Lean and Clean Manufacturing

Module 8
Pulp and Paper production
June 4th 2013
Paper production essentially 2 steps

1. Conversion of fibrous material into pulp
   - Fibrous material can be
     - Non-wood, e.g., bagasse, bamboo, straw
     - Hardwood or softwood
     - Textile or recycled fibers

2. Conversion of pulp into paper through different processes, depending on raw material and desired paper product
Pulp and paper production

Conversion of fibrous material into pulp

Conversion of pulp into paper

Uses
- Large amounts of energy to drive pumps, boilers, conveyors, water to wash, transport fibers, chemicals to loosen the pulp, bleach the paper.
Production - 7 sub-processes

- raw materials processes;
- wood-yard;
- fibre line;
- chemical recovery;
- bleaching;
- paper production;
- products and recycling.
The manufacturing areas include:

- wood preparation
- mechanical pulping
- kraft pulping
- bleaching
- evaporators
- recausticizing
- paper and pulp machines
- effluent treatment
- general areas (for example, buildings)
The different processes:

1. Raw material digested into its fibrous constituents via chemical, mechanical, or a combination.

2. Most common pulping material, WOOD - release cellulose fibers when chemical bonds in lignin are mechanically broken or chemically dissolved.

3. Fibers separated and impurities removed.

4. Pulp may be bleached to improve brightness and processed to a form suitable for papermaking equipment.

5. At papermaking stage, depending on intended end product pulp can be combined with dyes, resins to add strength, fillers to add texture.

6. Mixture is dewatered, leaving the fibrous constituents and pulp additives on a wire or wire-mesh conveyor.

7. The fibers bond together as they are carried through a series of presses and heated rollers.

8. Final paper product is usually spooled on large rolls for storage.
Pulping is delignification, i.e., removing lignin from wood while leaving cellulose fibers intact. Most pulping is done using sodium hydroxide and sodium sulfide ("Kraft" process).

After delignification, the pulp is dark brown and liquor is black. If white paper is desired, the pulp is bleached.

Delignified, bleached pulp is fed into paper machines after undergoing other chemical processes that produce desired paper quality and characteristics.

"Sizing" gives paper resistance to moisture; chemicals added to bind fillers & shorter fibers into the paper; and ensures that products like paper towels will not disintegrate in water.
# Chemical pulping in paper production

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sulfate/soda process</th>
<th>Sulphite process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material</td>
<td>Low lignin materials</td>
<td>Any kind that is free of certain hydroxy phenolic compounds</td>
</tr>
<tr>
<td>Pulp properties</td>
<td>Sulfate: Strong fibers, resistant to mechanical refining, brown colour. Soda: weaker fibers</td>
<td>Weaker fibers</td>
</tr>
<tr>
<td>Beating and refining</td>
<td>Require extensive beating and refining to develop paper properties</td>
<td>Requires less extensive beating and refining</td>
</tr>
<tr>
<td>Bleaching</td>
<td>Difficult to bleach, require more chemicals</td>
<td>`Easy to bleach, require less chemicals</td>
</tr>
<tr>
<td>Typical final paper products</td>
<td>Strong brown bag, wrapping paper, building paper and board, while paper from bleached sulfate</td>
<td>Fine paper and tissue</td>
</tr>
</tbody>
</table>
Flow chart of integrated mill operations (Jankunaite n.d.)
A more detailed chart
Production Flow chart

1. Wood Chips
   - Cooking
   - Washing
     - Oxygen Delignification
       - Bleaching
         - Dewatering Drying
   - Evaporation
   - Acidulation
     - Soap
     - Tall Oil
       - Effluent Treatment
         - Waste Water
           - Market Pulp
   - Combustion
   - Causticising
     - CaO
     - Calcination
       - CaCO₃
   - green liquor
   - strong black liquor
   - weak black liquor
   - white liquor
Production Process Flowchart

1. Fiber raw material
2. Chemicals & energy
3. Water
4. Energy
5. Chemicals & energy
6. Energy
7. Energy, chemicals & water

- **Handling fiber raw material**
- **Chemical Pulping**
- **Washing**
- **Screening**
- **Bleaching**
- **Drying**
- **Paper machine**

**Outputs:**
- Solid wastes
- Gaseous material, water vapour
- Dissolved material & residual chemicals
- Solid wastes
- Dissolved material & residual chemicals
- Solid waste, & dissolved materials
VIDEO ON CLEANER PRODUCTION IN PULP AND PAPER INDUSTRY
Specific environmental concerns

- **Air:** Noxious air emissions
- **Solid:** Fiber, fiber fragments wastes – cloud streams, add BOD, affect light penetration, threat to aquatic life
- **Effluents:** Process chemicals (may include metal ions, anti-foam agents, slimicides, pitch control agents) in wastewater – threat to health of humans, aquatic life
<table>
<thead>
<tr>
<th>Group of substances</th>
<th>Source</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulates</td>
<td>Fuel combustion: recovery system</td>
<td>Local nuisance, BOD</td>
</tr>
<tr>
<td>Reduced sulfur compounds</td>
<td>Recovery system</td>
<td>Odour, acidification</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>Fuel combustion, recovery system</td>
<td>Acidification</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>Fuel combustion, recovery system</td>
<td>Acidification, Eutrophication</td>
</tr>
<tr>
<td>Chlorine compounds</td>
<td>Bleaching</td>
<td>toxic</td>
</tr>
</tbody>
</table>
Cleaner production opportunities
CP measures: in increasing complexity

A. Material substitution – use of higher quality raw material and less hazardous chemicals

B. Process control to enhance efficiency by e.g., better training of workers

C. Equipment modification – e.g., installing drip pans and slash guards to collect waste process water or change the equipment

D. Technology change – replace technology or synthesis sequence
CP measures at specific stages:
Wood-yard (1) (Jankunaite nd)

- Pulp mills integrated with lumbering facilities: acceptable lumber wood is removed during debarking; residual or waste wood from lumber processing is returned to the chipping process; in-house lumbering rejects can be a significant source of wood furnish.

- Avoiding hydraulic debarking – saving energy and water consumption, reducing wastewater volumes.
Wood-yard (2) (Jankunaite n.d.)

- Reusing leachate water.
- Co-production from bark: mulch, ground cover, charcoal.
- Burning bark from debarking and small chips from chipping for energy production (depends on the moisture content).
CP measures in Pulp production (1) (Jankunaite n.d.)

- Increasing brown stock washing efficiency. Any remaining cooking liquor will increase the chemical consumption in subsequent stages.

- Water reuse from evaporators. Evaporation plant is among largest steam consumers. Condensate might be used instead of fresh water in the mill.

- Repulping the rejects from screening rather than putting them into the landfill.
CP measures in Pulp production (... 2)
(Jankunaite n.d.)

- Using **pulp centrifuging** to remove any remaining impurities.

- **Sludge utilization** by means of land-spreading. Provided sludge constituents are identified.

- **Use of Air emissions control devices.**

- Providing **spill containment and collection system.**
CP measures Chemicals recovery (1) (Jankunaite n.d.)

- Using of new technologies (CHP, BLG, heat transfer, heat exchanger).

- Improvements technical parameters of recovery boiler or furnace (geometrical shape etc.).

- Using light gas strippers and gas collection systems removes hazardous and foul smelling pollution from the air and increase workplace safety.
CP measures in Chemicals recovery

(... 2) (Jankunaite n.d.)

- Deaerator tanks ahead of the boilers to help reduce the intake of freshwater.
- Air emissions control devices.
- Providing spill containment and collection system.
CP measures in Bleaching

(Jankunaite n.d.)

- Avoiding chlorine bleaching.
- Continuing research on biotechnological bleaching and electrochemical bleaching.
- Air emissions control devices.
- Providing spill containment and collection systems.
CP measures in Paper production (1)
(Jankunaite n.d.)

- Cleaning the roll in the paper machines to avoid broken paper line.
- Adjustment of edge cutter to reduce side trimming loss.
- Use of soft water as a boiler feed water.
- Recycling water evaporated from drying process by condensing.
CP measures in Paper production (Jankunaite n.d.)

- Optimizing the thermal effects on water used in the paper machine and stock preparation area.
- Providing **disk save-all** for paper machine.
- Repulping rejected paper in a closed loop manner.
CP measures in Products processes and recycling (Jankunaite n.d.)

- Increasing recycling rates. Recycling reduces energy consumption, decreases combustion and landfill emissions, and decreases the amount of carbon dioxide in the atmosphere. This process also saves money.

- Possibility for easy **packaging recycling**.

- Using “green” fuel for transportation.
Recycling measures (Jankunaite n.d.)

In Europe an average of 56% of used paper is recovered. The recycling process includes following stages:

- Sorting
- Dissolving
- De – inking
- Mixing
- Papermaking process
Recovery and handling of spent pulping liquors (UNEP 1998)

- Concentrate by evaporation of liquor in cooking and pulp washing
- Burn concentrated spent liquor to produce steam and recover inorganic chemicals as ash, smelt, gas
- Convert ash, smelt, gas into active cooking chemicals

Caution: Non-wood raw materials
- High viscosity because of high silica & polysaccharide content
- High silica creates problems with sealing
- Low heat value of solids because of low lignin and high inorganic content
- High content of organic fines
- Harder liquor to burn
On-site Recovery and Reuse

Creation of useful byproducts

Good housekeeping

Input Material Change:
- Use non-toxic dyes.
- Use better selection of raw material, e.g. by applying quality standards.

Better Process Control:
- Optimize cooking.
- Refine at highest possible pulp consistency.
- Install calibration equipment.

Technology Change:
- Modify pulping processes.
- Modify washing and dewatering, e.g., by using twin-wire belt press.
- Use alternative bleaching processes.

Equipment modification:
- Install efficient showers.
- Provide broke pulper.
- Use high pressure fibre saver in centricleaner.
- Install consistency regulator.
- Use pumps of adequate size.

Source Reduction

Product Modification

Recycling

Cleaner Production

- Repair all leaks.
- Keep taps closed when not in use.
- Cover vibratory screens to avoid spills.
- Remove blockage in wire and felt showers.

- Recycle back water and white water in washing, bleaching and dilution.
  - Recycle steam condensate.
  - Recycle fiber in white water.

- Produce high yield varieties of paper.
  - Produce unbleached instead of bleached paper.

- Use waste fibre for board making.
  - Use raw material residue as fuel in boiler.
  - Manufacture lignosulphate from black liquor.

- Use alternative bleaching processes.
- Use raw material residue as fuel in boiler.
- Use high pressure fibre saver in centricleaner.
- Recycle fiber in white water.
- Install consistency regulator.
- Use pumps of adequate size.

- Manufacture lignosulphate from black liquor.
- Use raw material residue as fuel in boiler.
- Use high pressure fibre saver in centricleaner.
- Recycle fiber in white water.
- Install consistency regulator.
- Use pumps of adequate size.

- Manufacture lignosulphate from black liquor.
- Use raw material residue as fuel in boiler.
- Use high pressure fibre saver in centricleaner.
- Recycle fiber in white water.
- Install consistency regulator.
- Use pumps of adequate size.