TECHNICAL SOLUTIONS TOWARDS AN INTEGRATED OPTIMIZATION OF ENERGY – FIBER FRACTIONATION

Stefan Radl, Thomas Schmid (Graz University of Technology)
Elvis Ahmetovic, Nidret Ibric (University of Tuzla)

Presented at: INTERNATIONAL CONFERENCE: NEXUS: ENERGY WATER & (BIO)INDUSTRY – TECHNOLOGICAL SOLUTIONS TOWARDS INDUSTRIAL RESOURCE EFFICIENCY. Jan 30th 2020, Vienna, Austria

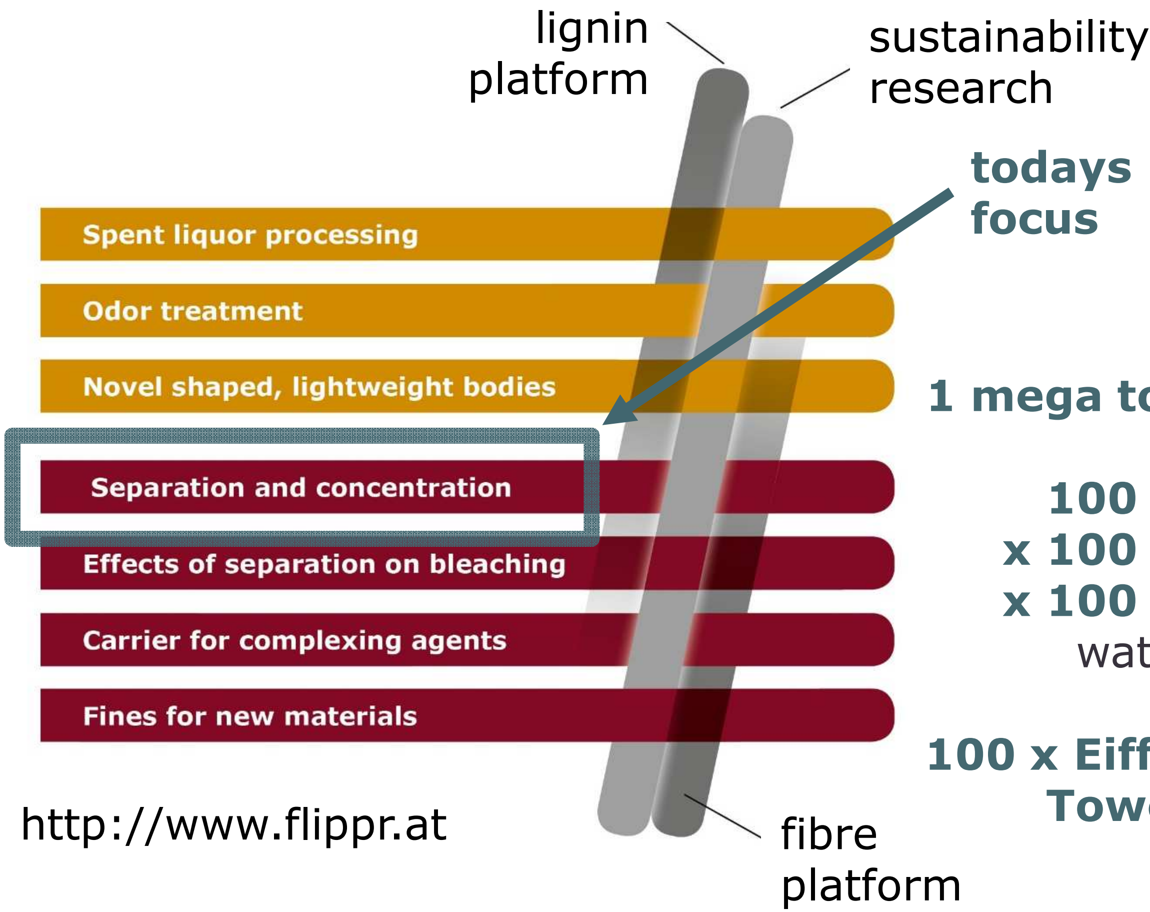
INTRODUCTION

A “**Pulp and Paper” biorefinery** for us means

1) **Extract & utilize lignin** from classical & **existing cooking processes**
2) **Fractionate** cellulose pulp into **fines and fibres**

Our Mission

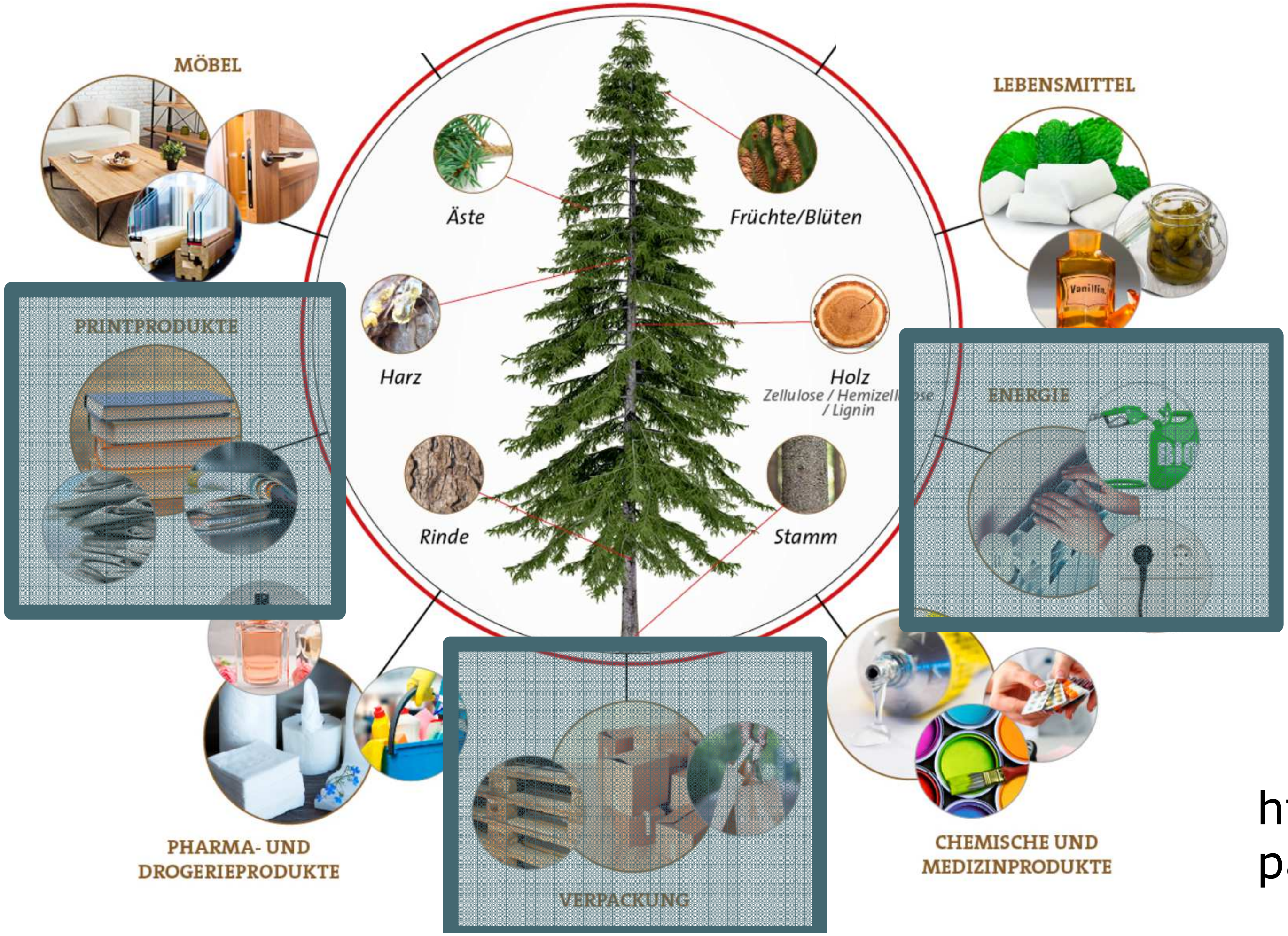
…more **added value from wood** on a **mega ton per year** scale



1 mega ton = **100 m x 100 m x 100 m** water = **100 x Eiffel Tower**

http://www.flippr.at

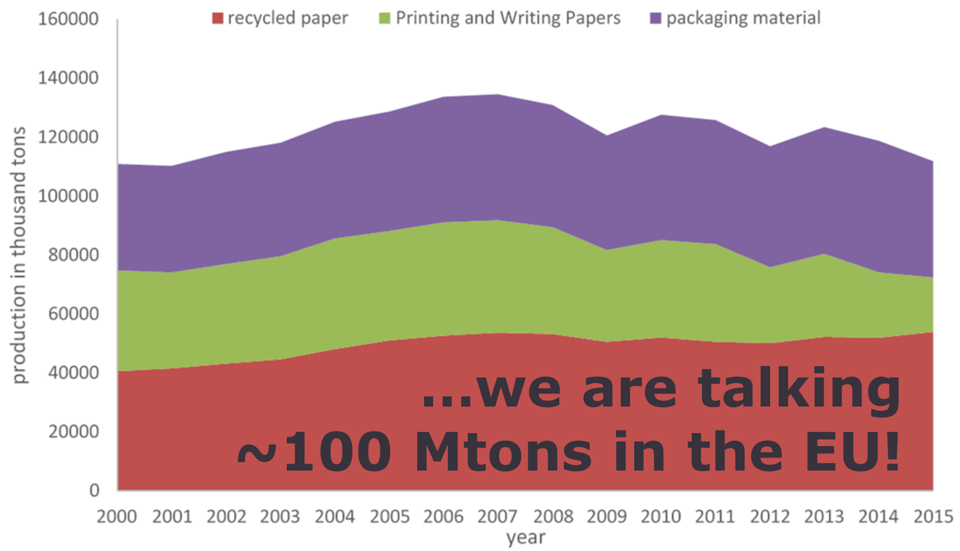
INTRODUCTION



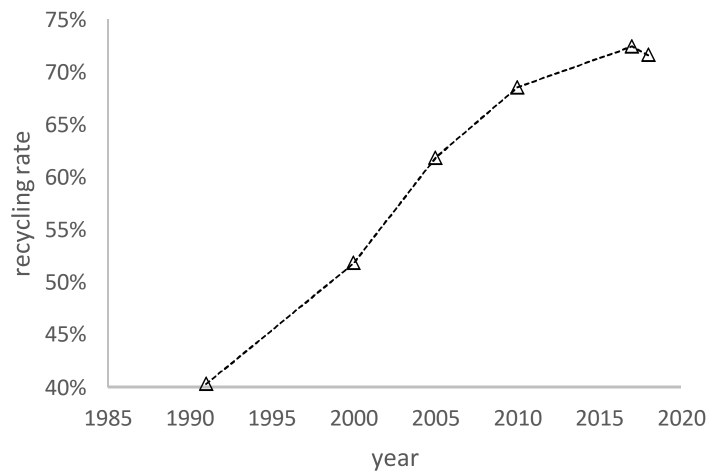
https://www.austropapier.at

MOTIVATION

- **Why fibre fractionation?**



EUROSTAT, Faser-und Zellstoffe, Papier und Karton (2018).

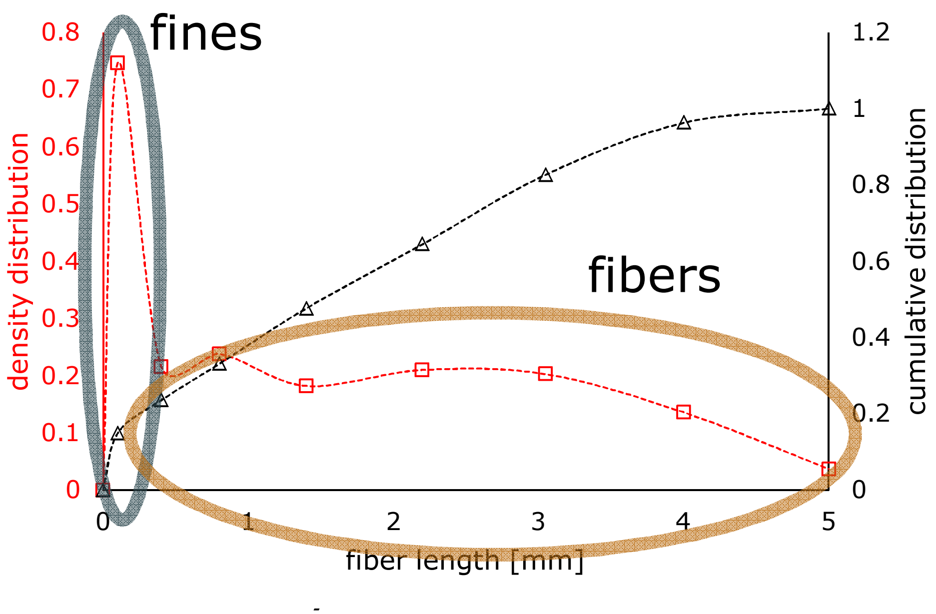


Key statistics European pulp & paper industry, CEPI (2018)

...increasing resource efficiency by a small percentage helps a lot!

MOTIVATION

Fiber length distribution of pulp



Fines

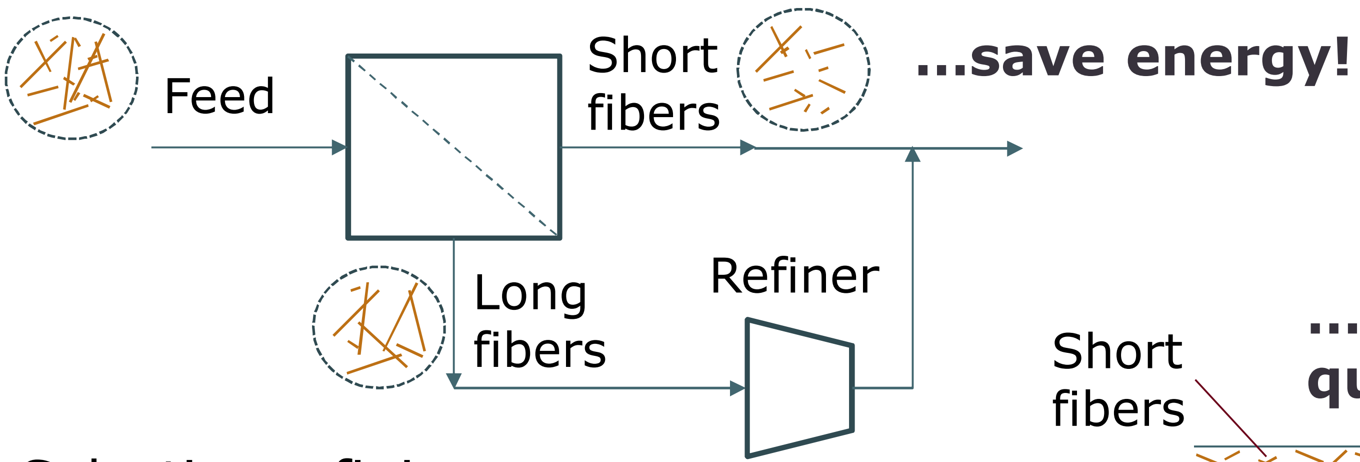
- Increase paper density
- Slow down dewatering
- Consume bleaching chemicals
- Low mass content VS high surface content

Fibers

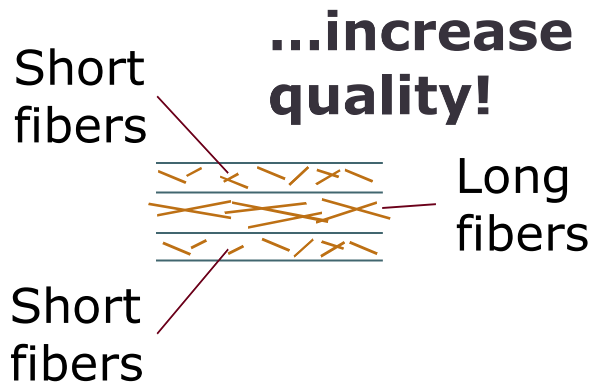
- Long fibers increase paper strength
- Must be flexibilised (refining)

MOTIVATION

State of the art fractionation concepts



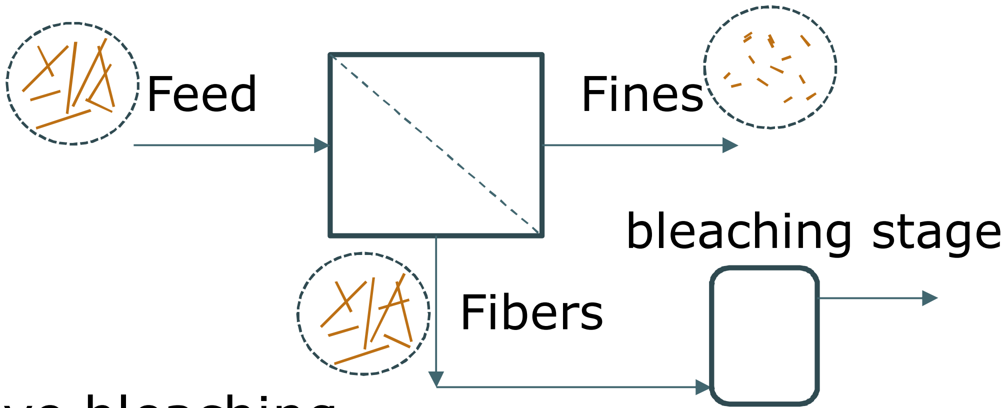
- Selective refining
- Multilayered paper
- Added value products



MOTIVATION

Advanced fractionation concepts

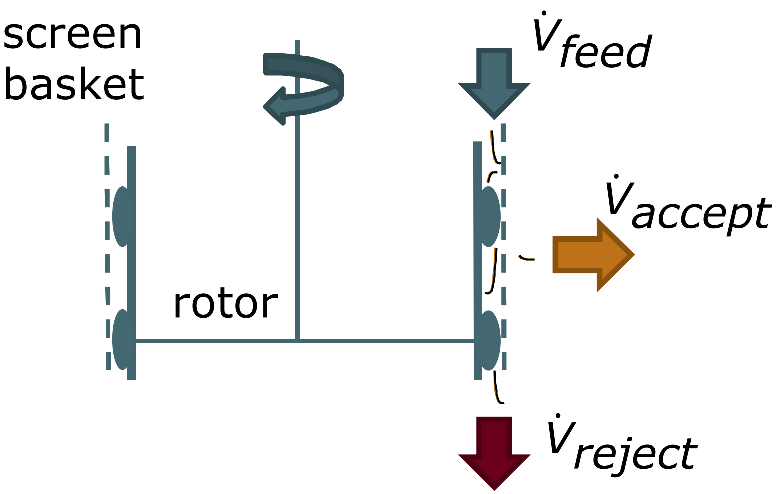
...save resources!

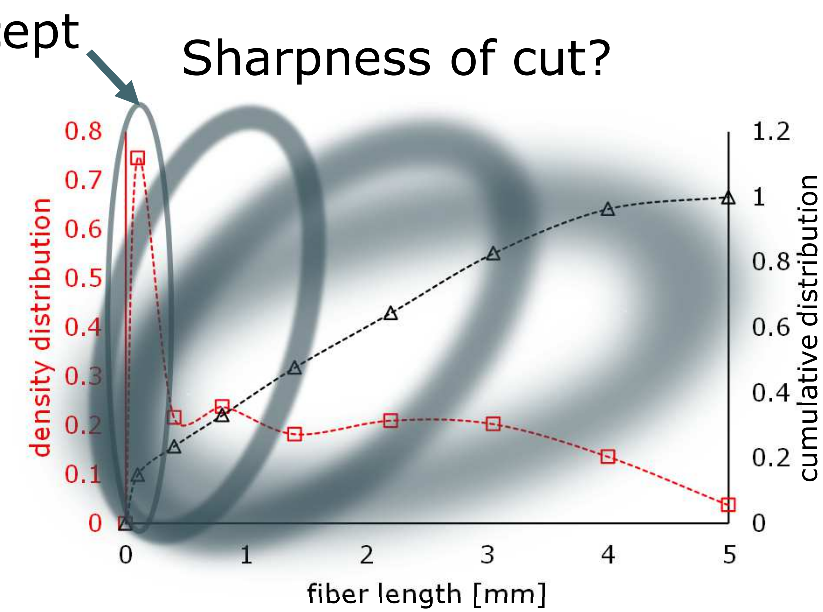


- Selective bleaching
- Fines for new products – “paper VS plastic”
- Process flexibility and control (e.g., for recycled pulp)

FRACTIONATION TECHNOLOGY

Pressure screen



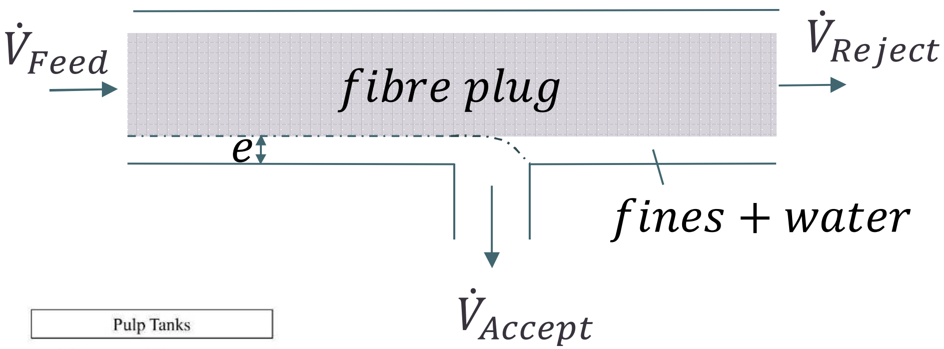


- **high** energy consumption for high selecticity - $P \sim u_{tip}^3$

Delfel et al., Appita 64(1), 2011

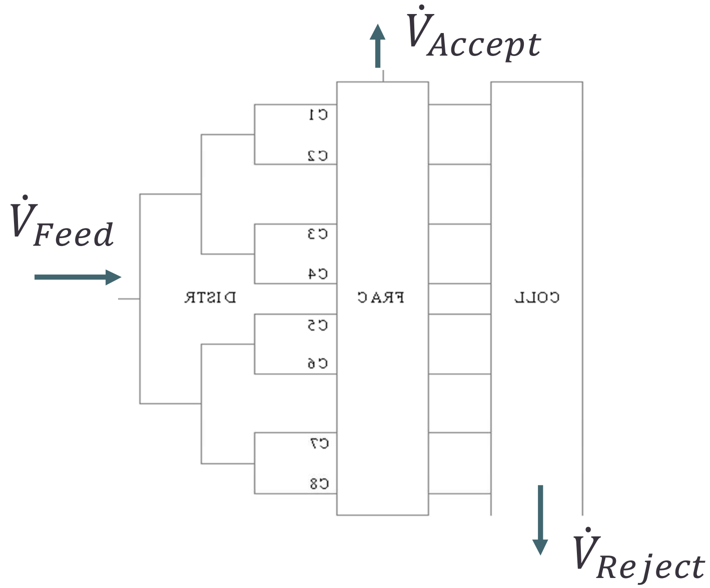
FRACTIONATION TECHNOLOGY

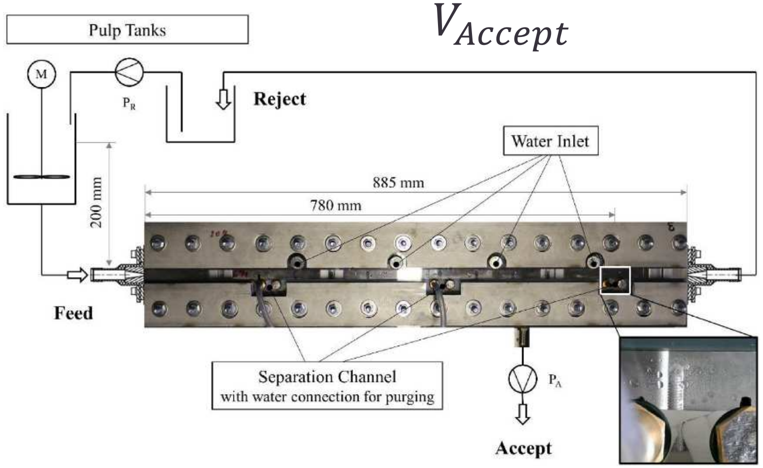
Hydrodynamic Fractionation - The Concept



Scale-up strategy

- Numbering-up of channels
- Multi-step design





Redlinger-Pohn et al., ChERD 126 (2017), 54–66

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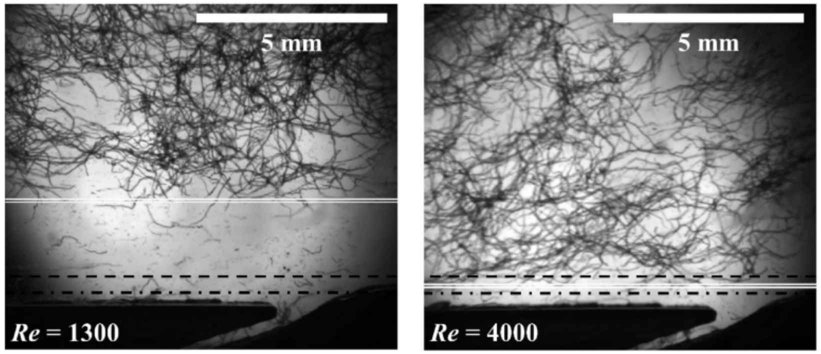
FRACTIONATION TECHNOLOGY

Hydrodynamic Fractionation

Redlinger-Pohn et al.,
ChERD 126 (2017), 54–66



Re ≈ 1,500 → C_{max} ≈ 0.1 [%]
high selectivity, but thirsty!

Re ≈ 4,000 → C_{max} ≈ 0.5 [%]
low selectivity and thirsty!

Re ≈ 1,500 → C_{max} ≈ 0.1 [%]

↓

- Number of channels ↑
- Apparatus Size ↑
- High production cost

↓

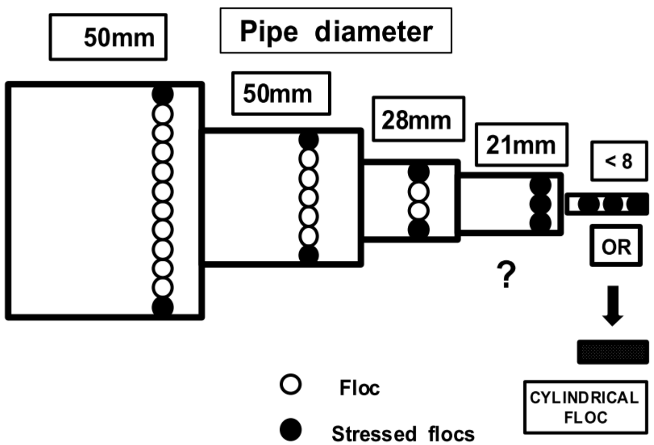
- Dilution / Thickening

↓

- **High water demand (extremly thirsty!)**

FRACTIONATION TECHNOLOGY

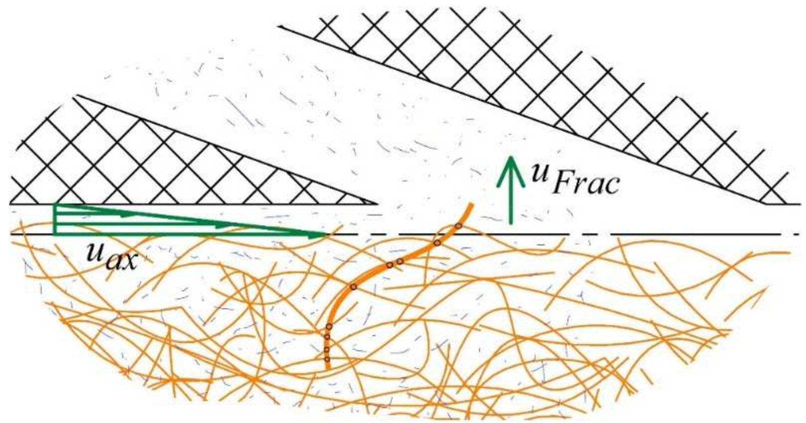
Hydrodynamic Fractionation in a mini-channel - *miniFRAC*



G.G. Duffy, L. Abdullah, Appita J. 56 (2003)

- Compressed, extruded floc
- Stable lubrication layer
- enables fractionation at higher flow speed

- **High selectivity for a wide operational window (C_{max}>1.0%)**



FRACTIONATION TECHNOLOGY

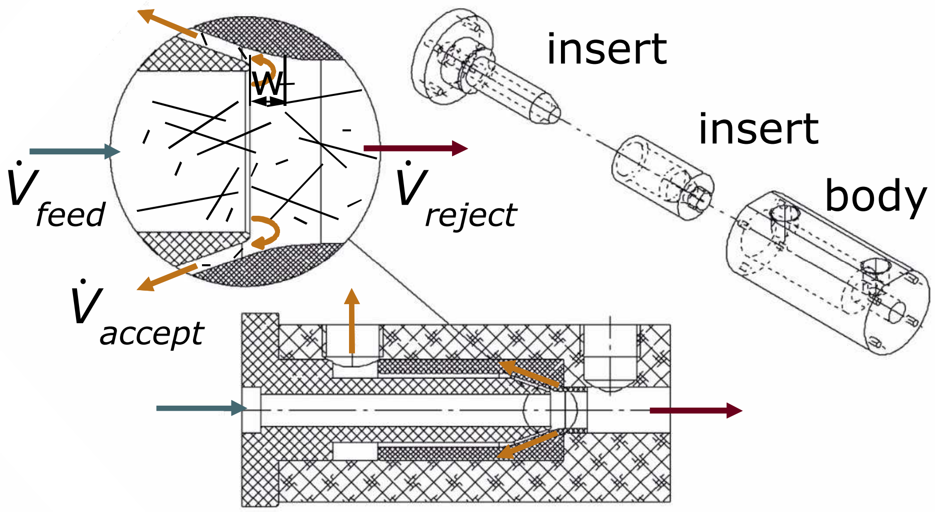
***miniFRAC* – water-energy nexus**

Schmid et al., Nord. Pulp Pap. Res. J. 34(2), 2019

- **no** rotating parts!
- **extremely low** energy consumption

$$P=\dot{V}_{feed}\Delta p;$$

- $\boldsymbol{\Delta p \approx \Delta p_{water}}$



✓ **Highly energy efficient**
✓ **Highly water efficient**

+

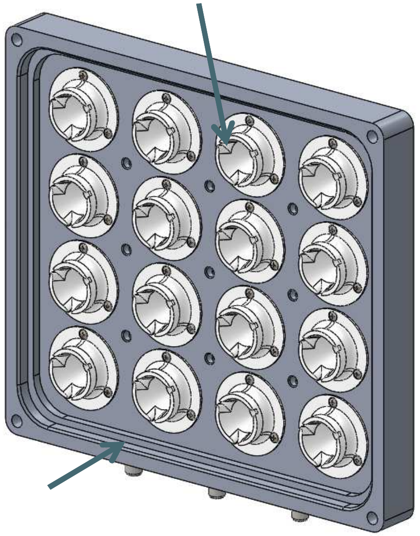
FRACTIONATION TECHNOLOGY

miniFRAC – from lab to industry

…demonstrated on pilot scale ***at typical industrial consistencies (>2%).***

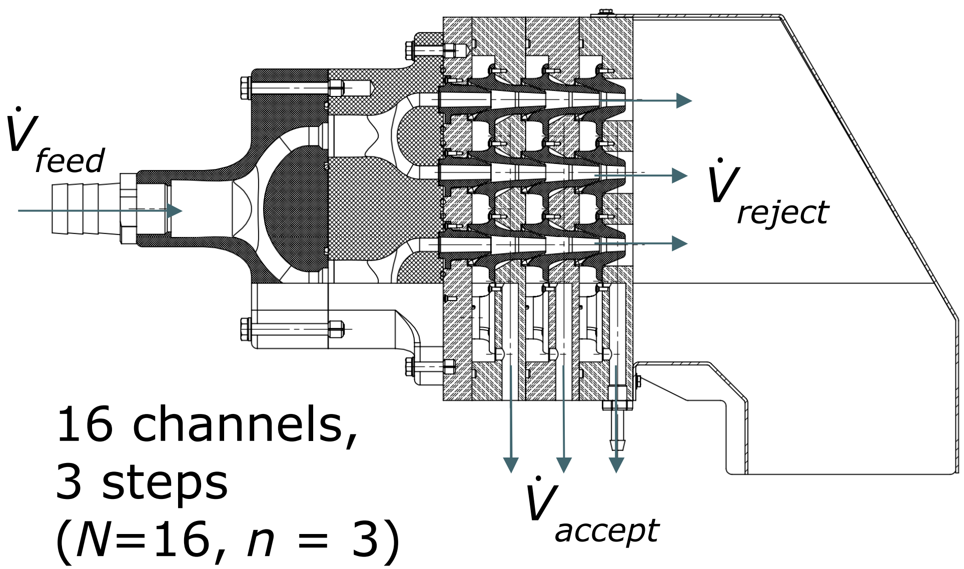
Numbering-up of channels

Insert
3D-printed: ABS
Injection molded: PP



Body
Machined: PP,
aluminum, etc.

Patent AT 521055 B1 2019-10-15



16 channels,
3 steps
(N=16, n = 3)

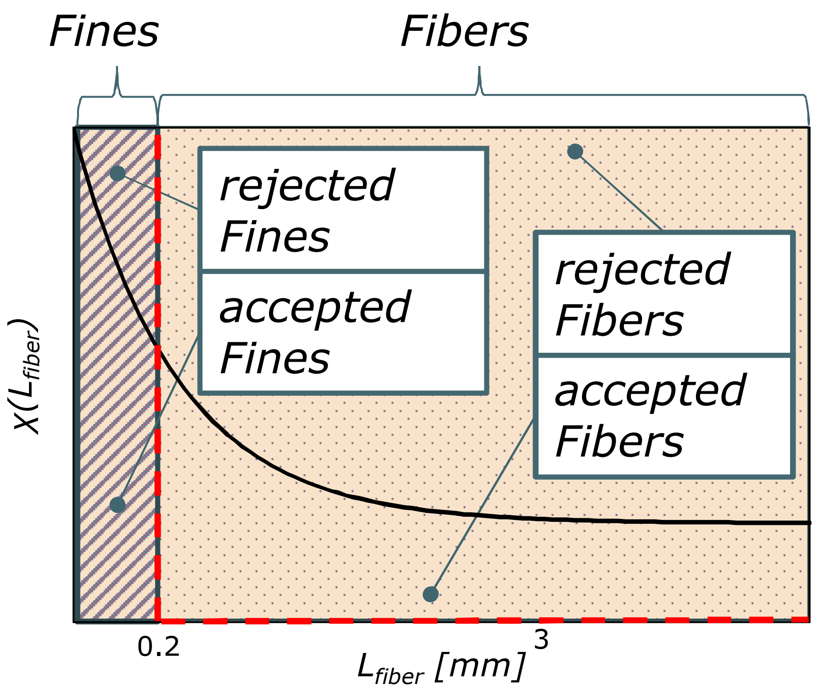
OPERATIONAL WINDOW

Fractionation efficiency

$$\chi(L_{fiber}) = \frac{\dot{m}_{Accept}(L_{fiber})}{\dot{m}_{Feed}(L_{fiber})}$$

$$0 < \chi(L_{fiber}) < 1$$

$\Longrightarrow$ relative mass of accepted fibers

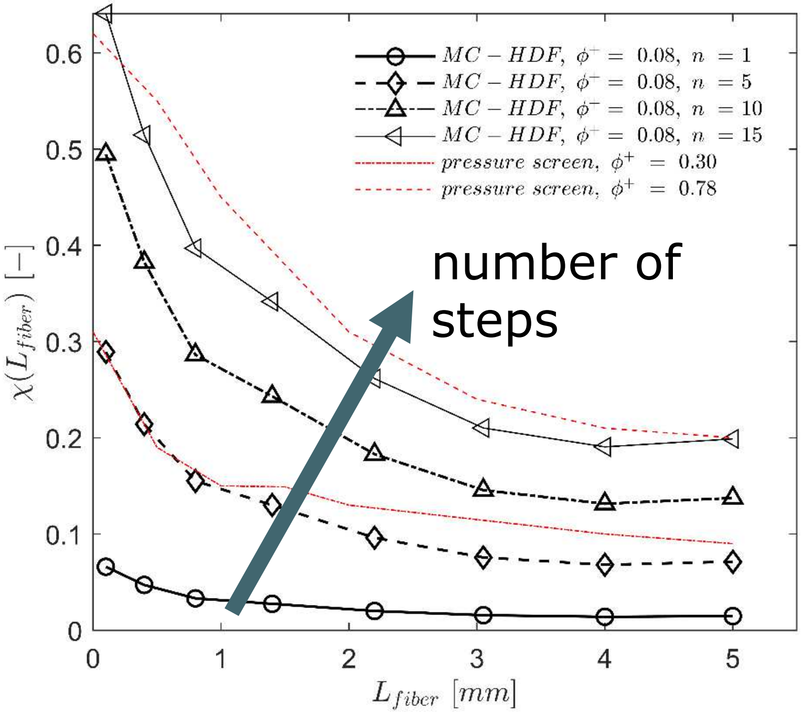


Ideal separation (step function)

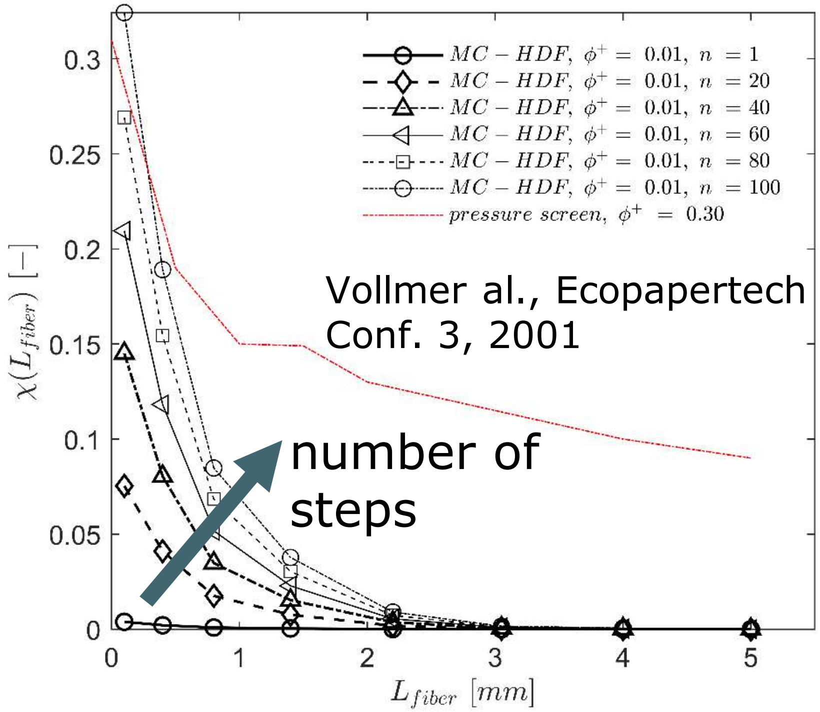
$\dot{m}_{Accept} = \dot{m}_{fines}$

OPERATIONAL WINDOW

State of the art fractionation



Highly selective fines fractionation



CONCLUSION 1/2

- ✓ miniFRAC closes gap between
  - "Energy efficiency dilemma" (pressure screen) and
  - "Water efficiency dilemma" (classical hydrodynamic fractionation)

- ✓ New possibilities for pulp & paper industry
  - Selective refining
  - Selective bleaching
  - Multilayered paper
  - Novel fiber based products
  - … many more

source: pixabay.com

- ➢ Adaption to further industries/applications (e.g., carbon fibre recycling)?

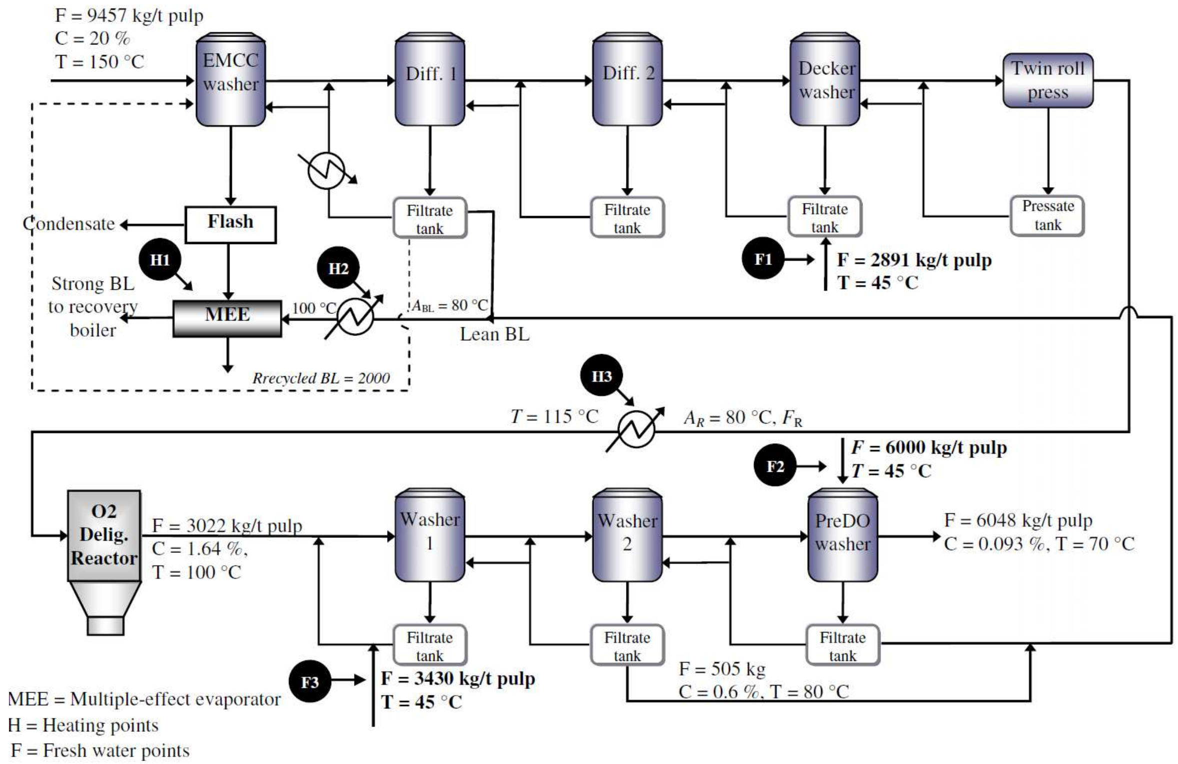
WHERE COULD WE GO NEXT?

- Realistic Scenario: Kraft Pulp Mill Energy & Water **Optimization**
  - Optimization needs a **mathematical model**
  - Optimization typically goes to „the boarders“ of a model. We need a **rigorous model**!
  - **Each process step needs** to be modeled as accurate and rigorous as possible

- The Challenge: consider a **non-isothermal water-fibres-fines-chemicals** networks
  - Example: **brown stock washing system** (similar to Chew et al., Appl. Thermal Engineering 2013)

WHERE COULD WE GO NEXT?

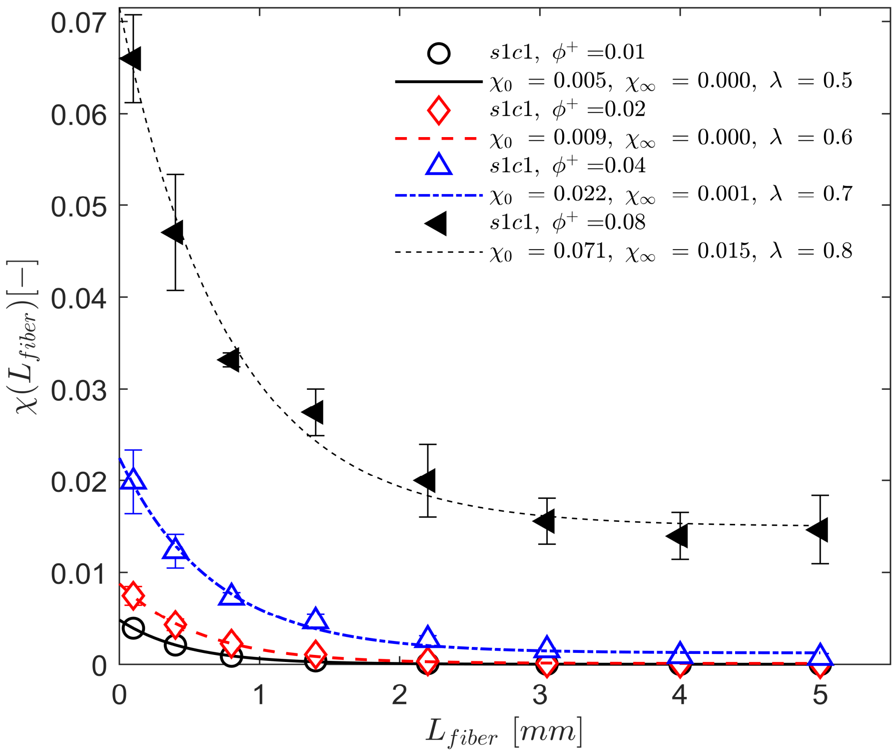
- Previous work: consider an **isothermal water-fibre-chemicals** network



Chew et al. (Appl. Thermal Engineering 51 (2013) 393-400)

WHERE COULD WE GO NEXT?

- Inclusion of fibre-fines separation aspect: predict **fractionation performance** at different operating points



Symbols
Experimental Data

Lines
Model predictions (inspired by König, Master Thesis, TU Graz 2016)

CONCLUSION 2/2

- ✓ Modeling of fibre-fines fractionation process is limiting scientific progress
  - More difficult due to complexity of phenomena
  - Currently purely driven by experiments
  - Quality attributes of product (e.g., fibres) must be defined
- ✓ Optimization framework is already available
  - Non-isothermal water network synthesis & optimization is state of the art in other applications (Ahmetovic et al., CACE 82 (2015) 144–171)
- ✓ Due to modular design of fibre fractionator: optimization on a device-level is also interesting

PROJECT PARTNERS

Industrial partners:

Scientific partners:

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FUNDED BY

The K-Project Flippr² is funded as part of COMET - Competence Centers for Excellent Technologies promoted by BMVIT, BMWFJ, Styria and Carinthia. The COMET program is managed by FFG.

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KWF Kärntner Wirtschaftsförderungs Fonds

FFG Promoting Innovation.

SFG NEUES DENKEN. NEUES FÖRDERN.

„MOBI WATER HEAT" FUNDING

The Project "Modeling and Simulation of Biorefinery Concepts in the Context of Water and Heat Integration" (**MoBi-WaterHeat**) is funded by the Austrian Agency for International Cooperation in Education and Research (OeAD) under project number **BIH 06/2019**