EG60411 Bio-Material Science

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2G103, 10:10-11:25, Tuesday

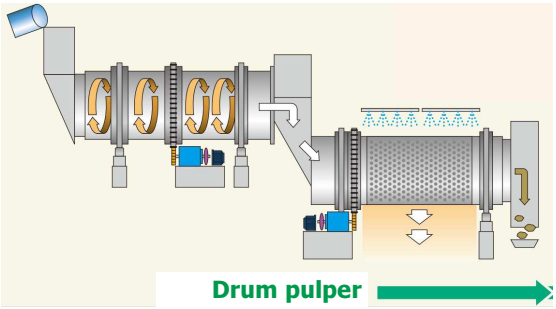
Biomaterial Science （Schedule）

#	Date	Content
1	4/15	History of papermaking
2	4/22	Pulps – Beating and fiber properties
3	5/9, Fri	Pulps – Additives and functions
4	5/13	Papermaking processes & interfiber bonding
5	5/20	Paper– Structural and absorption properties
6	5/27	Paper– Mechanical and optical properties
7	6/3	Polysaccharide chemistry by Assoc Prof Akiko Nakagawa
8-9	6/10, 17	Pulping science and technology by Professor Hiroshi Ohi
10	6/24	Recent trend of paper science and technology

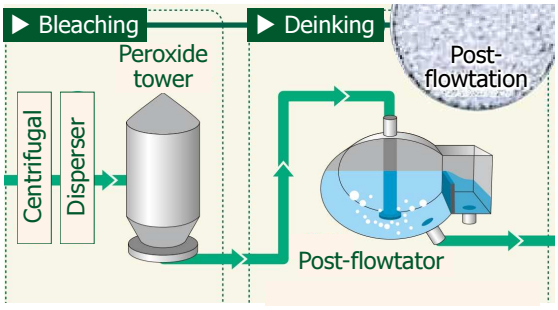
Lecture information and contact

- Homepage of “Biomaterial Science (T. Enomae)”
- http://www.enomae.com/
  → Handouts in lecture(講義資料)
- E-mail address
  → t@enomae.com
  for any questions and visit to laboratory
  (Bio-Agr. Bldg. 生農C209 or E201)

Disintegration in industry (Drum pulper)



Floatation



Floatation (flowtator)

Beating (refining)

- Post-disintegration process
- Process where shear stress is applied to water-containing fibers resulting in **fibrillation** (formation of small filaments or fibers) on the surface and **concentrically loose structure**

Beating (refining)

- Beating achieves large bonded area between fibers and thus higher paper strength.

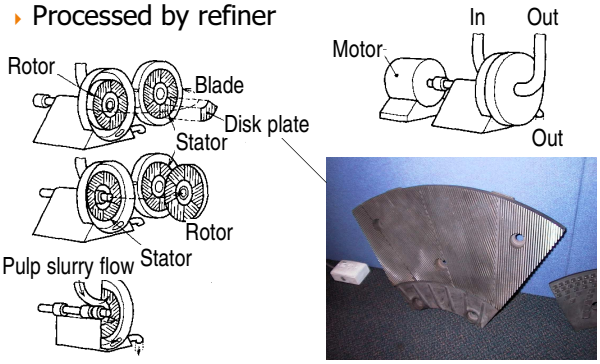
Q. Why can this breaking process increase paper strength?

Difference between disintegration and beating

- **Disintegration** is a process to separate fibers bonded or entangled, keeping fiber characteristics
- **Beating** is a process to treat mechanically individual fibers, changing fiber characteristics

Beater – Refiner(refining)

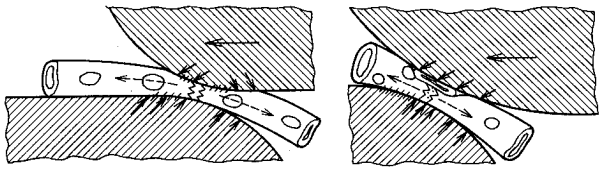
- Processed by refiner



Beater – PFI mill (beating)

https://www.youtube.com/watch?v=b17d6ssw8f4

Beating – mechanism

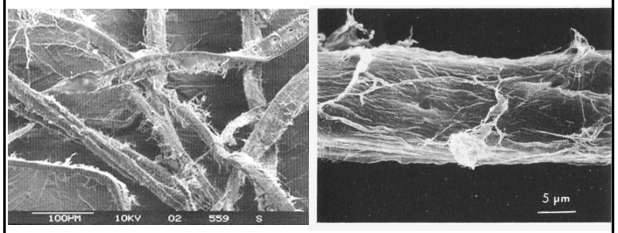


Effect of blades on pulp fibers during beating

Refining – movie – refiner

Beating – change of fibers – **external** fibrillation

- External fibrillation
- Internal fibrillation



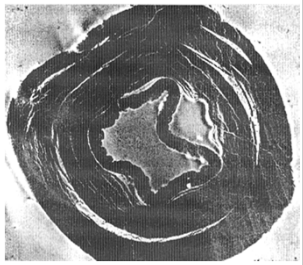
Scanning Electron Micrographs of freeze-dried softwood pulp fibers after beating

Beating – change of fibers – **internal** fibrillation

- External fibrillation
- Internal fibrillation

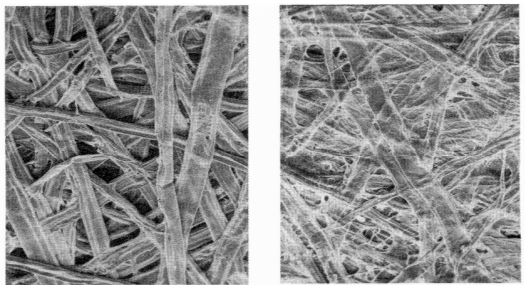
＝Concentric loosening (Lamellar separation)

Connection of small pores formed by lignin removal



Lamellar separation of fiber cell wall by beating

Beating – change of paper structure



Unbeaten (left) and beaten (right) softwood pulp sheets

Q. How did fibers and sheets change by beating?

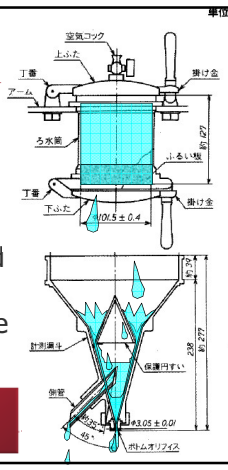
Evaluation of fiber properties

- Freeness (Drainability)
- Specific surface area
- Fiber length distribution
- Distinguishment by staining
- Fiber coarseness
- Curl index

Evaluation of Freeness

- Canadian standard freeness (mLCSF)
  - One L of pulp suspension at 0.3% and 20 °C is pored and the volume (mL) of water drained from the side pipe is measured.

Q. Does CSF increase or decrease by beating?



Evaluation of Freeness

- Canadian standard freeness
  - Unbeaten pulp ca. 650 mL CSF
  - Beaten pulp ca. 400 mL CSF
  - Reasons why freeness (E) by beating are
    - More fines (small pieces of fibers)
    - Fibrillation

    make paths between fibers in a pulp mat thin, winding, and long.

Water Retention Value (WRV)

- M_w : Mass of pulp after centrifugation
  M_d : Mass of the pulp after oven drying

$$WRV(\%) = 100 \times (M_w - M_d)/M_d$$

Q. Calculate WRVs to 2 decimals in percentage.

Pulp	After cent.(g)	Oven dried(g)
SBKP beaten	**0.61**	**0.23**
SBKP unbeaten	**0.59**	**0.28**
HBKP beaten	**0.54**	**0.22**
HBKP unbeaten	**0.45**	**0.24**

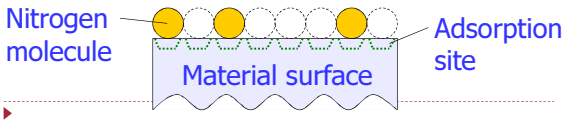
Sample	WRV, %
Bleached softwood	102
Bleached hardwood	101
TMP	139
CTMP (hardwood)	122
CTMP (50% HW + 50% SW)	124
Unbleached sulphite	104
Recycled pulp	159
Non-wood pulp	204
Never-dried Kraft pulp	114

Nitrogen adsorption method

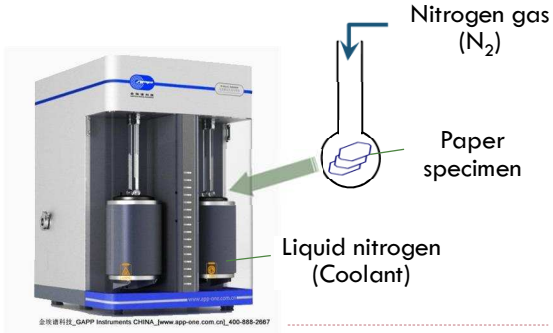
- Langmuir model
  - All the adsorption sites are equivalent and the surface is homogenous.
  - Monolayer coverage
  - No interactions between adsorbate molecules on adjacent sites

Nitrogen adsorption method

- Langmuir model (cont'd)
  - The fractional coverage of the surface θ changes at the adsorption rate proportional to gas pressure p and the number of empty sites $N(1-\theta)$.
  - The desorption rate proportional to $N\theta$.



Nitrogen adsorption method

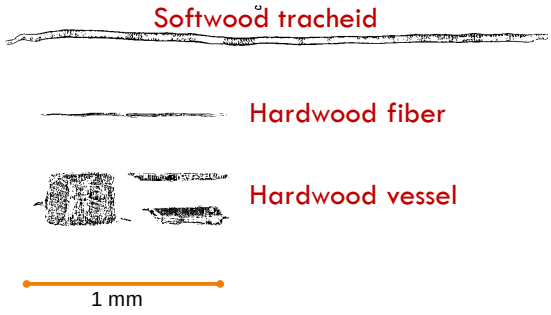


Specific surface area (SSA)

Drying method	Sample	BET SSA, m^2/g
Solvent exchange	Unbleached Spruce KP	230
	Bleached Spruce KP	185
	Spruce α-cellulose	185
	Spruce GP	25
	Birch KP	129
Evaporation at 105 °C	Unbonded pulp fibers	1.2
	Paper	0.5 – 1.0

KP=kraft pulp, GP=ground wood pulp

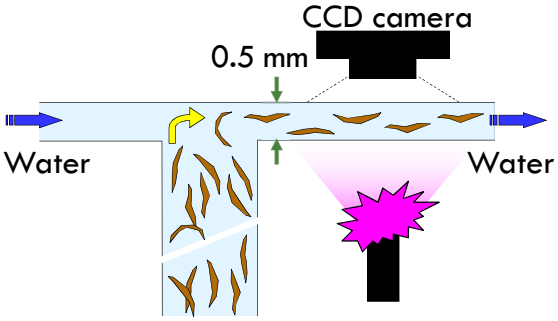
Length and width of fibers



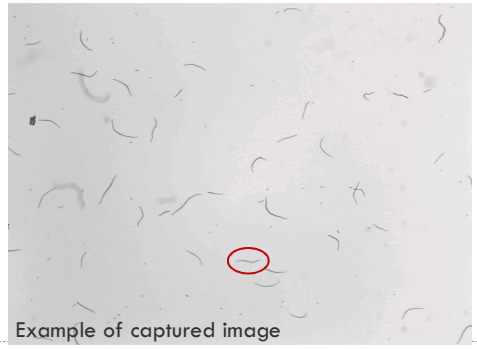
Fiber length and width distribution

Fiber tester, ABB(L&W), Sweden

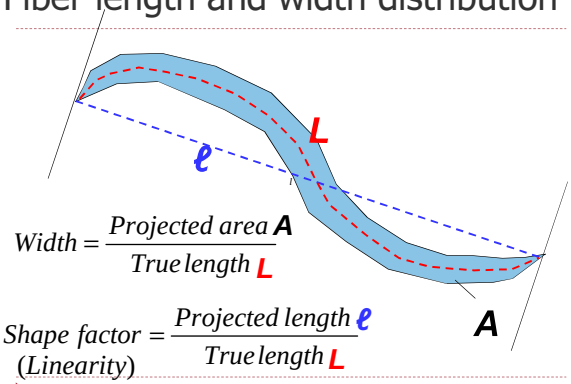
Fiber length and width distribution



Fiber length and width distribution



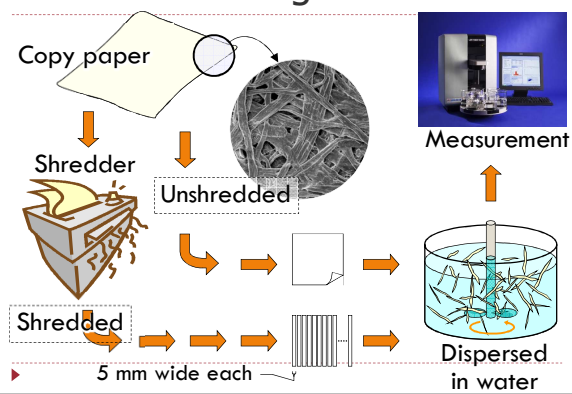
Fiber length and width distribution



$$Width = \frac{Projected\ area\ A}{True\ length\ L}$$

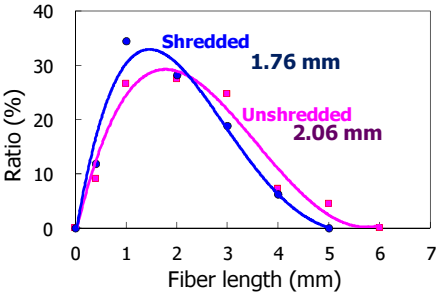
$$Shape\ factor\ (Linearity) = \frac{Projected\ length\ \ell}{True\ length\ L}$$

Mean fiber length



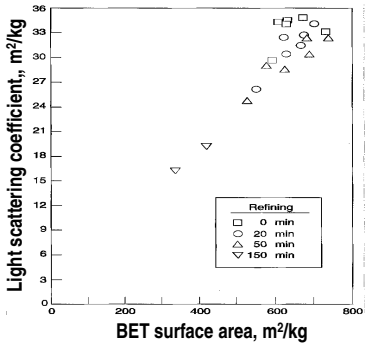
Mean fiber length

- Comparison in fiber length between shredded and unshuredded copy papers



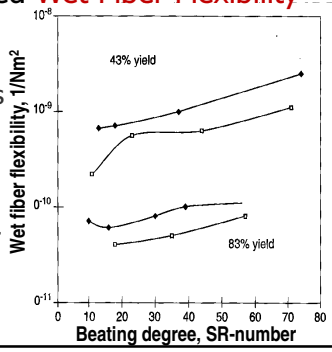
Effect of beating on paper properties

- **S**pecific **S**urface **A**rea on **L**ight **S**cattering **C**oefficient
  - LSA decreases as fiber bonding area increases.
  - Interfiber bonding area can be evaluated by SSA.
- Beating increased interfiber bonding area.



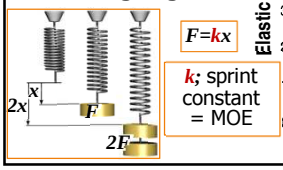
Effect of beating on paper properties

- Beating decreased Wet Fiber Flexibility (WFF)
  - Bending strength of single wet fibers was measured for determination of WFF.
  - SR = Schopper-Riegler method for determination of drainability



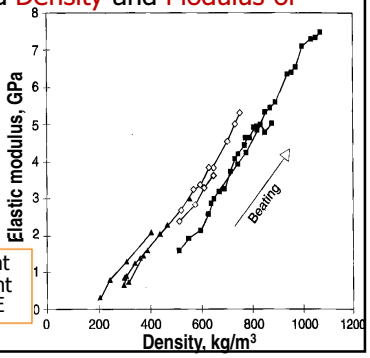
Effect of beating on paper properties

- Beating increased Density and Modulus of Elasticity (MOE)
  - Linear relationship between density and MOE regardless of beating degree



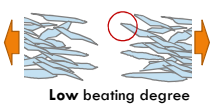
$F=kx$

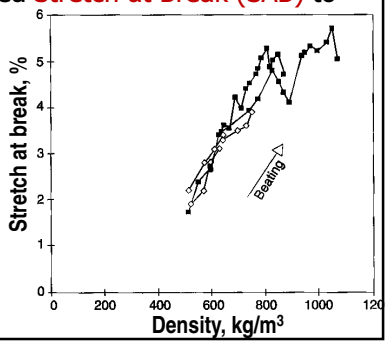
k; sprint constant = MOE



Effect of beating on paper properties

- Beating increased Stretch at Break (SAB) to certain degree
  - SAB increased with as well, but leveled off.





Stock preparation – additives

- **Paper quality** control
  - **Size (sizing agent)** - water repellency
  - **Filler** - brightness and opacity
  - **Strength agent** – dry or wet strength
  - **Dye** – optical brightening agent (OBA)
- **Paper manufacturing** control
  - **Retention aid** – ex. *aluminum sulfate* – fines, fillers, and size retained more
  - **Aintiseptic** (preservative)