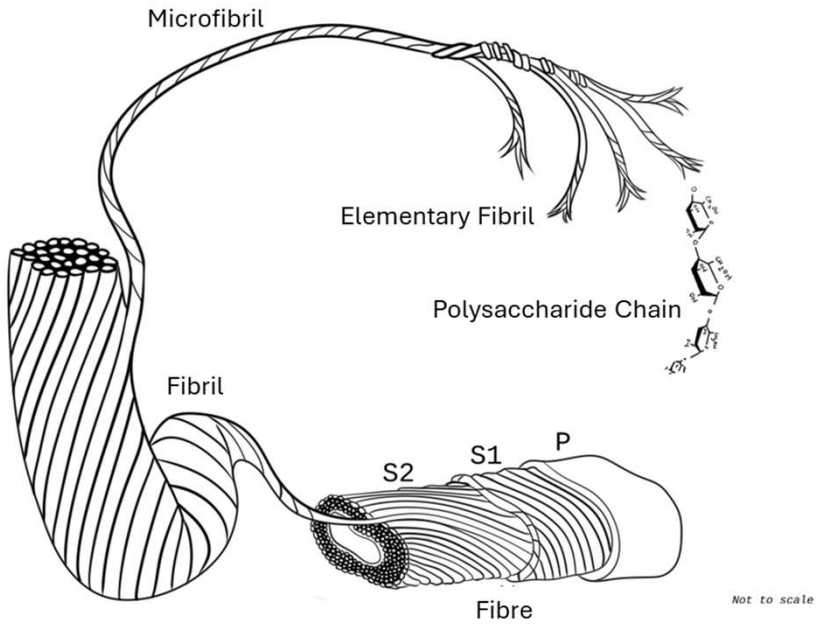
- ***Vertical Wet Stirred Media Mill Grinders*** for the production of microfibrillated cellulose.
- ***Entirely mechanical process***, no chemical or enzymatic pre-treatment.
- ***Flexible operating conditions*** enable tailoring product characteristics and optimising for a wide variety of fibre feedstocks.

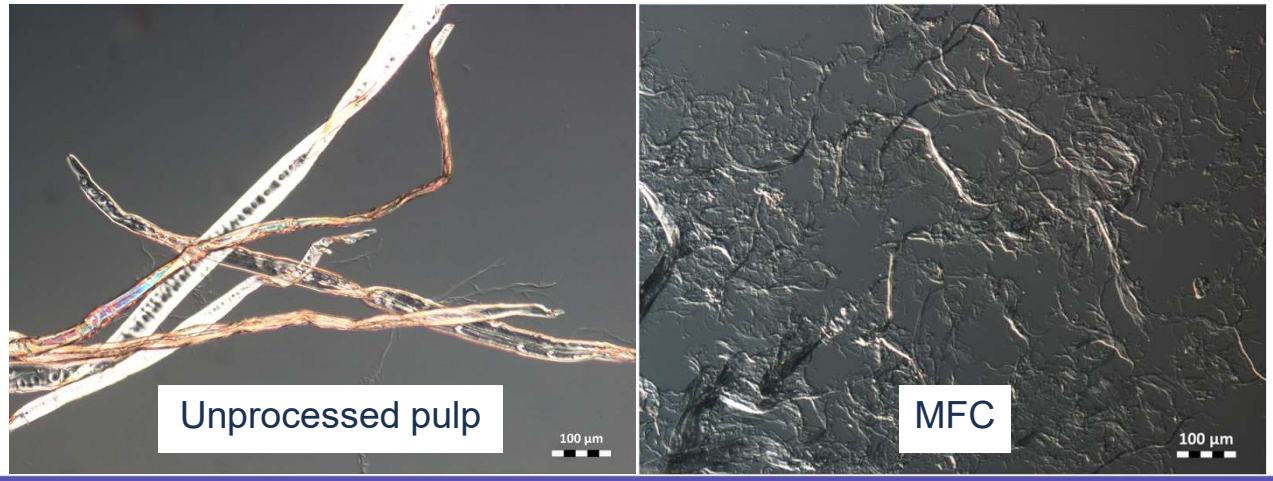




What is MFC?

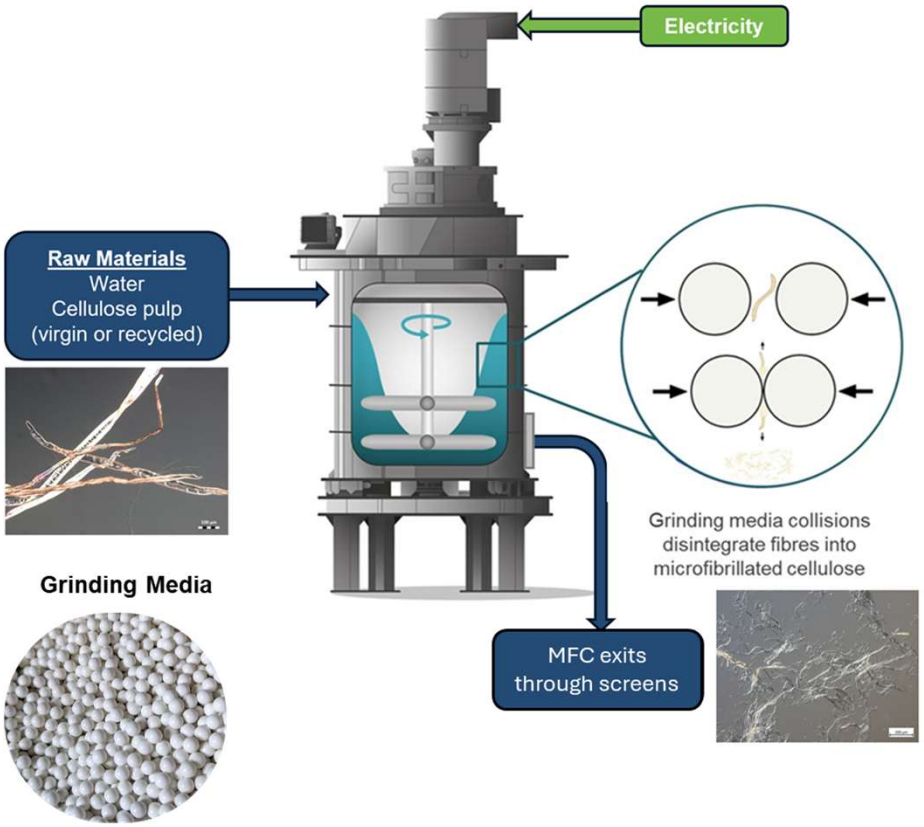
- Micro-fibrillated Cellulose (MFC) is made from cellulosic feedstocks such as wood pulp, which are ***mechanically disintegrated*** to liberate their ***fibril and microfibril sub-structures.***
- This greatly increases specific surface area and fibril aspect ratio. Enhances bonding ability.





- When added to the paper-making process, improved mechanical and barrier properties, reduced porosity, smoother surfaces.

Stirred Media Mill Grinder Working Principles



Stirred vessel, charged with water, pulp and ***ceramic grinding media***.

Mechanical method, no chemical / enzyme pretreatment needed.

Fibrillation occurs when fibres gets trapped between colliding grinding media particles.

Grinding media are the 'working surfaces' for fibrillation; very high active surface area; permits high throughput and efficient production of MFC.

Continuous, single pass operation; energy input controlled by flow rate and motor power.

Production solids ~ 1-2% - on-site production

Large-scale Grinder in Operation

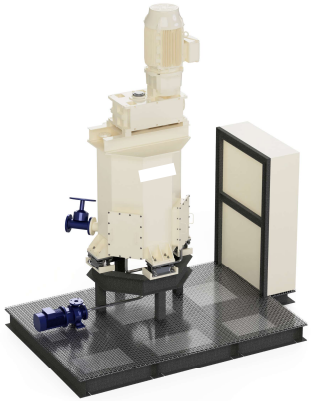
Grinder-Produced MFC: Regulatory, End-of-life, ESG

- BfR, FDA, Canadian and Chinese **food contact paper clearance**.
  - FDA FCN 002413, BfR Recommendations XXXVI, XXXVI/1, XXXVI/2 & XXXVI/3
- **Not a nano-material** according to US EPA and EU definitions*.
- **No negative health effects** found. https://pmc.ncbi.nlm.nih.gov/articles/PMC6994281/; https://pmc.ncbi.nlm.nih.gov/articles/PMC7329166/; https://pmc.ncbi.nlm.nih.gov/articles/PMC6474143/
- MFC not a final product but we have carried out the following testing to confirm MFC has no negative impact on end of life:
  - **Recyclable** – PTS-RH 021:2012 – bleached and unbleached grinder MFC coated papers passed.
  - **Biodegradable** – OECD 301B – grinder MFC suspensions with and without biocide were biodegradable.
  - **Compostable** – ISO 14855 – bleached and unbleached grinder MFC coated papers were biodegradable under industrial composting conditions.
- Allows lighter products, reducing transport related emissions.
- Supports recyclability / circular economy by enabling plastic replacement in packaging.

MFC Grinder Sizes

Large MFC Grinder
Capacity ~ 1200 dry metric tonnes of MFC per grinder per year. Appropriate size for most paper and board applications.

Medium MFC Grinder
Capacity ~ 600 dry metric tonnes of MFC per grinder per year. Small paper mills, tissue mills.

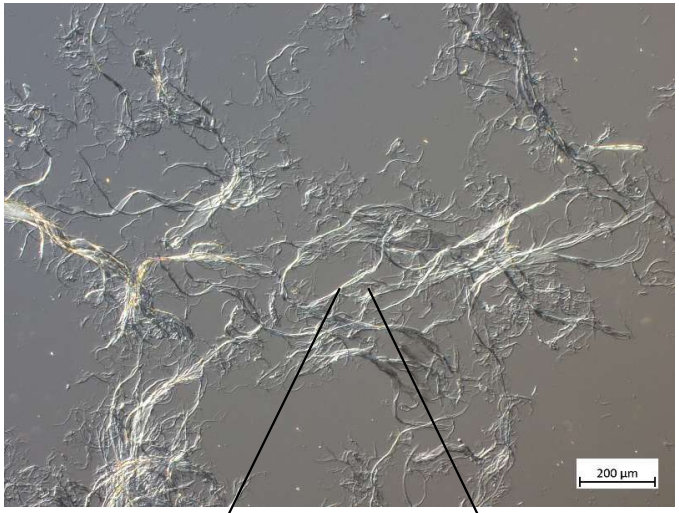


Small MFC Grinder
Capacity ~ 100 dry metric tonnes of MFC per grinder per year. Speciality applications, moulded fibre etc.

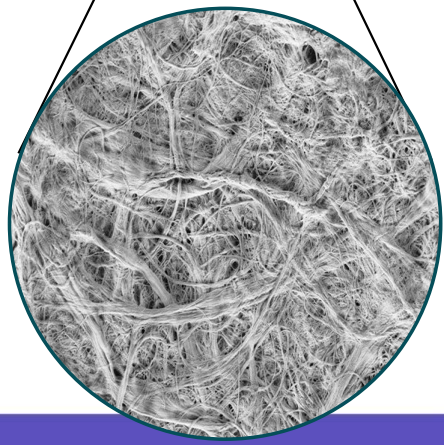
Morphology of Grinder Produced MFC

- Grinder-produced MFC is best described as '***surface-nanostructured macromaterial***'.
- Micrometre and nanometre scale fibrillar surface structure on a sub-millimetre scale macrostructure.
- ***Fine*** and long ***micro and nano fibrils*** in the ***nanostructure*** enhance ***bonding*** at fibre-fibre joints and with filler particles.
- A ***coarse macrostructure*** improves ***bridging*** between fibres and ***improves MFC retention***.
- The objective is usually to efficiently generate a ***high level of microfibrillation whilst retaining coarse macrostructure***.

Optical micrograph showing MFC **coarse macrostructure**



SEM showing MFC fibrillar **micro and nano structure**



Grinder-Produced MFC: Properties in paper and board

Typically, use of MFC ***in a paper furnish*** is associated with:

- Improved performance stability.
- Increased initial wet web strength.
- Minimal impact on wet end chemistry.
- Improved dry mechanical properties.
- Improved opacity.
- Improved formation.
- Reduced porosity.
- A smoother sheet.
- Improved coating hold out.
- Loss of bulk and slower drainage are negatives but can be managed.

Typically, use of MFC ***as a coating*** on a web-based system is associated with:

- Improved wet and dry mechanical properties.
- Much reduced porosity.
- A smoother sheet.
- Grease barrier performance.
- Improved coating hold out.

Grinder-Produced MFC: Applications in Paper and Board

Typically, use of MFC ***in a paper furnish*** is associated with:

- **3D Moulded Objects** – fibre reduction by light-weighting, improved formation, reduced porosity. Potential ~30% weight reduction. Grease barrier properties.
- **Specialty papers** – For example flexible packaging base paper:
  - Improved wet strength – improved runnability, especially at low basis weight.
  - Improved wet and dry elongation.
  - Low porosity, smooth dense sheets.
  - Improved coating behaviour.

Typically, use of MFC ***as a coating*** on a web-based system is associated with:

- **Primers and Barriers**– MFC can form a low porosity layer with increased oil and grease resistance and oxygen barrier properties for food packaging. The MFC coatings can also form a suitably smooth surface for further barrier layer application.

Grinder-Produced MFC: Examples

In-furnish

- 3D Moulded Objects
- Specialty papers – Base paper

As a coating

- **Primers and Barriers** – Wet-end coating

MFC in Furnish: Moulded Objects I

Bleached NBSK unrefined: Pilot study

(**0%** MFC)
KIT = 0 out of 12

(**10%** MFC)
KIT = 0 out of 12

(**17%** MFC)
KIT = 4 out of 12

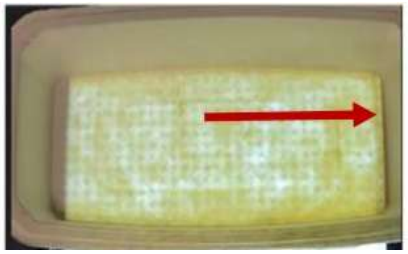
MFC Content (%)	Tray Basis Weight (g/m^2)	Tensile stiffness index ($N\ m\ g^{-1}$)	Tensile strength index ($N\ m\ g^{-1}$)	Tensile stiffness ($N\ m^{-1}$)	Tensile strength ($N\ m^{-1}$)	Bendtsen Porosity ($ml\ min^{-1}$)
0	480	2.63	21.2	1270	10.2	2750
10	**380**	**3.45**	**37.2**	**1300**	**14**	**160**
17	**280**	**5.04**	**53**	**1430**	**15.1**	**15**
25	**175**	**5.37**	**56.4**	930	**9.8**	**4**

- Up to **50% reduced object weight** whilst maintaining strength, stiffness and mouldability.
- **Greatly improved smoothness**, and **reduced permeability**.
- **Potential improved hold-out** of functional coatings and effectiveness of sizing.
- **OGR barrier properties** (≥30% MFC results in KIT 12).
- ***Opportunity for replacement of PFAS.***

MFC in Furnish: Moulded Objects II

Commercial trial results, 5% grinder MFC

0% Reference



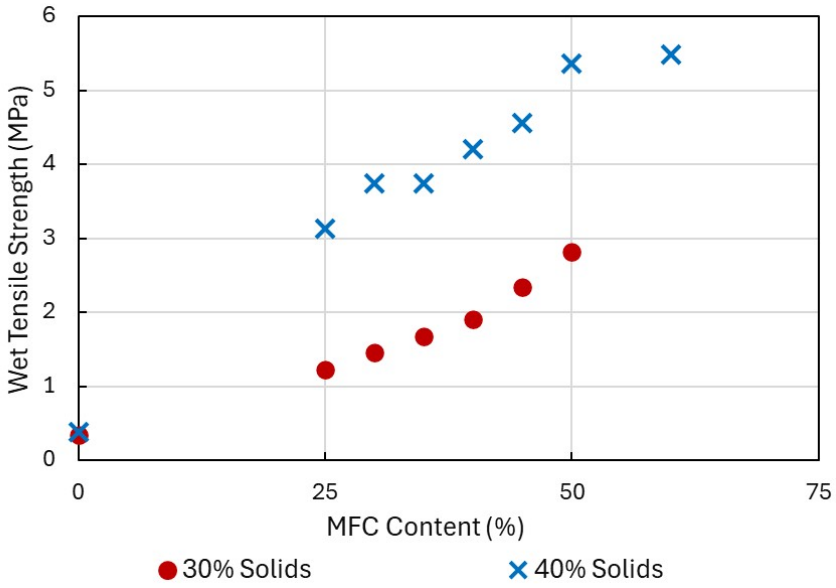
5% MFC

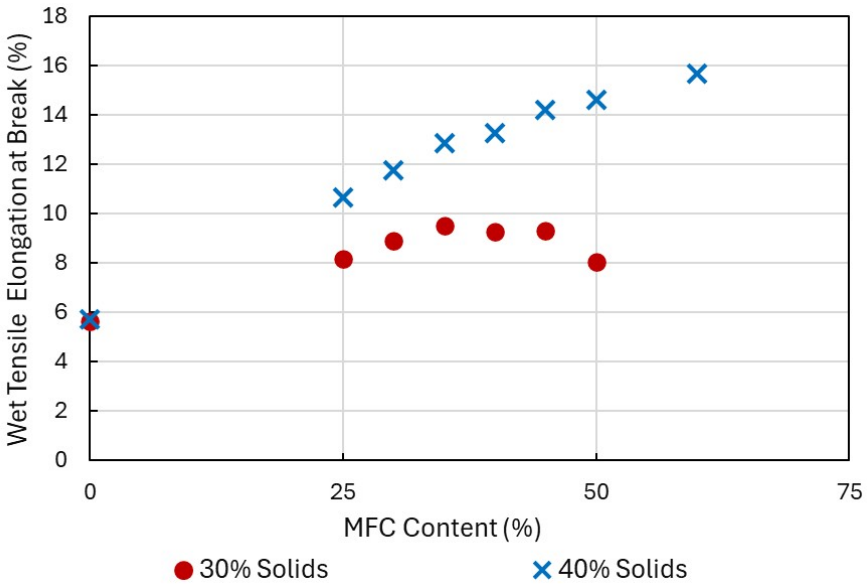
Improved Formation

Property	Performance
Article weight	-15%
Density	+16%
Gurley porosity	+1250%
PPS Roughness	-5.50%
Scott Bond	+120%
Tear strength	+96%
Tensile stiffness	+15%
SCT	+13%

- **Most properties improved** with addition of MFC.
- An increase in cycle time was observed with the addition of MFC at a constant article weight, but this was offset by lightweighting.

MFC in Furnish: Base Paper I – Wet Sheet Properties

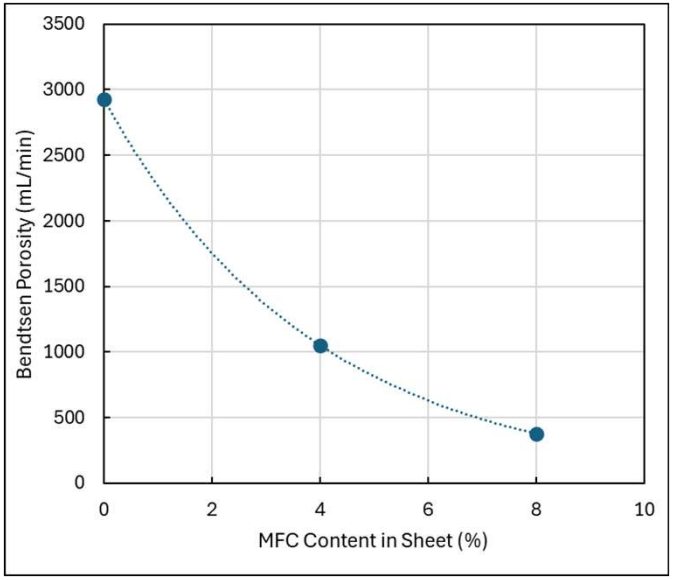


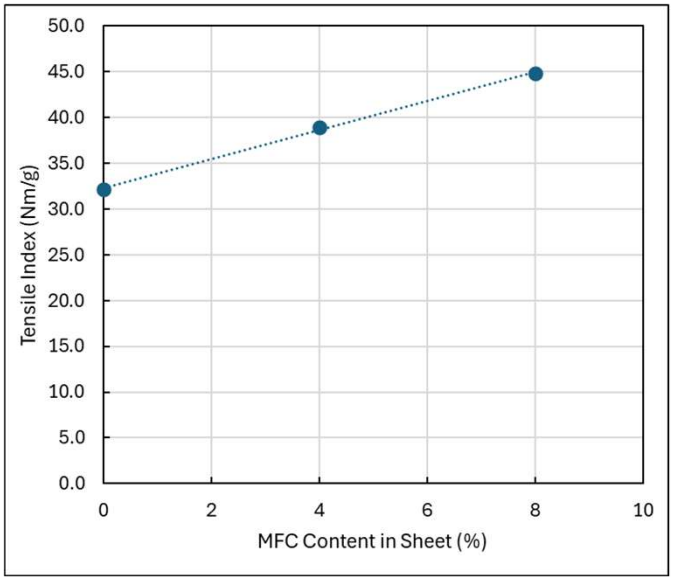


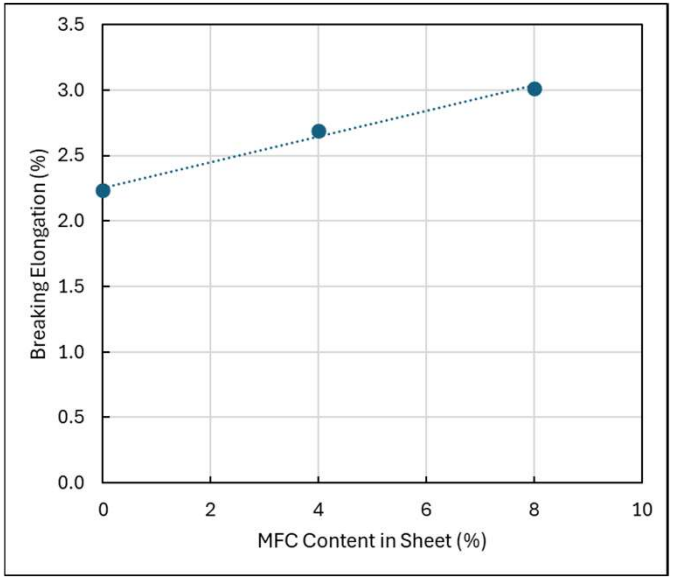
Increased wet tensile strength and **breaking elongation** with MFC addition

Tested on 225 gsm handsheets in a NBSK furnish with MFC contents varying from 0% to 60%. Sheets measured after pressing but before drying.

MFC in Furnish: Base Paper II – Dry Sheet Properties





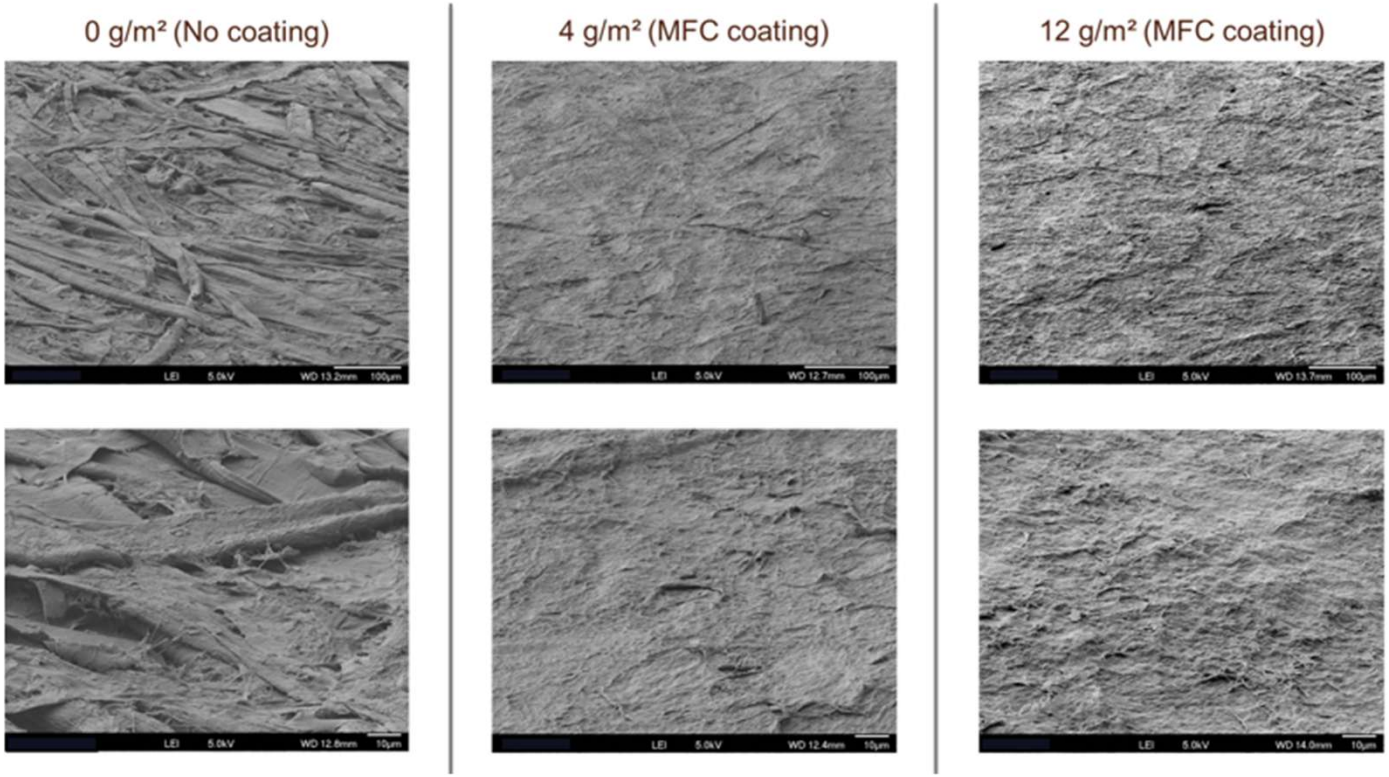


Reduced porosity and increased dry tensile index and breaking elongation with MFC addition

MFC offers opportunities to prepare light weight, flexible, low porosity base papers

MFC as a Coating: Wet-end Coating I

Scanning Electron Microscope (SEM) Images of MFC coated papers (lab data)

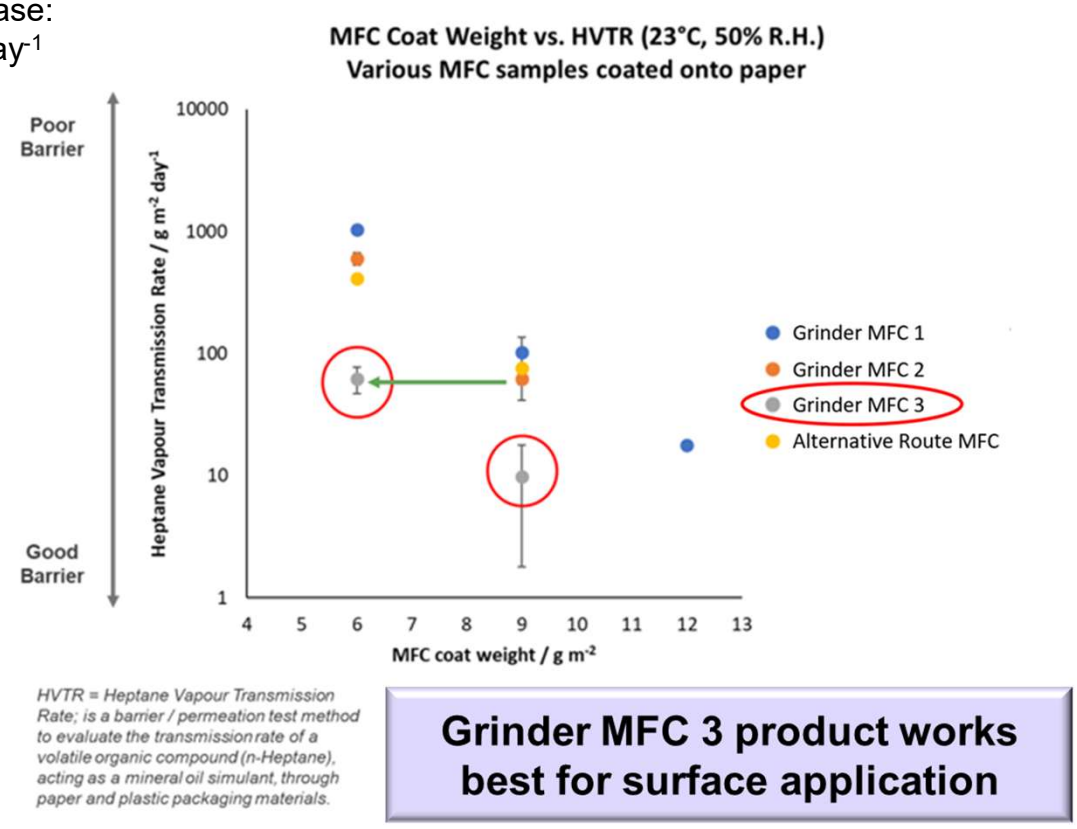


- The lowest coat weight, 4 g/m² provided substantial changes to the surface topography and structure.
- By 12 g/m², the MFC has formed a film and reached sufficient thickness to achieve high barrier properties.

The effect of pre-treatment and process conditions on the gas barrier properties of fibrillated cellulose films and coatings: A review, Hill et al, Carbohydrate polymers 337 (2024) 122085

MFC Applications: Example 3 – Surface Application

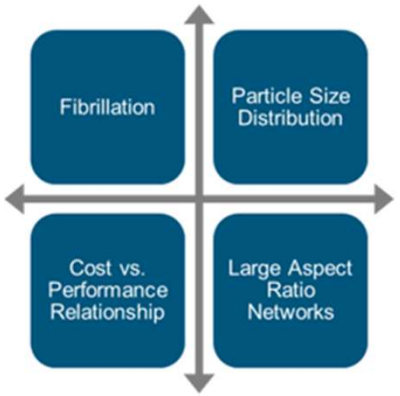
Uncoated base:
2300 $gm^{-2}day^{-1}$



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.

Grinder MFC 3 product works best for surface application

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

MFC as a Coating: Wet-end Coating III

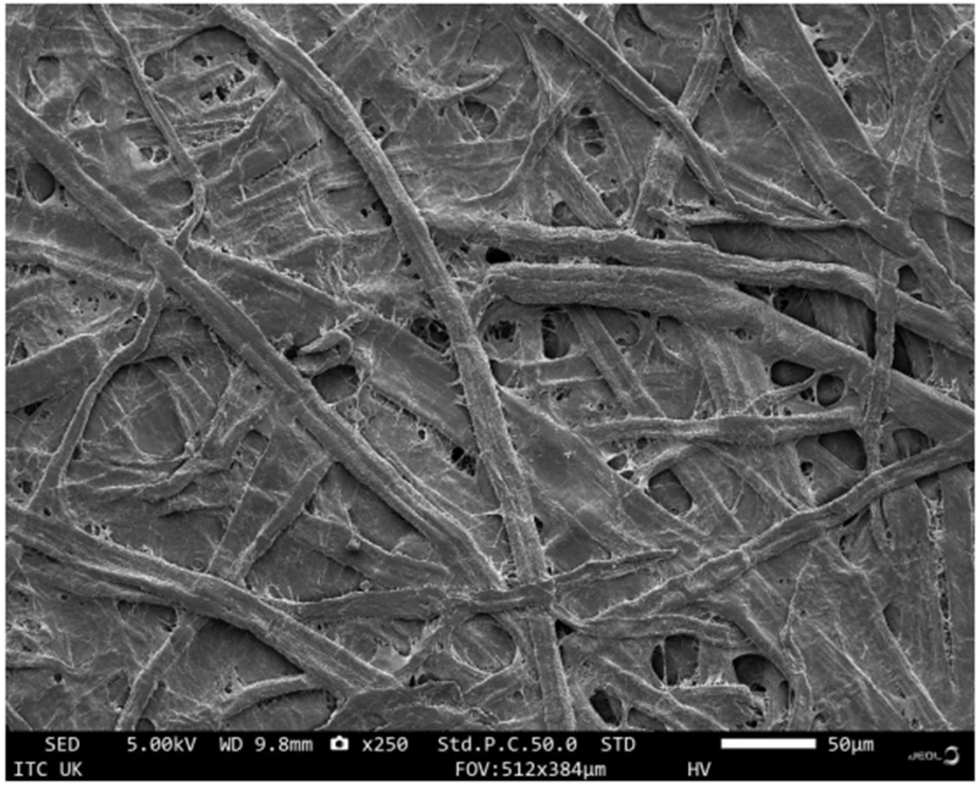
MFC is applied during the paper making process using surface applicator

Image: 3-meter wide surface applicator operating on a paper machine running at 500 m/min

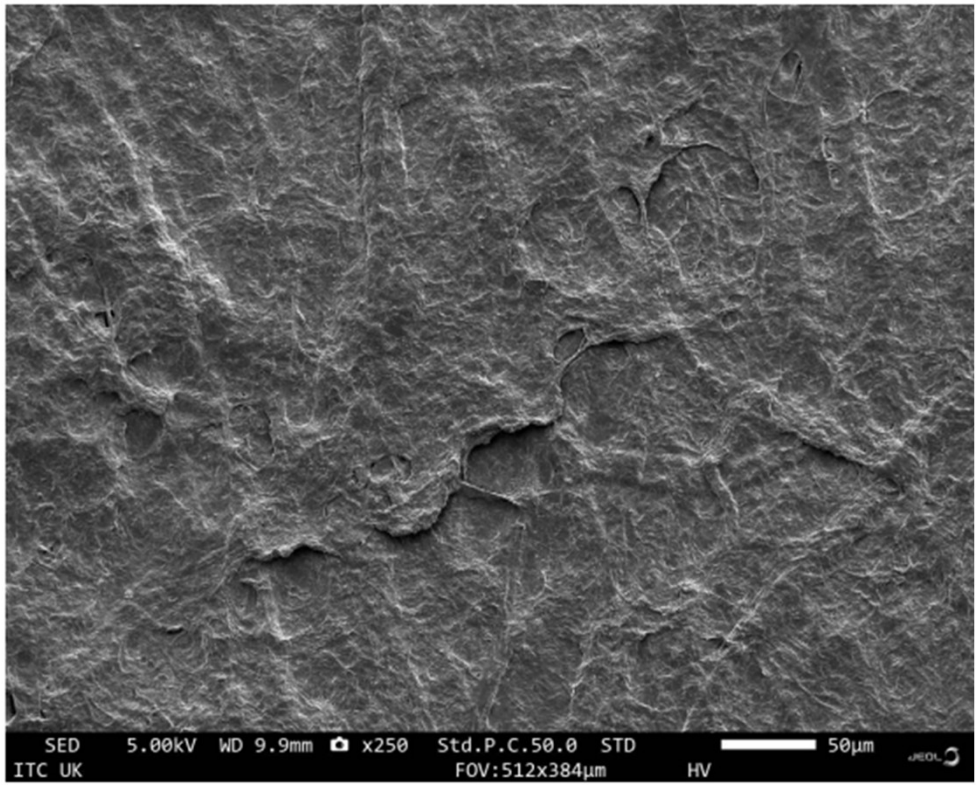
- Specifically designed for application of optimized MFC with jet speed similar to wire speed, i.e., at high-shear conditions. Gradual shear-thinning of MFC through the approach flow system and applicator with maintained laminar flow.
- Low cost and light weight, for easy mounting across paper machine.
- Working with a major coating equipment manufacturer to provide the engineering, fabrication and servicing of these applicators.

MFC as a Coating: Wet-end Coating IV

SEM – Surface imaging



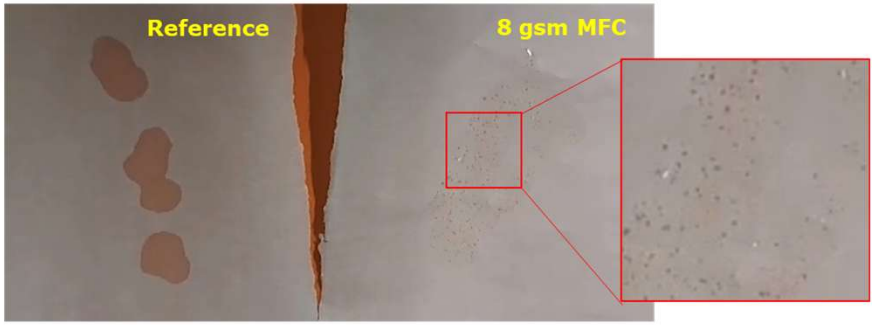
Base paper reference 45 g/m² (0 g/m² MFC)



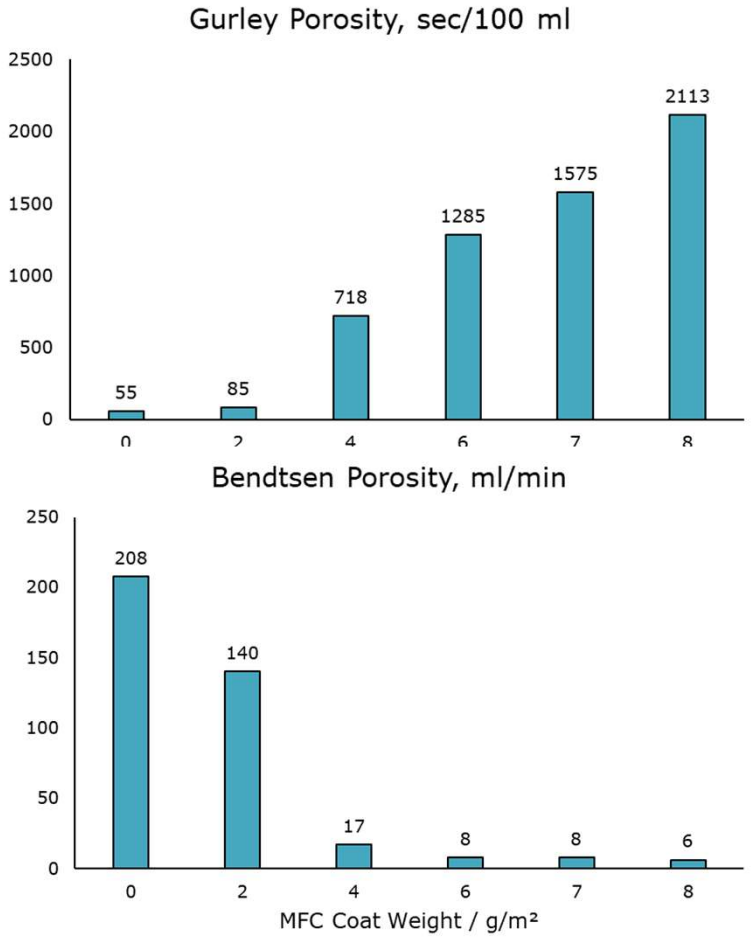
MFC coated paper 45 g/m² (+6 g/m² MFC)

MFC as a Coating: Wet-end Coating V

- Significant closure of the sheet was observed through the application of MFC.
- Pinholes were visible in oil draw down tests, so the surface was not yet “completely closed” to a point where barrier properties could be achieved.
- Nonetheless, the significantly lower permeability should enable improved performance of topcoats applied or enable a reduction in topcoat weight to achieve a target performance.
- **Post trial addition of starch coating by customers resulted in chemical free-mid level grease resistant paper for fast food wrap.**



8 gsm MFC (Day 1) – Droplet test with Oleic Acid during trial.



Summary

- Vertical wet stirred media mill grinders are an efficient and high throughput method for producing MFC.
- Implementation of these grinders is well established.
- The resultant MFC has:
  - High levels of surface micro and nano fibrillation whilst maintaining a coarse macrostructure.
  - Broad food contact clearance, is not a nano-material according to US EPA and EU definitions and no observed negative health effects.
  - Recyclable, biodegradable and compostable.
- Use of MFC from these grinders allows lighter products, reducing transport related emissions and supports recyclability and the circular economy by enabling plastic replacement in packaging.
- Use of MFC in paper and board leads to enhanced mechanical properties and reduced porosity sheets. Hence, offers opportunities for considerable cost savings in many specialty paper and board segments.
- Use of MFC “in” paper sheets offers opportunities for lightweighting and property improvement, in particular porosity reduction. For example, in moulded object and barrier base applications.
- Use of MFC coated “on ” paper surfaces as a primer/ pre-coat or barrier layer allows preparation of significantly lower porosity sheets that display grease barrier properties.

FiberLean
Strength by Design

Thank you for your attention

david.skuse@fiberlean.com

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