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Evaluating studies in refiner loadability

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Introduction

- Successful fibre treatment in a refiner requires:
  - Sufficient loadability of fibre (network), which implies:

1. Trapping of fibre(floc)s by refiner bar edges
2. Working of these into the gap between rotor and stator bar surfaces
3. Release of treated fibres

Goal of study

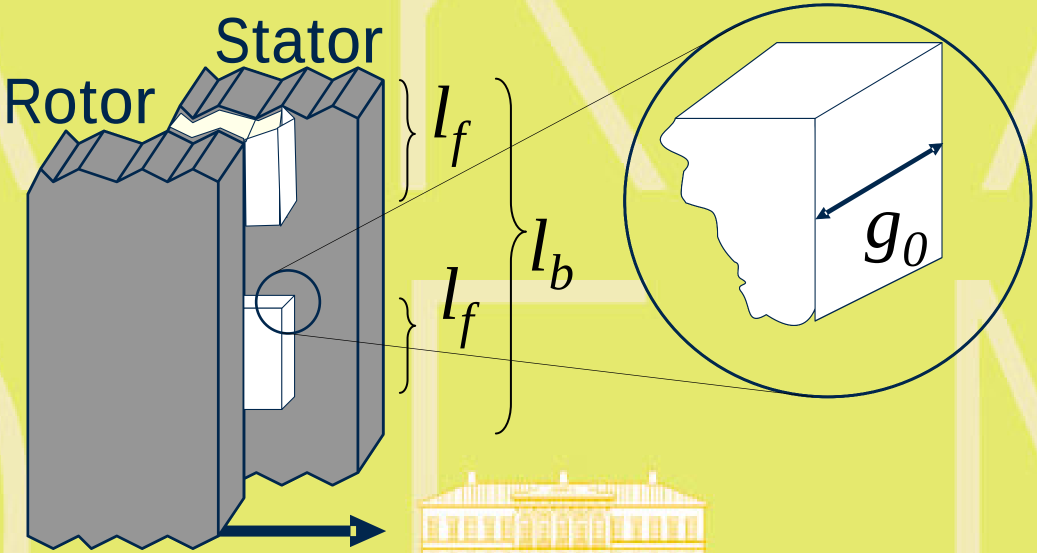
- To develop a method by which relative changes in fibre trapping can be estimated as refining conditions change, *e.g.*:
  - Pulp consistency (c, %)
  - Rotational speed (n, 1/min)
  - Crossing Edge Length (CEL, m/rev)
  - Degree of beating (SEC, kWh/t)
  - Fibre length (softwood and hardwood)
  - Bar edge wear (wear/rounding of the leading bar edge)

Contemporary refining theories

- Machine Parameters Only
  - SEL, calculates
    - Average energy consumption per length of crossing bar edges per rotor revolution, (J/m)
  - SSL, accounting for bar widths; calculates
    - Average energy per crossing area, (J/m^2), impact length (mm)
  - MEL and MSSL
    - Minor parameter adjustments, (J/m) and (J/m^2)
- Machine and Fibre Impact Parameters
  - C-factor
    - Probability of single fibre trapping in terms of fibre, bar and groove dimensions, (impacts/fibre), (J/impact)

Our concept

- Refiner action characterisation based on
  - Fibre trapping and treating parameters:
    - The fraction of bars that traps fibres, f, bar coverage
    - The number of fibres trapped, g_0, fibre mat thickness



$$f = \frac{\sum l_f}{\sum l_f + l_b}$$

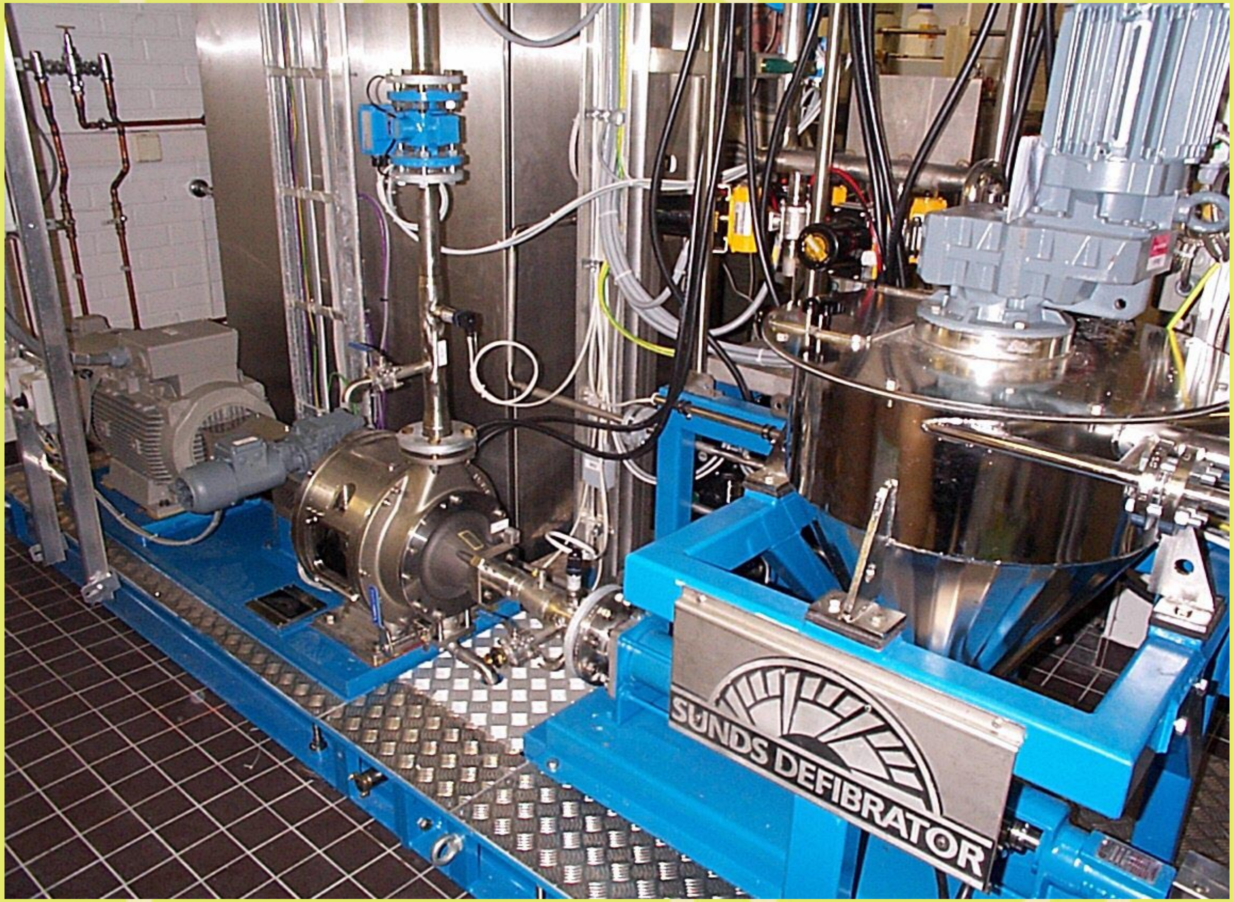
Our concept

- Available data (loadability trials):
  - Refiner total and net power, P_{Tot} & P_{Net} (kW)
  - Gap between rotor and stator, g (mm)
- Key concept:
  - The number of trapped fibres will determine the refiner loading point, where fibres begin to take up strain, g_0
  - Average bar coverage f will be proportional to applied refiner net power

ProLab™ refining station

- ProLab™ refiner
  - Power 30 kW
  - Rotor $Ø_{min / max}$ 46 / 130 mm
  - Consistency 1-7 %
  - Pulp flow 50-120 L/min
  - Feeding pressure 0.5-6 bar
  - Speed
    - Rotational 600-4500 1/min
    - Peripheral 5-14 / 10-27 m/s
  - Conical fillings
    - LM-type: 52 m/rev
  - SEL 0.1-8* J/m
  - SEC 10-45* kWh/t

*Depending on fillings and type of pulp

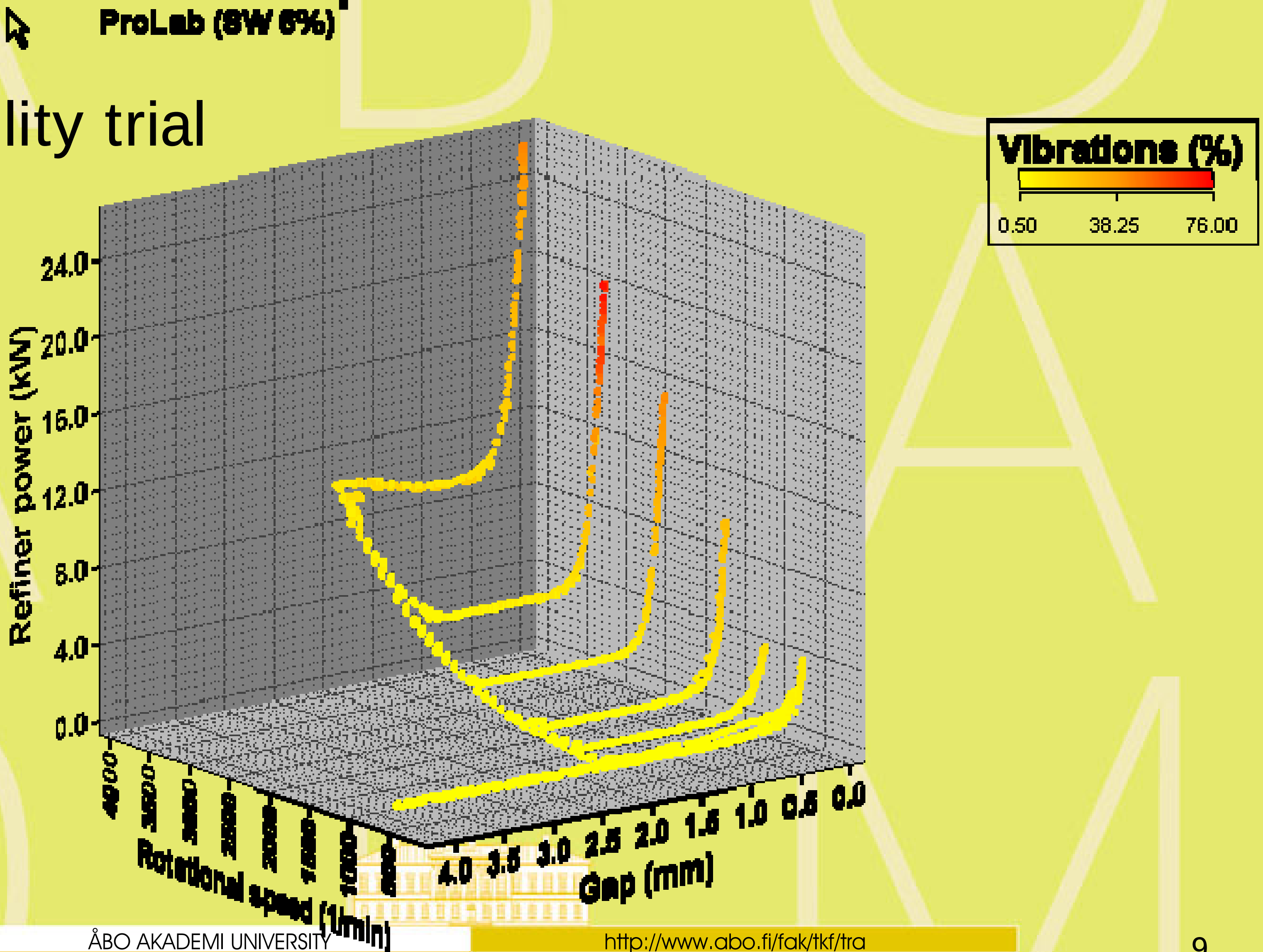


Experimental

- Finnish dry-lap reinforcement pulp
  – ECF-bleached
  – 2.44 mm average length-weighted fibre length
  – 0.183 mg/m average coarseness

Experimental

- Loadability trial



Experimental

- Loading at 600, 1500, 2250, 3000, 4000 rpm

Trial (#)	Gap (mm)	Cons. (%)	SEC (kWh/t)
1	1.2–min–1.2	1	~0
2	1.2–min–1.2	2	~0
3	1.2–min–1.2	3	~0
4	1.2–min–1.2	4	~0
5	1.2–min–1.2	4	283
6	1.2–min–1.2	5	~0
7	1.2–min–1.2	6	~0

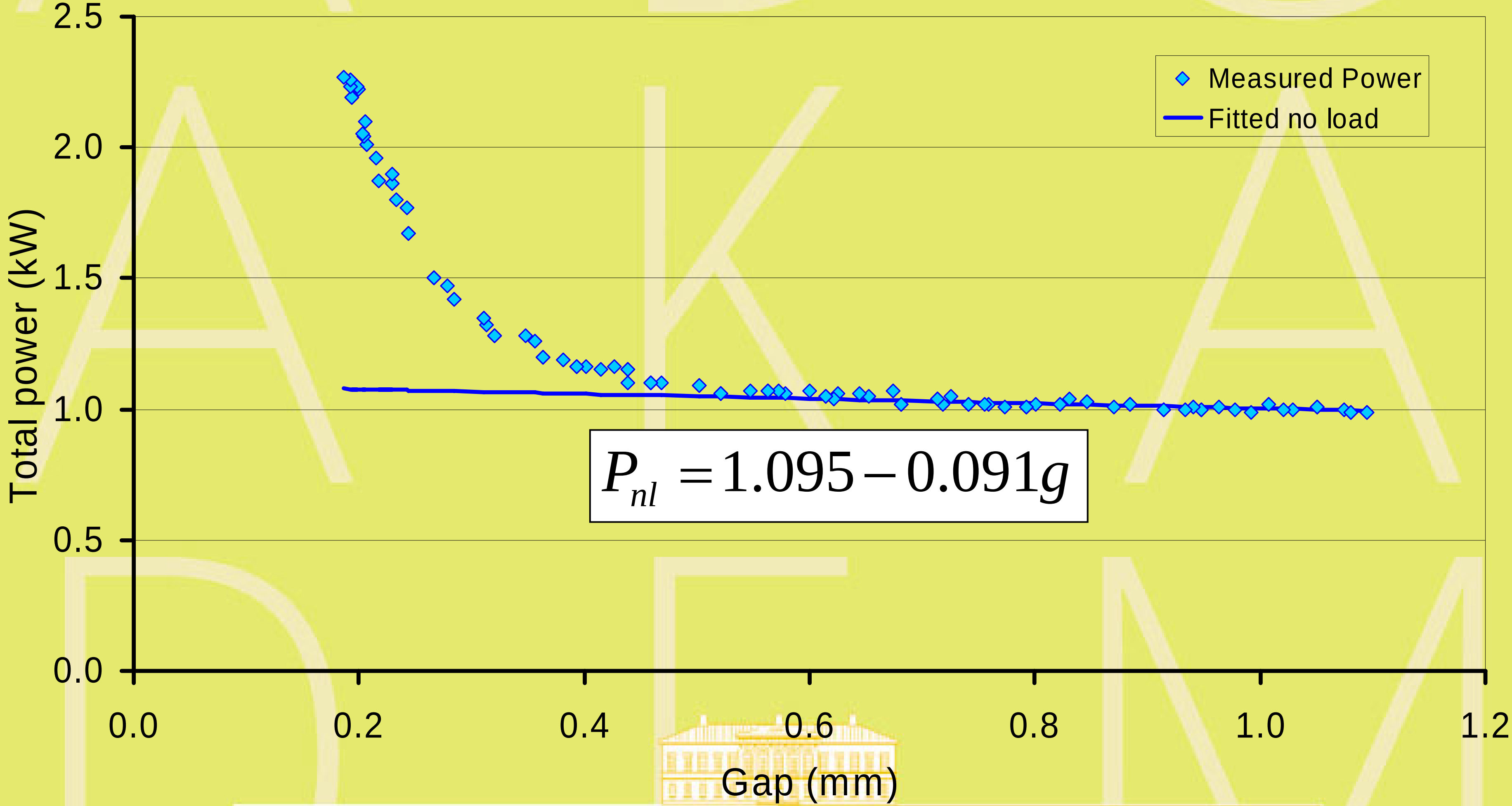
Data analysis

- Method

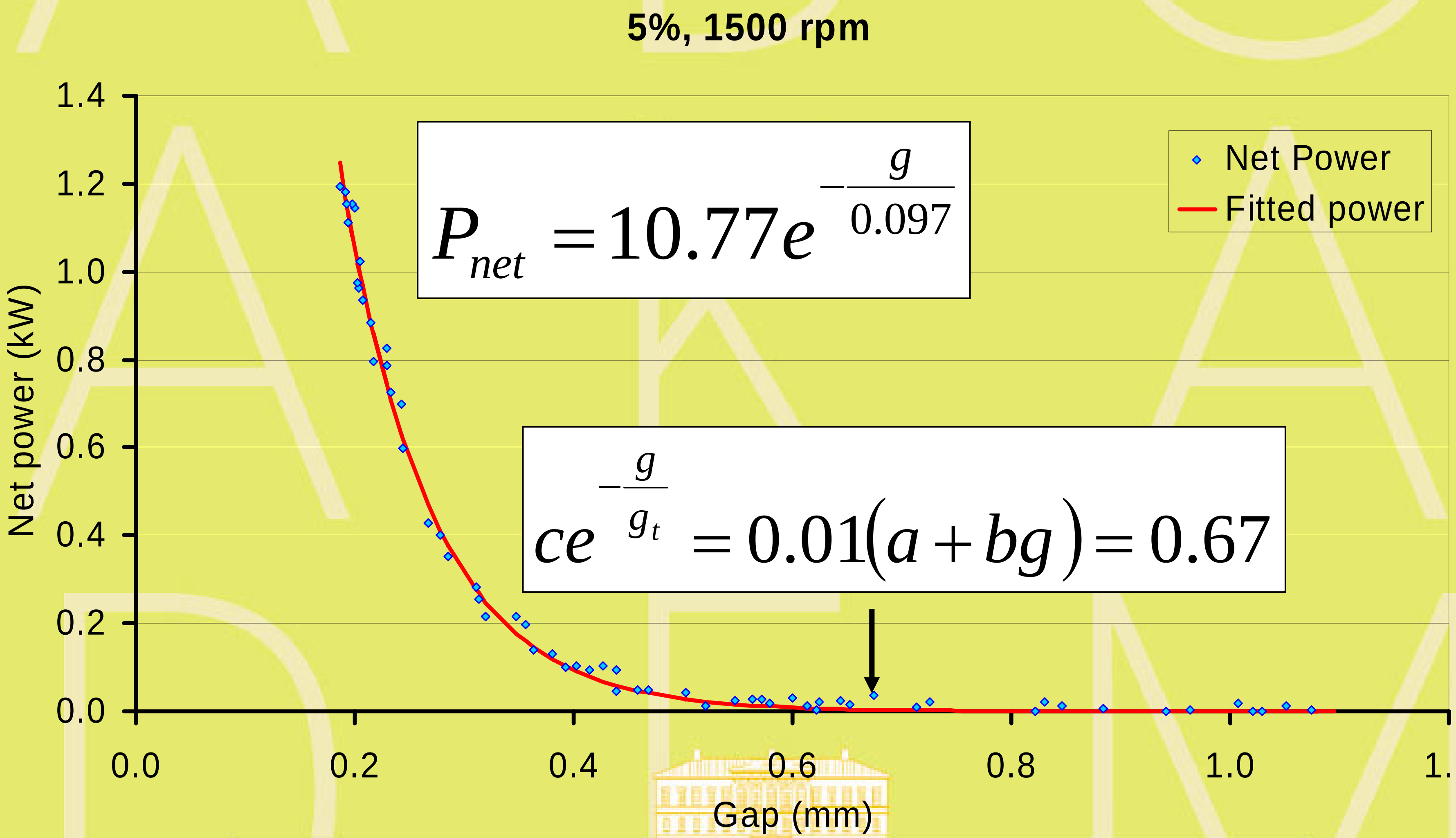
1. Fitting a linear no-load function $P_{nl} = a + bg$
2. Fitting the net power data $P_{net} = ce^{-\frac{g}{g_t}}$
3. Determination of g_0 $ce^{-\frac{g}{g_t}} = 0.01(a + bg)$
4. Calculation of strain $\varepsilon = (g - g_0)/g_0$
5. Estimation of bar coverage, f $P_{net} \propto f$

Results- Raw Data

5%, 1500 rpm



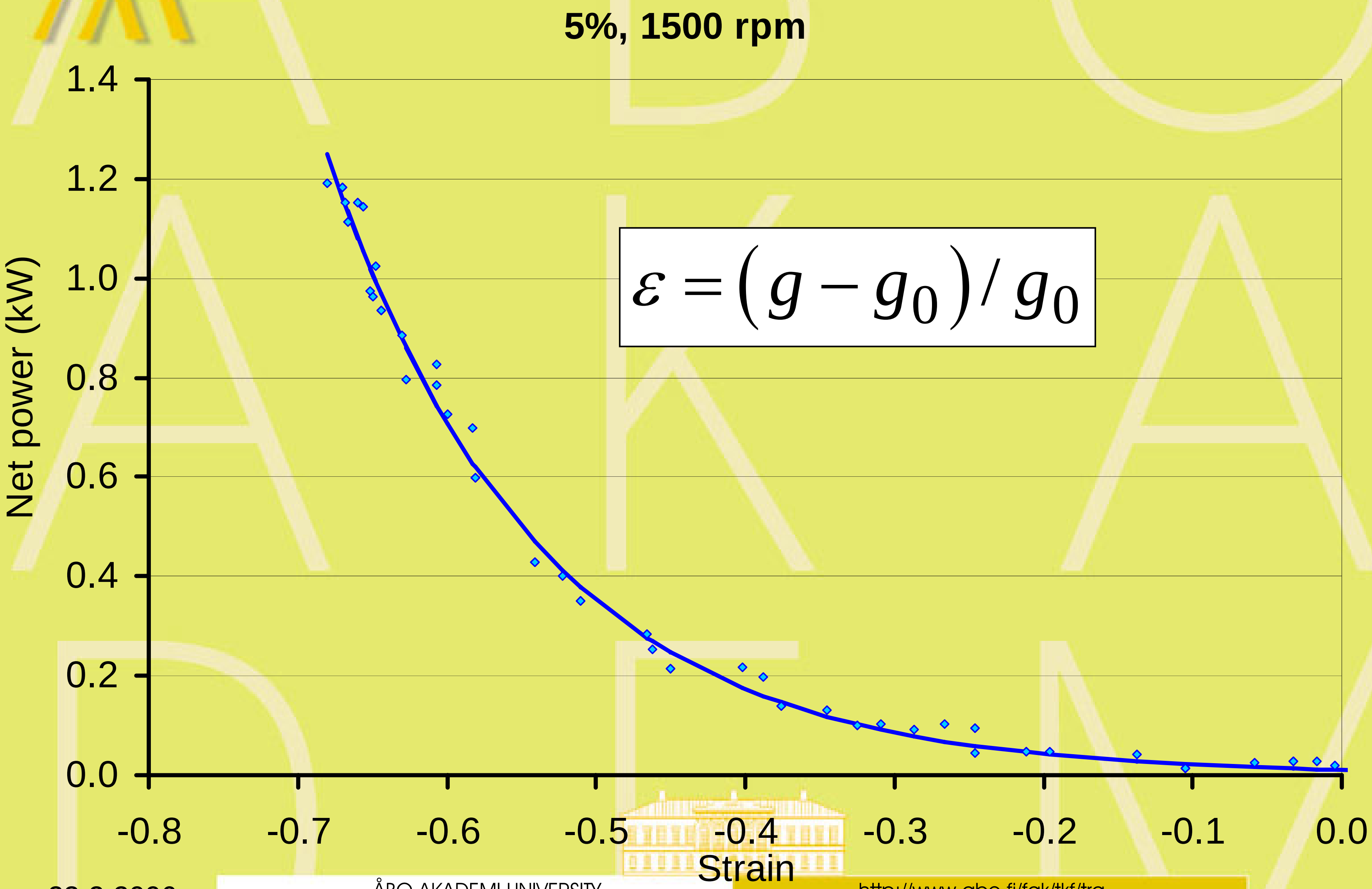
Results- No load subtraction and fitting



$$P_{net} = 10.77 e^{-\frac{g}{0.097}}$$

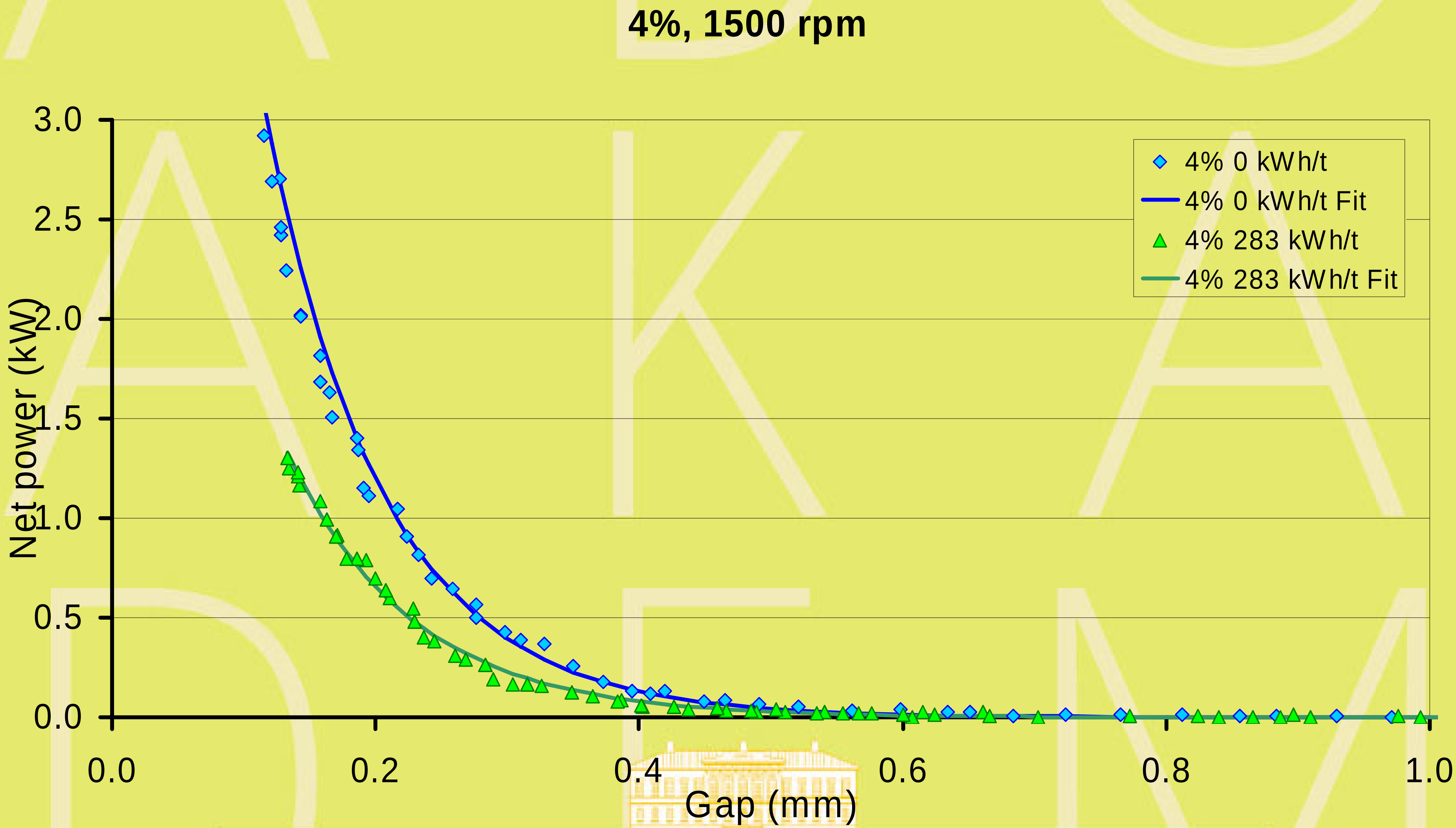
$$ce^{-\frac{g}{g_t}} = 0.01(a + bg) = 0.67$$

Results- Conversion to strain

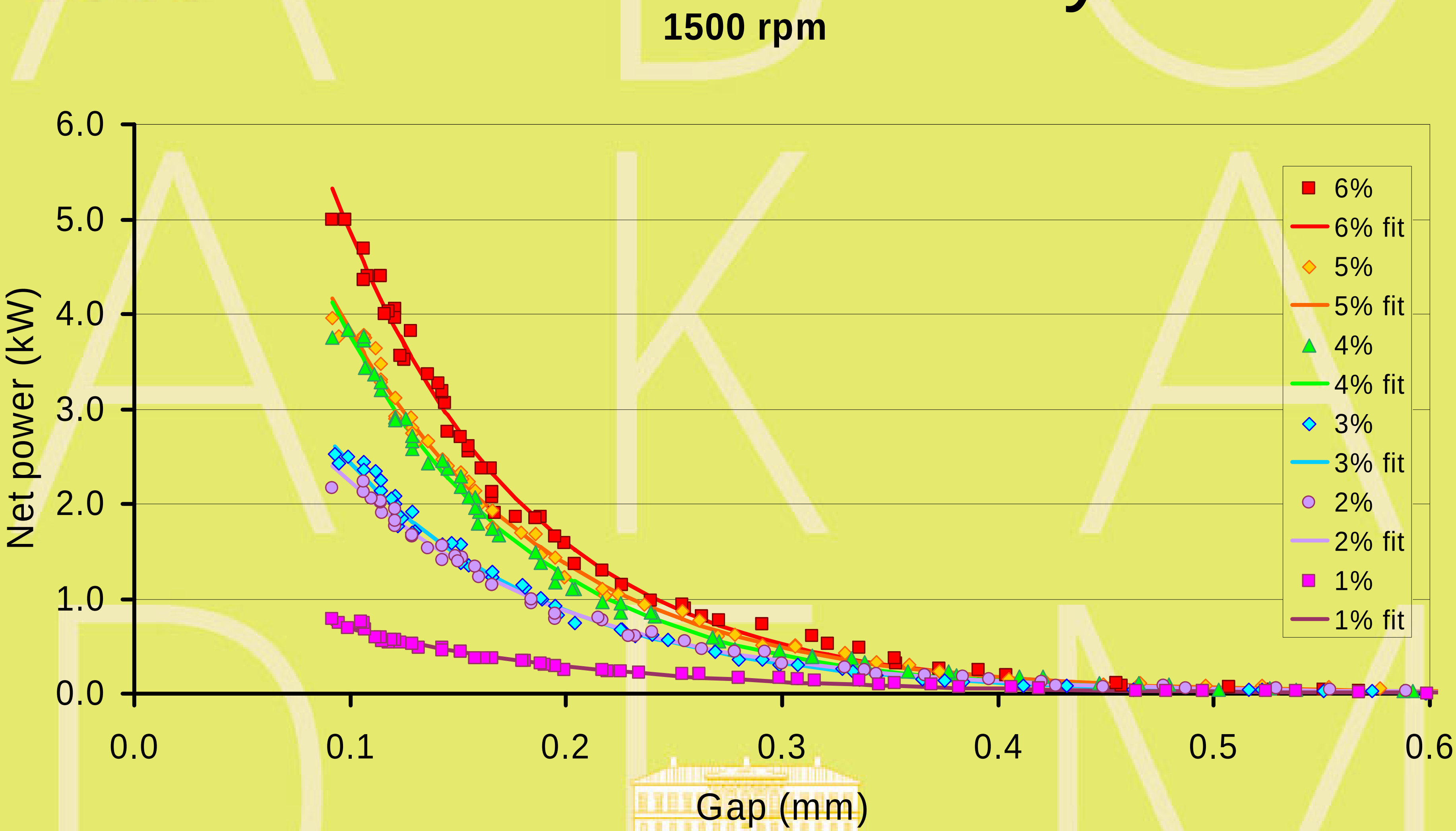


$$\varepsilon = \left(g - g_0\right) / g_0$$

Results- Effect of SEC on refiner loadability



Results- Effect of consistency on refiner loadability



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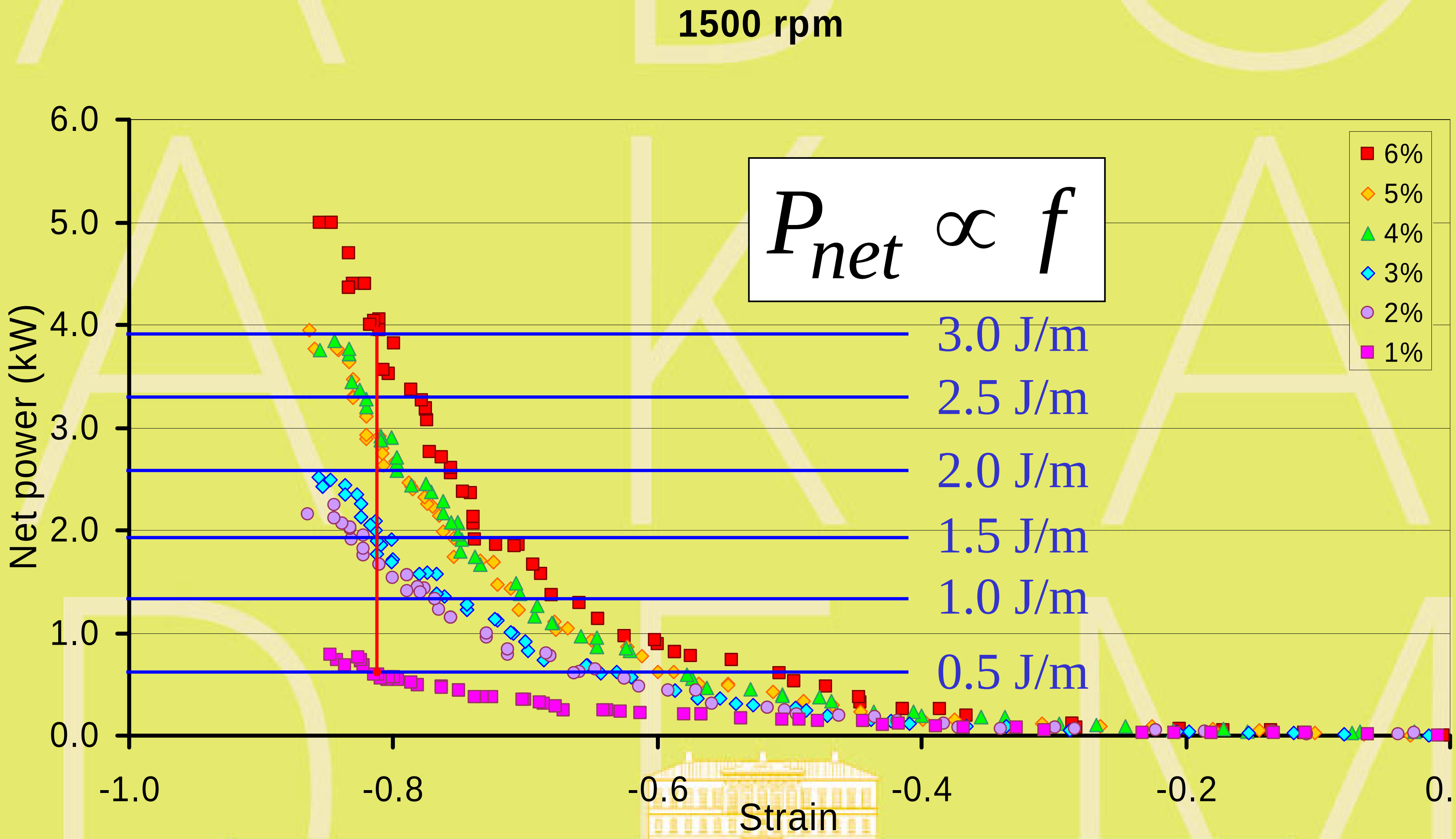
Results- Effect of consistency on strain



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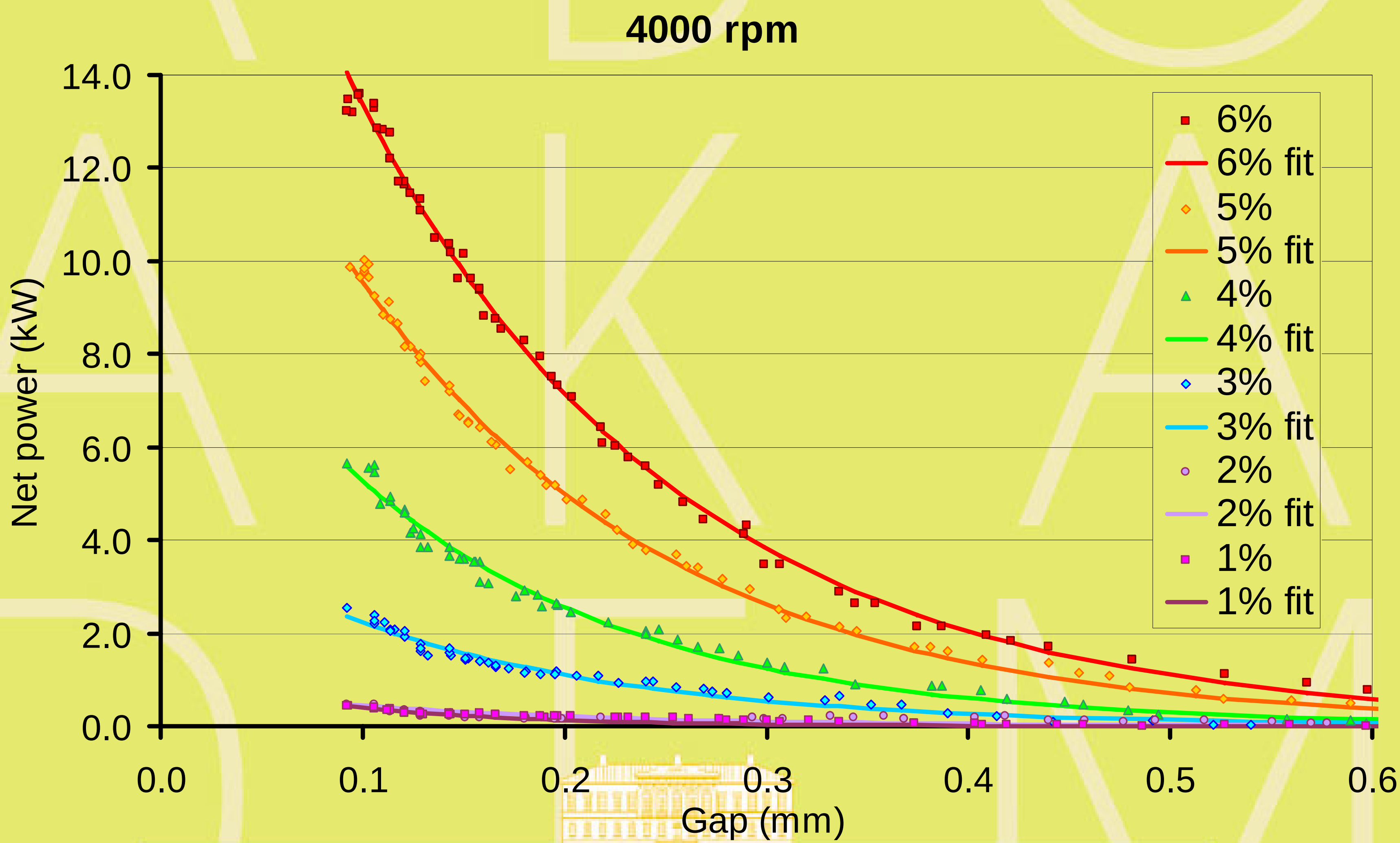

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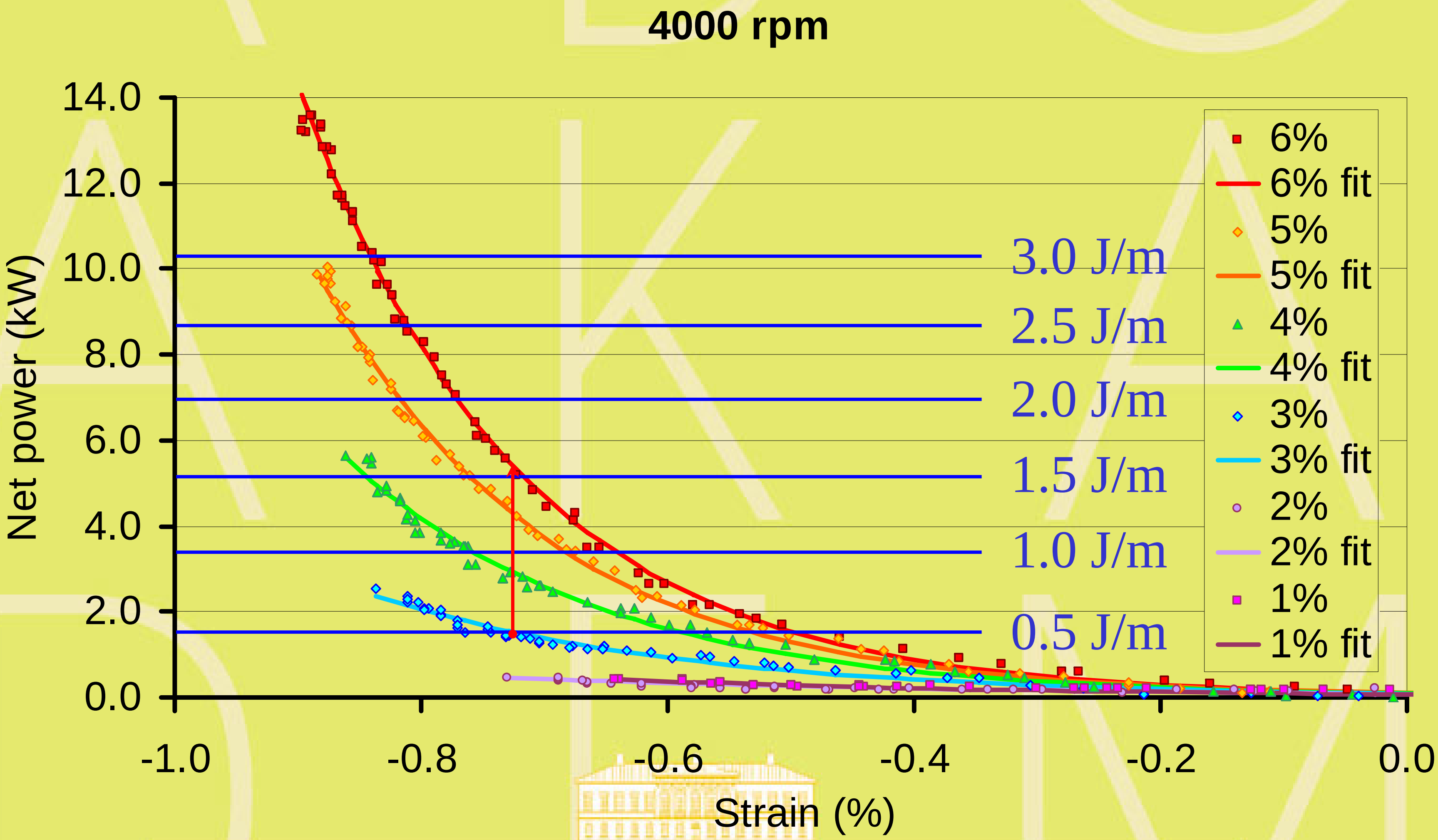

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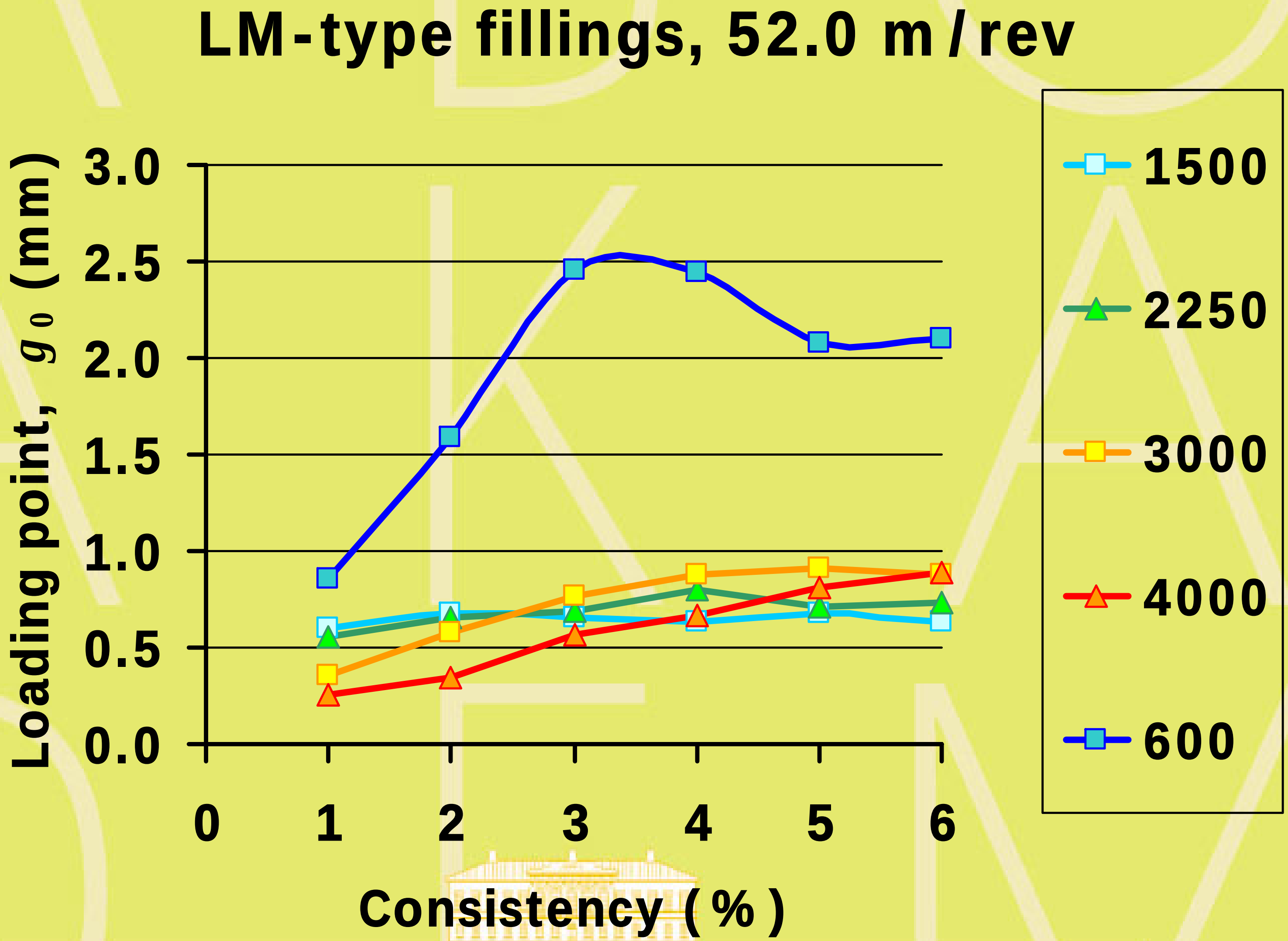
Results


LM-type fillings, 52.0 m / rev
Loading point, g_0 (mm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
Consistency (%)
1500
2250
3000
4000
600

Conclusions

- Refiner loadability – a function of
  - Pulp consistency
  - Rotational speed

  } Fibre trapping
- Sensitivity to consistency grows with rpm
  - Low rpm: ~equal loadability at 2-6 %
    - Good loadability (5-10 m/s & 1-6 %)
      - Fibre flocculation effects predominant
  - High rpm: impaired loadability, especially 1-4 %
    - Poor loadability (20-27 m/s) at 1-2 %
    - Limited loadability at 3-4 %

Conclusions

- Gap at loading point dependent on consistency at higher rpm's (>2250/15 m/s)
  - Measure of the amount of trapped fibres
- Applied fibre strain proportional to pulp consistency
  - Measure of bar coverage
- Fitting loadability curves can estimate changes in fibre trapping at different refining conditions

Acknowledgments

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