Producing Microfibrillated Cellulose using a Stirred Media Mill Grinder

Lewis Taylor, Chris Bonds, David Skuse

FiberLean Technologies

Presented by: Lewis Taylor

Outline

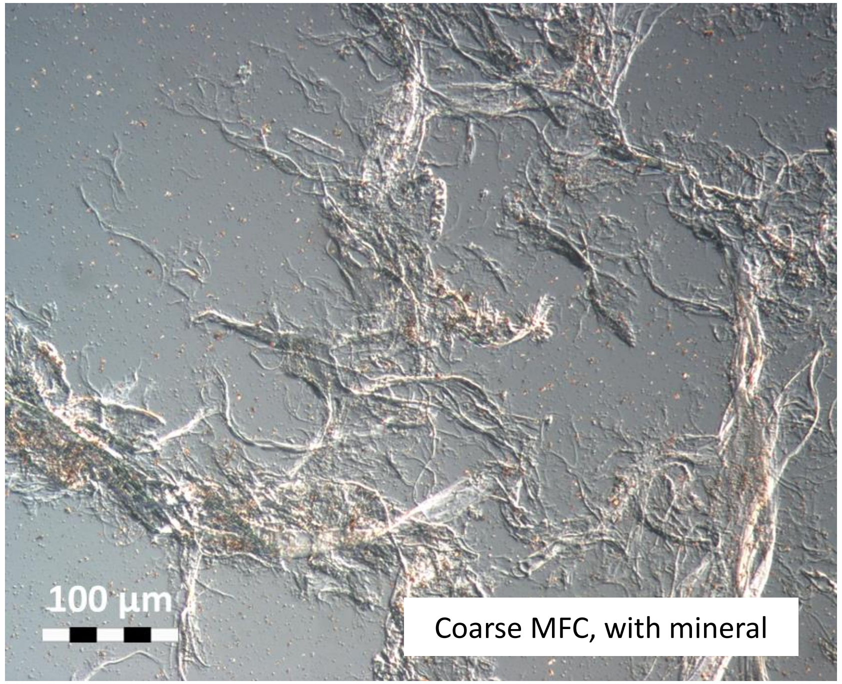
- Introduction
- Applications of MFC
- Stirred media mills
- Product characterisation
- Influence on particle size and fibrillation
- Optimisation for various fibre substrates

Introduction

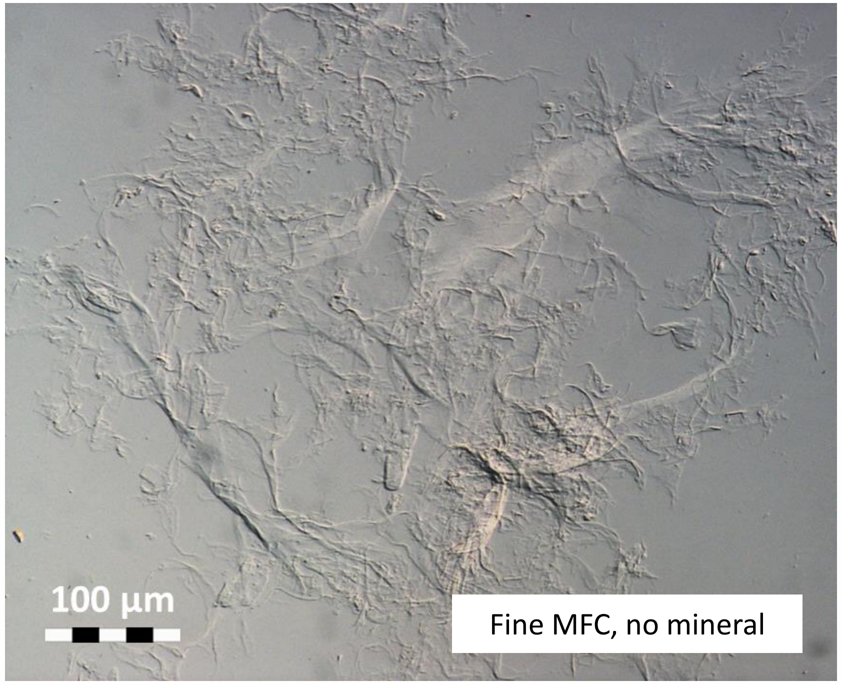
- **MFC** – produced by **mechanical treatment** of cellulose
- Highly viscous aqueous suspension
- Typically **satellite production** adjacent to final use location
- **Continuously produced at large scale using stirred media mills**
- **Flexible process enables a wide variety of product characteristics**

Product families

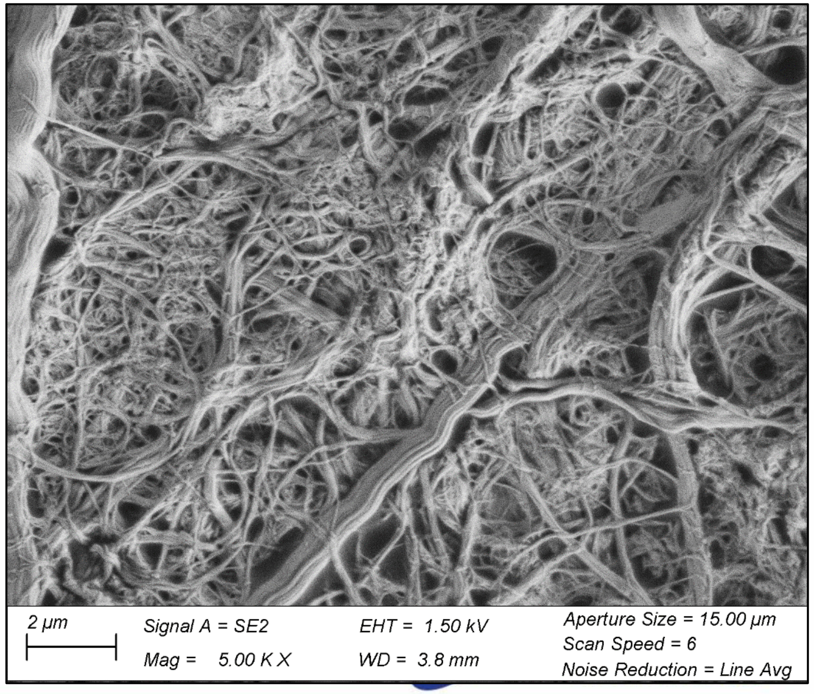
- **MFC from 100% virgin pulp**
- **MFC from recycled fibres**
- **MFC mineral composites**
- **NB Two of these families have no added minerals. MFC only**



Coarse MFC, with mineral



Fine MFC, no mineral



Pilot-Plant Production Facility, and Product Forms

Production plant in the UK, **2000 dry metric tonnes pa of fibril capacity**. Operational since Q4 2013: **Slurry** (< 2% fibre solids) and **press-cake** (10 – 20% fibre solids) product forms

Slurry

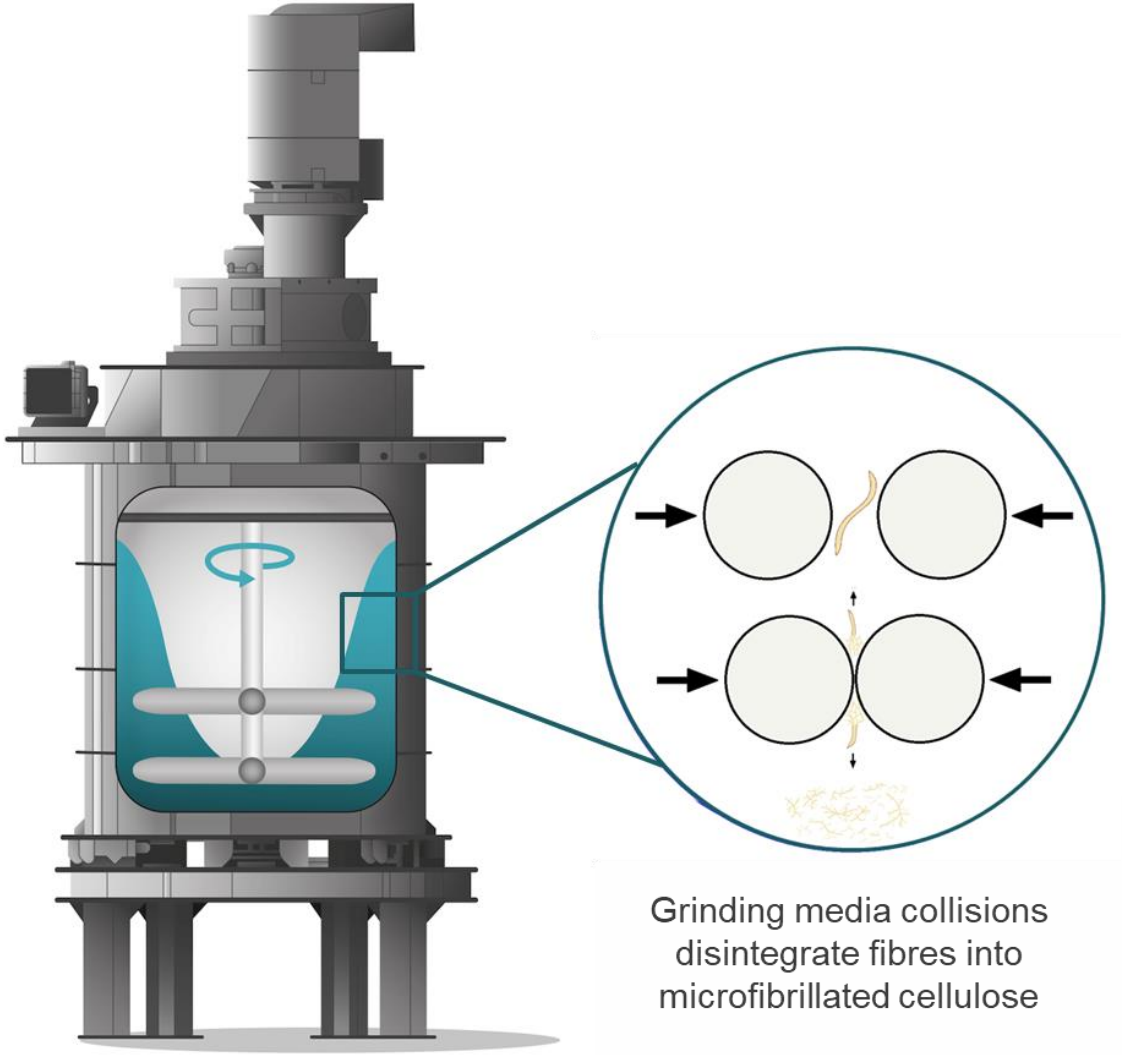
Press cake

MFC Applications

The strengthening and viscosifying properties of MFC have shown benefits in applications such as:

- **Paper and board** – generally improved mechanical properties, increased filler, softwood replacement, lightweighting, new products and grade development.
- **White top liner:**
  - – Improved optical properties from formation and filler increase, significant reduction in fibre use.
  - – Wet-end coating of MFC to upgrade brown boxboard to WTL with minimal capex.
- **Barriers** – MFC forms a barrier layer which greatly improves oil and grease resistance and oxygen barrier properties for food packaging, is a recyclable and compostable alternative to PFAS.
- **Specialty papers** – various (e.g. low porosity improves coating holdout in thermal papers; significant increases in wet web strength enables low GSM papers on machines configured for much higher GSM).
- **Construction materials** – binders in furniture (MDF, particle boards, substitutes), ceiling tiles.
- **Agriculture** – in fruit coatings to delay ripening and increase shelf life / reduce food waste.
- **Rheological additives** – highly shear-thinning, robust to pH / salt / degradation.

Stirred Media Mills – Introduction



- ***Stirred vessel***, where ***collisions between grinding media beads*** break intervening particles.
- Widely used in minerals and mining industry due to efficiency, scale, and flexibility.
- We have adapted this technology to ***break and fibrillate fibres into MFC***; requires modifying theory and operating principles.
- ***Very high active surface area*** of media and ***inherent scalability of stirred vessels*** permits ***high throughput*** and ***continuous production*** of MFC.

Stirred Media Mills – Advantages

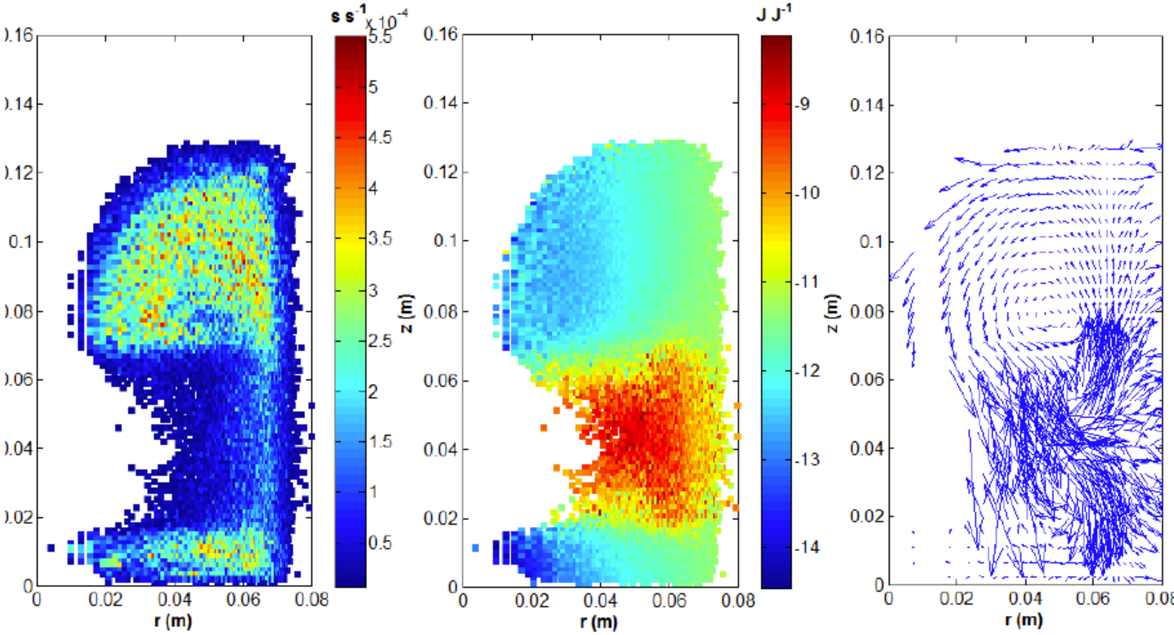
For large-scale MFC production, stirred mills confer many benefits:

Video of Grinder

- **Robust technology, operational since 1950s for minerals processing, since 2013 for MFC**
- **No close tolerances or precision engineered components**
- **Continuous single stage process**
- **Availability > 95%**
- **Low capital and running costs**
- **High throughput in a small footprint (typically >1000 dry tonnes / annum per grinder)**
- **Modular easily-scalable design**
- **No additives or pre-treatments**
- **Flexibility in tailoring MFC properties**

Stirred Media Mills – Optimisation

- Unlike minerals processing, where minimising particle size is usually the goal, effective MFC production requires ***high surface area generation whilst maintaining fibril aspect ratios***.
- Stirred mills are ***conceptually simple***, though ***optimising is complex*** due to the number of parameters (charge formulation, grinding media properties, machine operation parameters, grinder geometry); a purely empirical approach is not sensible.
- Effective optimisation requires the following:
  1. An ***intimate understanding of the feed fibre properties*** (i.e. what forces are required for breakage and fibrillation).
  2. Tailoring the ***type, frequency and magnitude, of forces*** applied by the media to the fibres.
  3. Modifying the energy distribution within the vessel by ***controlling flow patterns***.
- Stirred mills have the key advantage that the ***strength of forces can be varied by many orders of magnitude with little to no equipment modifications.***



PEPT tracking *of a lab-scale grinder – (left) occupancy, (middle) kinetic energy distribution, (right) velocity vectors.*

Product Characterisation

- **Particle size and morphology analysis -** Microscopy, fibre analysers, laser diffraction
- **Viscosity / rheology -** Over a range of shear conditions
- **Permeability and drainage**
- **In-application testing**
- **Mechanical properties** – "**FLT**" – (FiberLean Tensile) strength test (hereafter referred to as ***high loading tensile index***) - Good correlation with in-application mechanical properties.

Particle size alone is not sufficient to characterise MFC performance.

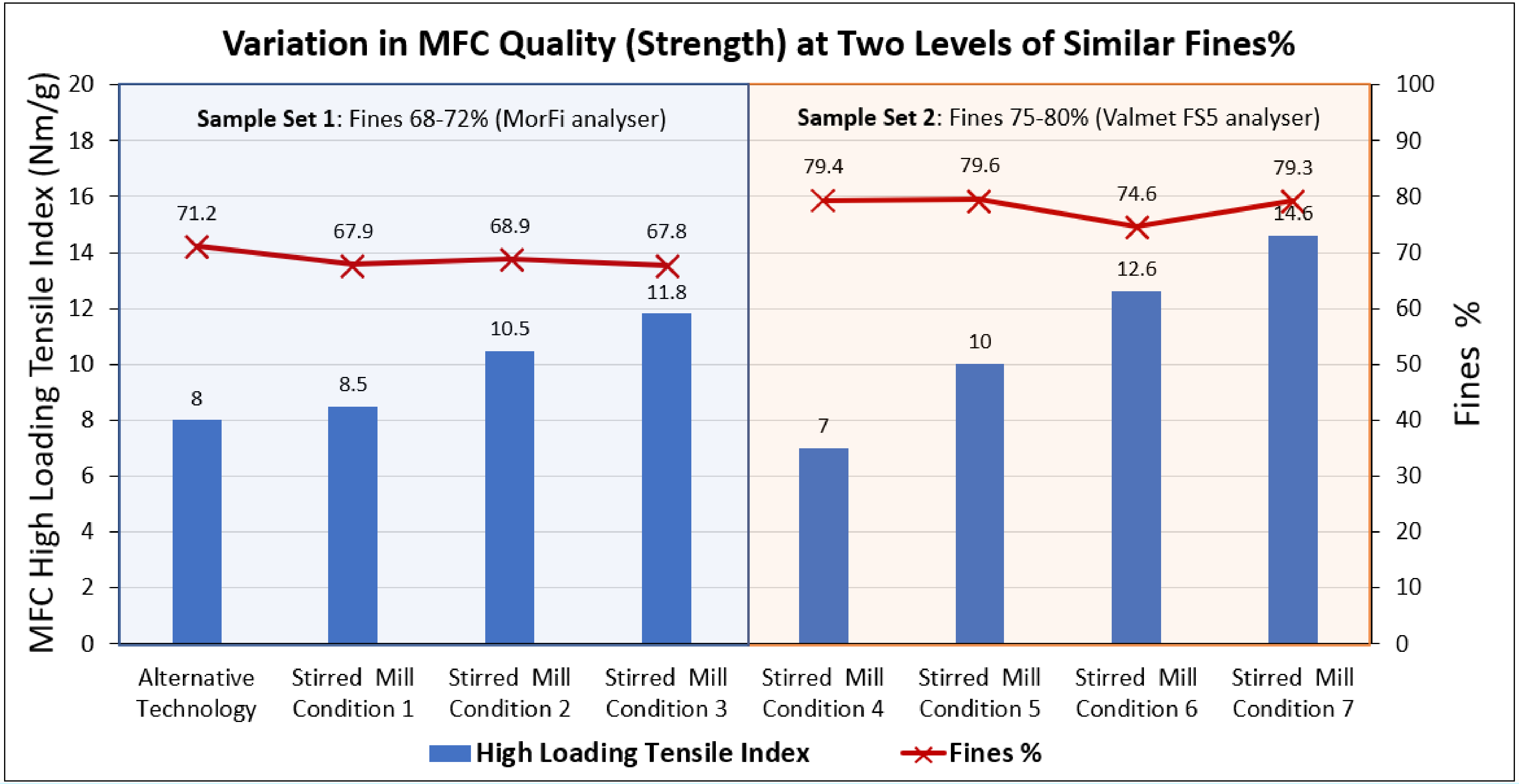
A test of performance is also required

High Loading Tensile Index

- Since ***particle size alone*** (e.g. laser diffraction d_{50}, Fines%) ***says nothing about the extent of fibrillation or quality of fibrils***, we instead use such measurements largely to aid understanding of the process, and for process control and diagnostics.
- Many MFC applications rely on the ***bonding ability of the MFC***; measuring a proxy for this can be expected to correlate more generally with performance.
- The high loading tensile index test does this using a direct measurement of the ***tensile strength of an MFC - mineral film.***
  - A sheet of 100% MFC will be so heavily bonded that the sheet will largely fail by breakage of fibril cross-sections (i.e. zero-span strength) rather than bonding failure.
  - Therefore, the ***high loading tensile index test is performed at extreme mineral loadings*** (many times more mineral than fibre) to greatly weaken sheet bonding, thereby ***forcing bonding failure*** to be the dominant failure mechanism.
- Such a measurement gives a ***good general correlation with performance*** in many applications, that is largely ***robust to changes in pulp type and processing conditions***.

Fibre Breakage and Fibrillation (i)

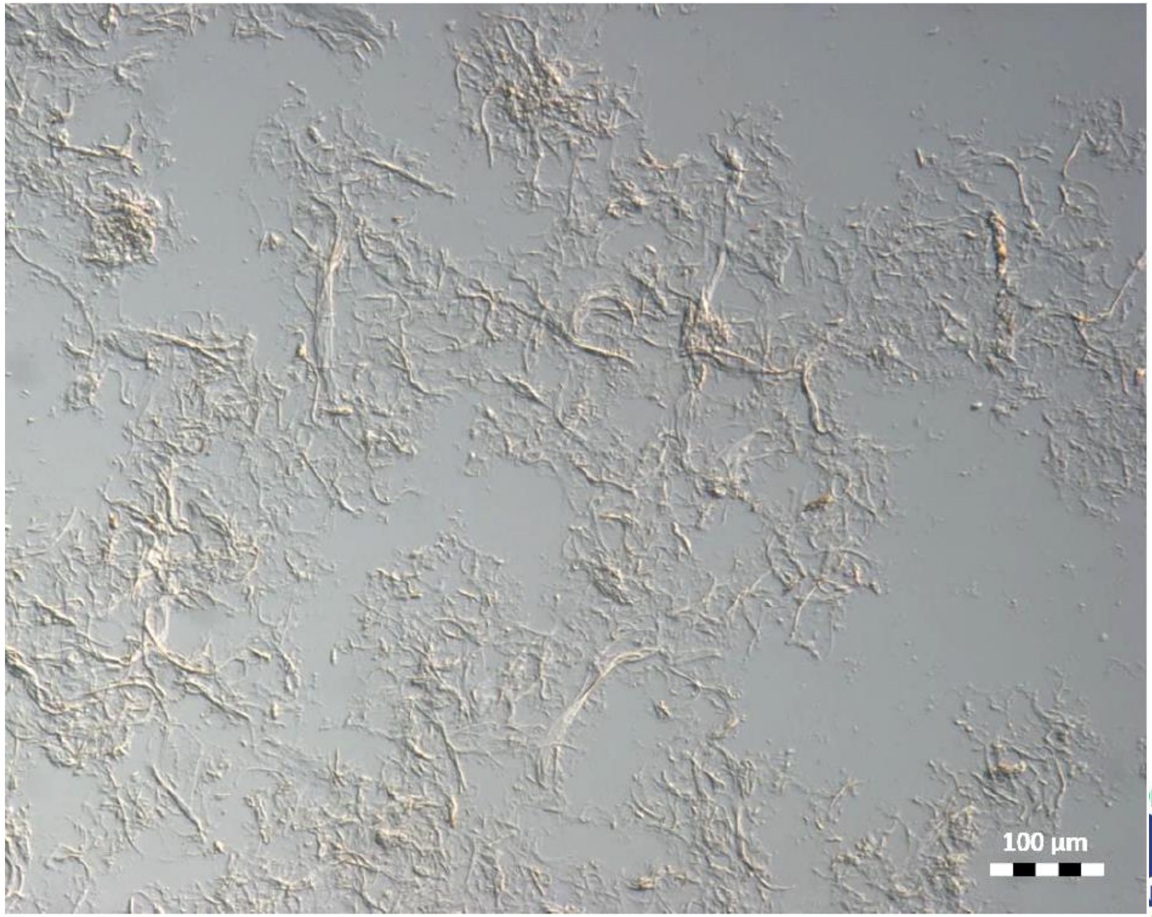
- Using a stirred media mill, parameters can be changed to ***decouple fibre breakage from fibrillation***, and control them independently based upon application requirements.



Fibre Breakage and Fibrillation (ii)

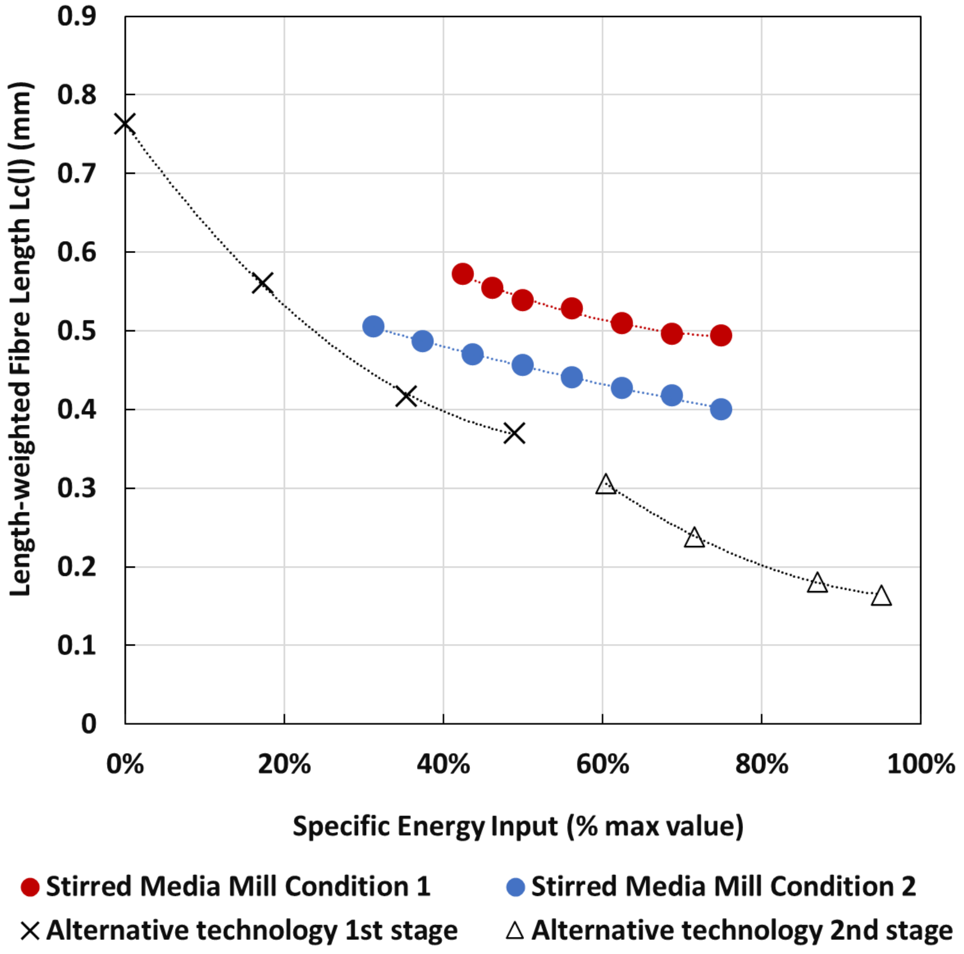
Very different product morphology possible with the same feedstock.

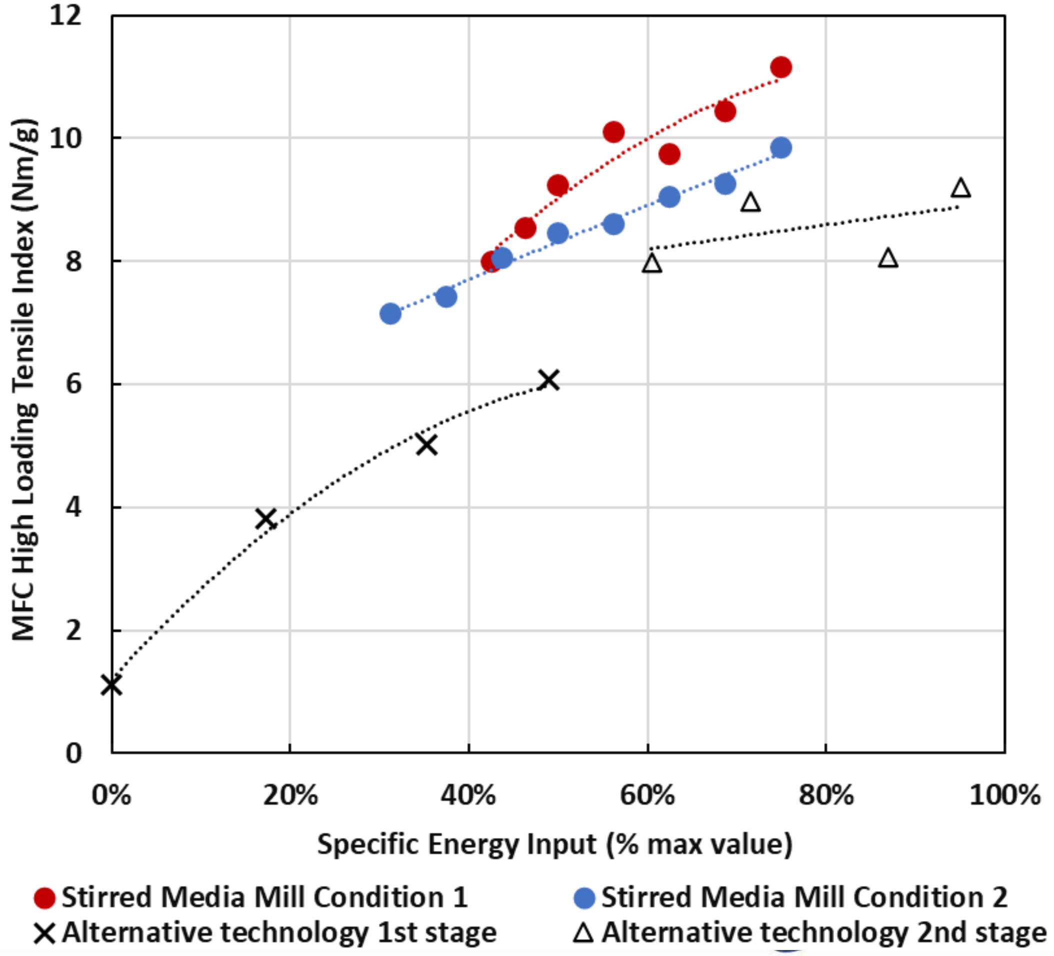
- Below have very different particle sizes, but similar high loading tensile index (bonding) values.



Performance / Energy Balance

Stirred media mills are economical at generating a highly fibrillated product compared to alternative technology, though tends to maintain larger particle dimensions.

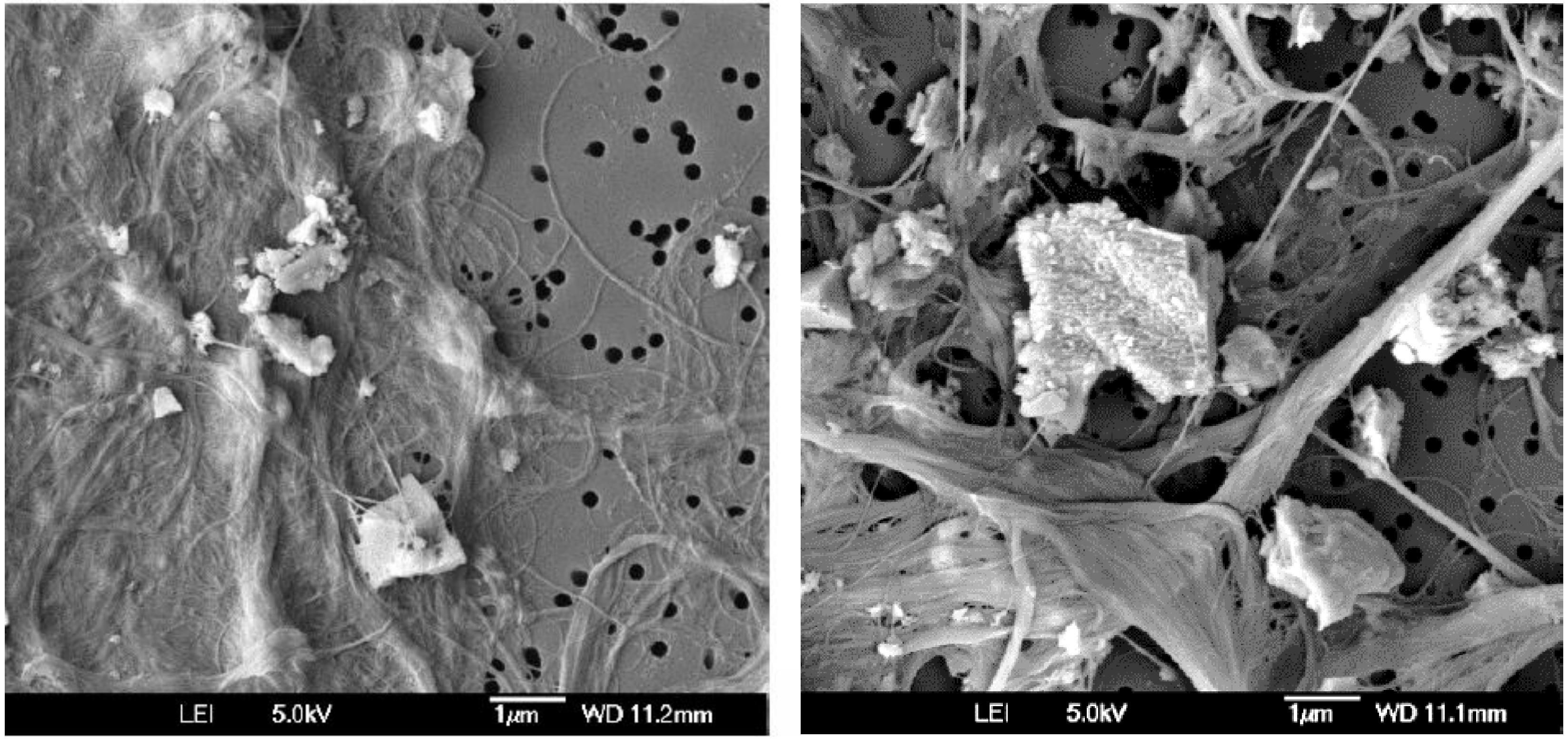




Optimisation for Fibre Substrate (i)

Fibre Hemicellulose Content

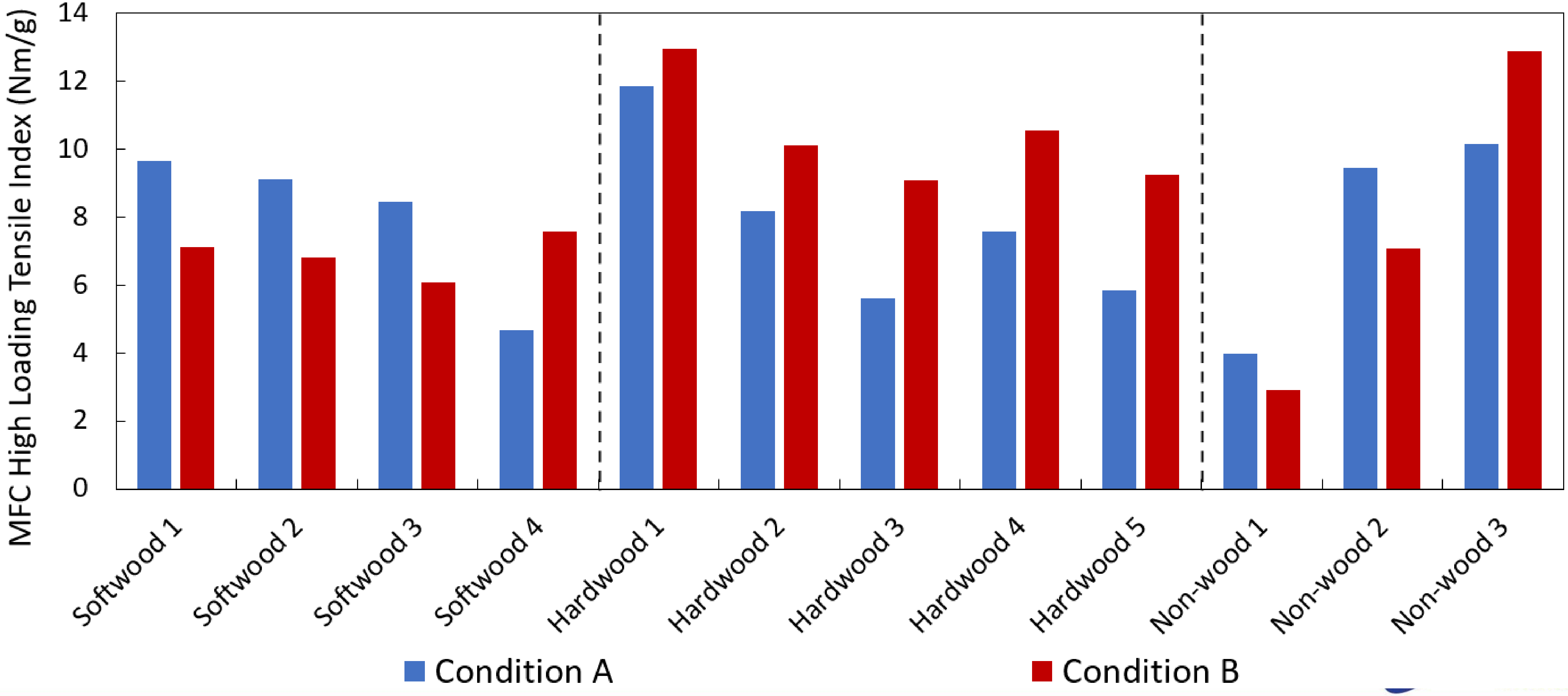
- Hemicellulose is a polysaccharide that forms a weak, amorphous layer ***spacing apart microfibrils***.
- All else being equal, a fibre with a ***high amount of hemicellulose*** more readily ***generates finer microfibrils***, improving bonding ability / high loading tensile index.
- Such fibre chemistry advises on suitable grinder operating conditions.



MFC – mineral composite *produced from fibres with* ***high hemicellulose content*** *(left) and* ***low hemicellulose content*** *(right)*

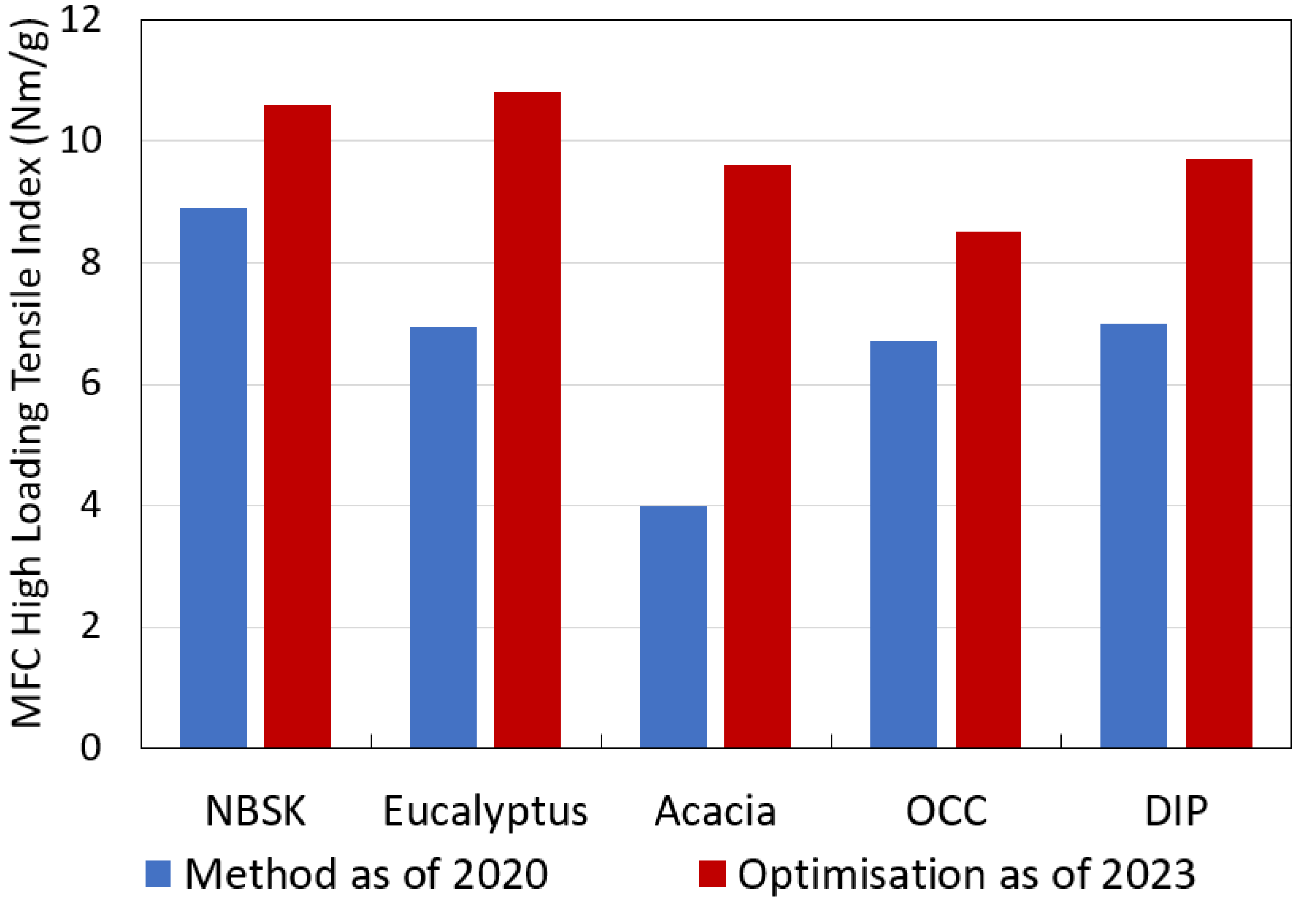
Optimisation for Fibre Substrate (ii)

Optimum conditions change based upon fibre type and properties



Improvements Since 2020

- Understanding how to adapt the process conditions based upon the properties of the feed fibres has:
  - ***Improved product quality*** at a given energy input.
  - ***Lowered the energy required*** to obtain a target quality.
  - Produced good quality MFC out of ***previously nonviable substrates.***
  - Enabled us to produce ***100% MFC products without requiring minerals*** as a co-grinding aid.



*MFC quality produced in **continuous mode** at **pilot scale** with various substrates. Specific energy input is maintained as constant.*

Conclusions

- ***MFC and mineral / MFC composites*** are produced from ***virgin and recycled pulps***, and are important additives for a wide range of paper, board, and other applications.
- Stirred media mills efficiently and continuously produce MFC at large scale.
- Their nature allows for effective ***decoupling of fibre breakage and fibrillation.***
- Stirred media mills are ***highly tuneable***, giving flexibility for a ***wide range of product characteristics*** depending on application need.
- Although ***conceptually simple***, they are ***complex to optimise***.
- ***Efficient optimisation requires an intimate understanding of the feedstock and process physics.***
- ***Several key fibre characteristics influence optimum operating conditions***, and adapting the process accordingly has yielded substantial efficiency and quality benefits.

Thanks for your attention

Any Questions / Comments?

Presented by:
Lewis Taylor
FiberLean Technologies
lewis.taylor@fiberlean.com