Department of Textile and Fibre Engineering

Indian Institute of Technology Delhi

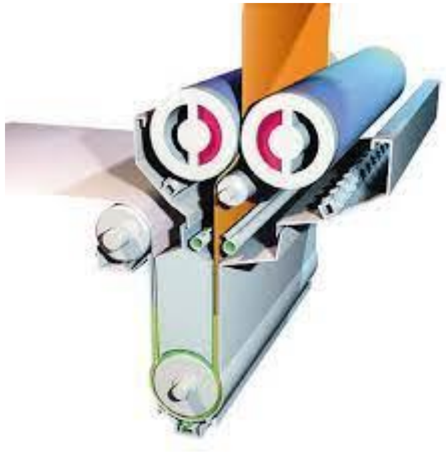
Technology of Pre-treatment and Finishing

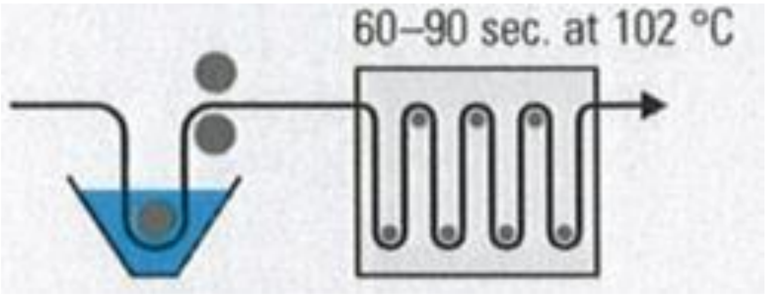
(TXL-241)

Chemical Finishing of Textiles

Application Concepts

DIP AND NIP PADDING





- The objective of this process is to ***mechanically*** impregnate the fabric with the solution in bath having finishing chemicals.
- Three main actions involved
  - ***Dipping*** or immersion of fabric to ***wet and swell*** the textile.
  - ***Squeezing*** or mangling to compress and ***force the liquor*** into fabric.
  - Simultaneous ***transport*** of fabric in ***forward*** direction.
- Constant immersion time, constant speed, constant liquor level and uniform pressure between roller is required to main uniformity in finishing.
- Used for continuous processing open width fabric.

DIP AND NIP PADDING

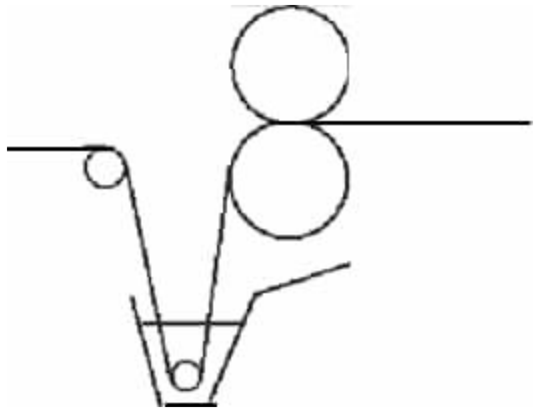
The fundamental principles of the operation of mangling for liquor application and removal were set down by Potter

It was considered that the two main aims of mangling are:
(1) uniformity of nip
(2) efficient water removal.

Potter deduced a simple equation relating the take-up, T, to the minimum thickness of the fabric tm

$$T = \frac{t_m - w/\rho}{w} . \sigma . 100$$

where σ = liquor specific gravity
ρ = fibre density
w = weight per unit area



DIP AND NIP PADDING

Potter assumed that the amount of *air contained within the fibre is negligible at the point of maximum compression* – that is, the fabric is fully wet-out.

He further deduced that:

- a *greater load* means *less take-up*;
- for the same *load per unit length of pressure area*, bowls of smaller diameter give smaller take-up – in fact, the load required to produce a constant take-up is proportional to the *square root of the radius* of the bowls;
- if we have n thicknesses of fabric passing through the mangle and if it requires a load, *Ln*, to produce a take-up, *T, as compared with L for a single layer*,

$$L_n = \sqrt{n}L$$

Pad application of chemicals

In order to obtain consistent chemical application,

- the *nip pressure* should be *uniform* across the fabric width,
- the *solution level* and *temperature* in the pad should be *constant* and
- the *fabric speed* should not vary throughout the application process.

Pad application of chemicals to dry fabric

- Chemical finishes are often pad applied to dyed or printed fabrics after a drying step is called a '*wet on dry*' process.
- The wet pickup of a chemical solution in a pad mangle is influenced by many factors.

Factor	Effect on wet pickup
Fibre type	Higher wet pickup with hydrophilic fibres
Yarn construction	Higher wet pickup with low twist and/or open end yarns
Fabric construction	Higher wet pickup with loose constructions (knit vs. woven)
Wettability	Higher wet pickup with more easily wetted fabrics
Pressure of squeeze rolls	Higher pressures lead to lower wet pickups
Nature and hardness of squeeze roll coverings	Harder coverings lead to lower wet pickups
Length of immersion time	Higher wet pickup with longer immersion time
Viscosity of solution or emulsion	Higher wet pickup with higher viscosity
Surface tension of solution or emulsion	Higher wet pickups with faster wetting solutions
Temperature of solution or emulsion	Viscosity and surface tension change with temperature, changing wet pickups
Concentration of solution	Viscosity and surface tension change with component concentrations, changing wet pickups

Pad application of chemicals to dry fabric

- In continuous padding, the amount of chemical applied to the fabric depends on the amount of finishing solution applied, the concentration of the supplied chemical in the finishing solution or emulsion and the solids or active compound concentration of the supplied chemical.

- The amount of finishing solution or emulsion applied is referred to as *the 'wet pickup' (wpu).*

$$\%\ \text{wpu} = \frac{\text{wt of solution applied} \times 100}{\text{wt of dry fabric}}$$

  - To determine the amount of supplied chemical added to the fabric, the '% add-on'

$$\%\ \text{add-on} = \frac{\%\ \text{conc in solution (wt/wt)} \times \%\ \text{wpu}}{100}$$

Pad application of chemicals to dry fabric

- To determine the necessary solution feed rate to maintain a constant liquid level in the pad.

$$\text{solution flow rate (l min}^{-1}\text{)} = \frac{\text{fabric mass flow (kg min}^{-1}\text{)} \times \%\ \text{wpu}}{\text{solution density} \times 100}$$

Where fabric mass flow is defined as:

$$\text{fabric mass flow} = \text{fabric speed (m min}^{-1}\text{)} \times \text{fabric linear density (kg m}^{-1}\text{)}$$

Pad application of chemicals to wet fabric

- To avoid the costs of a drying step after dyeing, chemical finishes are often pad applied to wet fabric in a process called ***'wet-on-wet'***.
- ***Wet pickup*** of the fabric exiting the pad must be maintained at a higher level than that of the incoming fabric, usually at least ***15–20 % higher***.
- Water entering the pad from the incoming fabric can interchange with the finishing solution, in effect diluting the concentration of the components and causing tailing of the finish effect.

Pad application of chemicals to wet fabric

- In order to determine the pad solution or emulsion concentration of the finishing chemicals, an effective percentage wet pickup, wpu_{eff}, is calculated.

$$wpu_{eff} = (wpu_0 - wpu_i) + wpu_i \times f$$

where wpu_0 is the percentage wet pickup of the fabric exiting the pad, wpu_i is the percentage wet pickup of the fabric entering the pad and ***f*** is the interchange factor (*Typically f is between 0.7 and 0.8*).

$$\text{pad conc (g l}^{-1}) = \frac{\%\ \text{add-on} \times 1000 \times \text{solution density}}{wpu_{eff}}$$

Pad application of chemicals to wet fabric

- The concentration of the chemical feed solution must be higher than the pad concentration since the pad bath is being diluted by the water on the incoming wet fabric.

$$\text{feed conc (g l}^{-1}\text{)} = \frac{\text{pad conc} \times \text{wpu}_{\text{eff}}}{\text{wpu}_0 - \text{wpu}_i}$$

The feed flow rate

$$\text{feed flow rate (l min}^{-1}\text{)} = \frac{\text{fabric mass flow (kg min}^{-1}\text{)} \times (\text{wpu}_0 - \text{wpu}_i)}{\text{feed solution density (g ml}^{-1}\text{)} \times 100}$$

Foam Finishing

- A *foam is an agglomeration of gas bubbles* separated from each other by *thin liquid films*.
- Foam is generated by *dispersing air in the finish liquor* which may contain the finishing chemicals together with the *foaming agent(s)*.
- Foam finishing is used when *fabrics to be processed at a low wet pick-up*, with considerable savings in water and energy consumption *as much as 95%.*
- Water normally used to apply finishes to fabrics may be replaced by air, markedly *decreasing drying costs*.

Foam Stability

- The foams used in textile finishing are generally of the metastable type that have a halflife period ($t_{50\%}$) of between *30 and 45 minutes*. The half-life period is the time in which 50% of the liquid volume contained in a foam has been drained. The shorter the half-life period, the lower the stability of the foam.
- Foam *stabilisation* is usually achieved by *increasing the viscosity of the liquid* in the walls of the bubbles to decrease the rate of thinning.
- Additives such as *xanthan gum, hydroxyethyl cellulose and other thickening agents* may be used to increase the viscous drag on neighbouring molecules, decreasing the drainage rate.

Foam drainage

- If three bubbles are joined, the three separating films meet to give a small triangular column of liquid known as *Plateau's Border.*
- The liquid in the border channel is at a *lower pressure* than that in the body of the film, and because of this pressure difference film thinning takes place.

In practice, *foam drainage* is caused by four simultaneous processes:

(1) rearrangement of the films or lamellae between bubbles;

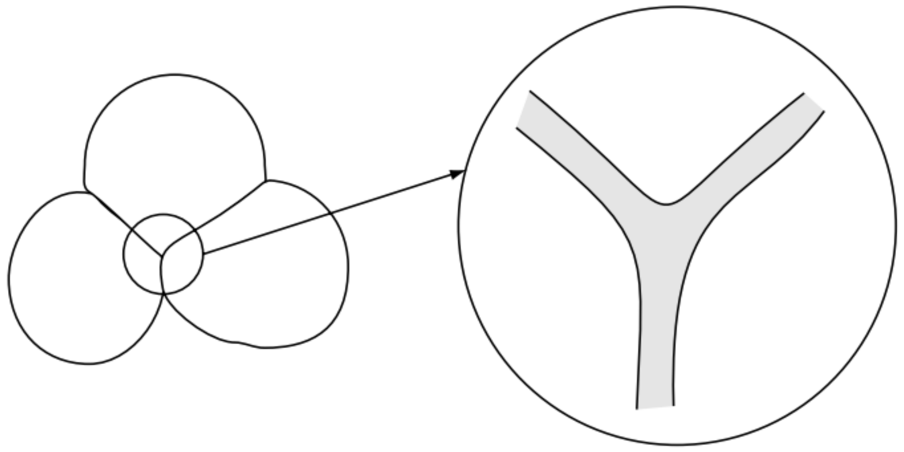
(2) drainage of the lamellae

(a) by gravitational force

(b) by suction at the Plateau's borders

(3) diffusion of gas through the lamellae;

(4) bursting of the bubbles.



Foam Density

- A decrease in foam density will result in a *decrease* in the wet pick-up.
- In general, bubbles with diameters in the range *20–100 μm* with a sharp bubble size distribution give consistent creamy foams with the desired properties for foam processing.
- The half-life of a foam is the time in which *50 %* of the liquid in a given foam volume has been drained from the foam. Foams for textile applications can have half-lives from a few seconds to several hours.

Foam Density

- The foam density used in textile finishing applications is generally within the range 0.08–0.15 g cm^{-3} corresponding to a blow ratio range of 6.6 to 12.5.

$$\text{Blow ratio} = \frac{\text{Weight of a given volume of liquid before foaming}}{\text{Weight of the same volume of foam}}$$

$$\text{blow ratio} = \frac{1}{\text{foam density}}$$

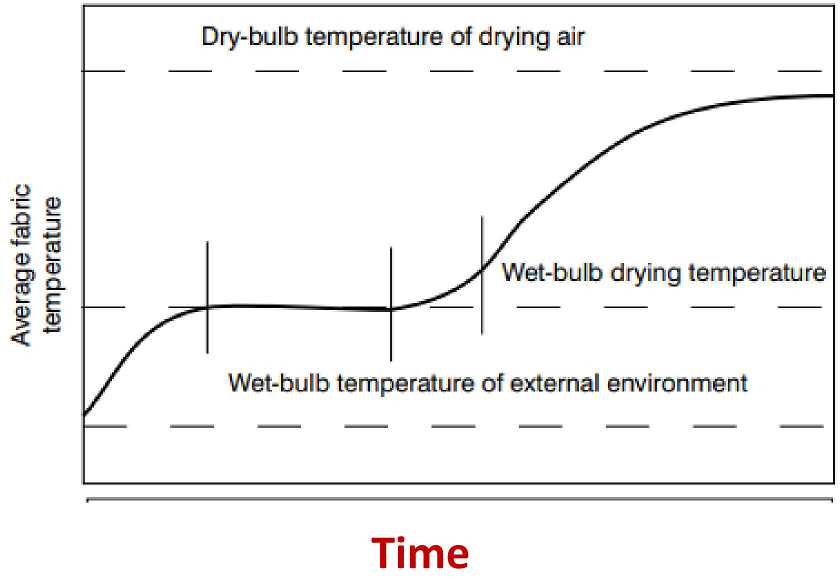
Evaporative Drying

Convective Drying

- The temperature of the wet fabric is lower than that of the surrounding air, and heat transfer will start.
- The two processes – *evaporation causing heat loss, and heat transfer from the air proceed* and soon reach an equilibrium. There will then be no further change in fabric temperature until the equilibrium is disturbed.
- The energy balance can be expressed thus:

$$(\text{rate of heat loss}) = (\text{rate of heat gain})$$

$$Ak(P_2 - P_1)L = Ah(t_1 - t_2)$$



where A = surface area of evaporation/heat transfer

t_1 = air temperature

t_2 = wet fabric temperature

P_1 = partial pressure of water in the air at t_1

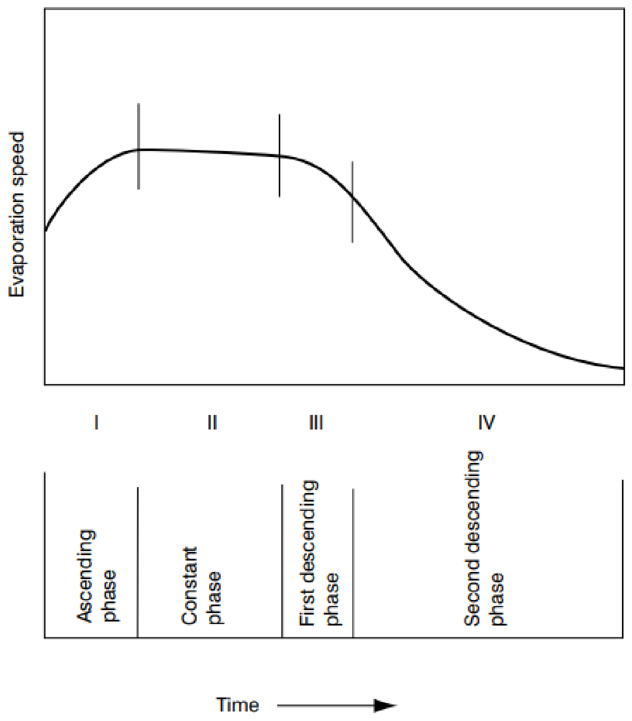
P_2 = vapour pressure of water at t_2

L = latent heat of evaporation at t_2

k = mass transfer coefficient of water vapour at t_2

h = heat transfer coefficient from air to fabric

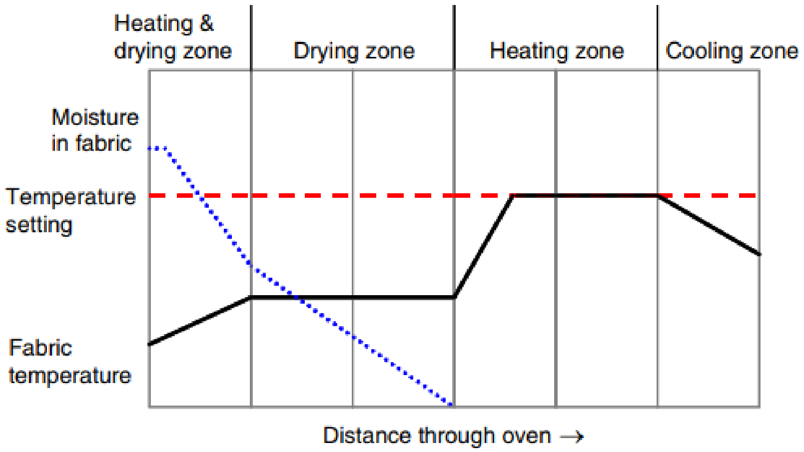
Evaporative Drying



- The drying starts during the short period of warming up,
  - proceeds at a constant rate (and temperature) while evaporation occurs from the surface only.
  - then at a decreasing rate when water cannot be transported to the surface.
- Heat transfer by convection has been shown to increase with air velocity (v), a heat transfer coefficient of 2 $Wm^{-2}K^{-1}$ in still air increased to 20 $Wm^{-2}K^{-1}$ in air at 26 ms^{-1}.
- For economic and technical reasons, the average moisture content *should not be reduced below normal regain*.

Curing chemical finishes

- After application of the chemical finish, the fabric must be dried and if necessary, the finish must be fixed to the fibre surface, usually by additional heating in a ***'curing'*** step
- The same heating equipment used to dry wet textiles can also be used to heat the fabric and finish to the temperatures desired for optimal curing.
- For all equipment, it must be remembered that the temperature of the fabric cannot exceed 100 °C until all of the water has been removed.



$$\text{curing time} = \frac{\text{amount of fabric in machine}}{\text{speed of the fabric through the machine}}$$

Shock-condensation or shock-curing processes may lead to over or under curing of chemicals.