Lecture 9:
Manufacturing of paperboard and corrugated board packages

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

After lecture 9 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

Paperboard Packaging 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:

1. Converting and 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

Printing and varnishing → Cutting and creasing → Folding and gluing → Forming, filling and closing
Paperboard printing
Driving forces

• Graphic quality
  – High emphasis on point of purchase appearance
  – Correct and consistent colours

• Functional quality (Runnability)
  – 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 cartonboard folding cartons accounted for 29% of the ink usage in packaging
Printing
Runnability problems

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

Runnability requirements

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

Printing process components

- Pre-press
- 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 and photography
- Typesetting (electronically)
- Assembling the image electronically
- Creating colour separations
- Proofing the art

Printing
Screening/Rastering

Conventional

Stochastic

Hybrid

Source: MeadeWestbaco
Majority of all paperboard packages printed by

- Lithographic Offset
- Flexography
- Rotogravure

Other methods used in limited number of applications

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

Lithographic Offset

- 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.

Offset lithography
Misregister

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

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
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)
+ 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)
Rotogravure

Advantages of gravure printing

+ Ideal for long run lengths (less waste)
+ 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)
+ Inks dry immediately
+ Prints metallic inks much better than any other printing process
+ Gravure cylinders can last for over a million impressions
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

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

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.
  - Finally the toner is fused to the paper by heat and pressure.

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

![Graph showing Total cost vs. Volume]
Lamination of paperboard

- Internal coating
- External coating

Die-cutting
Creasing and folding
Printing is combined with other converting processes that include:

- De-curling
- 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

1. Die board
2. Paperboard
3. Counter plate
4. impression
5. Reverse cut score bar
6. Female embossing die
7. Male embossing die
8. Debossing slug
Different types of rule

- Knives
- Score
- Relief
- Perforation

Cutting and creasing a box

- Nicks - hold multiple impressions together
- Trim Waste
- Creases
- Cuts

Edge of Sheet

Source: Graphic Packaging International
Examples of cuts and creases

Flat bed die-cutting

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

A commercial flat bed die
Rotary die cutting

Flat bed vs. rotary die cutting

• Rotary die cutting is best suited for
  – Long runs
  – Repeat orders
• Rotary cutting dies are more expensive than flat bed cutting dies
Theory of creasing

- Paperboard must delaminate to create a good crease
- 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 for carton performance

- 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

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 analysis
Folding force – folding angle

Different creasing geometries

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 and timed straight line gluers

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
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. Flaps and gluing complete
6. Compression station

Source: Paperboard Packaging Council
Loading and fracture of adhesive joints

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)
Erecting of cartons - 1

Erecting of cartons - 2
Erecting of cartons – 3
Incorrect deformation mode

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

Erecting of cartons - 4
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
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 to 140.5 °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 - Typical defects

K-crack
Corner fold
Deep drawing of paperboard
Applications

Marek Hauptmann, TU Dresden
Test machine

Accuracy to SHAPE and OPTICAL quality
Design Project

Design in organic materials (paper, board and polymers) a package for a food product that is today primarily packed in tin cans or glass jars.

Consider ....

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<td>Material savings</td>
<td>Environmental concern</td>
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<td>Promotion</td>
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as well as manufacturing issues and costs
Assessment

- **Preliminary design review** not later than Wednesday, March 2
- **Oral presentation** on Friday, March 12
- **Short report** not later than Thursday, March 24

Grading

- Combination of technical content (60 %), short paper (20 %) and oral presentation (20 %).
- The grade will be given as a score between -3 and 6 that will be added to the score on the written exam (if passed).
- Thus, the design project can increase as well as decrease the final grade on the course.
Additional information

• Teams of 3(2) students
• Sources of information
  – Lack of information
  – Make assumptions
  – Ask
• Software for strength and stiffness analysis
  – Billerud Box Design
  – Optipack
  – Laminate theory

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