Estimation of fibre trapping from refiner loadability measurements

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http://www.abo.fi/fak/tkf/tra

Paper Science

Motivation

- Successful pulp 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 our investigation

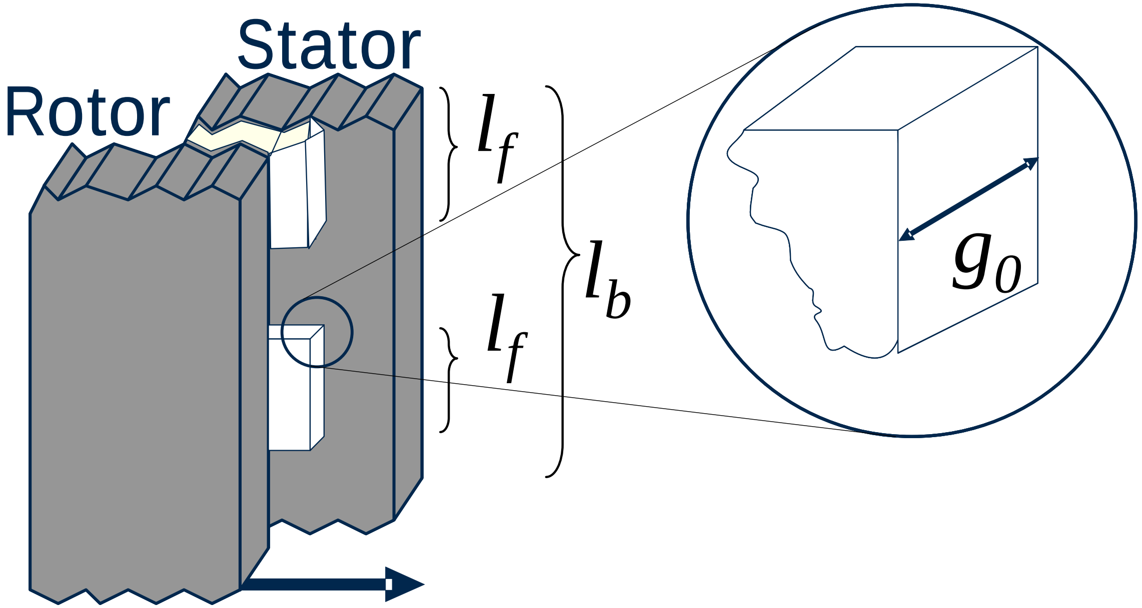
- To develop a method by which relative changes in fibre trapping can be estimated as refining conditions change, *e.g.*:
  - Pulp consistency (c, %)
  - Rotational speed (n, 1/min)
  - Crossing Edge Length (CEL, m/rev)
  - Fibre length (softwood and hardwood)
  - Bar edge wear (wear/rounding of the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

Contemporary refining theories

- Machine Parameters:
  - Specific Edge Load (SEL):
    - Average energy per unit length of crossing bar edges, (J/m)
  - Specific Surface Load (SSL), accounting for bar widths:
    - Average energy per unit area of crossing bars, (J/m^2)
  - Modified Edge Load (MEL)
  - Modified Specific Surface Load (MSSL)
- Machine and Fibre Impact Parameters:
  - C-factor
    - Probability of single fibre trapping in terms of fibre, bar and groove dimensions, (impacts/fibre), (J/impact)
- None considers fibre trapping

Fibre trapping concept

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



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

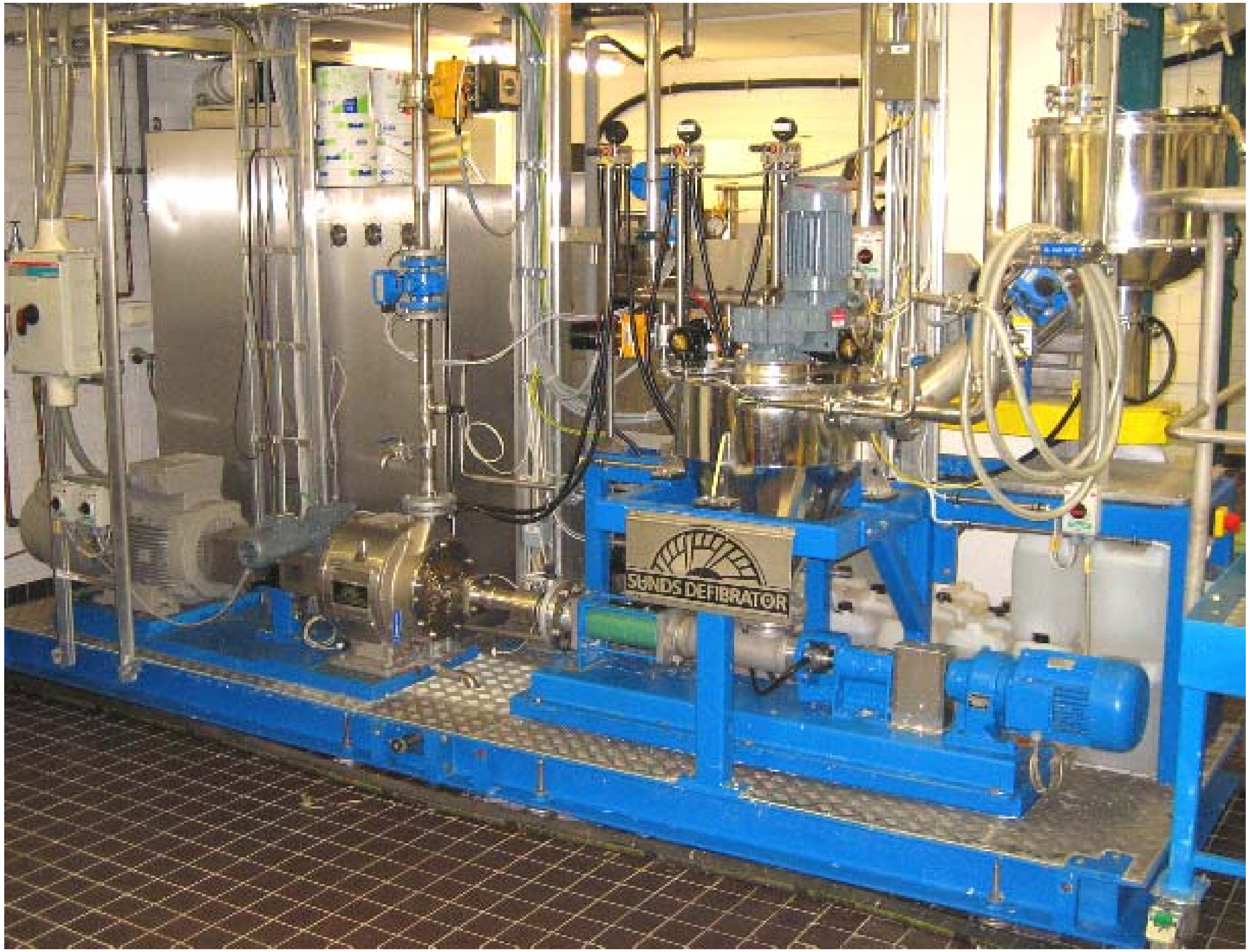
Our concept of fibre trapping

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

*Depending on fillings and type of pulp

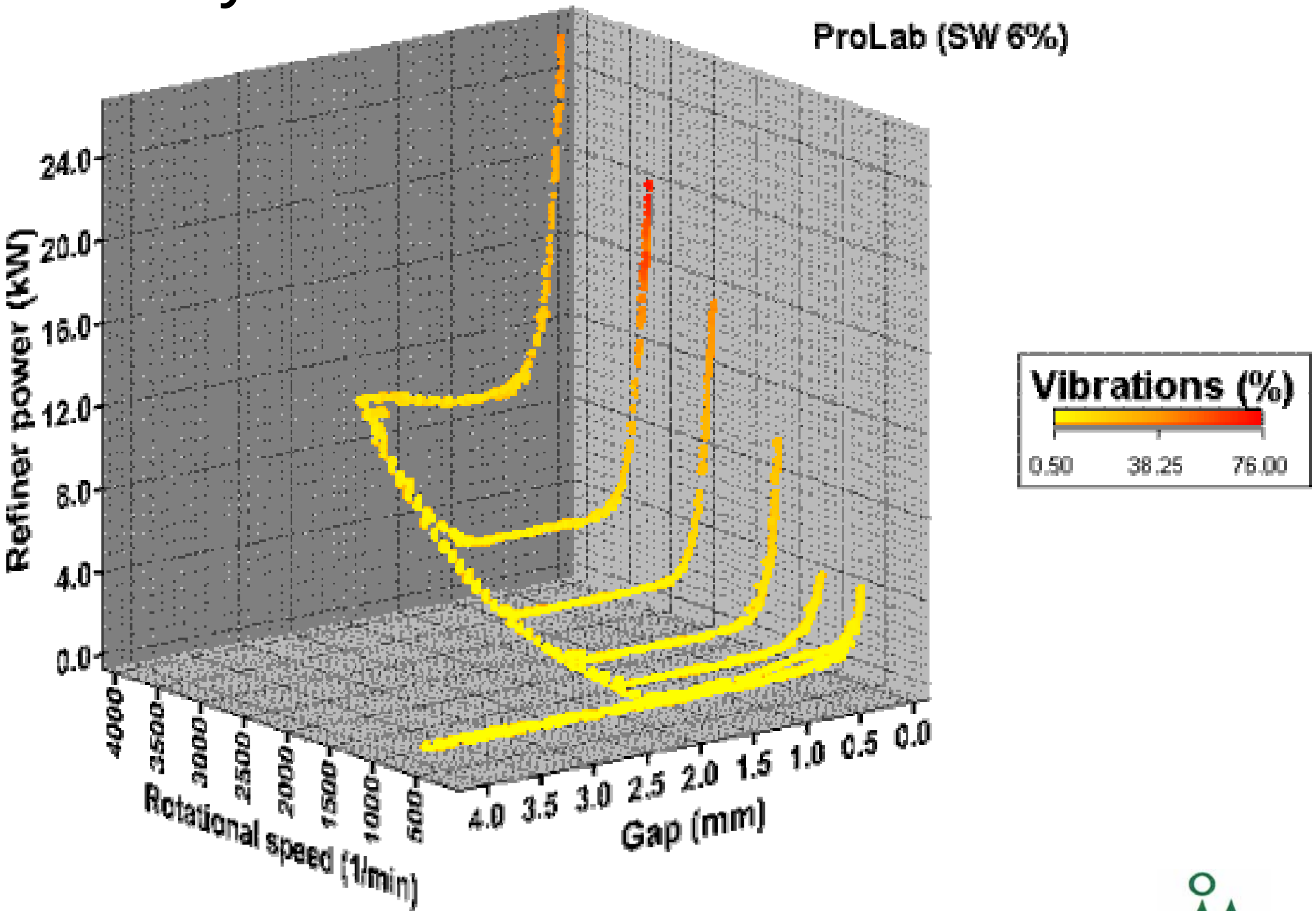


Experimental

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

Experimental

- Refiner loadability trial



Experimental

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

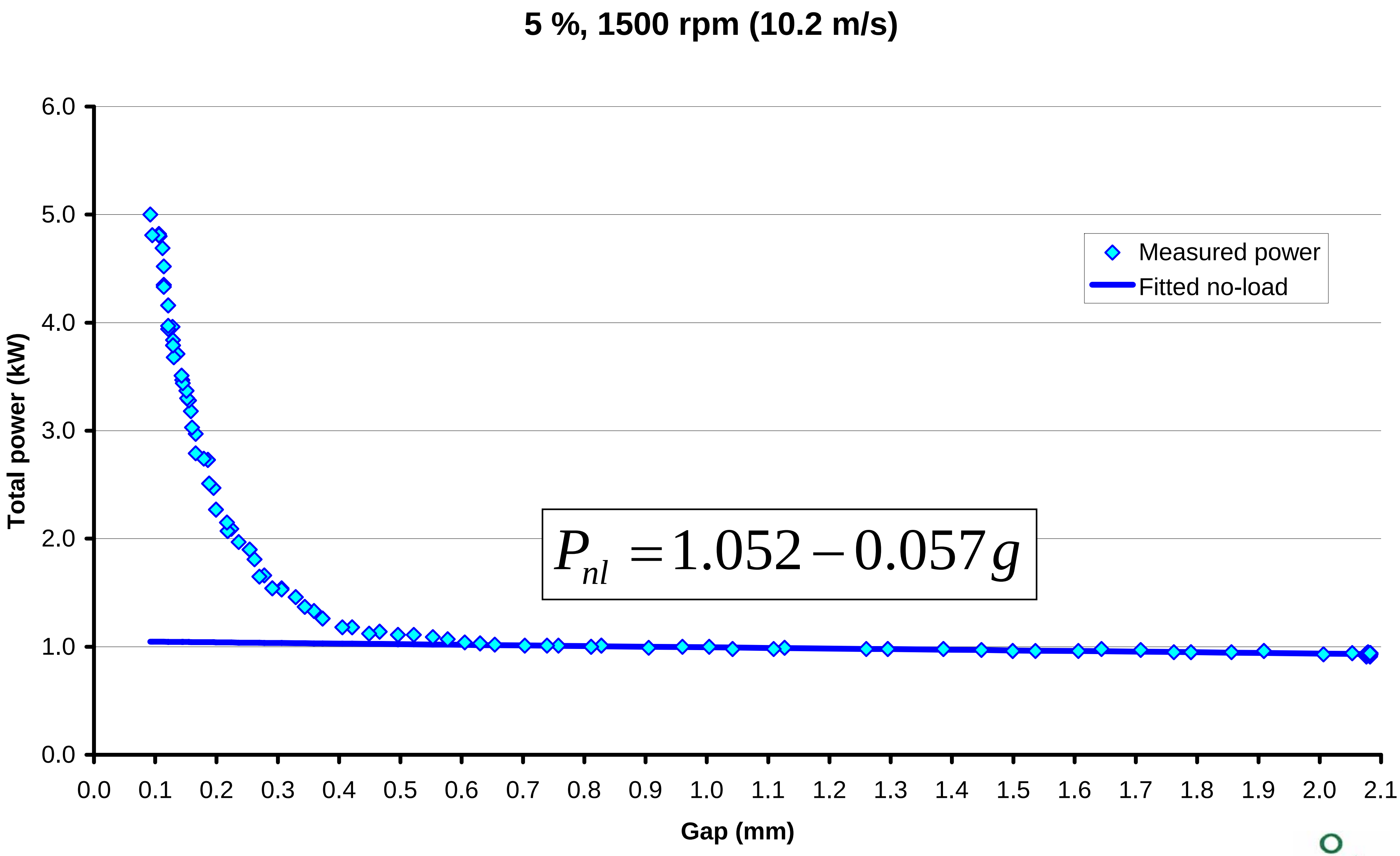
Trial (#)	Gap (mm)	Cons. (%)	SEC (kWh/t)
1	1.2–min–1.2	1	~0
2	1.2–min–1.2	2	~0
3	1.2–min–1.2	3	~0
4	1.2–min–1.2	4	~0
5	1.2–min–1.2	4	283
6	1.2–min–1.2	5	~0
7	1.2–min–1.2	6	~0

Data analysis

- Method

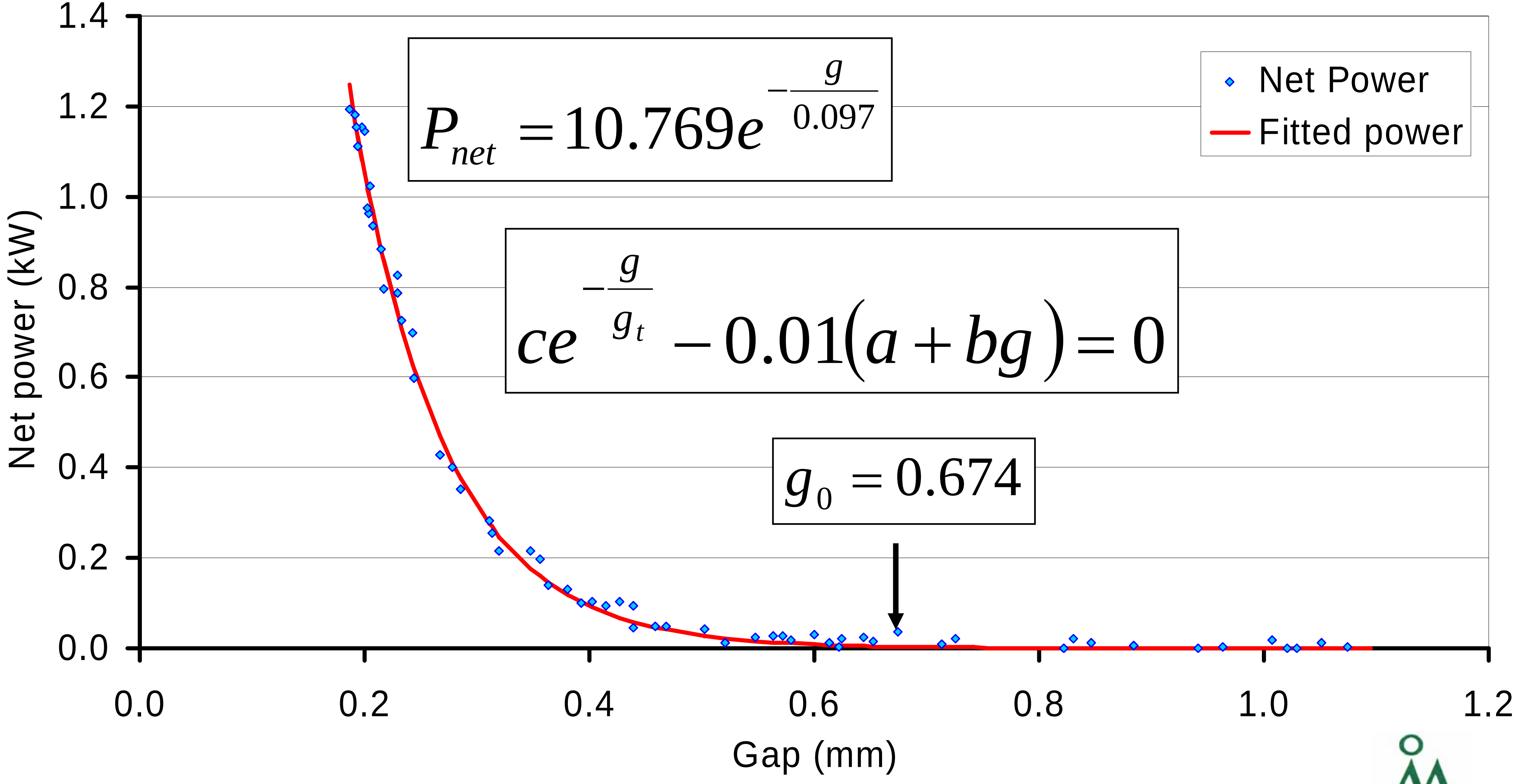
1. Fitting a linear no-load function and subtracting the no-load power at each gap $$P_{nl} = a + bg$$
2. Fitting the net power data $$P_{net} = ce^{-g/g_t}$$
3. Determination of g_0: solve $$ce^{-g/g_t} = 0.01(a + bg)$$
4. Calculation of strain $$\varepsilon = (g - g_0)/g_0$$
5. Estimation of bar coverage,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

Results- Raw Data

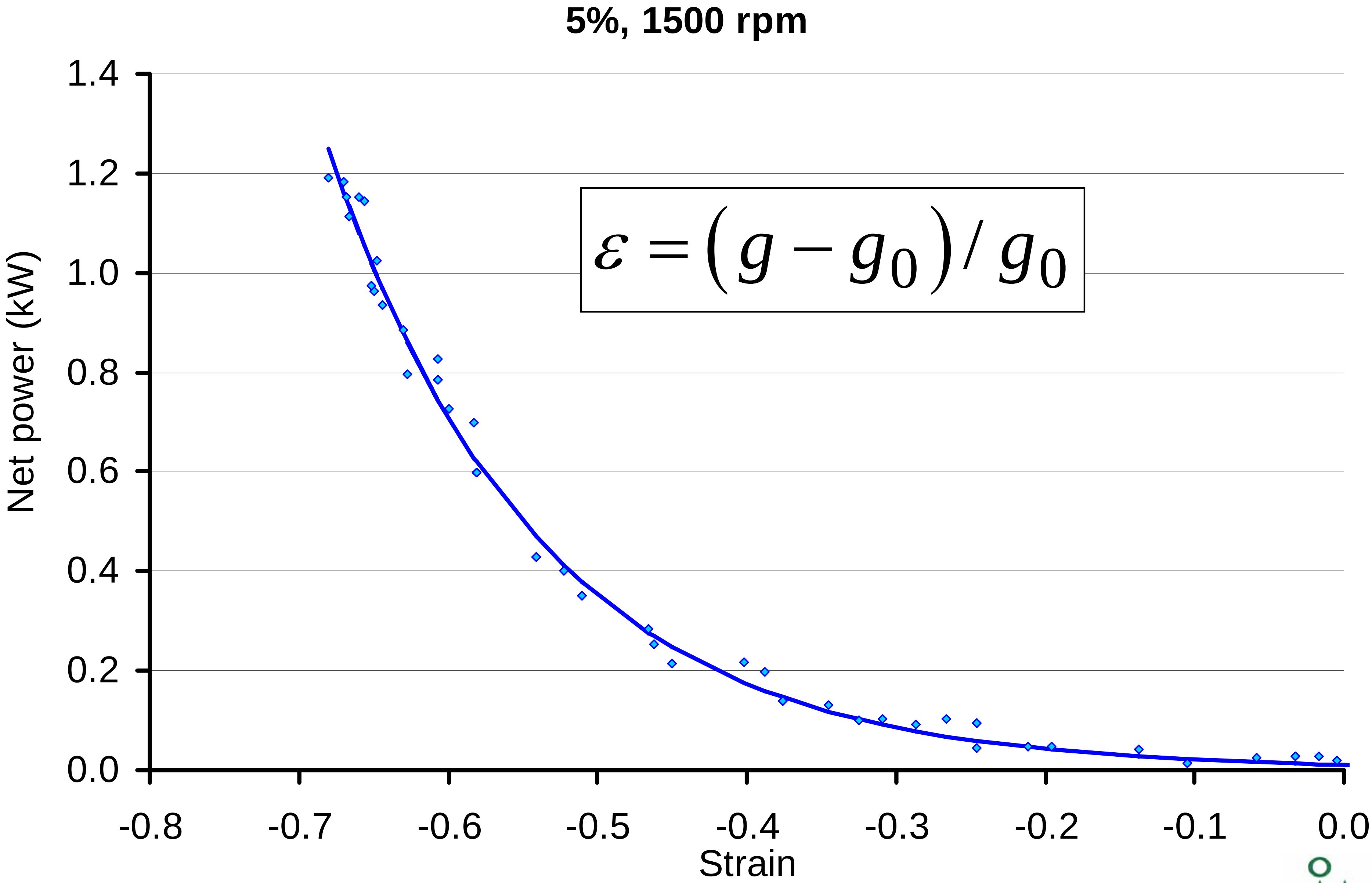


Results- No-load subtraction and fitting

5%, 1500 rpm

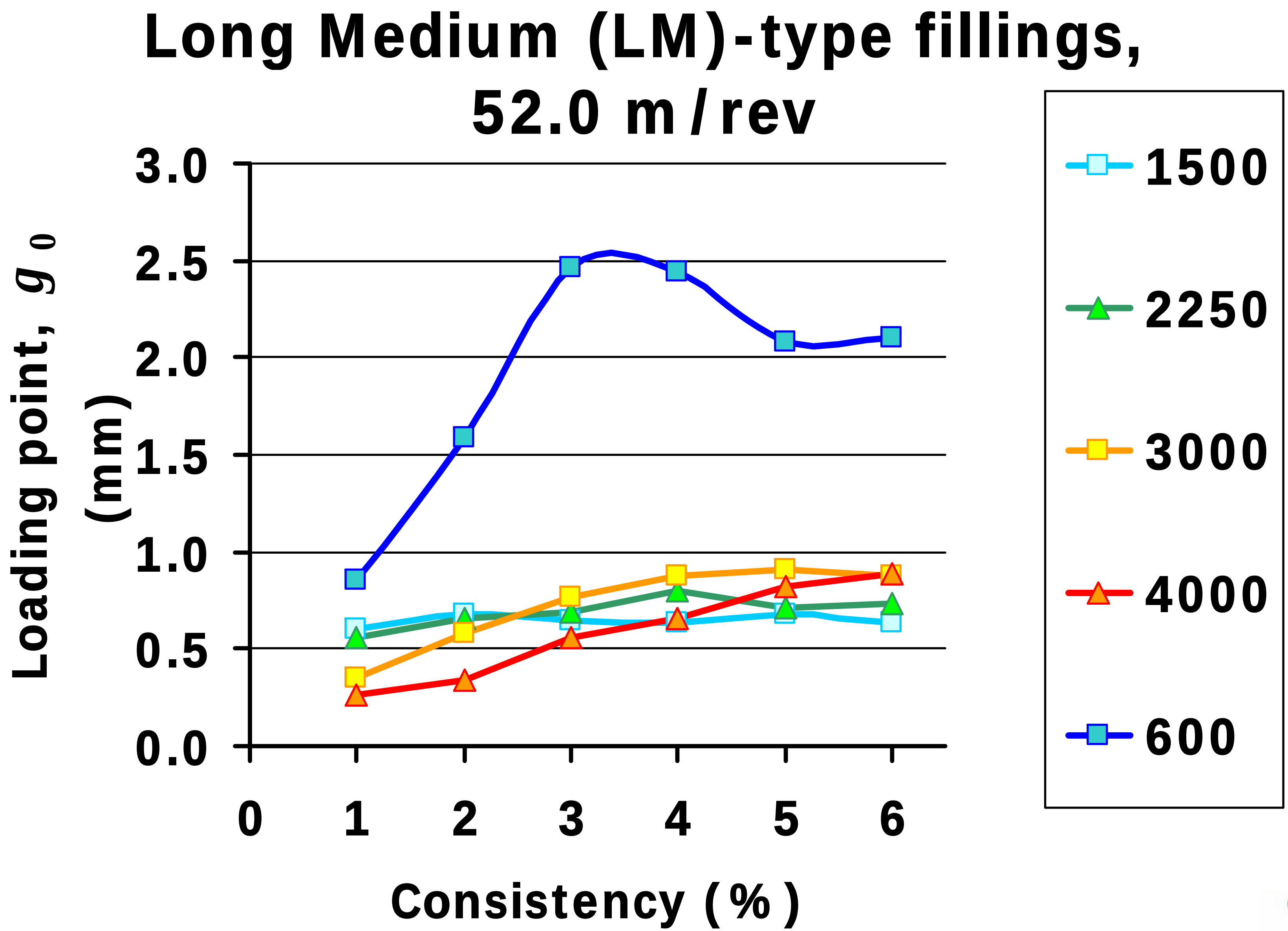


Results- Conversion to strain



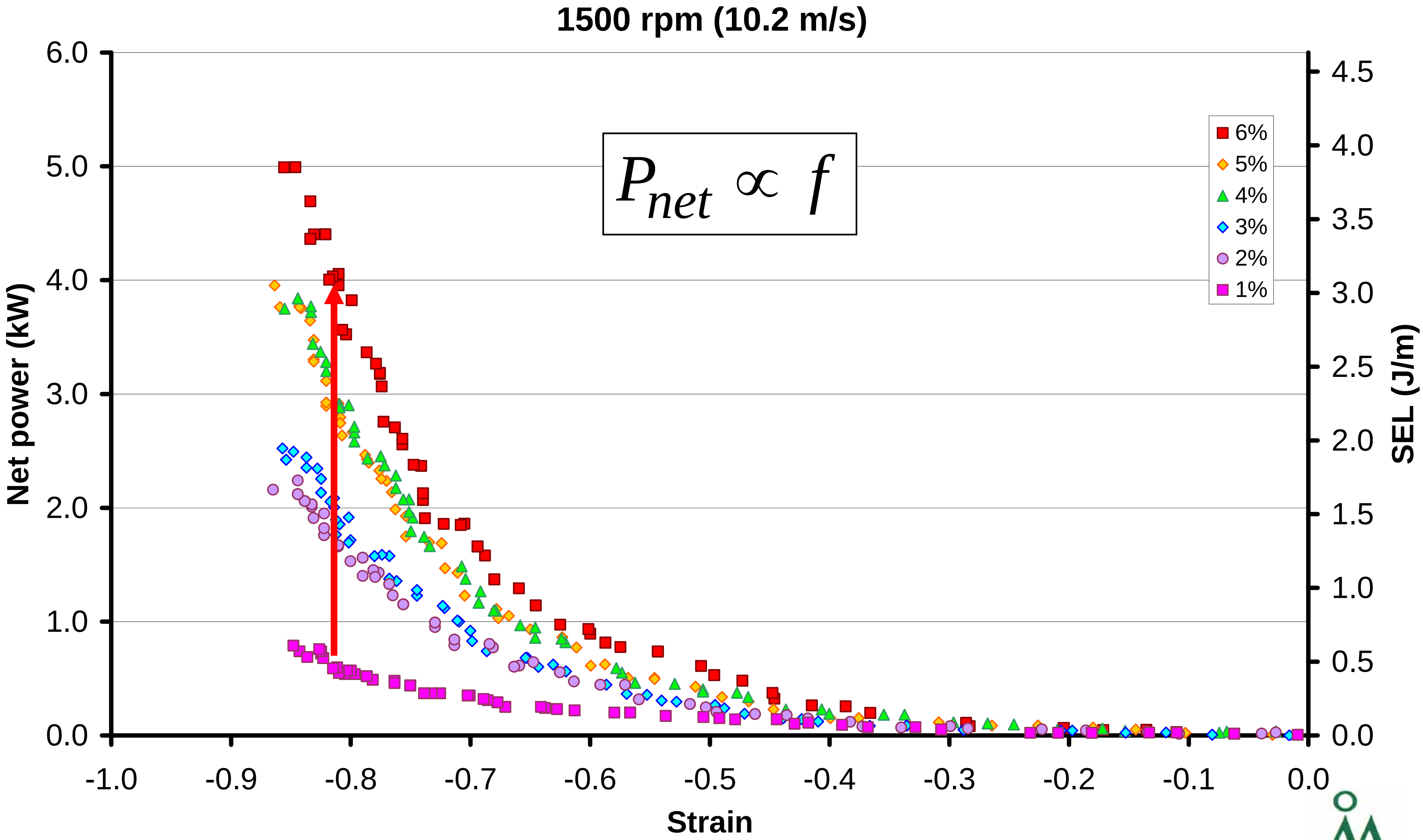
$$\varepsilon = (g - g_0)/g_0$$

Results



Long Medium (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

Results- Effect of consistency on strain



Conclusions

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

  } Fibre trapping – bar coverage
- Sensitivity to consistency grows with rpm
  - Low rpm: ~equal loadability at 2-6 %
    - Good loadability (5-10 m/s & 1-6 %)
      - Good loadability at 600 rpm: thicker fibre mats - fibre flocculation effects predominant (at the low shear rates)
  - 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 increased with pulp consistency at higher rpm's (>2250/15 m/s)
  - Measure of the amount of trapped fibre layers
- Refiner bars possess a (maximum) intrinsic capability of trapping fibres at a given speed
  - Of same order in the range 1500-4000 rpm (10-27 m/s) while not affected by fibre flocculation
- Applied fibre strain proportional to pulp consistency
  - Proportional to, and a measure of, refiner bar coverage
- Laboratory refining trials imply that SEL is an insufficient control parameter if pulp consistency varies

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