Aalto University
School of Chemical
Technology

Web based fiber Products
CHEM 2125
Introduction

Thad Maloney

120124

Why this course?

- Overview of paper manufacturing process (wet laid process)
- Understanding of key unit operations
- Relationship between process/raw materials and products for paper and board
- Necessary background to work in/for a paper mill.

Course contents

- **Project work 50% of your grade**
  - Eero Hiltunen in charge
  - More info after 16.1. (registration for course ends)
  - Groups of ~3 persons
  - Ready by 13.3. -> return slides to MyCourses
  - Presentation by all groups on Fri 15.3.

- **Personal Oral Examination, 50%**
  - ~30 minutes per student
  - Thad
    - More info later

Lecture	Lecture/activity	Lecturer	Date	Notes
1	Introduction	T. Maloney	12.1.24	
2	Paper properties	E. Hiltunen	19.1.24	
3	Stock Preparation and Refining	T. Maloney	26.1.24	
3	The Approach Flow System	T. Maloney	2.2.24	
4	Web Forming	T. Maloney	09.2.24	
5	Dewatering	T. Maloney	16.2.24	
6	Wet pressing	T. Maloney	1.3.24	
7	Foam forming	J. Ketoja, VTT	08.3.24	Read article in MyCourses before class
8	Presentations from student groups	all	15.3.24	hall L2 (Puu)
----	No lecture!	-------	22.3.24	
	Personal Oral Exam	Thad	Info later	

Project Topics 2024

1. On a paper machine the web is breaking several times a day between the press and dryer section, leading to a loss in production. Why does paper break, how can breaks be analyzed and how can the problem be solved? Expert: Eero Hiltunen.

2. A new type of specialty pigment is introduced on a paper machine. The machine is forced to slow its speed 10% due water removal problems. Why do different raw materials including pigments affect paper machine dewatering and runnability? Expert: Thad Maloney

3. A production supervision on a board machine suspects that the dryer section is not operating a peak efficiency, causing reduced operating speed. How does paper drying happen and what kinds of factors influence dryer efficiency? Expert Jouni Paltakari.

4. Corrugated board boxes used to ship televisions produced in China to markets in North America are found to fail in warehouse storage. The bottom box in a stack sometimes crushes and fails, damaging the television inside. What strength properties of the board are relevant, how can these be measured and how can the situation be improved? Expert: Eero Hiltunen

5. Liquid packaging board used in milk containers is found to absorb milk at the board edges. How is water sorption in paper and board usually controlled and why is absorption at the paper edges especially challenging. How is this controlled in liquid packaging board. Expert: Todorovic, Aleksandar atodorovic@ecolab.com

6. A board machine has a moisture streak at a certain location leading to quality problems in converting operations. What are moisture streaks, why are they problematic and how are they controlled. Expert. Juha Lipponen.

7. Production of nanopaper. A company would like to produce a grade of paper that contains a large fraction of nanocellulose (more than 10%). Since nanocellulose is very difficult to dewater, this will have an impact on the machine design and operation. How can a paper machine be modified to produce nanopaper? Expert: Hamid Ahadian (Hamidreza.Ahadian@vtt.fi).

8. Aluminum based compounds (e.g. alum, aluminum sulfate) are used in several places on many paper machine wet ends. For example, as part of a retention system, as part of a sizing system, in fixation. However, aluminum is now recognized as a toxic substance. So there is desire amongst paper manufacturers to replace aluminum with alternative chemistries. How could this be done? Expert: Jonni Ahlgren jonni.ahlgren@kemira.com

Reading material 2024

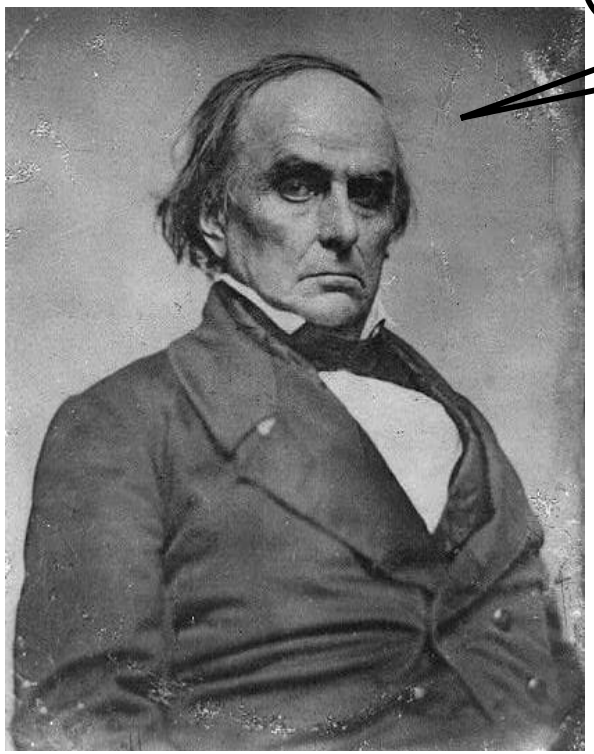
Read for the course exam 1-4:

1. Lecture slides

2. Prof. Hubbe's eight videos "9. Retention and retention aids" - videos 9A-9H
https://hubbepaperchem.cnr.ncsu.edu/minicourses/
* watch these videos before Dewatering lecture on 16.2.
3. Foam forming article: *Foam forming of fiber products: a review - Tuomo Hjelt, Jukka A. Ketoja et.al. 2021, Journal of Dispersion Science and Technology.*
* read this before Ketoja's visiting lecture on 8.3. (article at MyCourses)
4. Papermaking Science and Technology, Volume 9, Papermaking Part 2, Drying, read two chapters: Chapter 1 *Introduction to Paper Drying* and Chapter 2 *Fundamentals of Paper Drying*
* To access no 4 you need to register for ForestBioFacts - see separate word-file for instructions (at MyCourses)

What is paper?

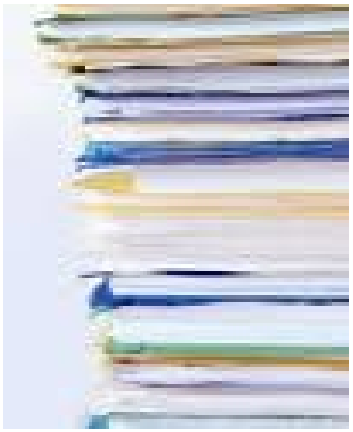
1 a (1) : a felted sheet of usually vegetable fibers laid down on a fine screen from a water suspension.

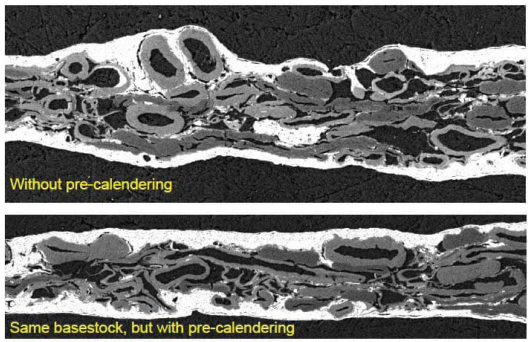


Daniel Webster

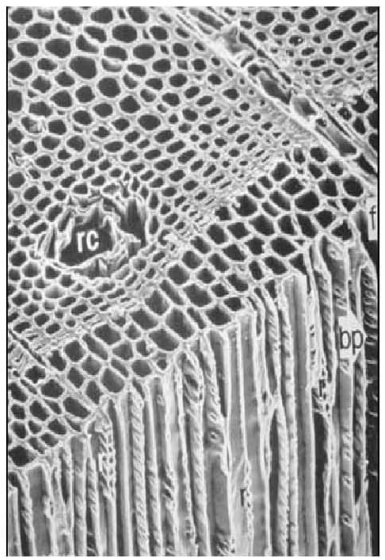
Paper characteristics

- Macroscopic structure: A 2 dimensional material e.g. dx =1000, dy=1000, dz=1.
- Microscopic structure: A 3- dimensional material composed of nearly random (stochastic) structural elements.
- Raw materials: A material made largely from natural fibers and pigments, with nanomaterials growing in importance.
- Mechanical architecture: A material composed of random fibers with hydrogen bonded joints. A hydrogen bonded continuum
- A visco-elastic material
- Manufacturing method: a material produced in a roll-to-roll operation from a fiber suspension





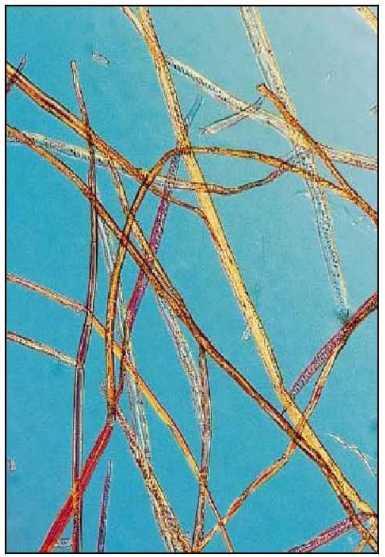
The papermaking process



Wood

Separation of fibres

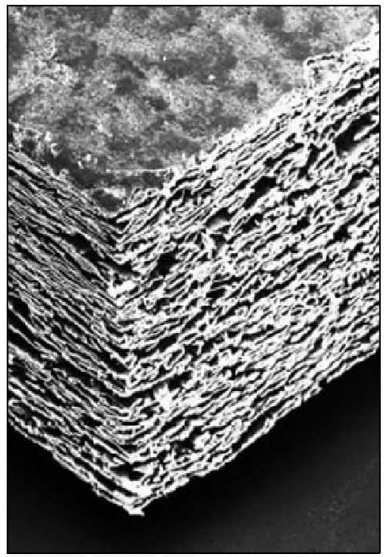
Dilution In water



Fibres

Forming of web

Removal of water



Paper

Characteristics of the manufacturing process

1. Paper manufacturing is a mature manufacturing technology, characterized by cost sensitivity
   - Massive scale at the expense of process flexibility
   - High degree of integration
2. The process must achieve high degree of functional quality and low quality variation
3. The overall manufacturing process consists of many interlinked continuous and semi-continuous processes. Each sub process must be optimized and the overall process must be optimized.
4. Process automation is a key part of the manufacturing platform.
5. The paper machine has traditionally been the center of the manufacturing process, but recently focus has shifted upstream to pulp, chemical and energy related process.
6. An essential aspect of paper manufacture is that it is an aqueous process

Key targets and demand on raw material

1. Paper mills may exists as stand alone operations or *integrated* together with pulp manufacturing.
2. The central target for pulp mills has historically been to produce even, high quality fiber for the paper mill, though other targets are gaining importance.
3. Other raw materials, pigments and chemicals can be produced on site or delivered to the mill.
4. Raw materials are one of the most important product development tools, as the manufacturing equipment tens to be large and inflexible.
5. The various raw material streams interact in complex ways, placing challenges on mill operations and introduction of new raw materials.

Why was paper invented?

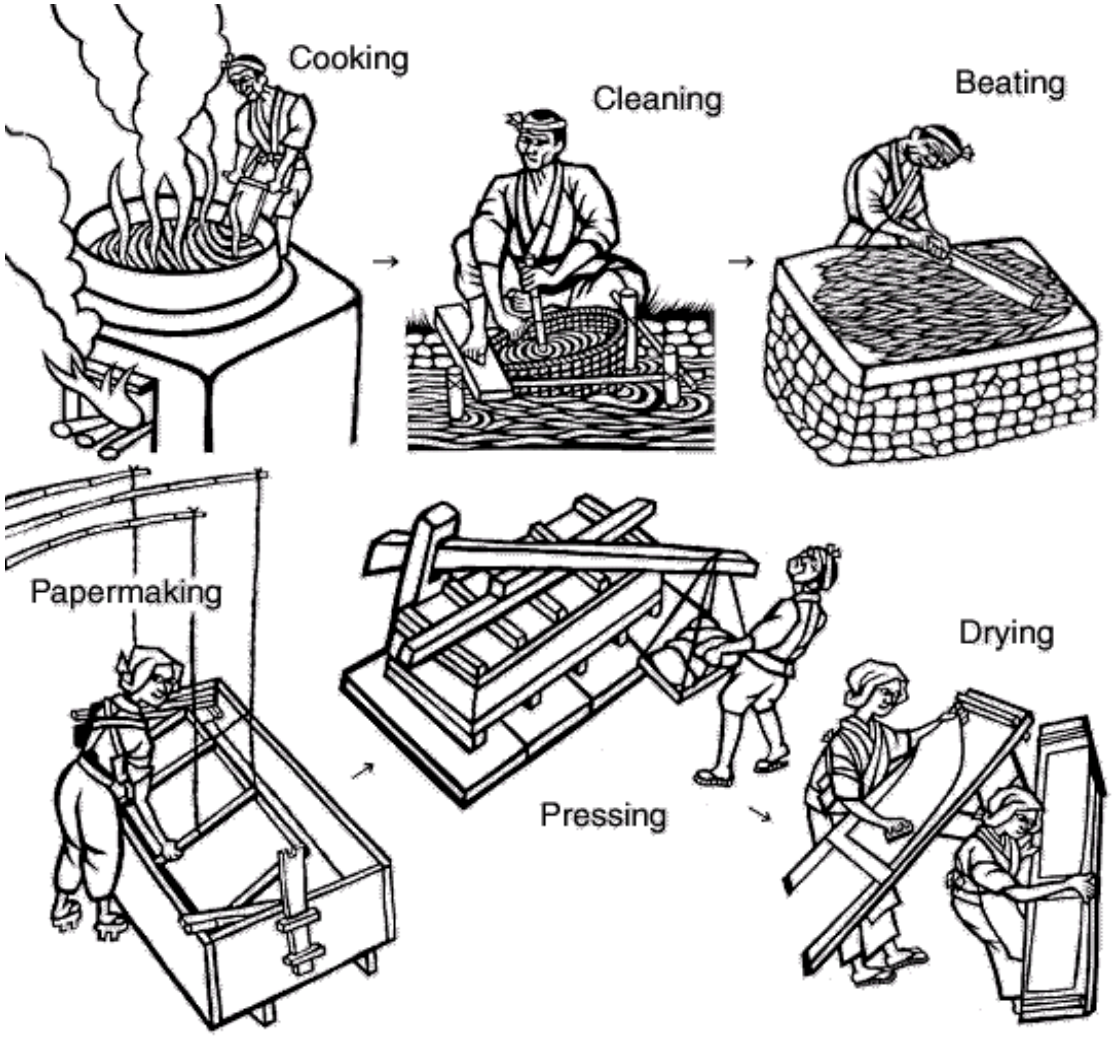
Man has a deep and basis need to communicate!

Tsai Lun solved his problem

In circa 104 ad the chinese eunich Tasa Lun discovered that mashed up mulberry bark could be filter from a water suspension on a silk cloth and would form a web that, when dried, was strong and suitable for writing. Later on, other fiber sources were explored.

The secret stayed in China for centuries, but was smuggled to Europe by Arab traders sometimes after the 10th century.

Papermaking by hand - Asia



Invention of movable type printing press

In 1440 Johannes Gutenberg completed the first changable type printing press in Mainz, Germany. The invention reduced the costs of books dramatically, spreading literacy and culture rapidly throughout Europe.

Paper has always been closely associated with culture, education and the development of man-kind

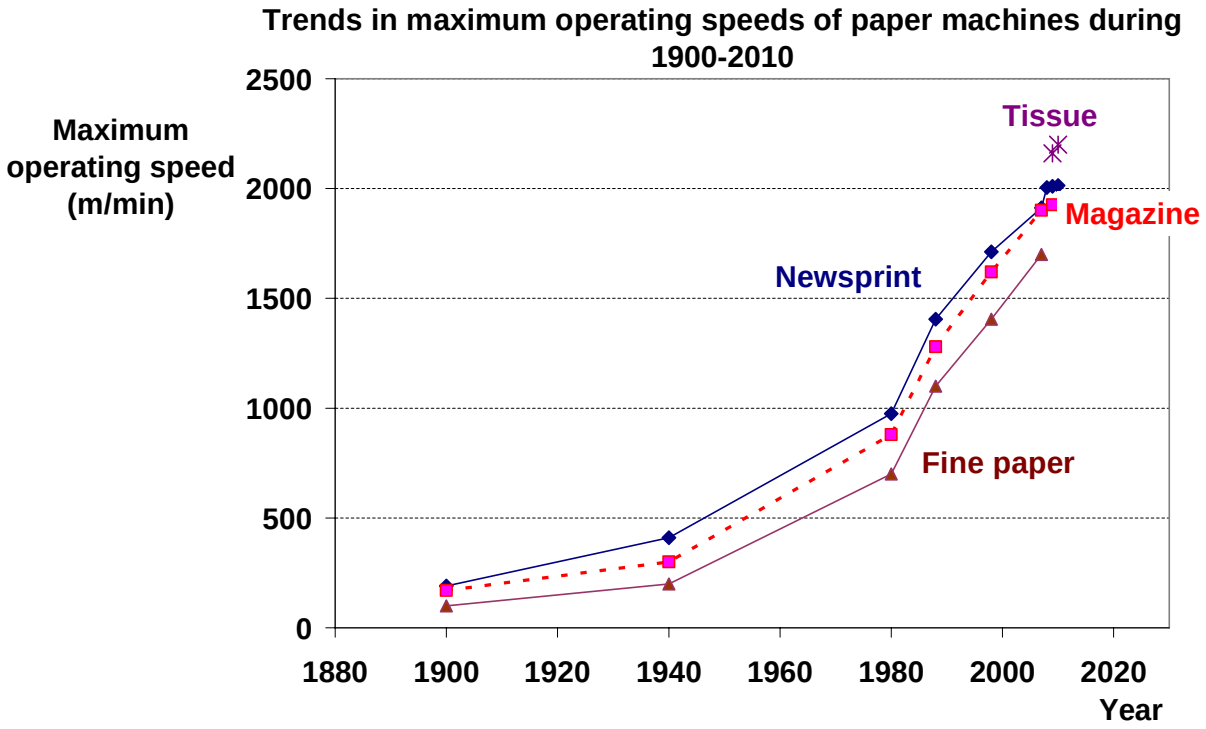
- After the discoveries of Gutenberg the *need of paper* began to grow quickly
- In the 1500's and 1600's France produced most of the paper needed in Europe.
- The demand for paper greatly exceeded supply.
- In 1803 the Fourdrinier brothers' paper machine produced continuous web.
- Paper machines replaced hand-manufacture during the first half of 19th-century- the supply of paper expanded greatly and the price of paper fell dramatically. The era of mass media was born!

The early papermaking machines were of two main types: the Fourdrinier and the cylinder. The former, invented in 1799 by Louis Robert, but called after the Fourdrinier brothers, who greatly improved the basic model, consists essentially of an endless wire cloth stretched between rolls. The wire forms a flat horizontal or slightly inclined surface onto which the pulps is poured.

Early paper machine

The development costs for the first paper machines were extremely high, and eventually drove The Fourdrinier brothers bankrupt

History paper machine speed



Paper & Board Grades

- Paper Grades
  - Printing and Writing Papers
  - Wrapping and Packaging Papers
  - Tissue
  - Specialty Papers

- Board Grades:
  - Carton Board
  - Container Board
  - Special Board






Tissue Products

Quality Demands Tissue Papers

Toilet

- softness
- dry strength
- appearance
- no wet strength

Facial

- surface softness
- appearance
- lotion additives

Napkins

- appearance
- printing properties
- colorfast

Towels

- absorption
- wet strength
- feeling
- appearance

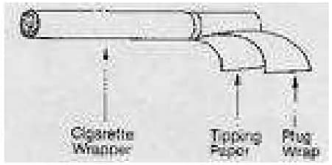
Paper Grades – Wrapping & Packaging Papers

- Sack Paper:
  - Toughness and high porosity crucial parameters
  - High consistency refining
  - Micro creping
  - Mainly SW chemical pulp

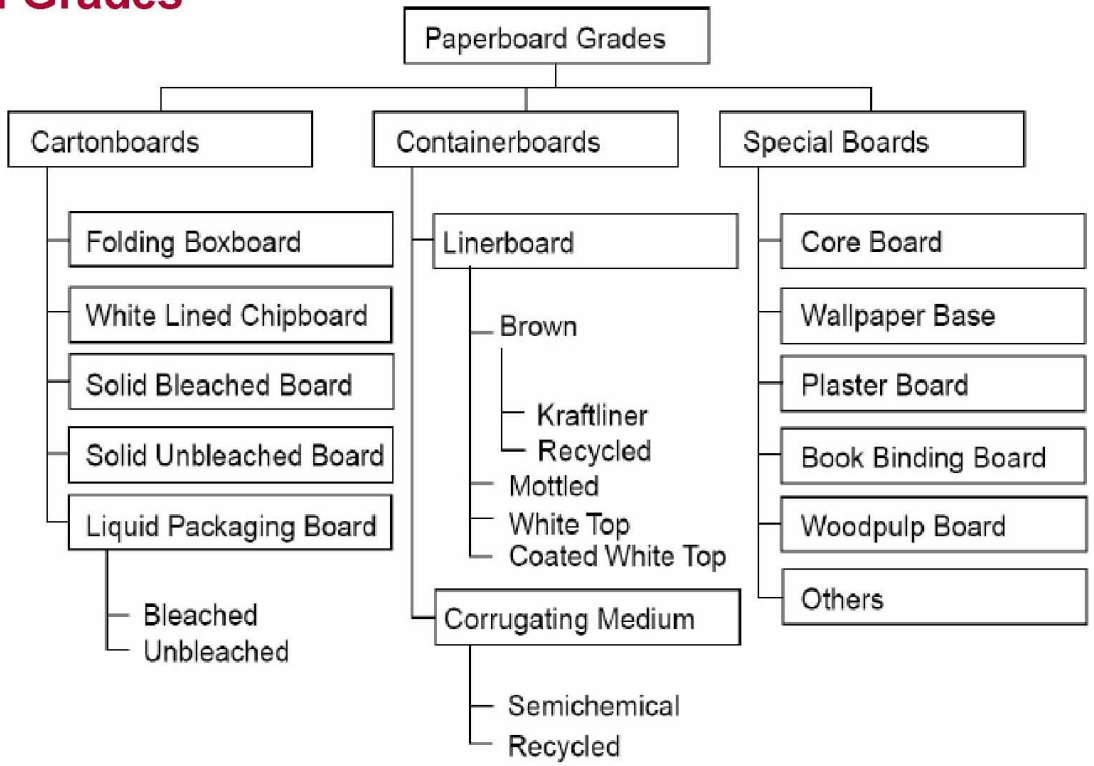
- Kraft Paper:
  - Carrier bags
  - Wrapping papers
  - Greaseproof for cooking and baking => low porosity

Paper Grades – Specialty Papers

- Electrical papers
- Absorbent papers
- Filter papers
- Cigarette paper
- Building papers
- Functional papers



Board Grades



FBB

WLC

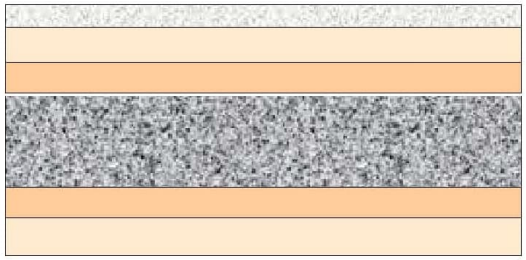
SBS

LPB

Corrugated Board
Liner + Corrugating Medium

Cartonboard – White Lined Chipboard

5 PLY WLC



DOUBLE OR TRIPLE COATED

TOP PLY	BLEACHED HW & SW
UNDERTOP PLY	DIP, BCTMP, GW
FILLER PLY	OCC, OMP, ONP, GW
UNDERBACK PLY	OCC, DIP, OMP, ONP
BACK PLY	BLEACHED HW & SW, OCC

- Basis Weight 200 – 450 g/m^2
- Typically 3 – 5 plies with Fourdrinier forming technology
- High content of recycled fibers, primarily in Filler ply
- End use: Dry food, tools, electronics

Paper functional properties and structure

Properties of different Materials compared to Paper

Table 1.2 Material properties

Material	Elastic modulus	Density	Tensile stiffness index	Bending stiffness-index
	E	ρ	$E^w = \frac{E}{\rho}$	$S^w = \frac{S^b}{w^3} = \frac{E^w}{12 \cdot \rho^2}$
	MN/m^2	kg/m^3	MNm/kg	$Nm^7/kg3$
Steel	210 000	7 800	25	0,03
Titanium	120 000	4 500	25	0,10
Aluminium	73 000	2 800	25	0,30
Magnesium	42 000	1 700	25	0,70
Glass	73 000	2 400	25	0,40
Concrete	15 000	2 500	6	0,08
Carbon fibre composites	200 000	2 000	100	2,00
Wood in grain direction	14 000	500	25	8,30
Paper, linerboard in MD	15 600	700	22	3,70

Functional Paper Properties

During manufacturing, converting and end-use of paper there are many demands for functional mechanical properties. A few illustrative examples of this are given below.

- *Example 1)* Bending stiffness paper is probably the most important mechanical proper of paper and carton board. *Figure 1.1* illustrates the obvious importance of bending stiffne for a milk carton.

Figure 1.1 **The bending stiffness is important for milk cartons as well as most paper grades.**

It was shown already half a century ago that the lifetime decreases linearly in a semi-logarithmic plot as shown in *Figure 1.3*.

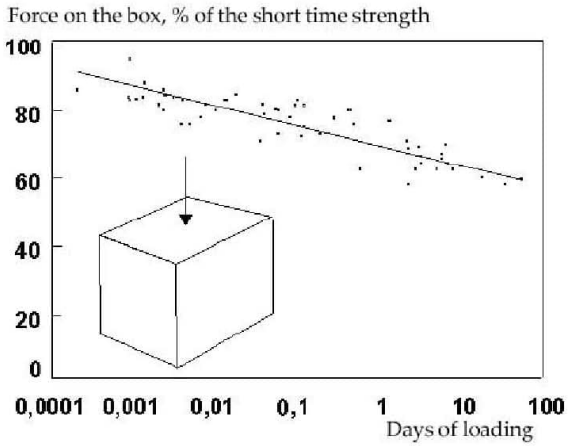


Figure 1.3 **The lifetime, the time to failure of corrugated boxes as a function of the time of loading.**

- *Example 2)* During storage of corrugated boxes and cartons, the structure may collapse due to creep in compression forces after a certain time of loading, *Figure 1.2*. The term lifetime is sometimes used to describe the time to break.

▫ *Example 3)* During manufacturing, rewinding and printing, thin paper grades may experience web breaks. The breaks may be caused by high loads, defects or inferior fracture properties. *Fig. 44.4* shows a web break in a paper machine.

Figure 1.4 **A web break in a paper machine.** (Nordiskafilt)

- *Example 4)* Sacks are expected not to break during filling, transportation and end-use. In the worst case the sack breaks which is shown in the following *Figure 1.5*.

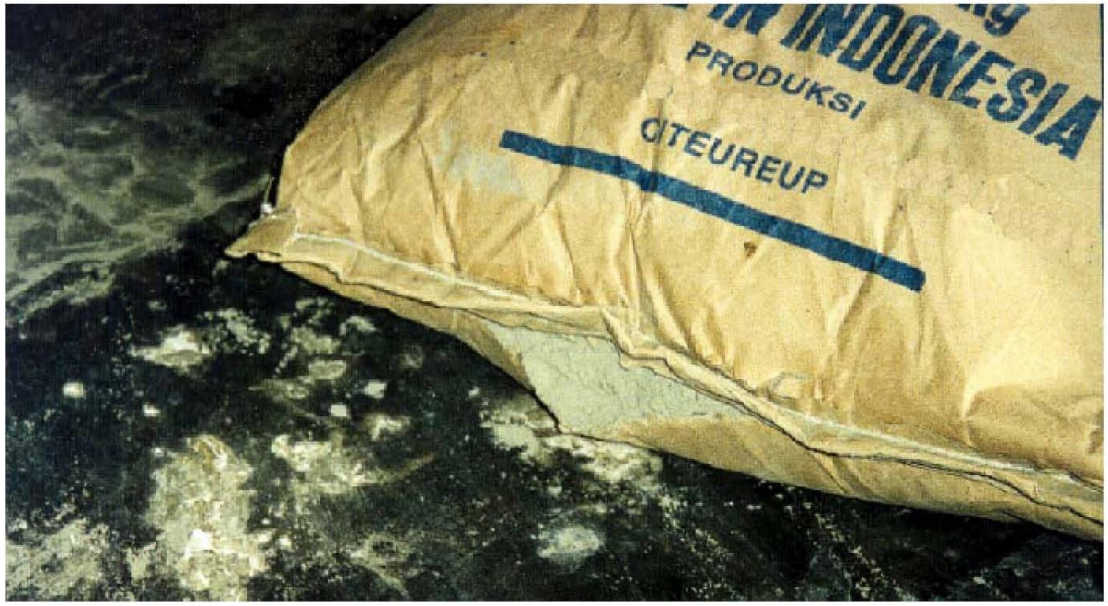


Figure 1.5 **Break of a sack filled with cement.**

- *Example 5)* During certain printing operations, for example as offset printing, the material is exposed to high stresses in the thickness direction which may lead to delamination, *Figure 1.6*.

Many functional properties may be difficult to evaluate for the purpose of trade and pulp evaluation. However efforts are made to standardise important methods for property evaluation in ISO and national standards.

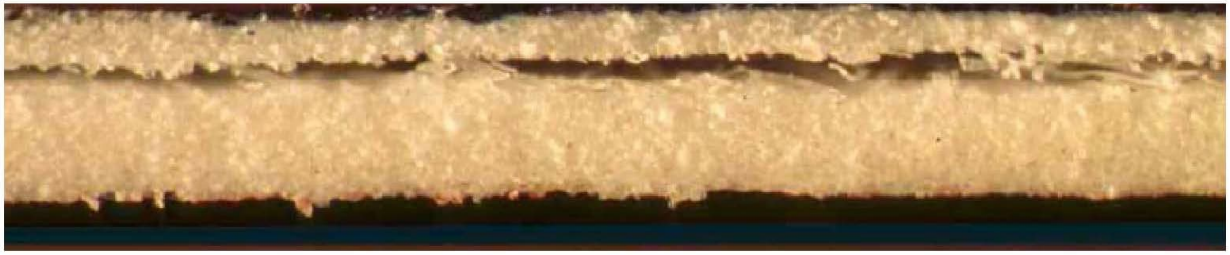


Figure 1.6 **Delamination of a carton board in offset printing.**

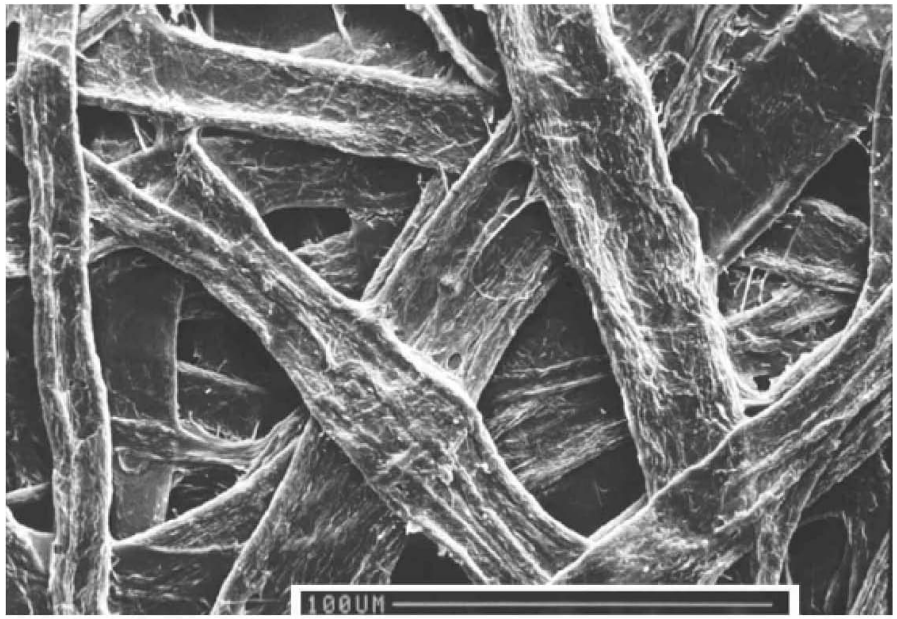


Figure 1.16 **Linerboard,** the surface-layer in corrugated cardboard, is manufactured mainly from bleached pine Kraft pulp in a yield interval of 47–52%. The pulp is only slightly beaten. The pulp and structure is chosen mainly to give high compression strength, creep resistance, toughness in converting and delamination resistance.

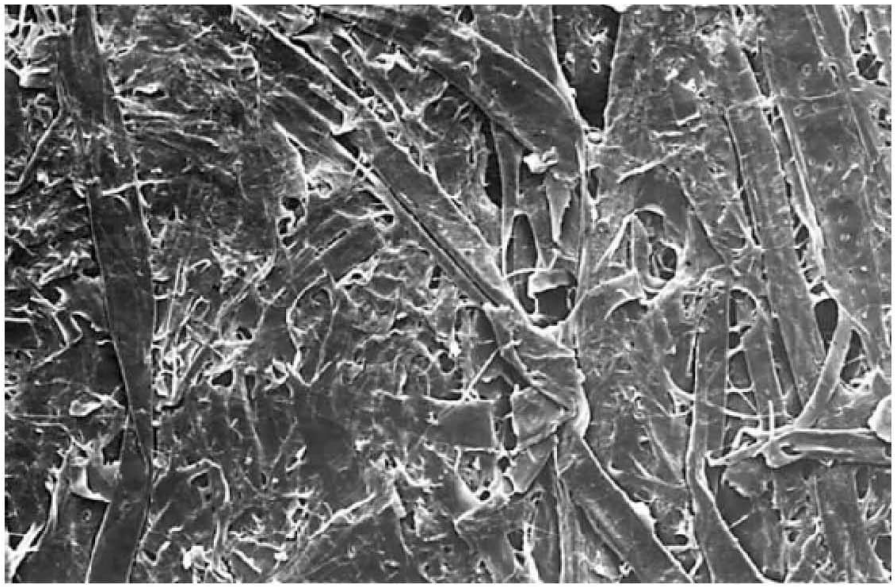


Figure 1.17 **Newsprint,** may be manufactured from different fibre sources. The most recent pulp is thermomechanical pulp of softwood Still newsprint is manufactured from groundwood and from recycled newspapers. To improve strength properties often the paper is reinforced with an addition, in the order of 5–10 % of chemical softwood pulp. The pulp and structure is chosen mainly to give good runnability during manufacturing and end-use, good opacity and printability.

The Structure of some Paper Products

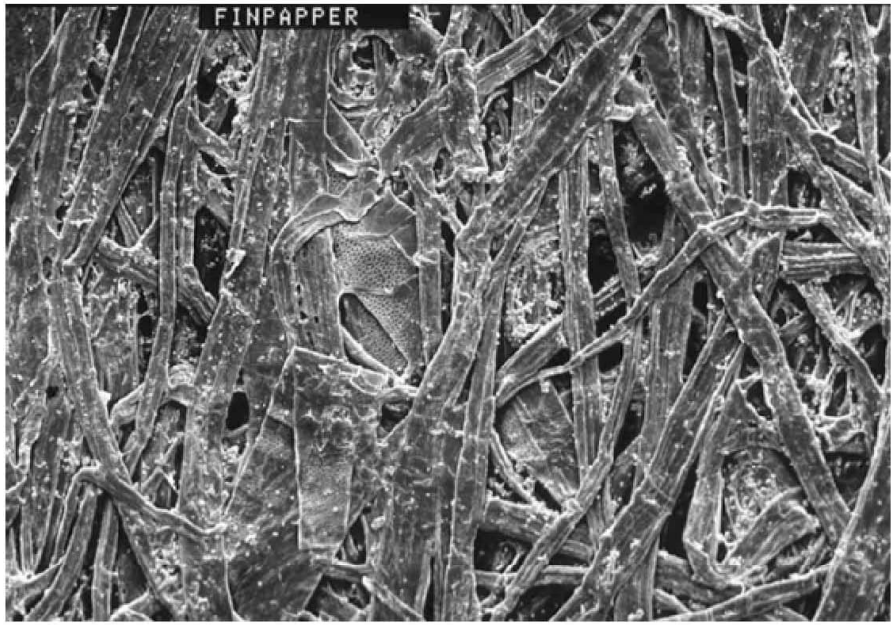


Figure 1.18 **Fine paper**, consists of chemical, undamaged fibres, which are often a mixture of hardwood and softwood. Note the filler particles. The pulp and structure is chosen mainly to give good opacity and surface properties.

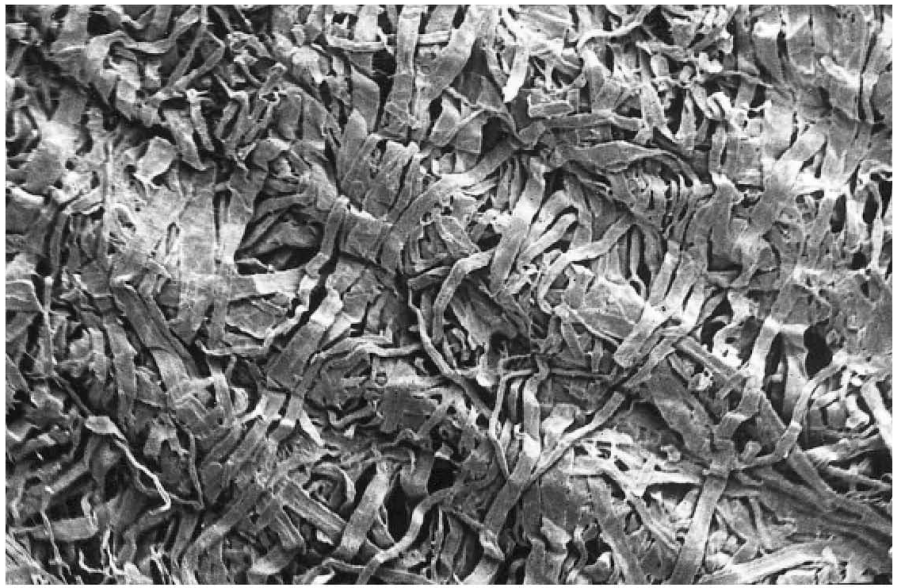


Figure 1.19 **Tissue.** Creped paper with low grammages, 14–25 g/m^2. The type of fibre can vary. Note the creped structure in the picture. (The magnification is slightly lower than in the other pictures).

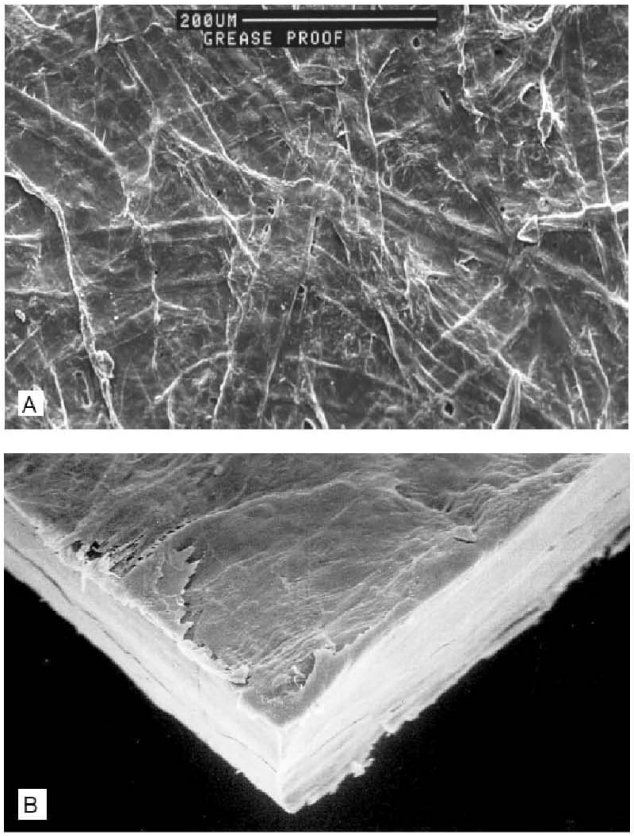


Figure 1.20 **Greaseproof paper.** The fibres in the greaseproof paper are so well beaten that the fibre structure in the paper has been "erased". The paper becomes transparent, has a low opacity. Greaseproof paper is used e.g. for drawing, baking and sandwich paper.

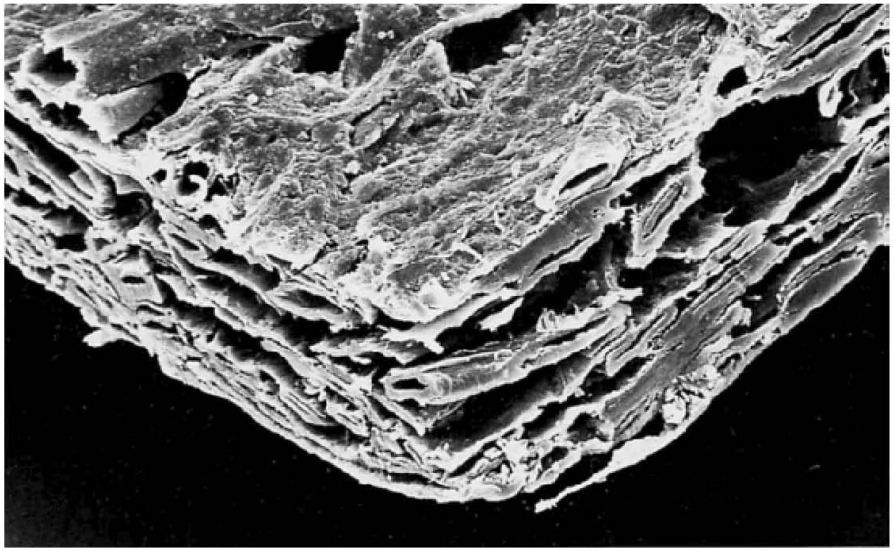


Figure 1.21 **Copy paper,** often consists of chemical, undamaged fibres, often a mixture of softwood and hardwood. Note the open paper structure. The fibres and structure is chosen mainly to give flatness and, good surface properties.

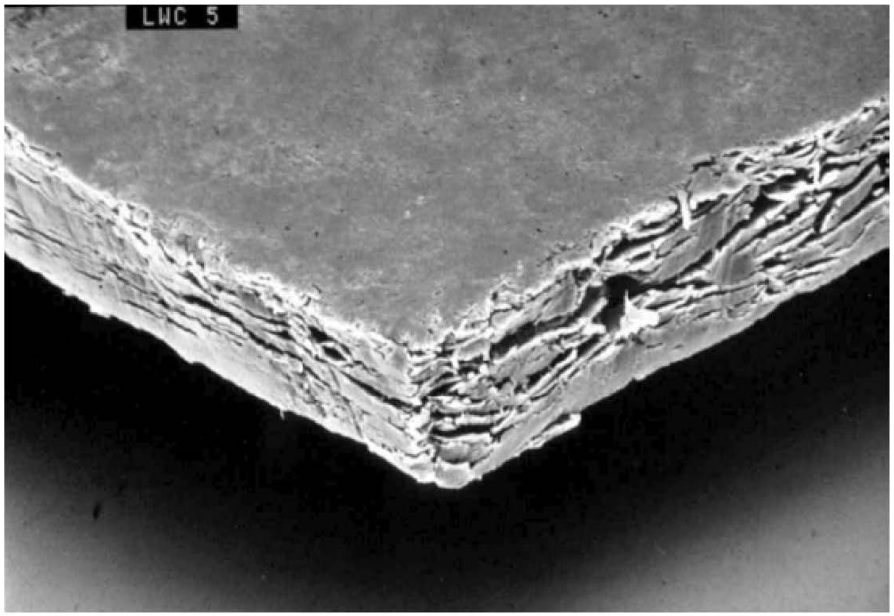


Figure 1.22 **LWC, Light Weight Coated paper,** consists of mechanical, fibres, reinforced with chemical fibres and with a coating layer. The fibres and structure is chosen mainly to give good runnability in printing presses and to provide a good base paper for the coating.

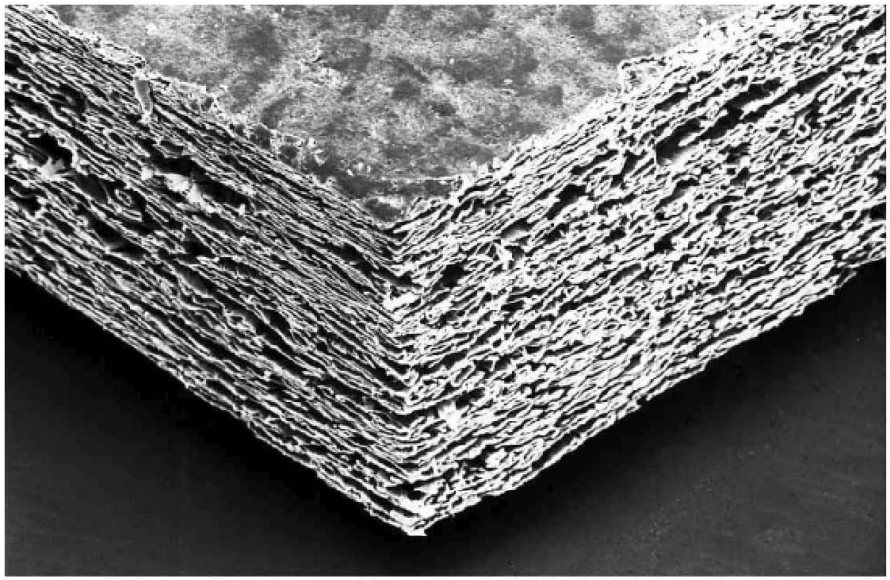


Figure 1.23 **Coated carton board.** Carton board is manufactured by a multi-layer technology, e.g. with a surface layer of bleached kraft pulp and mechanical pulp in the middle, or with several layers of the same type, e.g. bleached Kraft pulp. The coating layer makes the carton board surface more even and more suitable for high-class print. The fibres and structure is chosen mainly to give bending stiffness, good converting properties and surface properties.

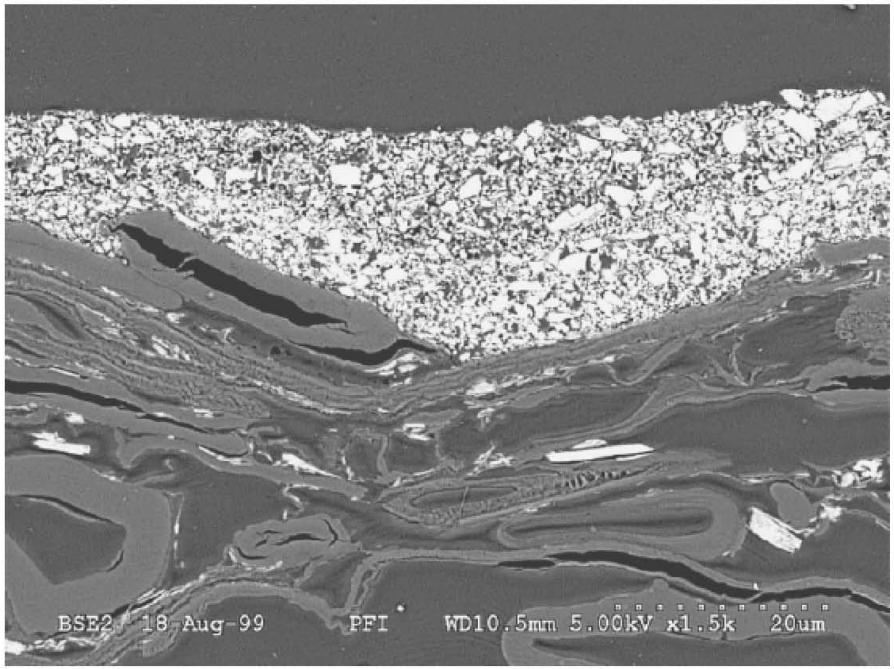


Figure 1.24 **The coating layer of a coated carton board seen in the thickness direction. Note the cross-sections of the fibres.**