

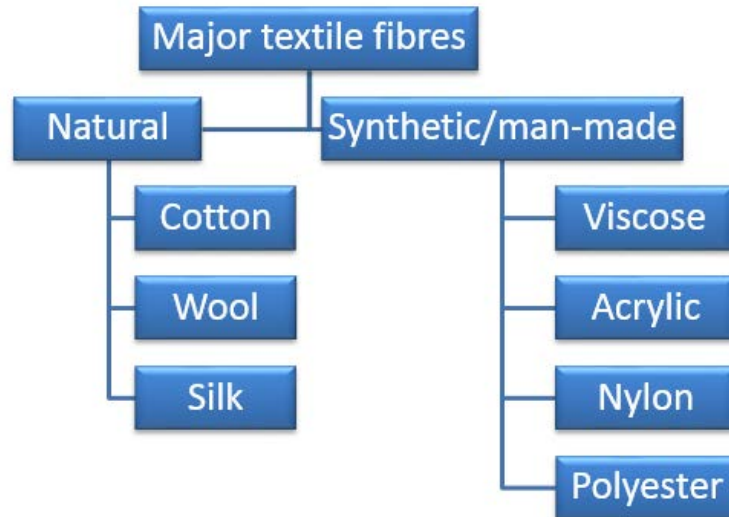
Textile chemistry

Contents

Textile fibres.....	2
Pretreatment of textiles.....	3
Typical pretreatment processes	4
Desizing	4
Singeing.....	5
Scouring	6
Bleaching.....	7
Mercerisation.....	9
Carbonising	9
Pretreatment of man-made fibres.....	10
Principles of dyeing	11
Dyeing process	12
Dyeing machinery and processes.....	12
Dye classification.....	15
Dyeing progress	16
Printing.....	17
Intermediate processes	20
Textile finishing	20
Coating	21
Coating process:.....	22
Lamination	23
Summary	24
Further reading	24

Textile fibres

Fibres are generally classified into natural fibres and synthetic/man-made fibres.



Cotton

Cotton's constituent:

- Cellulose (88-96%)
- Protein (1.1-1.9%)
- Pectic matter (0.7-1.2%)
- Wax (0.4-1.0%)
- Mineral matter (0.7-1.46%)
- Organic acids (0.8%)
- Sugars (0.5-1.0%)

Wool

Wool is protein fibre. Impurities in wool fibres are depending on fibre thickness. The finer fibre, the higher proportion of impurities. The wool's impurities are:

- Fat and suint (5-30%)
- Sand and dirt (5-40%)
- Vegetable matter (0.2-2.0%)

Silk

Silk's composition:

- Fibroin (70-80 %)
- Sericin (20-30%)
- Waxy matter (0.4-0.8%)
- Inorganic matter (1.2-1.6%)
- Pigment (0.7%)

Sericin is the major impurity of silk fibres.

Synthetic fibres

These fibres are mostly free from natural impurities being present in most natural fibres. But the following may be present in synthetic fibres being added during spinning, weaving or knitting processes which may require to be removed:

- sizing materials
- anti-static agents
- processing oils (especially in knits)
- dirt
- loom stains (lubricants).

Pretreatment of textiles

Pretreatment/preparation means preparing the textile fibres properly for downstream processes such as dyeing, printing and finishing.

Pretreatment is an important step prior to dyeing and finishing, which is a requirement and prerequisite for good results in dyeing and finishing.

The preparation processes focuses on:

- improving absorbency (higher dye or finish uptake and more uniform treatment)
- reducing shrinkage
- removing impurities
- obtaining the desired degree of whiteness
- improving comfort.

Typical pretreatment processes

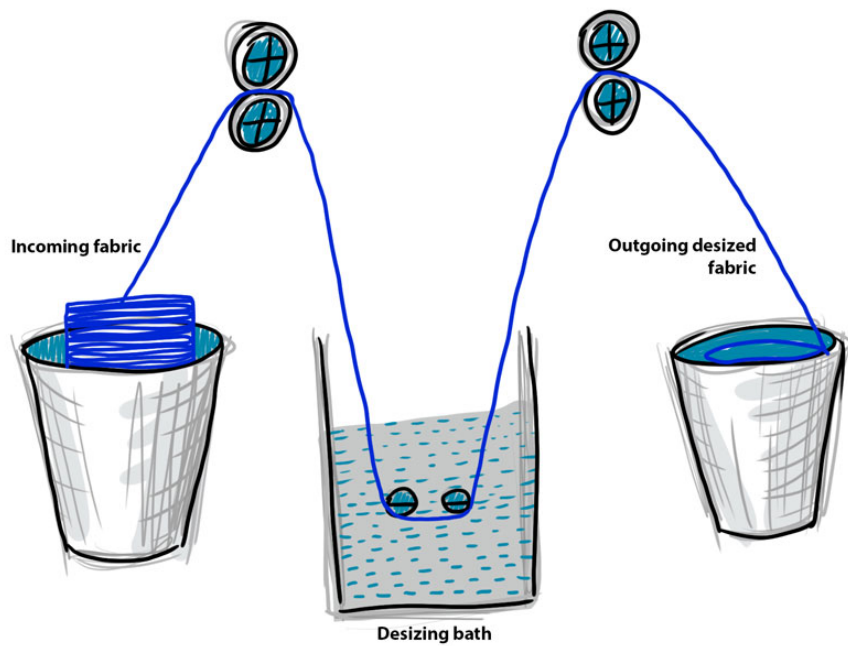
The following shows the general preparation processes.



Desizing

The desizing process is carried out to remove the sizes and other substances applied on warp yarns to facilitate the weaving process. For effective desizing, different desizing means such as enzymes, oxidising agents, acid desizing or hot washing may be used, depending on the type of sizing agents. The desizing process is essential to ensure that dyes and finishes will bond to yarns.

Sizes: Size material forms a stiff and smooth coating on warp threads to enable them to resist the cyclic tensions during the weaving process and diminish breakage

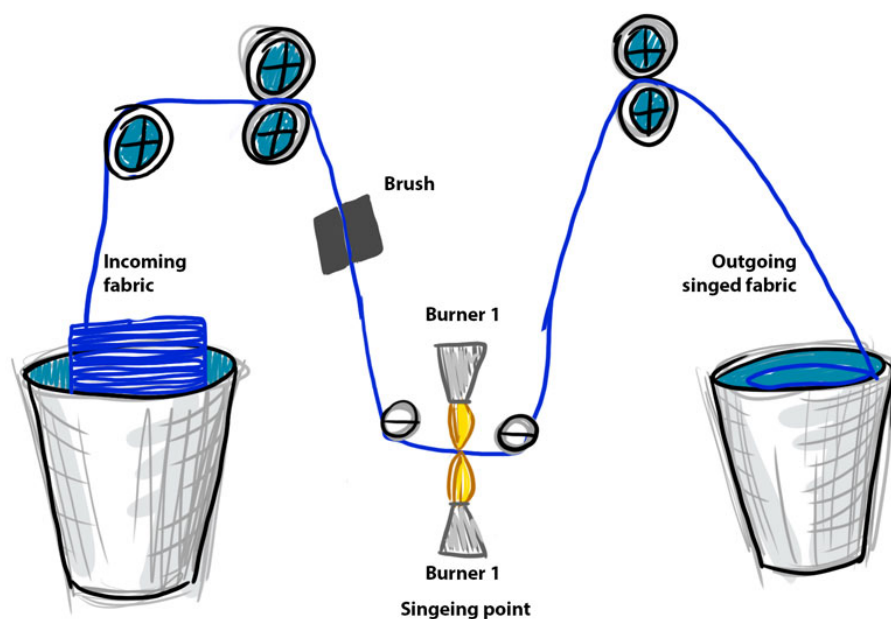


Principle of desizing machine
© University of the Highlands and Islands

Singeing

The singeing process is carried out to burn-off the loose protruding fibres from the surface of yarn/fabric which will improve the fabric luster, make the fabric surface smooth and clean, reduce soiling and prevent pilling.

Singeing generally involves exposing either one or both sides of a fabric over a gas flame to burn off the protruding fibres. The flame temperature is rather high and the fabric's passing speed over the flame is high therefore the loose protruding fibres are burnt off but the fabric itself remains undamaged.



Principle of gas singeing machine
© University of the Highlands and Islands

Scouring

Scouring is the process of removing all undesirable impurities such as foreign matter, soil or processing aids (waxes, lubricants, etc.) from fabric/yarn prior to dyeing or finishing. This pretreatment is an important stage, especially for natural fibres which have a significant presence of natural impurities. Conventionally, scouring involves the use of wetting agents (surfactant), Emulsifiers (Non-ionic surfactants) and alkaline solutions to remove hydrophobic components from the primary wall. Synthetic fibres may need only a mild detergent scour.

Scouring will make fabric sufficiently hydrophilic, remove impurities, increase absorbency and produce clean surface for next processes.

Methods of scouring

Continuous method: J-BOX (see graphic)

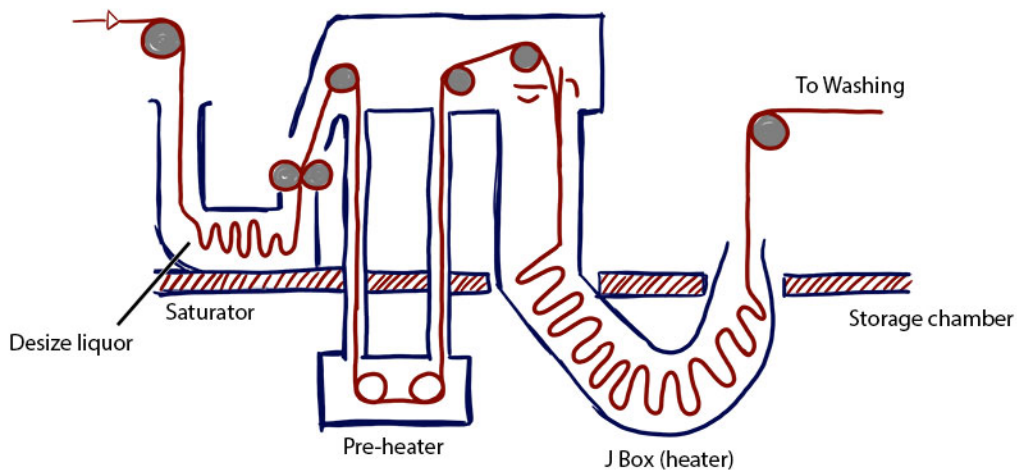
- It is called J-BOX process since the scouring vessel looks like “J”.
- Feeding fabric from one end and coming out the scoured fabric from the other end.
- Impregnation box (Impregnation temperature: 70-80°C, impregnation time: 40-90 sec).

Textile Chemistry

- Pre-heating (at 90-100°C for 30 sec).
- J-BOX (1-4 hours at 100°C).
- Washing unit.

Discontinuous method: Kier Boiling (Pressure kier)

- Removal of impurities by alkaline boiling under pressure.
- Very good removal of impurities.



© University of the Highlands and Islands

Bleaching

After the desizing and scouring processes, most of the fabrics retain slight colouration. The natural or acquired colour needs to be destroyed to bring the textiles to a white state.

Bleaching will be essential if:

- pure white colour is needed in the finished textile;
- the fabric is to be dyed to a clear pastel shade;
- the fabric is to be printed.

Bleaching agents can be classified as:

1. Oxidative bleaching agents

- Peroxy compounds (Hydrogen peroxide (H_2O_2))
- Chlorine based compounds (Sodium hypochlorite (NaOCl), Sodium chlorite (NaClO_2)).

2. Reductive bleaching agents

- Sulphur dioxide, Sodium hydrosulphite, etc.

Methods of bleaching

1. Batch process:

- a defined weighed fabric is loaded into small machine;
- the process is carried out step by step.

2. Continuous process:

- the fabric will travel through a long machine made up of a series of units;
- each unit is specified for one step of the process.



Bleached (left) and unbleached (right) fabrics
© University of Borås

Mercerisation

Mercerisation is a process of treatment of fabric/yarn under tension and in a concentrated solution of cold NaOH.

Mechanism of Mercerisation:

- causes the fibre cross-section to become swollen and rounder;
- increases the fibre/fabric strength;
- leading to more lustrous surface;
- higher moisture gain, reactivity and dye-uptake.

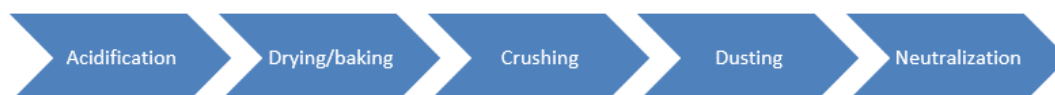
Q. Name a pretreatment process that makes the cotton stronger.

[Feedback: Mercerisation]

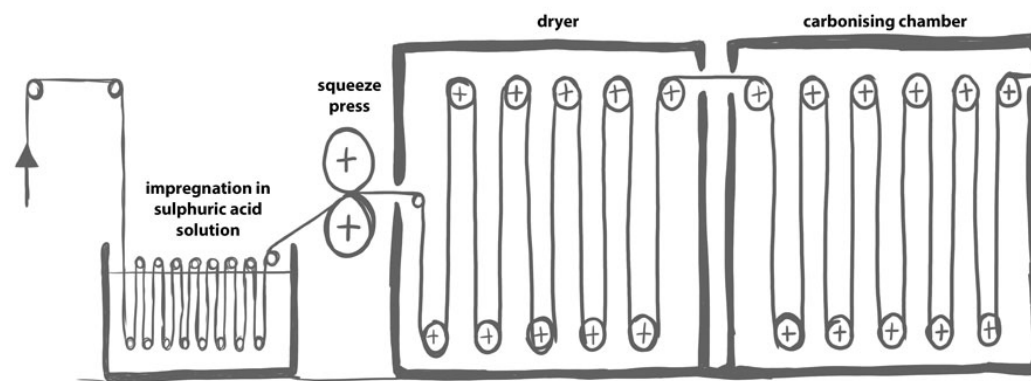
Carbonising

Carbonising is a chemical treatment to destroy the cellulose impurities in wool using strong acid (sulphuric acid).

Processing stages:



Carbonising process



Carbonising process © University of the Highlands & Islands

Q A. On which type of product carbonisation will be done?

Q B. Why do you perform this process?

[Feedback: A) Wool B) To destroy and remove cellulosic impurities.]

Pretreatment of man-made fibres

Synthetic fibres are usually free from natural impurities but they contain secondary impurities being added during spinning, weaving and knitting processes. These include sizing agents, spin finishes, sighting colours, lubricants, etc. The sizing agents are usually easily removed from synthetic fibres at the desizing stage since these agents are either water-soluble or self-emulsifiable compositions. Therefore the scouring of man-made fibres is easier than natural fibres and most of the impurities mentioned can be removed by mild alkaline conditions in the presence of a surfactant.

Scouring conditions for synthetic fibres:

- **Polyester:** Scouring can be carried out with alkali (NaOH, etc.) or anionic surfactant depending on impurities.
- **Nylon:** The scouring conditions are commonly mild alkaline with presence of non-ionic surfactants.
- **Acrylic (PAN):** Acrylic fibres are sensitive to alkaline conditions; therefore strong alkalis are usually avoided for scouring.
- **Viscose:** These fibres can be scoured by non-ionic or ionic surfactant and they should be rinsed in less tension as they have poor wet strength.

Bleaching conditions:

- **Polyester (PET):** Sodium chlorite in acidic pH is preferred for PET bleaching.
- **Nylon:** Sodium chlorite is the most appropriate bleaching agent for nylon. Nylon should be bleached in acidic conditions due to its sensitivity to basic pH.
- **Acrylic (PAN):** Acrylic can be bleached with sodium chlorite in acidic pH.
- **Viscose:** Bleaching with NaOCl or H₂O₂ can be carried out.

Heat-setting:

Heat-setting is a heat treatment applied for fabrics made of synthetic thermoplastic fibres. During all of the processes from fibre to dyed fabric, the material is subjected to different tensions having resulted in sorted stress within the fibre. If the stresses are not relieved, they will cause an irregular fabric appearance and dimensional instability. Excellent dimension stability and good crease-proof properties will be obtained by this heat treatment followed by cooling at the required fibre dimension. This treatment affects (reduces) the dye-ability of fibres thereby it is extremely important to apply heat-setting uniformly and fabric must be treated in precisely controlled temperature and moisture conditions. This heat-treatment is carried out by passing fabrics through a heating zone for specified temperature (160-170°C) and time (15-50sec) depending on fibre type, fabric density and previous heat story of the fibres.

Stenter is the machine used for heat-setting.

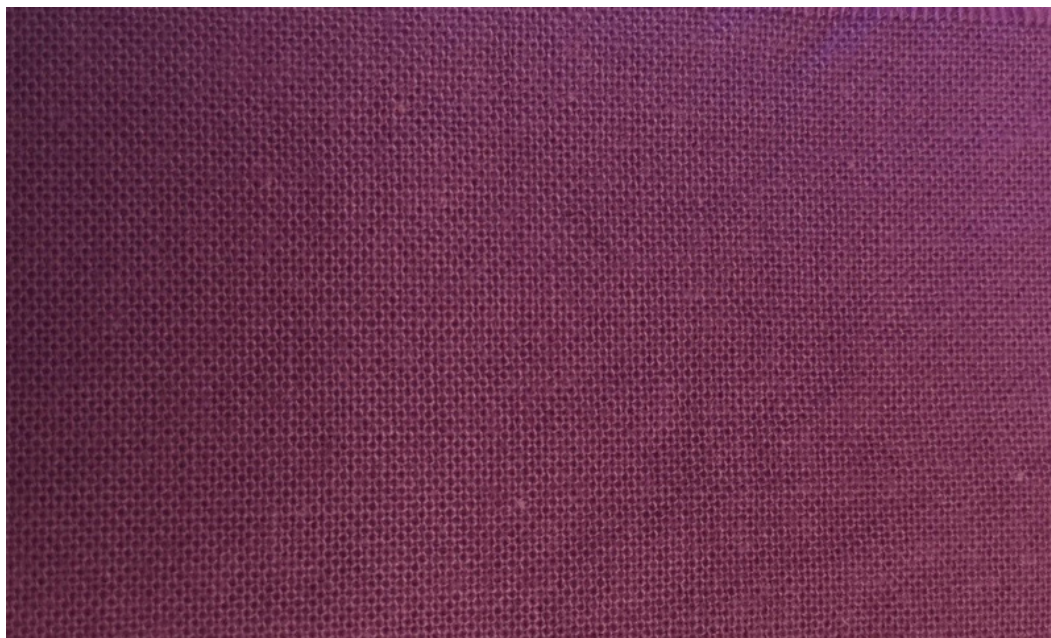


Flexible line for coating and printing
© University of Borås

Principles of dyeing

The aim of dyeing is to make uniform colouration of a substrate. The colour should be uniform; it means that it should be a solid shade with no change in the shade over the whole substrate. There are many parameters affecting the appearance of the final shade including substrate's texture, physical and chemical construction of substrate, pretreatments and post treatments applied after the dyeing process.

The substrates may be divided into two major classes: hydrophilic and hydrophobic. Examples of hydrophilic fibres are cotton, wool, silk and etc. synthetic polyester, acrylics, polyamides and polyolefin fibres are some examples of hydrophobic substances.



A dyed fabric sample © University of Borås

Dyeing process

Textile fabrics are dyed in aqueous solutions or dispersions of dyestuffs together with additives such as acids, alkali, salt and other auxiliary chemicals in a dyebath.

Dyeing machinery and processes

The dyeing process can be carried out in different modes:

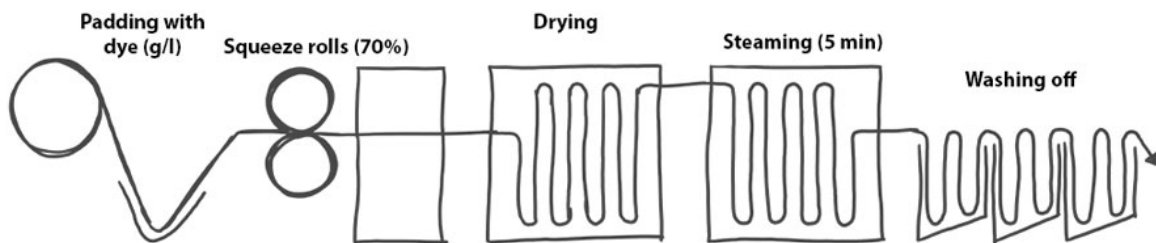
1. Continuous
2. Semi-continuous
3. Discontinuous (batch)

The choice of dyeing equipment depends on the type of fabric (woven, nonwoven and knitted), fibre (natural or synthetic) and the chosen class of dye.

Continuous dyeing

Textile Chemistry

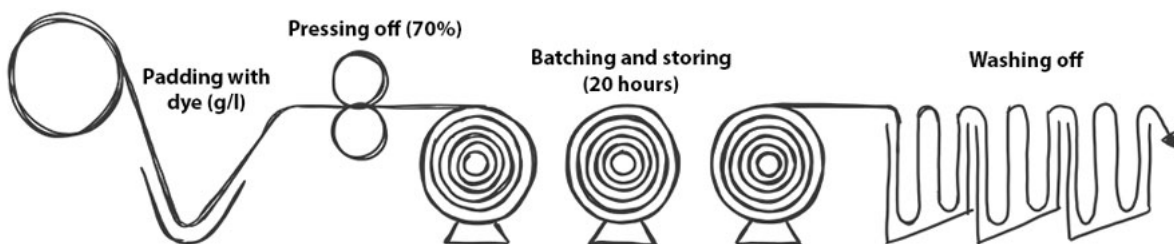
- Feeding the textile substrates continuously into a relatively small pad bath containing the dyestuff and auxiliaries.
- Aiming high production.
- Consists of dye application, dye fixation with heat or chemicals and finally washing.
- Most suitable for woven fabrics.
- The machine's length controls the speed.



Continuous dyeing process © University of Borås

Semi-continuous dyeing

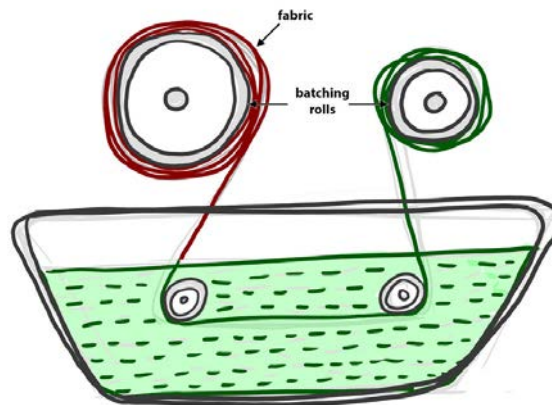
- Consists of pad batch, pad-jig and pad-roll
- Cotton, linen and viscose
- Reactive dyes



Semi-continuous dyeing process © University of Borås

Batch dyeing process (Exhaust dyeing)

- Most common method used for dyeing of textile materials.
- All types of fibre.
- All dye classes.



Jigger © University of Borås



Jet dyeing machine © University of Borås

Dye classification

Dyes can be categorised according to several factors such as colour, synthetic route, fibre type, the method of application to the substrate and chemical structure, etc.

Classification of dye by method of application:

	Substrate	Method	Fastness
Direct dyes	Mainly used for cellulosic fibres: cotton, viscose, linen. Can also be applied on silk and wool.	Applied directly to the substrate in a neutral or alkaline bath.	Give bright shades but exhibit poor wash and light-fastness. After-treatments with dye fixing agent.
Reactive dyes	Commonly used for all cellulosic fibres: wool, silk and rayon.	Reacts chemically with the fibre being dyed.	Very good fastness properties.
Vat dyes	Cotton, linen, rayon, wool, silk and sometimes nylon.	Insoluble in water. Requires reduction treatment to make soluble in water and oxidation to resume insoluble state after dyeing.	High fastness to chlorine, washing, light, rubbing and boiling.
Sulphur dyes	Cotton, linen and rayon.	Insoluble in water, similar to vat dyes.	Excellent resistance to washing but poor resistance to sunlight.
Azoic dyes	Cotton, linen and viscose.	Insoluble in water. Two components react to produce the dye (Coupling Compound (Naphthol) and Di-azo – compound).	Good fastness properties.
Metal complex dyes	Wool, nylon and silk.	Pre-metallised dyes, pH<7	Good fastness properties due to high molecular size and metal complex structure.
Acid dyes	Wool, nylon and silk.	Applied from a dye bath containing acids.	Fastness properties may vary among individual dyes and fibre types.
Disperse dyes	Nylon, polyester and cellulose acetate.	Insoluble in water, pH 4-5. Diffuse into the fibre at high temperatures.	Good fastness properties.
Basic dyes	Mainly used for Acrylic.	Generally pH<7. Reaction with acidic groups.	Good fastness properties.

1. Which two fibres can be dyed with both reactive dyes and acid dyes?

[Feedback: Wool, silk, polyamide]

2. Which dye class is used for dyeing acrylic fibre? What kind of bond is created during this dyeing?

[Feedback: Basic dyes / ionic bonds.]

3. Which fibre can be dyed with basic dyes?

[Feedback: Only acrylic fibre.]

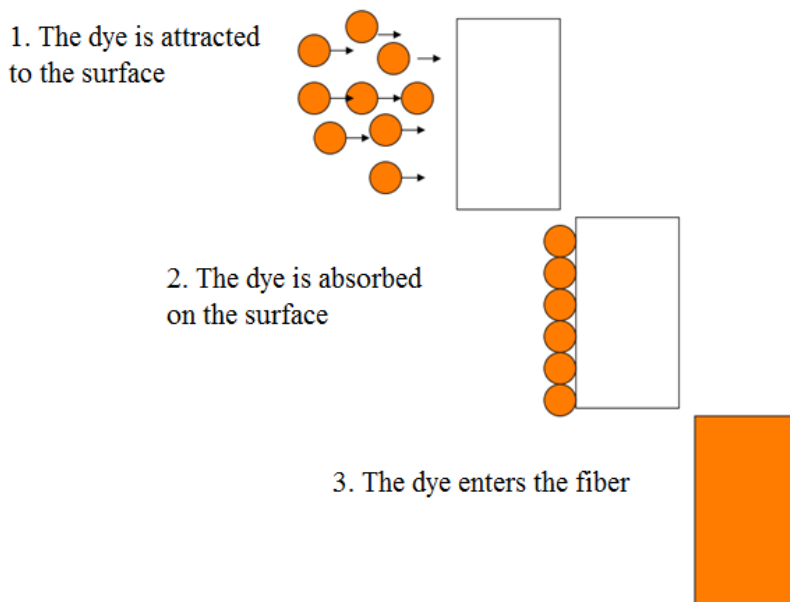
4. Which dye class do you use to dye a polyester knitted sweater with 5% elastane elastomer?

[Feedback: Disperse dyes, no specific dyes for elastane.]

5. Name 2 dye classes that can be used for dyeing polyamide.

[Feedback: Reactive and acid dyes. Pre-metallised dyes (similar as acid) can also be used.]

Dyeing progress



Dyeing progress © University of Borås

[How to dye fabrics](#) (YouTube, 4:05)

Printing

Printing can be described as localised dyeing in different patterns on a substrate.

There are several basic approaches to print colour on a fabric. Click on each item below for more information:

Direct printing

Applying the printing paste directly to the fabric surface with desired pattern.

[Direct printing on fabric](#) (YouTube, 3:40)

Discharge printing

Overprinting a plain dyed fabric with a discharge paste which changes or destroys the colour in the designed areas

[Discharge printing](#) (YouTube, 2:07)

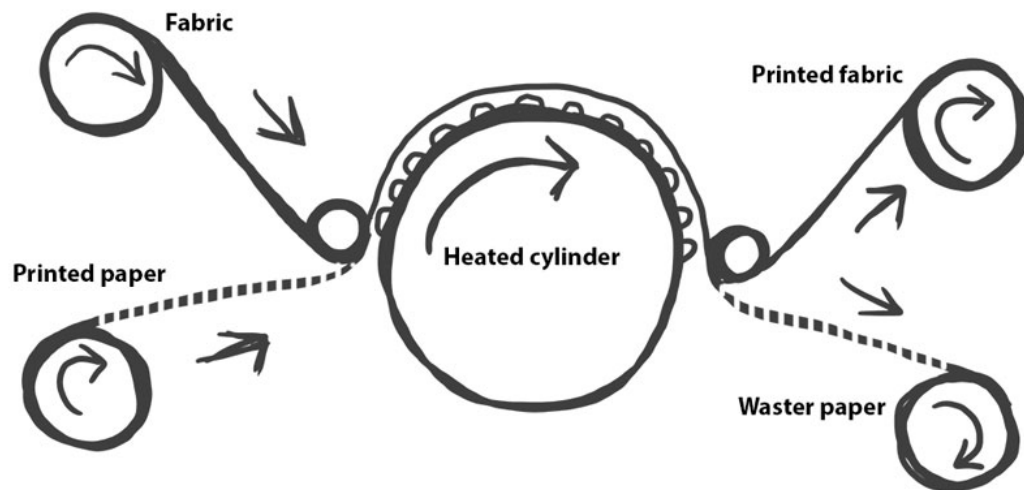
Resist printing

Printing with a resist paste and passing the fabric through a subsequent dyeing process (the printed area is not coloured).

[Resist printing](#) (YouTube, 1:38)

Transfer printing

Literally moving a design from one surface to another. Printing the design on to a special type of paper and transferring the pattern to the fabric with the help of a heated calendar.



Heat transfer printing © University of Borås

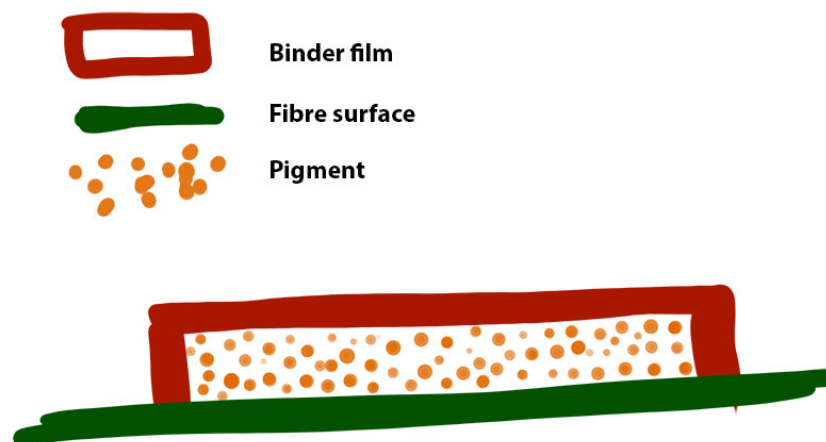
Flock printing

Flock printing or flocking is a printing process in which glue is printed on the fabric and then the fibre flock is applied on the adhesive-coated surface.

[Flock printing](#) (YouTube, 2:31)

Pigment printing

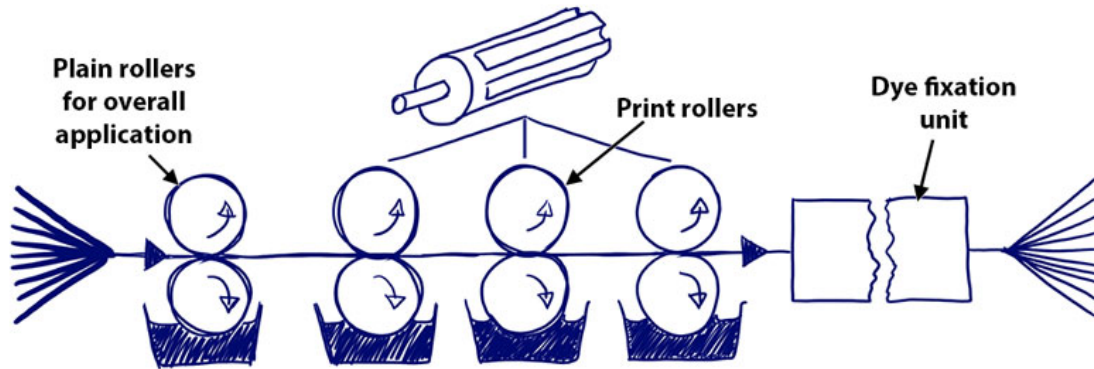
Pigments are colour that are insoluble and do not penetrate into the fibres. Embedding the pigment colour with a film-forming binder.



Pigment printing © University of Borås

Warp printing

Printing the pattern onto the warp sheet before weaving.



Warp printing © University of Borås

Roller printing

The oldest mechanised method of continuous printing. Printing the fabric with engraved metal roller with the printing design. One roller per colour in printing design

[Roller printing](#) (YouTube, 5:07)

Hand printing

The oldest method of printing. Applying the printing paste by means of a wooden block or by a stencil.

[Block printing](#) (YouTube, 5:29)

Screen printing

The most important printing method. Forming the design on a screen by blocking off those parts of the screen where no printing is to happen. Coating the screen with light-sensitive polymer and then selectively exposing through a stencil. Washing away the unexposed area (Exposed areas are made insoluble.)

Flat screen printing

- Holding the fabric firm and flat on a conveyor blanket.

Textile Chemistry

- Supplying printing paste to the screens and forcing through the patterned areas by a squeegee roller or blade.

[Flat bed screen printing](#) (YouTube, 2:12)

Rotary screen printing

- Continuous production.
- Pumping the printing paste from the reservoirs to the inside of the cylindrical screens.

[Rotary screen printing](#) (YouTube, 4:56)

Intermediate processes

After printing or dyeing, the fabric needs to go through additional treatments in order to prepare it for the final finishing stages. These treatments include:

- Fixation
- Washing
- Dewatering and drying
- Heat setting

Textile finishing

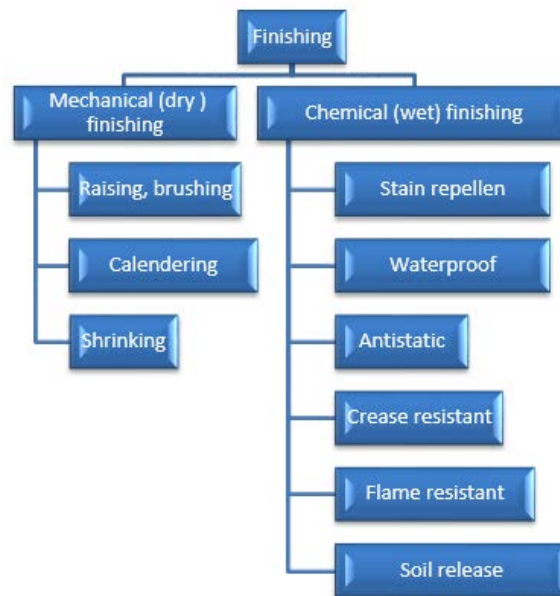
Finishing is the final process to make fabric suitable for its intended end-use.

The basic objectives of finishing are:

1. surface modification (smoothing, raising, embossing, ...);
2. wearing properties modification (creasing, draping, staining, ...);
3. aftercare characteristics modification (shrinking, ironing, ...).

Classification of finishing

Mechanical finishing is concerned mainly with modifying the surface of fabric, while chemical finishing aims to modify and improve the basic fibres or fabric properties.



Coating

Coating is the application of a suitable synthetic or natural polymer on the substrate to add or improve the function of the material by giving it specific properties.

Polymers used for coating:

- Polyvinyl chloride (PVC)
- Polyurethane (PU)
- Acrylic
- Ethylene vinyl acetate (EVA)
- Styrene butadiene rubber(SBR)
- Natural rubber
- Silicone
- Polyolefins
- Polypropylene

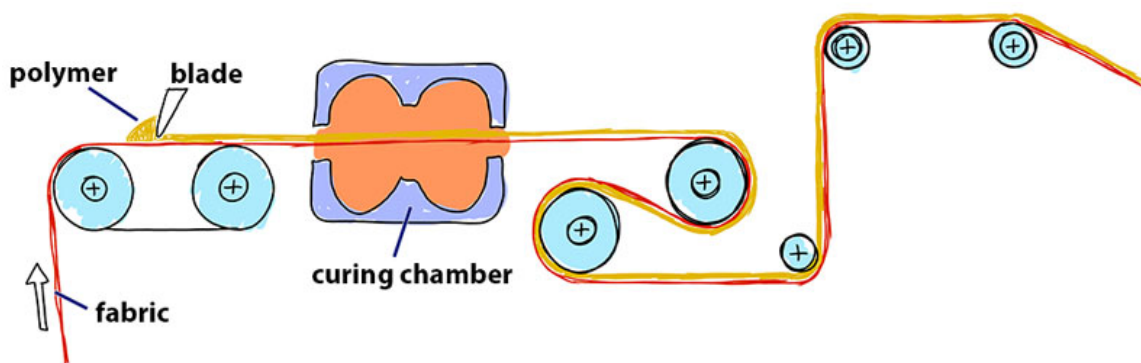


A coated fabric © University of Borås

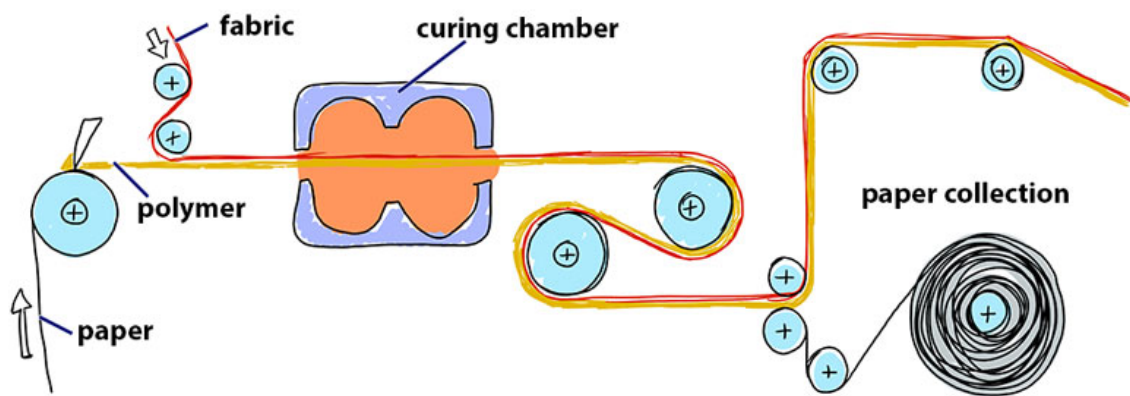
Coating process:



Coating methods:



Direct coating © University of Borås

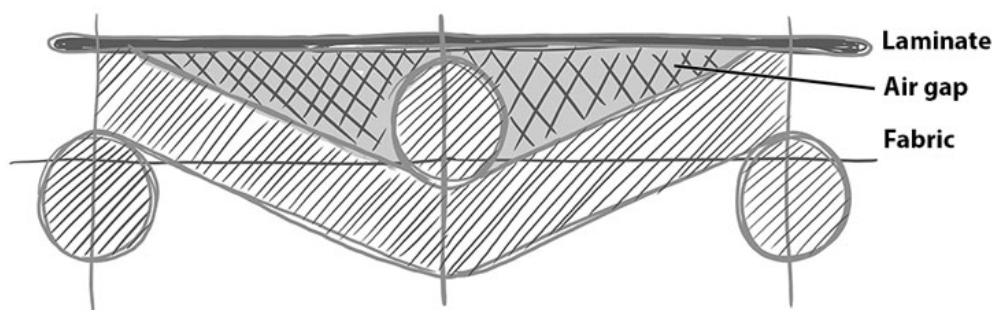


Indirect coating © University of Borås

Applications: Sporting, protective cloths; Leather cloth; Shower curtains; Conveyor belts; Floor and wall covering etc.

Lamination

Lamination is a process of bonding two or more prefabricated sheet materials. The bonding can be achieved by either applying adhesive or heating. Curing is generally not required.



Schematic of a laminated textile © University of the Highlands and Islands

Summary

You should now be able to:

- Describe the pretreatment processes of different fibres for example:
 - **100% cotton fabric:** Singeing, desising, scouring, bleaching and mercerising.
 - **100% silk fabric:** Degumming and bleaching.
 - **100% wool fabric:** Carbonisation, scouring and bleaching.
- Describe the dyeing and printing of different fibres with different types of dye classes and under different conditions.

Degumming: Removing sericin gum by a gentle boiling in mild soap solution.

Further reading

Sara J. Kadoh, *Textiles*. Pearson New International Edition, Chapter 2, 16-21