Fashionable Destruction, Responsible?

Jeans, a voyage from the cotton plant to the wardrobe and beyond
History

• Work wear made out of blue cotton fabric (denim): waist overalls or (blue) jeans
  – Serge de Nîmes 17\textsuperscript{de} C
  – Gènes (Genua) \rightarrow Jeans

• Jacob Davis: jeans
  – Copper rivets
  – Levi Strauss: patent (1873)
History

• Europe: World war II, actors
  – First jeans in Europe in 1959

• Many brands and trends
  – ‘70: wide legs
  – ‘80: tight legs
  – ‘90 -‘00: revival of the styles from the forties and fifties
  • Different washings and decorations
  – 2010: eco jeans
Figures

• 2007
  – Belgium: 10,5 mio jeans
  – Europe: 389 mio jeans

• Price
  – From € 6 up to + € 1000 (average € 36 in Europe)
Denim Value chain – people (S)/planet (E)/profit (P)

- Agriculture: S: -/-, E: -/-, P: -/-
- Design: S: ++, E direct: +
- Textile mill: S: -/-, E indirect: ?
- Garment manufacturing: S: -/-, E: +/-, P: +/-
- Garment finishing: S: -/-, E: +, P: +/-
- Retail: S: +, E: +, P: +/-
Material: Cotton

Cotton covers 2.5% of the cultivated land but uses 16% of the world’s pesticides/insecticides.

Cotton picking in 1890
Fabric: yarn

- Past: 100 % ring spun cotton yarn
- Today: ring spun yarn replaced by open end yarn

Neps in rotor yarn tend to be spun into the solid yarn body → less structured fabric
Fabric: weave

• Yarn is processed into a twill fabric (2/1 or 3/1)
Colour

• Warp is dyed with (natural) indigo

(\url{http://www.youtube.com/watch?v=hXeectd1GSM})
Extraction of natural indigo
Indigo dyeing process

• Rope dyeing or beam dyeing
  – continuous process
  – Yarn is ring-dyed

• Indigo is not soluble in water
  – Solubilize by adding sodium hydrosulfite, thiourea dioxide or a commercial reducing agent in alkaline conditions, pH 9-11 (NaOH) (reduction): yellow-greenish solution (vat)
Indigo dyeing process

• Concentration of the vat: 1.5 to 5 %
• Yarn is dipped 5 to 8 times, exposure to air (oxidation) between each dip (more dips → darker colour)
• 2-3 rincing baths and neutralizing
• Dry and wet fastness to rubbing must be OK
• Light colours tend to be more perceptive to gasfading
Fabric treatment

- Mechanical: stabilizing yarn twist (Twin twister) and shrinkage (sanforisation)
Look and Hand

• Structured, worn look
• Soft touch
• Pleasant hand
Most common problems

- Loss of strength
- Corrosion of metal parts (zippers, rivets)
- Unpleasant hand
- High shrinkage
- Uneven washing effect
- Striped marks, stains, creases
- Staining of white parts (backstaining)
- Little contrast between warp and weft
- Colour change due to binding of free radicals (ozon or nitrogen oxide)
- Reproducibility
Special effects

- Yarn
- Weaving
- Dyeing process
- Coating
- Washing
- Brushing, 3D-effects, spraying, laser, sandblasting, …
Departement technologie

Dirty Dye  Enzyme  Sandblasted
Sunbleached  Stonewashed  Fabric Dyed
Yarn

• Use multitwist or multicount yarn in the warp
  – Multitwist: speeding up of the spinning machine over a certain distance → thicker and thinner areas in the yarn
  – Multicount: giving more or less feed to the spinning machine

• Crossedge effect by using multitwist or multicount in warp and weft
Yarn

- No longer 100% cotton, but blends with hemp, flax, polyester, polyamide, lycra
- 100% bamboo (viscose)
- Bio cotton
  - in 2009 production raise by 20%
  - 0.76% of the entire cotton production is ‘organic’
Weave

- Variations in type of twill
  - Z or S direction, opposite to or concurrent with the twist direction
  - Different angle

- Different weave
Dyeing

• Color denim
  – Sulphur dyes (mostly black, but also grey, green, brown, red, …)
• Sulphur bottom in black or grey before indigo dyeing process
  – Colour remains dark after washing
• Sulphur top with black, red (purple shine), yellow (green shine)
Dyeing

• “sandwich dye”: sulphur bottom – indigo – sulphur top
• Combinations NEVER wet on wet
• Use coloured weft
  – reactive dyed weft must not be bleached with NaOCl (javel)
Coating

- Mostly PU coating
- Protects the colour
- Pleasant hand
- Shiny effect
Denim Washing

- Desizing
- Enzyme or stone wash
- Bleaching
- Dyeing
- Post washing/neutralizing
- Softening, …
Desizing

- Avoid uneven bleaching effect
- Avoid stripiness

- **Chemical degradation** of starch and its derivatives into water soluble products. This degradation can be obtained by:
  - hydrolysis (enzymes)
  - oxidation

- By washing out after swelling of water soluble sizes
Desizing

- Enzymatic desizing
  - Amylases
  - +/- 60 °C
  - 10 – 20 min
  - pH 6 - 7
Enzymatic disizing

**Advantages**
- No fibre damage
- No use of aggressive chemicals
- Discontinuous, semi-continuous and continuous processes
- Highly bio degradable

**Disadvantages**
- Combination with other traditional pretreatments not possible. Enzymes are only active under precise conditions.
- Less simultaneous extraction of other impurities
- Possible loss of activity due to enzyme poisoning
Oxidative desizing

Advantages
- cheap
- several processes can be combined
- simultaneous extraction of other impurities

Disadvantages
- aggressive chemicals
- non-selective degradation with risk of fibre damaging
- polluting
Enzyme and/or stone wash

• Gives the trousers a worn look
• Improves the hand
  – More soft and supple
• With or without stones
  – Pumice or perlite
  – Cellulases (granules or liquid)
Advantages and disadvantages

<table>
<thead>
<tr>
<th>With stones</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>Shortened washing time</td>
<td>Formation of sludge</td>
</tr>
<tr>
<td>Soft hand</td>
<td>Stones in the pants</td>
</tr>
<tr>
<td>Less cellulases needed</td>
<td>More dull effect</td>
</tr>
<tr>
<td>More rinse baths</td>
<td>Damage to the machines</td>
</tr>
</tbody>
</table>

![After desizing](#)  
![After stoning and biopolishing](#)
Advantages and disadvantages

<table>
<thead>
<tr>
<th>Without stones</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>No sludge</td>
<td>Longer treatment times</td>
</tr>
<tr>
<td>No stones in trousers</td>
<td>Rougher surface</td>
</tr>
<tr>
<td>Less rinse baths</td>
<td>Large amounts of enzymes</td>
</tr>
<tr>
<td>Bluer</td>
<td></td>
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<tr>
<td>Less damage to equipment</td>
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Stone wash

- 1 kg stones for 1 kg fabric (1 trouser = +/- 750 g) + soap
- Effect of stones more visible on the seams
- 15 – 90 min
- Polluting (several rinses to removes grit)
- Labour intensive (manual removing of stones from pockets)
- Special washing machines (past: octagonal drums, present drums with ribs)
- rpm is important (not to fast, variable with drum diameter)
- Trousers must roll, not fall
Biopolishing

• Removes fluff
• Environmentally friendly (less water)
• Less damage to trousers and equipment
• Several types:
  – Neutral (pH 6 – 8)
  – Acid (pH 4 – 6)
  – Hybride (blend)
• Action is stopped by changing process conditions (pH, T)
Cellulases

Cellulose (crystal) → Endocellulase → Cellulose → Exocellulase → Cellobiose or Cellotetrose

Cellulase (β-glucosidase)

Glucose
Advantages and disadvantages

<table>
<thead>
<tr>
<th>Acid cellulases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Favorable ratio price/effect</td>
<td>More backstaining</td>
</tr>
<tr>
<td>Suitable for bleached fabric</td>
<td>Less contrast in darker shades</td>
</tr>
<tr>
<td>Lower contrast</td>
<td>Higher loss of strengh</td>
</tr>
</tbody>
</table>
Advantages and disadvantages

<table>
<thead>
<tr>
<th>Neutral cellulases</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Minor staining of white parts</td>
<td>Expensive</td>
</tr>
<tr>
<td>Recommended for dark colours</td>
<td></td>
</tr>
<tr>
<td>Minor loss of strength</td>
<td></td>
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</tbody>
</table>
Sludge & waste water from a stone washing plant (Tunisia)
Bleaching

• Provides a washed and bleached look
• Fashionable shades of blue
• Mostly chlorine bleach, also peroxide, permanganate, glucose and ozon
• No chlorine bleach for stretch-jeans, unless T400 (elastomers are sensitive to chlorine and alkali) or reactive dyeings
Chlorine bleach (oxidative)

- NaOCl (sodium hypochlorite or bleach) – 150 g/l active chlorine
- Cheap, highly active (beware of fibre damage), polluting, necessary to neutralize
  - 40 – 50 °C
  - Bleaching effect:
    - Light bleach: 5 – 10 ml/l
    - Medium bleach: 10 – 20 ml/l
    - Super bleach: 20 – 30 ml/l
  - pH 9 – 10 (the lower, the more aggressive and greener the effect)
  - 10 – 30 min
  - Neutralize with 2 – 4 g/l bisulphite of thiosulfate
Permanganate bleach (oxidative)

- KMnO₄ (potassium permanganate)
- Colour of bleach bath changes from purple to brown
  - Difficult to reproduce the effect
  - T: 20 – 30 °C
  - Bleach effect:
    - Light bleach: 1 – 5 g/l
    - Medium bleach: 5 – 10 g/l
    - Super bleach: 10 – 30 g/l
    - Snow wash effect (soak pumice stones in KMnO₄)
  - Neutralize with bisulfite
Washing/bleaching equipment
Other

- $\text{H}_2\text{O}_2$ (hydrogen peroxide, oxidative)
  - Ecologic, less aggressive, used on sulphur top
- $\text{O}_3$ (ozon)
- Glucose (reductive)
  - 10 – 15 g/l glucose
  - 80 – 85 °C
  - 30 – 45 min
Post washing/neutralizing

- Rinse well and neutralize to avoid fabric damage, bad odour, skin irritation and yellowing (gasfading)
- 50 – 60 °C met tensioactive product
- 10 – 20 min
- Several hot and cold rinses
Dyeing

- Overdye with a small amount of dyestuff to change the shade, mostly direct dyestuffs
- Garment dyeing with direct, reactive or sulphur dyes or pigments
Softening

- Improve the hand
  - Fatty acids
  - Silicones (not often used in indigo dyeing)
  - Risk of yellowing (gasfading) → special types of softeners
Points of interest

• Treated garments must not contain residues of alkali
• Chemicals must be applied evenly to obtain a uniform effect
• Garments must be instantly dried to avoid creases
• Do not overdry in tumbler
Points of interest

• During fixation in a tunnel dryer the image of the garment is permanently fixated (undesired pleats can no longer be removed)
• All process steps must rapidly succeed
• Accessories must be rustproof and resistant to high temperatures
• Loss of strength is inevitable
Points of interest

• Risk of yellowing by UV-radiation en noxious gasses (fotocchemical smog)
  – decomposition of indigo by $O_3$ or $No_x$
    • Degradation products are yellow
  – Damaging of natural rubber and PU-yarn
  – Higher risik during summer

• Bleaching can damage lycra $\rightarrow$ use T400 yarn (PES multicomponent)
Protect against corrosion

• Add a sequestring agent (prevents corrosion and staining by colorants)
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Washing machine

Dyeing machine

Tumbler

Dryer
Special effects

• Chemical
  – Spray, sponge, immerse, pour
  – 3D-effects (dependent on length (knee-height) and size)

• Mechanical
  – Local abrasion (abrasive paper or brushes, manual or mechanical) (dependent on length and size)
  – Laser
Spray/sponge

- KMnO₄
- Pigments
- Fix trousers on inflatable manikin
KMnO4 spraying (Tunisia)
Stain release finish

- Treatment in washing machine with fluorocarbon polymer
3D-effects

• Spray or dip garment with resine (PVAc), wash resistant extender (DHEU) and acid (sometimes local spray, but dipping is better to obtain a uniform effect) (formaldehyde !)

• Spin-dry

• Fix on manikin with flexible legs

• Dry at 100 °C (tunnel, caroussel or IR). As long as the fabric is not dry there is a risk for damaging or false creases while polymerising)

• Polymerise at 160 °C
Tunnel dryer

Spray tool

IR-dryer (Solarium)
‘3D-whiskers’
Dry carrousel (Bohemia)

3D-whiskers
Local abrasion

- Manual with abrasive paper
- Mechanical with rotating brushes
  - Adjust height and width according to size
  - Beware of differences between left and right leg
- Fix garment on inflatable manikin, with or without pattern in the rubber
- Lighting of 700 lux necessary
Scraping
Inflatable manikin for manual scraping or brushing

Brush robots
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Manikin with pattern in rubber

Holder for abrasive paper (manual scraping)

Brushes
used look  whiskers
Laser

- Light amplification by stimulated emission of radiation
- Colorants are being sublimated
- Can be applied before dyeing
Sandblasting
Sandblasting,
Tunisia April 2011
Denim sandblasters contract fatal silicosis in illegal workshops

Sandblasting jeans kills young people

Silicosis in Turkish denim sandblasters
Sustainable jeans

<table>
<thead>
<tr>
<th>Material</th>
<th>Need for energy/kg</th>
<th>Need for water/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>49-60 MJ</td>
<td>7000-29000 l</td>
</tr>
<tr>
<td>Polyester</td>
<td>109410 MJ</td>
<td>17 l</td>
</tr>
<tr>
<td>Acrylic</td>
<td>157 MJ</td>
<td>210 l</td>
</tr>
<tr>
<td>Wool</td>
<td>8 MJ</td>
<td>130-170 l</td>
</tr>
<tr>
<td>Hemp</td>
<td>5 MJ</td>
<td>1000 l</td>
</tr>
<tr>
<td>Bio cotton</td>
<td>54 MJ</td>
<td>7000-29000 l</td>
</tr>
</tbody>
</table>

1 pair of jeans weighs 750 g
→ 1 pair of jeans in 100% cotton consumes approx. 40 MJ and 5250-21750 l water
→ +/- 350 g pesticides
Individual aspects in purchasing clothing

![Bar chart showing individual aspects in purchasing clothing. The chart compares percentages for 2006 and 2002 in terms of factors such as quality, price, skin-friendly, fashionable, tested on harmful substances, functional materials, environmentally friendly production, and 100% natural fibers.]
Alternatives for cotton

• Bio cotton
• Hemp (grows easily without fertilizers or pesticides)
• Bamboo (grows easily without fertilizers or pesticides)
• Blends with ex. Polyester (difficult to recycle)
Ecological footprint of fibres (ha/ton)

- Bio Hemp 1.45
- Polyester 1.65
- Organic Cotton Punjab 3.35
- Cotton Punjab 3.50
- Cotton USA 3.00

Ecological footprint of a pair of jeans

- Production: 50 %
- Use and end of life: 50 %
Load of waste water of the dyehouse and washing plant

- BOD 200-3000 mg/l (biological oxygen demand)
- COD 500-5000 mg/l (chemical oxygen demand)
Working conditions
Challenges and bottlenecks

Be aware of greenwashing!
Challenges and bottlenecks

- Ambiguity about selection criteria
- Meaning and limitations
- Measurability
- No legal status
- Owned by profit organisations
- Difficult to market because of sprawl