Lecture 12:

Manufacturing of paperboard and corrugated board packages

Converting operations:
printing, die-cutting, folding, gluing

After lecture 12 you should be able to

- describe the most important converting operations in paper and paperboard package manufacturing
- discuss important runnability considerations in paperboard package handling
- relate factors affecting runnability to paperboard appearance and physical performance quality parameters

Literature

- *Pulp and Paper Chemistry and Technology - Volume 4, Paper Products Physics and Technology*, Chapter 10
- *Paperboard Reference Manual*, p. 157-225
- *Fundamentals of packaging technology* Chapters 4, 6, 15 and 18

The Paperboard Packaging Design Process

Package Design is the result of:

- Personal creativity plus
  - Knowledge and understanding of packaging materials, including:
    - Structural properties
    - Graphic capabilities
    - Converting processes and converting properties
    - Customer packaging systems
    - Marketing objectives
    - Distribution requirements
    - Retail outlet expectations
    - Needs and desires of end user
    - How end user will use the product
- Many people may contribute to the design

Overall, the design must provide:

- Containment of product
- Protection of product
- Ease in handling through distribution
- Prevention of product spoilage
- Tamper evidence
- Consumer convenience
- Brand identification
- Communications for the consumer:
  - Instructions for product use
  - Coding for quality assurance, expiration dates
  - Dietary and nutritional information

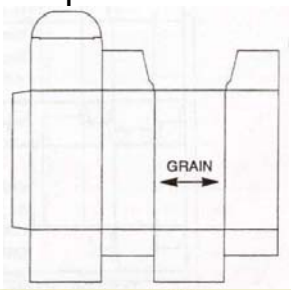
The design should consider three important areas

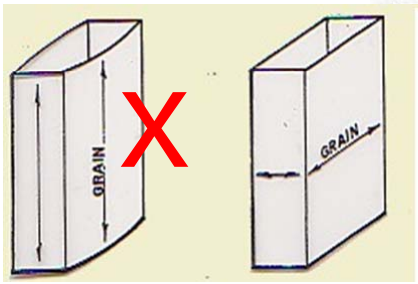
1. Converting or package manufacturing issues
2. Customer issues for filling and sealing
3. Consumer issues for convenience and performance

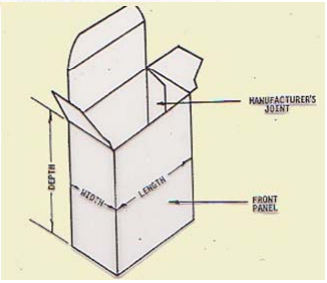
But first:

Grain direction of paperboard is important

- Printing
- Automated gluing
- Reduce bulge
- Reduce shrinkage

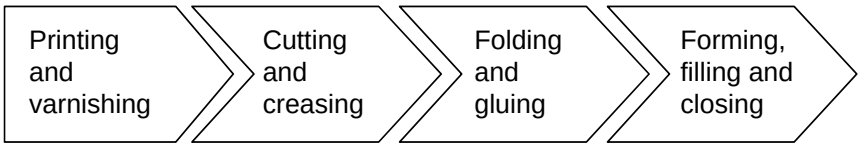






Converting operations

Productivity and quality parameters



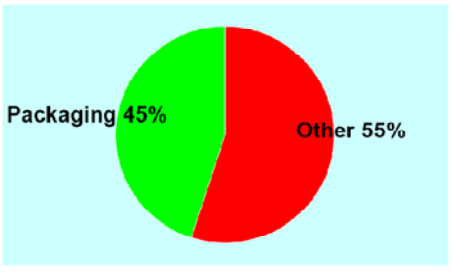
Paperboard and corrugated board printing

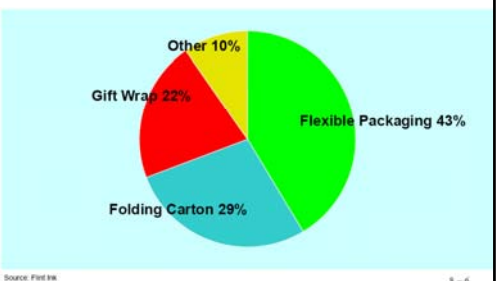
Driving forces for package printing

- Graphic quality
  - High emphasis on point of purchase appearance
  - Correct and consistent colours
- Functional quality
  - Printing must do its intended job without failure
- Ecological quality
  - Inks and coatings should pose no threat to the environment

Packaging accounted for 45% of printing inks used in 2002

…and paperboard folding cartons accounted for 29% of the ink usage in packaging

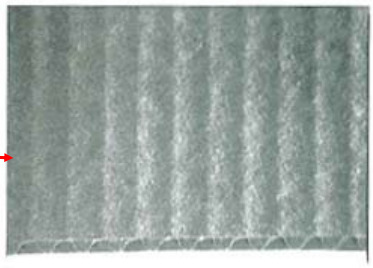




Printing

Runnability problems

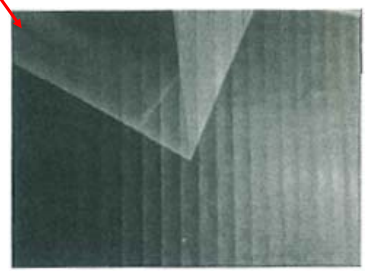
- Print quality
- Washboarding (corrugated)
- Misregister
- Delamination
- …



Unprinted board

Runnability requirements

- Flatness
- Dimensional stability
- ZD-strength
- Dust and debris free board



Printed board

Printing process requires four components

- Printing press (sheet or reel feed)
- Printing plate
- Substrate (paper, board, plastics, glass, metal etc.)
- Ink

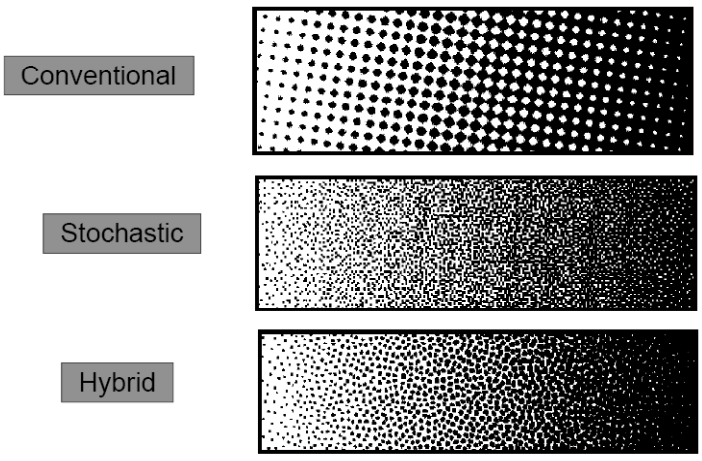
Pre-press operations

Steps involved in pre-press

- Creating graphic design concept
- Incorporating commercial art
- Incorporating photography
- Typesetting (electronically)
- Assembling the image electronically
- Creating colour separations
- Proofing the art

Printing

Screening/Rastering



Source: MeadWestvaco

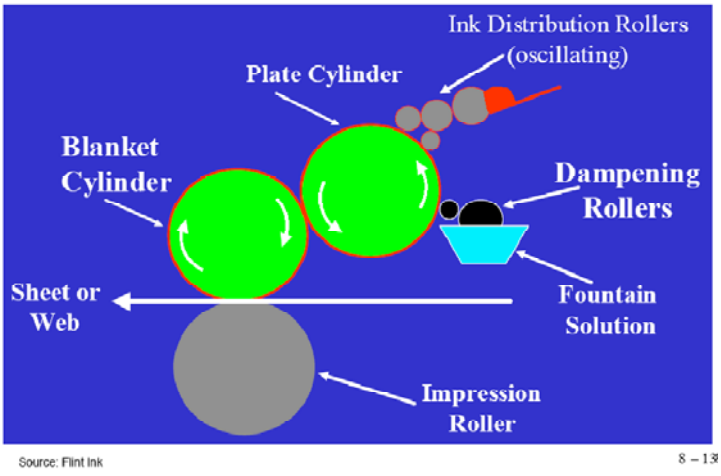
Majority of all paperboard packages printed by one of three methods

- Lithographic Offset
- Flexography
- Rotogravure

Other methods used in limited number of applications

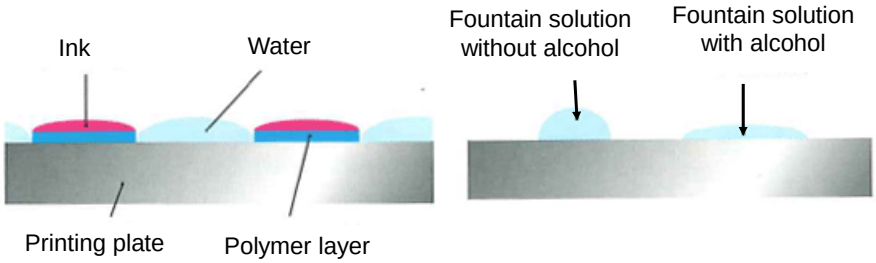
- Screen printing
- Digital printing
  - Ink jet
  - Electro photography

Offset lithography



- ❑ Web-fed offset
- ❑ Sheet-fed offset

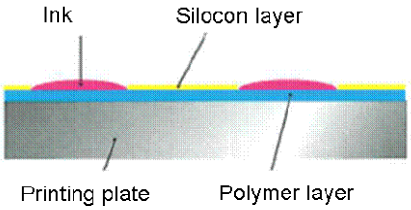
The lithographic principle



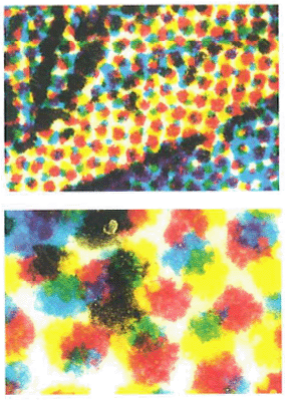
- Lithography is a planographic process, meaning that printing and non-printing areas are on the same plane.
- The non-printing areas of the plate are dampened by water. The ink is repelled from water-wetted areas.

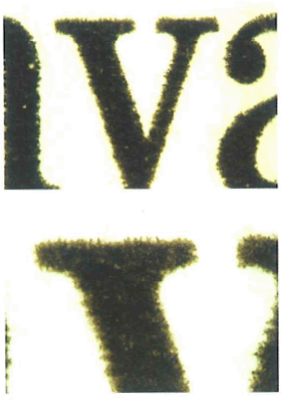
Water-free offset

+ No fountain solution:
  no alcohol,
  less negative environmental impact,
  less dimensional stability problems
- Tackier ink:
  blister and delamination problems,
  debris on the rubber cylinders

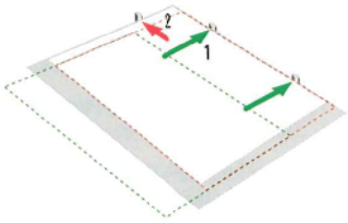


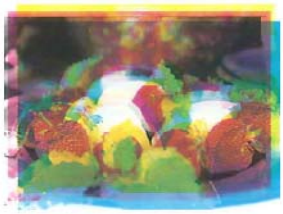
Offset lithography





Register - Misregister





- Web-widening due to the fountain solution and mechanical loading will affect the print quality.
- For a good print quality, it is important that raster dots are printed on the paper at the intended spots.

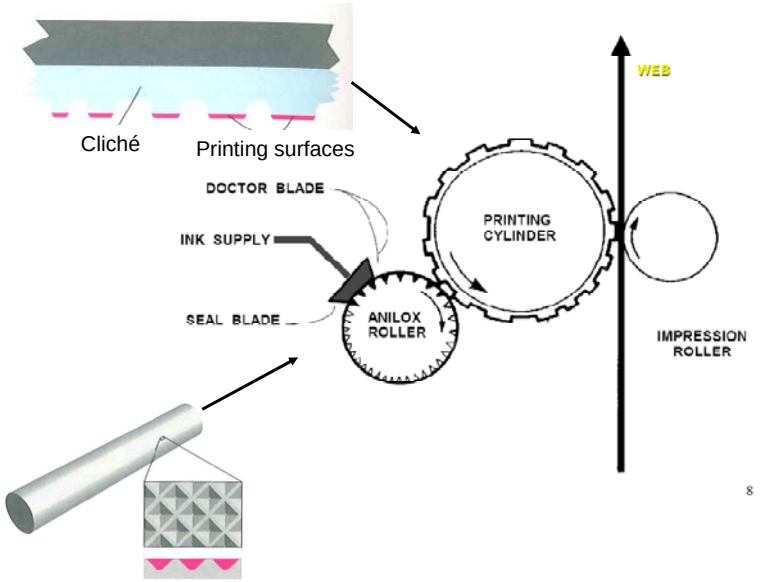
Advantages of offset lithography

- Offset print exhibits a clean interface between the image and non-image areas
- Printing plates are relatively inexpensive
- Make-readies are quick
- It is at least reasonably economic for “short” runs
- Offset produces the best “process printing” of all types of printing

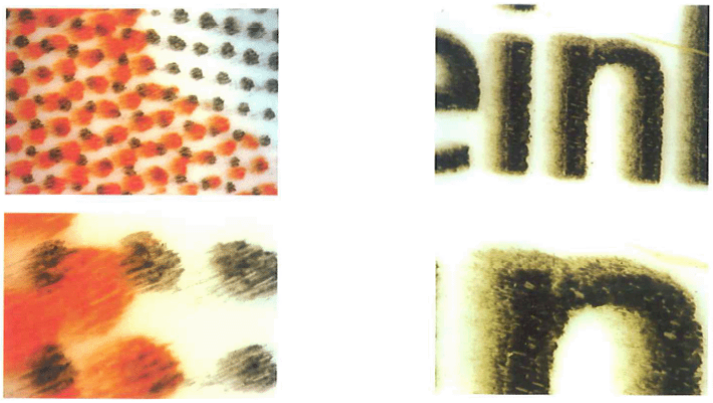
Disadvantages of offset lithography

- Requires over 60 possible adjustments on each print unit to obtain a proper print
- Requires more technical ability to balance ink and water
- Requires additional drying time before cutting
- Normally printed in sheet form, then has to be die-cut in a separate operation

Flexographic printing



Flexography

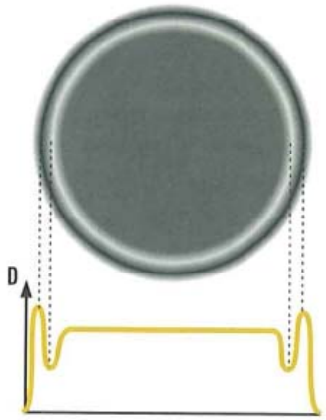


Advantages of flexographic printing

- Provides solid colour and good ink coverage
- Quality is improving to approach Rotogravure and better in some cases
- Flexographic plates are relatively inexpensive
- Typically in line with a die-cutter and are roll fed eliminating two processes (sheeting and cutting)
- Flexographic plates are good for up to 500 000 impressions
- Inks are dry before reaching the die-cutter
- Inks are normally inexpensive
- Flexographic printing can be done on several different substrates, such as plastics, corrugated, film etc.

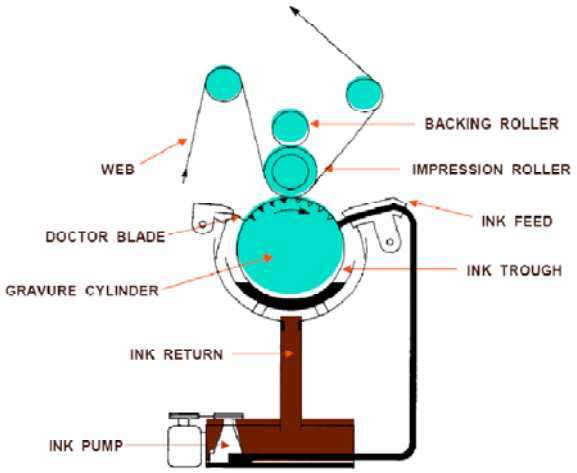
Disadvantages of flexographic printing

- A halo pattern develops around the edges of a solid colour on large format presses
- Limited process printing "150 line screen film" is the finest typically used on large format presses (some narrow web Flexographic presses are using higher line screens)
- Problems to reproduce details in the tuning



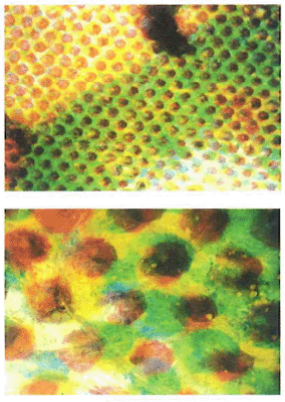
Rotogravure printing

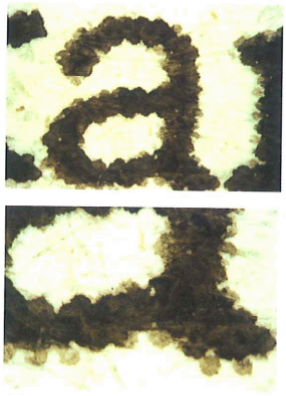
(Djuptryck)



Source: MeadWestvaco

Rotogravure





Advantages of gravure printing

- Ideal for long run lengths
- Best for high quality large scale commercial printing
- Colour is more consistent since there are not as many variables
- Normally roll fed and in line with a die cutter eliminating two processes (sheeting and die-cutting)
- Able to put on various amounts of coating with differently etched cylinders
- Prints metallic inks much better than any other printing process
- Because the runs are typically longer the waste is normally less
- Gravure cylinders can last for over a million impressions
- Inks dry immediately

Disadvantages of gravure printing

- Gravure printing has a “sawtooth” pattern on the edge of a single solid colour
- Printing plate cylinders are the most expensive
- Make-readies are longer
- Registration is not as good as offset but equal to Flexography
- Water based inks do not print as well as solvent based inks

Comparison of printing processes

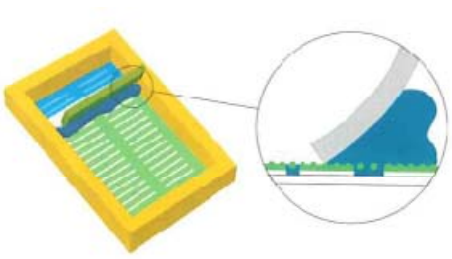
Printing processes compared.

	Lithography	*Flexography*	*Gravure*
Short runs	best	good	not suitable
Long runs	good	good	best
Plate lead time	shortest	medium	longest
Fine lines	best	good	poor
Large solids	good	better	best
Register	best	lowest	intermediate
Gain	lowest	most	intermediate
Uncoated paper	good	best	not suitable
Plastic film	not suitable	good	good
Screen range	200+	133 to 150	200+
Ink formulation	oil-based paste	widest latitude	low viscosity

From Soroka, W., “Fundamentals of Packaging Technology, 3rd ed.

Screen printing

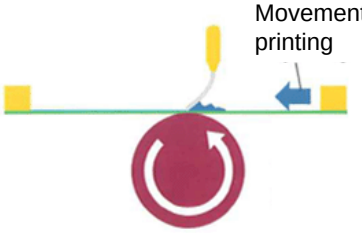
Screen masked off into a pattern



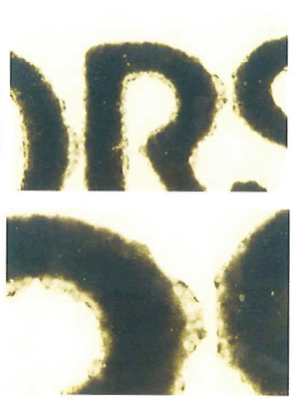
Wiper blade moves an ink puddle across the screen

Movement during printing

Screen printing on round object



Screen printing



Screen printing

Advantages and disadvantages

+ Inexpensive
+ Can print on any substrate
+ Large solid areas are uniformly opaque
+ Very large image carriers are possible

- Very low production speeds
- Expensive due to heavy ink lay-downs
- Not able to produce fine halftones (gradients in ink-density)

Digital printing

- Ink jet
  - Printers operate by propelling tiny droplets of liquid ink onto the substrate.
- Electro photography
  - Process used by *i.e.* laser printers. An electrical charge is placed onto the paper. Toner is then spread over the paper, attracting to the static charge portions of the paper where finally the toner is fused to the paper by heat and pressure.

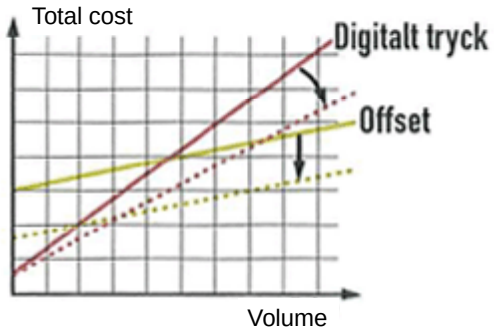
Ink jet

Digital printing

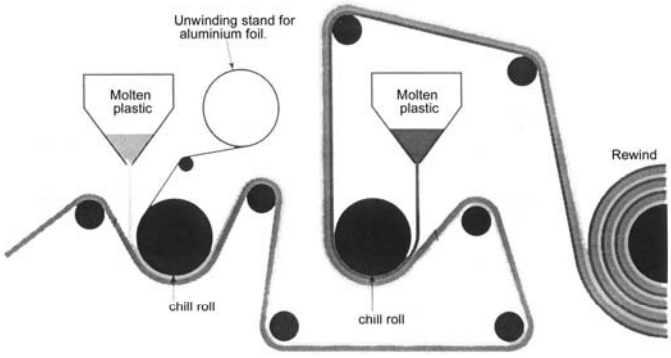
Advantages and disadvantages

+ Low costs for small quantities
+ Films and plates are not needed
+ Short set-up times
+ Variable data
+ Environmentally friendly

- High costs for large quantities
- Not as high print quality as offset



Lamination of paperboard

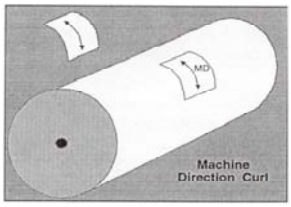


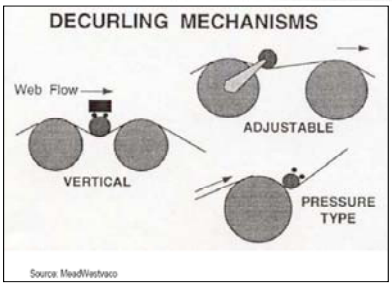
- Internal coating
- External coating
- Runnability in filling machine

Die-cutting
Creasing and folding

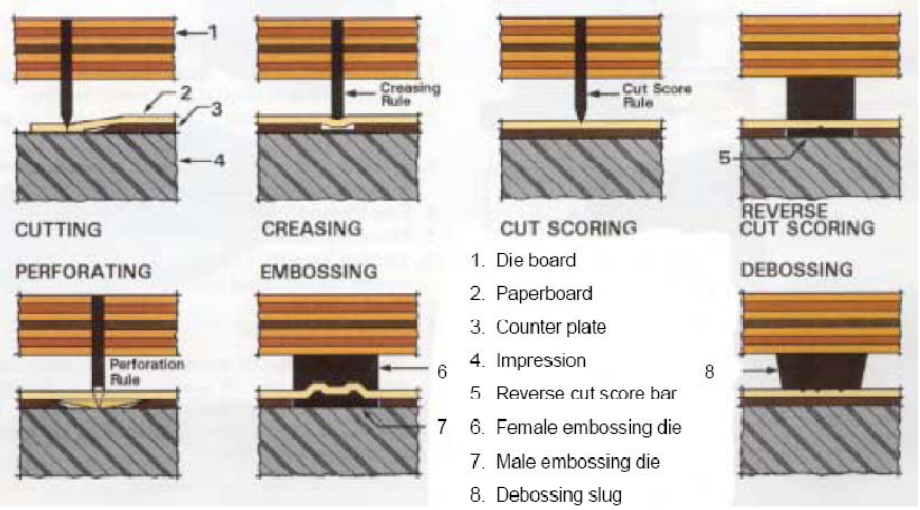
Printing is combined with other converting processes that include:

- De-curling from the MD roll-set curl or wrap curl
- Sheeting for offset presses and die cutting
- Die cutting:
  - Cutting
  - Creasing
  - Cut score
  - Reverse cut score
  - Perforation
  - Embossing
  - De-bossing
- Finishing, as required, including:
  - Windowing
  - Metal edge applications





Each process uses a different type of rule



Different types of rule

- Knives
- Score
- Relief
- Perforation

Knives - razor sharp edges for cutting

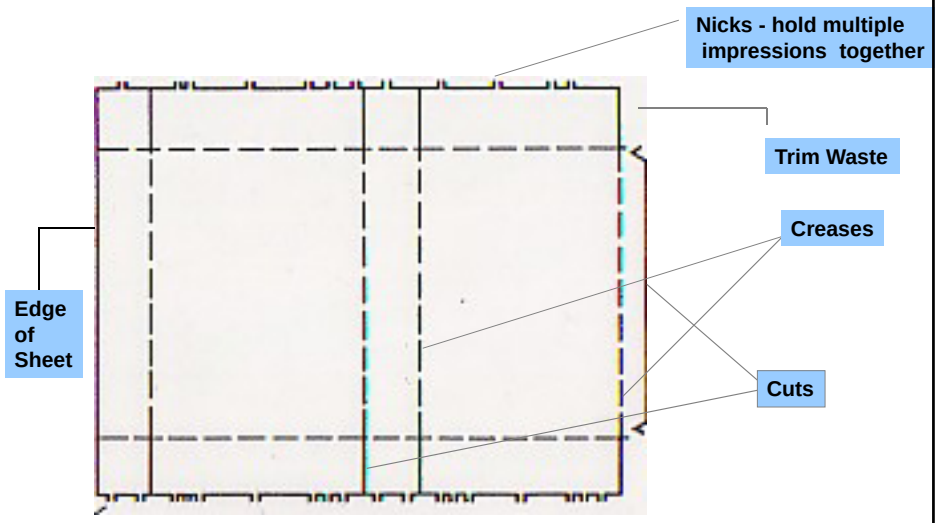
Scores - dull edges for folding

Relief or combo - combines sharp and dull edges

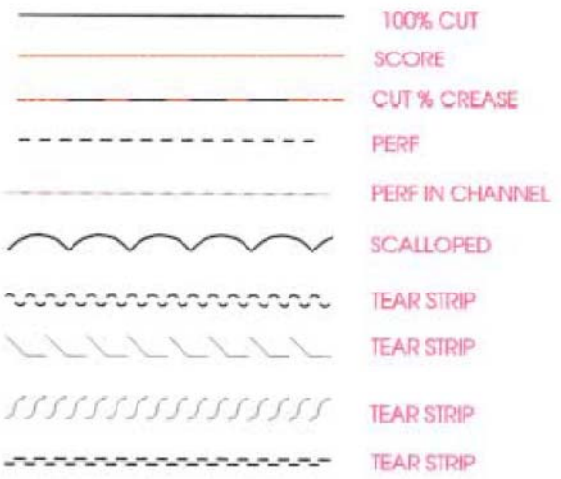
Perforating - series of repeating sharp edges

Source: Graphic Packaging International

Cutting and creasing a box

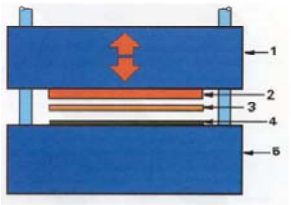


Examples of cuts and creases used in paperboard packaging



Flat bed die-cutting

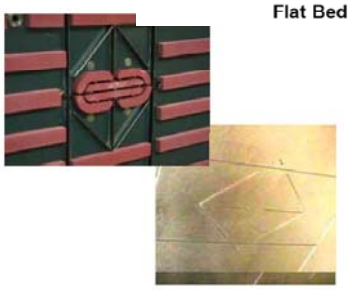
Flat bed die cutting



1. Platen
2. Die Chase
3. Paperboard sheet
4. Counter plate
5. Impression plate

A commercial flat bed die

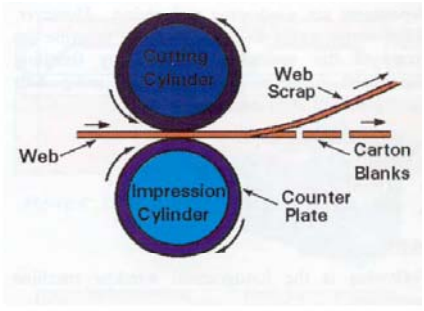
Flat Bed Cutting Die



- Die body
- Rule
  - Scoring slots
  - Die knives
- Ejection material

Source: Graphic Packaging International

Rotary die cutting



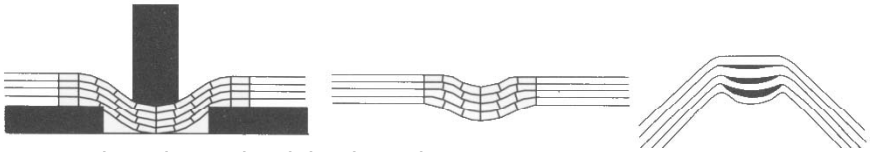
Source: Paperboard Packaging Council

Source: Graphic Packaging International

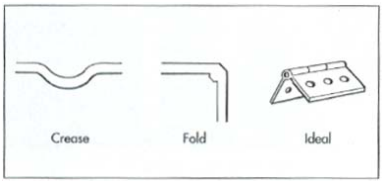
Flat bed vs. rotary die cutting

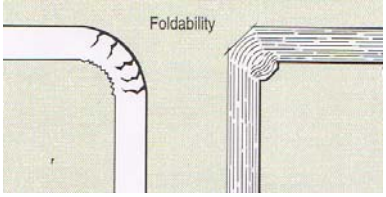
- Rotary die cutting is best suited for
  - Long runs
  - Repeat orders
- Disadvantage is that cutting dies are more expensive than flat bed cutting dies

Theory of creasing



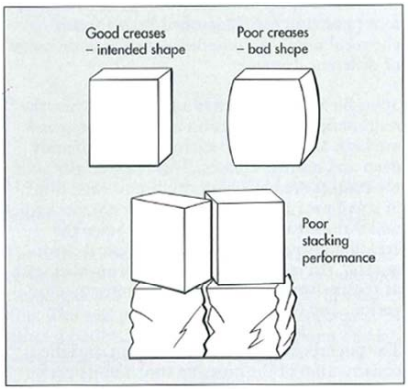
- Paperboard must be delaminated to create a good score
- In a well-defined folding line the ideal state is a hinge.
- A properly made score will allow a 180° board bend without top ply cracking





Creasability and foldability are important

- for obtaining the intended carton shape
- when designing creative shapes
- for packaging line efficiency and runnability
- for achieving box compression strength and stacking strength



Proper creasing is critical to a perfect carton

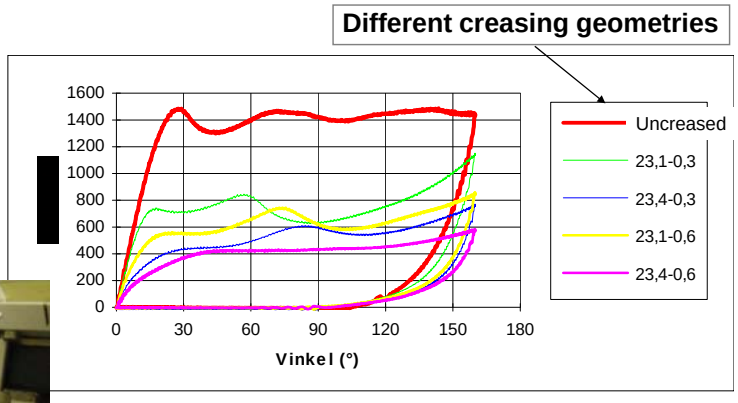
- Proper folding of the carton during gluing
- Efficient and reliable set-up in packaging lines
- Proper functioning of opening features, *i.e.*, tear strips
- Proper functioning of closing features, *i.e.* tuck tabs

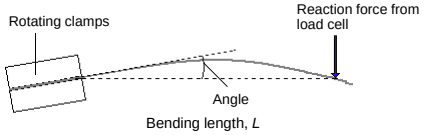
CREASING

Curled lid

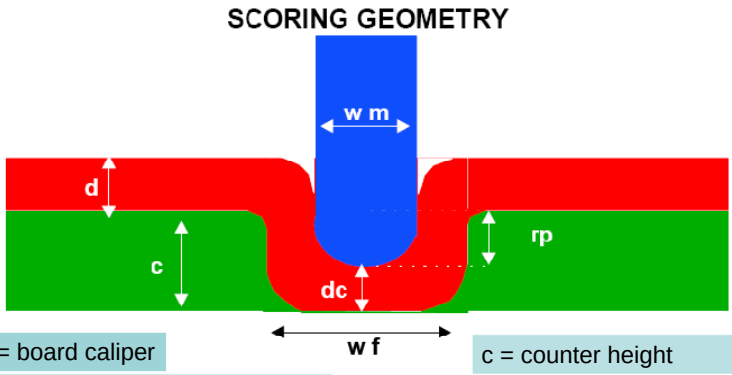
Creasing analysis

Folding force – folding angle





Six variables in every die set-up



d = board caliper

dc = compression board caliper

wm = creasing rule width

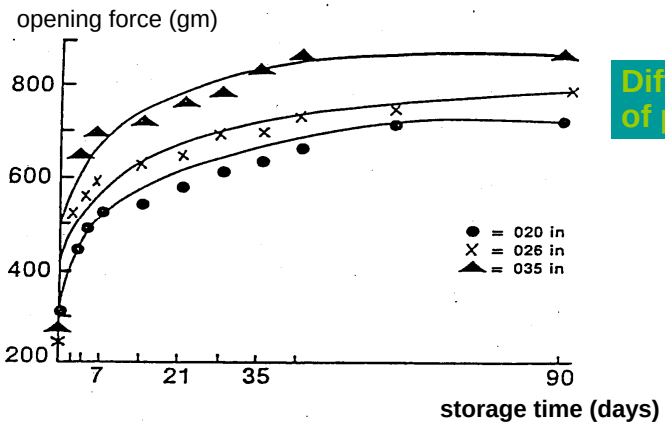
c = counter height

rp = rule penetration

wf = female die width

Creasing

Carton forming force as function of storage time



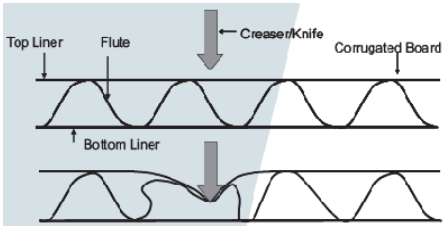
Different types of paperboard

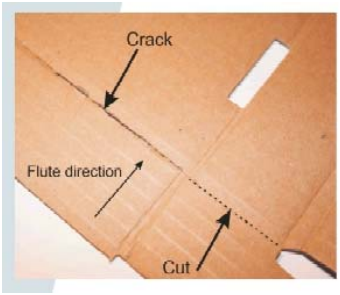
0,50 mm
0,65 mm
0,80 mm

Cutting and creasing of corrugated board

Problems

- The top liner cracks during creasing if the crease is too deep.
- The bottom liner cracks during folding if the crease is too shallow.



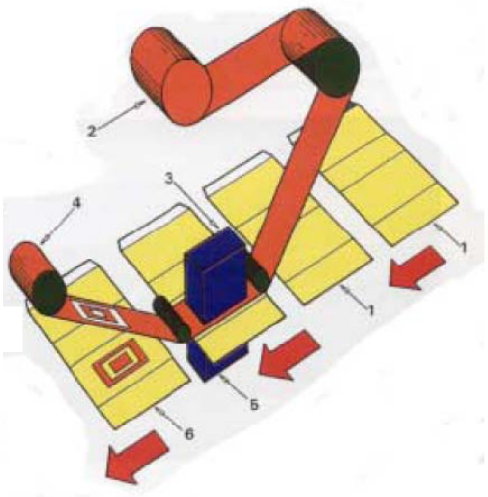


B.K. Thakkar, R.H.J. Peerlings, M.G.D. Geers
Eindhoven University of Technology, Department of Mechanical Engineering, 2006

Hot stamping

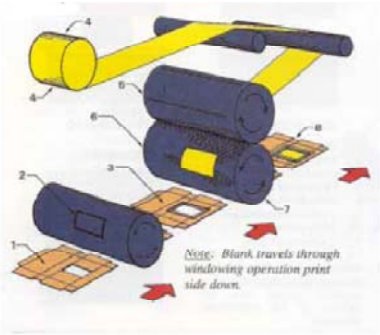
Separate function or integrated with embossing

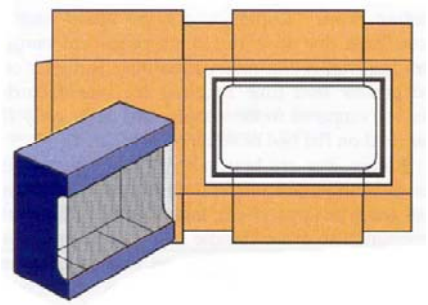
1. Carton blanks
2. Film unwind stand
3. Upper hot stamping/embossing die
4. Spent film rewind stand
5. Lower hot stamping/embossing die
6. Printed blank



Windowing

Windowing machine





Folding and gluing

PROCESS STEPS

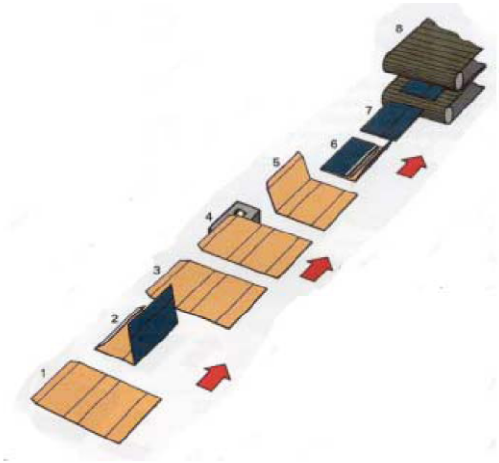
- Pre-folding
- Application of adhesive
- Folding
- Sealing
- Curing

RUNNABILITY PARAMETERS

- Open time (time from application of adhesive to sealing)
- Closing time
- Pressure
- Amount of glue
- Temperature
- Speed of gluing machine

Gluing

Untimed straight line gluer

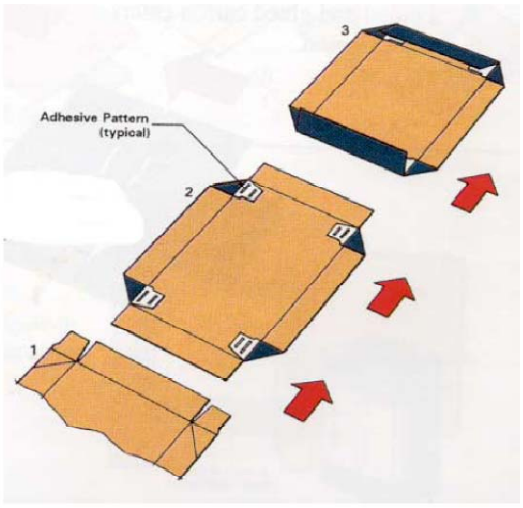


1. Blanks from hopper on conveyor
2. Pre-break non-working scores
3. Return blank to flat
4. Apply adhesive
5. Fold along working scores
6. Fold along working scores
7. Completed folding sequence
8. Compression section

Source: Paperboard Packaging Council

Gluing

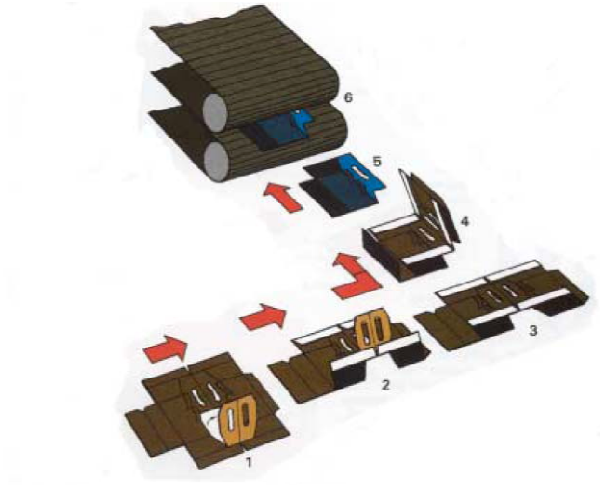
Timed straight line gluer



Source: Paperboard Packaging Council

Gluing

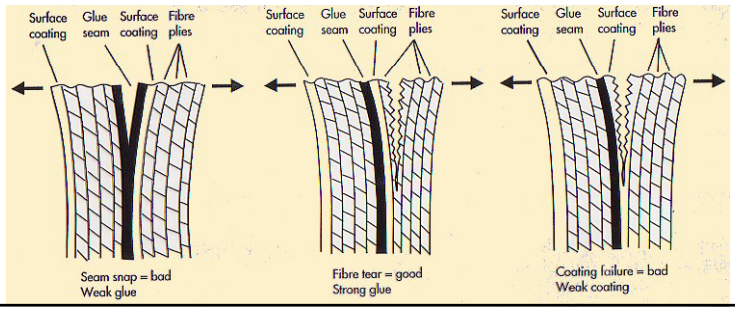
Right angle gluer



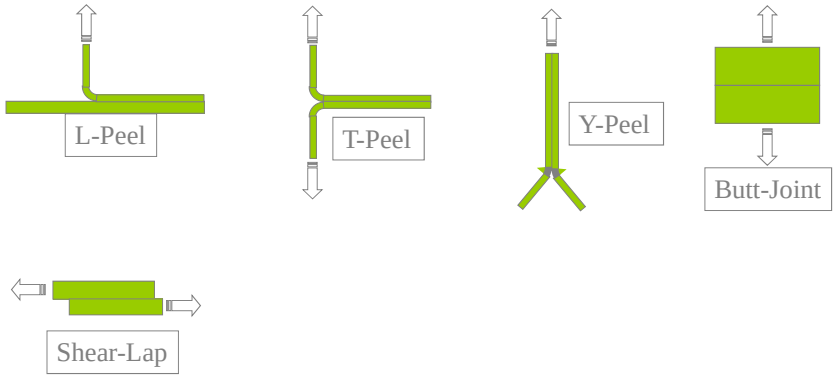
1. Blank from hopper, print side down on conveyor
2. Vertical folding and gluing
3. Blank changes direction
4. Horizontal folding and gluing
5. Folds and gluing complete
6. Compression station

Source: Paperboard Packaging Council

Loading and fracture of adhesive joints



Test methods for evaluation of the mechanics of the glue joint



Reference: M. Lestelius, KaU, 2001.

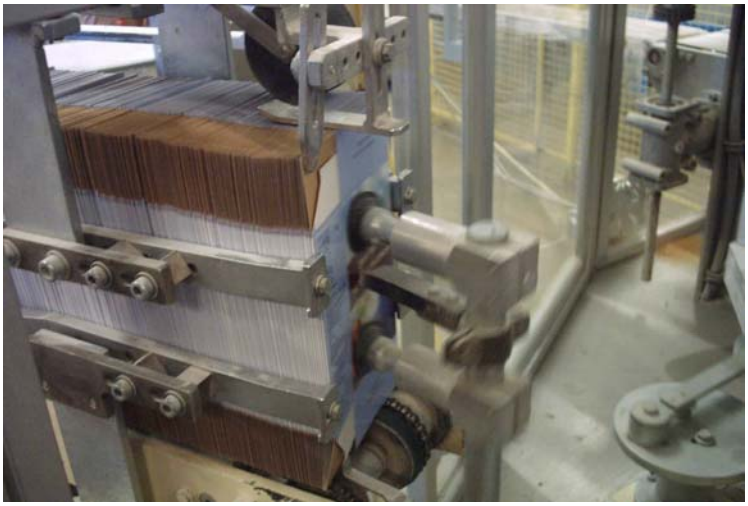
Forming, filling and closing

Productivity and quality parameters

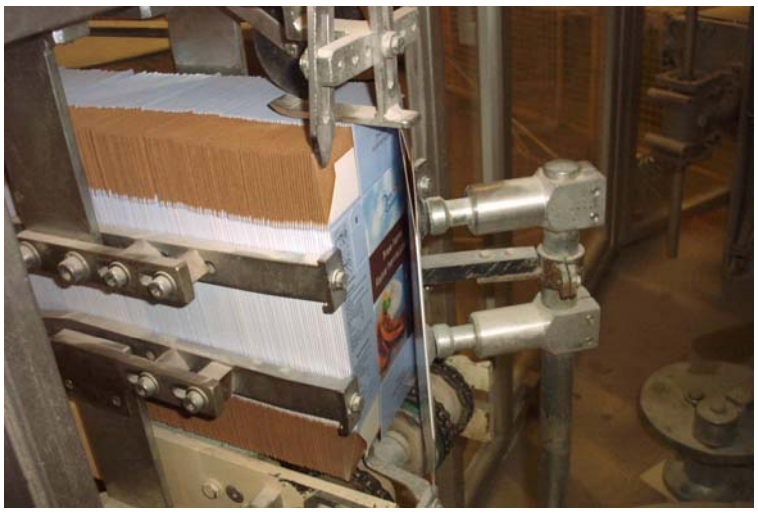
- Form the package
- Fill the package with a product
- Close (seal) the package
  - Reel
  - Blanks
- Transfers (within the packaging line)
  - Reel
  - Blanks

Erecting of cartons - 1

Erecting of cartons - 2



Erecting of cartons - 3

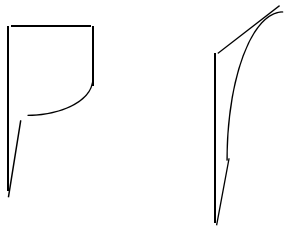


Erecting of cartons - 4

Erecting of cartons - 5

Erecting of cartons - 6

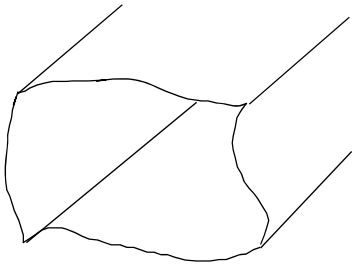
Incorrect deformation mode



IMPORTANT PARAMETERS
- Curl
- Bending stiffness
- Folding moment at creases
- Initial opening angle

Erecting of cartons - 7

Bulging panels



IMPORTANT PARAMETERS
- Spring back moment of creases
- Bending stiffness
- Difficult to close lids

Closing discussion of runnability

- Runnability affected by material properties and process parameters
- Complex relations which not seldom are difficult to describe
- Even small variations affect runnability therefore uniformity in material properties is VERY important
- Demands for higher productivity and better quality with reduced material consumption means that both materials and processes need to be further developed

Aseptic Packaging

(A procedure that is performed under sterile conditions)

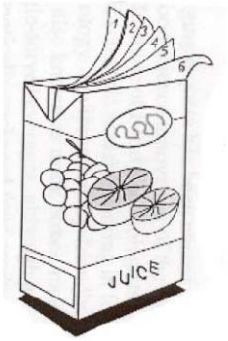
- Aseptic packaging is a food processing technology that functions as a system incorporating a paperboard based package.
- Aseptic packaging was developed in the 1940s in Sweden by Dr Ruben Rausing (Tetra Pak)
- Aseptic packages are available in a variety of sizes

Source: Tetra Pak, Photographer Owesson Lars

Aseptic packaging system

- Achieves room-temperature, shelf-stability
- Fills a sterilized package with sterile food in a sterile environment
- Food are processed using Ultra High Temperatures (UHT)
  - Rapidly heat food (3 to 15 seconds at 90.5 to140.5 ˚C)
  - Rapidly cool food
- Process places least amount of thermal stress on product

Aseptic package structure

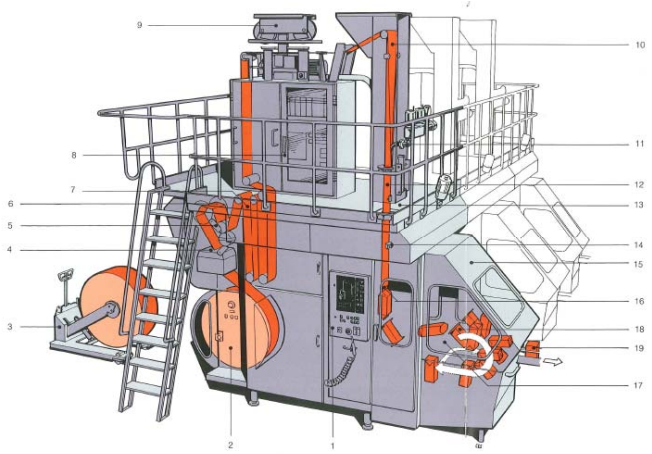


1. Polyethylene
2. Paperboard
   (contributes to structural integrity)
3. Polyethylene
4. Aluminium foil
   (not necessarily for dairy products)
5. Polyethylene
6. Polyethylene

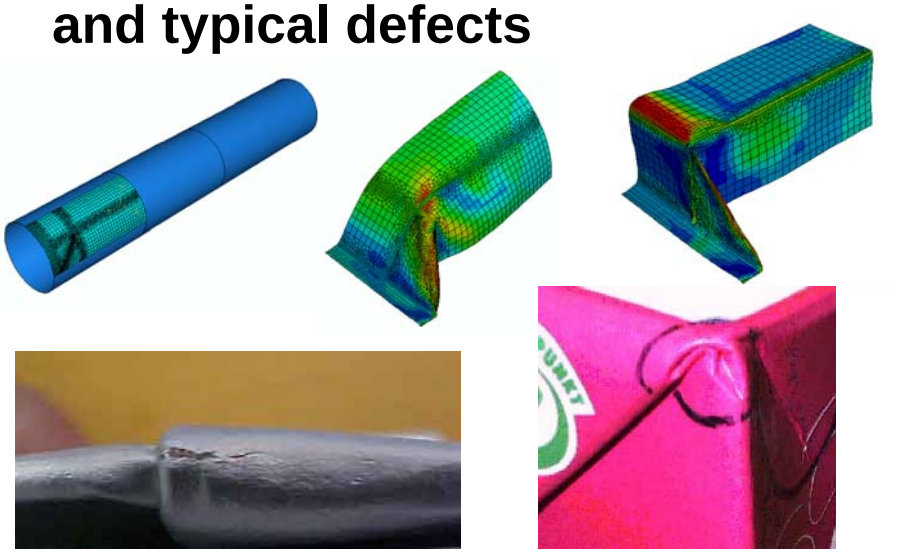
Aseptic packages are made from a continuous roll of material…
…on a specially designed machine

9. Application of a strip of polyethylene to one edge of the material that is later welded onto the other edge to form a seal.

11. Product filling pipe
12. Longitudinal welding



Forming of an aseptic packaging and typical defects



K-crack

Corner fold

Ulf Nyman, LTH, 2007

After lecture 12 you should be able to

- describe the most important converting operations in paper and paperboard package manufacturing
- discuss important runnability considerations in paperboard package handling
- relate factors affecting runnability to paperboard appearance and physical performance quality parameters