Textile Manufacturing – Fibre, Yarn, Knit, Weave and Finishing

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Lecture Content

• The Ambition & the Dream? 15 minutes!

• Textile Materials & Hierarchy

• Yarn Spinning

• Weaving

• Knitting

• Preparation & Coloration

• Finishing?
Textile Materials

- **Natural Fibres**
  - Cotton - Cellulosic;
  - Wool – Keratin;
  - Silk – Protein;
  - Bast – Lignocellulosic.

- **Man-made Fibres**
  - Synthetic
    - Polyester;
    - Nylon;
    - Acrylic;
    - Cellulose Acetate;
    - Aramids, Glass….

- **Man-made Fibres**
  - Regenerated
    - Viscose;
    - Lyocell/Tencel.
Fabric Properties and Performance

End-Use Aims:
• Fit for purpose and “Useful” Lifetime;
• Durable and strong;
• Dimensionally stable;
• Serviceable;
• Extensibility;
• Fashion or Technical Product, or both;
• Efficient conversion of fibres into fabric - Cost
Yarn Spinning
What is Textile Yarn?

“A textile yarn is an assembly of substantial length and relatively small cross section of fibres and/or filaments with or without twist”

*Textile Terms and Definitions, The Textile Institute*

Need cohesion and interfibre friction to hold yarn together

“A yarn is a continuous strand of textile fibres, filaments, or materials in a form suitable for knitting, weaving, or otherwise intertwining to form a textile fabric”

*American Society for Testing and Materials*
Yarn Spinning

**Staple Yarns (Short/Long)**
- Short staple Yarns
- Long staple Yarns

**Continuous Filament Yarns (Flat/Textured)**
- Monofilament yarns
- Multifilament yarns
- Textured yarns

**Composite Yarns (Staple & Filament)**
- Filament wrapped around staple core
- Staple fibres wrapped around filament core
Filaments can be produced by melt spinning, wet spinning, dry spinning and bicomponent spinning.

Simple process where extruded filaments can be positioned/wrapped around each other to produce a strong yarn.
<table>
<thead>
<tr>
<th>Operation</th>
<th>Purpose</th>
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</thead>
<tbody>
<tr>
<td>Opening (Blowroom)</td>
<td>Loosen bales, blends and cleans fibres</td>
</tr>
<tr>
<td>Carding</td>
<td>Cleans and align fibres, forms carded sliver</td>
</tr>
<tr>
<td>Drawing</td>
<td>Parallels and blends fibres, forms drawn sliver.</td>
</tr>
<tr>
<td>Combing</td>
<td>Parallels and removes short fibres, forms combed sliver</td>
</tr>
<tr>
<td>Roving</td>
<td>Inserts slight twist, forms roving</td>
</tr>
<tr>
<td>Spinning</td>
<td>Reduces size, twist, winds finished yarn on bobbins</td>
</tr>
<tr>
<td>Winding</td>
<td>Rewinds the yarns to spools or cones.</td>
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Yarn Characteristics

S-Twist and Z-Twist Insertion

General Yarn properties:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Staple</th>
<th>Filament</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenacity</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Elongation</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Comfort</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Double Yarns, Wrap Yarns, Hybrid Yarns etc*
End-Uses of Staple Yarns

**Coarse yarn** (>40 tex)

**Medium to fine yarns** (16–40 tex)

**Fine yarns** (7.5–16 tex)

**Super fine yarns** (2–7.5 tex)

- **Furnishing fabrics, terry, denim, carpet yarns**
- **Work wear**
- **Ticking/ poplin**
- **Night wear**
- **Sewing**
- **Shirts/blouses**
- **Leisure & sports wear**
- **Home textile & woven**
Weaving Processes
Weaving Mechanism

**Shedding**
Separate warp yarns by lifting and lowering the shafts to form a tunnel known as the ‘shed’

**Picking or Filling**
Passing the weft yarn (pick) across the warp threads through the shed

**Beating-up**
Pushing the newly inserted weft yarn back into the fell (body) using the reed
Weaving Processes

Following Shedding, Picking and Beating are:

- **Let off**: The warp yarns are unwound from the warp beam during the above three processes.

- **Take up**: The woven fabric is wound on the cloth beam during the above three processes.

All the mechanical operations are synchronized in the correct sequence and the full sequence is repeated for the insertion and interlacing of each weft yarn length with the warp yarns.

Overall known as ‘The Weaving Cycle’
Loom Evolution

In its simplest form a single wooden shuttle is inserted across the warp threads in the loom and fabric built-up. However in looking to increase loom production modern production machines have two metal rapiers transporting the weft yarn across the warp. A further variation on this weft insertion mechanism is to use compressed air-jets (fastest insertion) or water jets. Each type of loom has advantages and disadvantages.

The raising of the warp threads is now controlled by an electronic jacquard harness which is positioned above the loom and can control the movement of up to 1200 warp yarns.

In weave manufacturing the speed of the loom is vital in providing commodity woven fabric.
Weaving Looms

Handlooms with
CAD Software

Multi-Shuttle Loom with
Jacquard Harness
Woven Fabric Structures

Aerospace Composites - Seamless, Lightweight & Strong
3D Weaving

- 3D weaving is the weaving of “multi-layer” cloths that have a pre-designed three-dimensional shape or can be directly manipulated into a 3D shape immediately after being woven.

- A 3D woven fabric has lengths of its constituent yarns positioned in the z-direction to produce the fabric-thickness, as well as lengths being arranged in the x- and y-directions for the fabric width and length.
Knitting Processes
In weaving, threads are always straight, running parallel either lengthwise (warp threads) or crosswise (weft threads).

Yarn in knitted fabrics follows a meandering path (a course), forming symmetric loops above and below the mean path of the yarn. These loops can be easily stretched in different directions giving knit fabrics much more elasticity than woven fabrics (up to 500% stretch).

Knitting was initially developed for garments that must be elastic or stretch in response to the wearer's motions, such as socks and hosiery. Now commonly found in sportswear.
Knitting Processes

- There are two major varieties of knitting: weft knitting and warp knitting.

- In the more common *weft knitting*, the wales are perpendicular to the course of the yarn. In weft knitting, the entire fabric may be produced from a single yarn, by adding stitches to each wale in turn, moving across the fabric as in a raster scan.

- In warp knitting, the wales and courses run roughly parallel and one yarn is required for every wale.

- Since a typical piece of knitted fabric may have hundreds of wales, warp knitting is typically done by machine, whereas weft knitting is done by both hand and machine.
Weft Knitting

KNITTING - KNITTED
Interlooped-Intertwining the head, legs & feet

Knit Schematic

**WEFT** knitted loop and stitch formation:

Basic yarn loop is presented to the right in the simplest unit of a singular loop

H = head
L = legs
F = feet

Neighbouring loops of one course are created from the same yarn, although additional yarns, for alternative colour or properties can be added into the knitting process.
Weft Knitting

Circular Knitting  Latch Knitting  Needle  Flat Bed Knitting

Dubied V bed flat weft knitting construction

The knitted fabric is formed between the two needle beds.
Warp Knitting

**Interlooped-Intertwining the head, legs & feet**

Knit Schematic

**WARP** knitted loop and stitch formation:

- This the interlooping of individual yarns that run down the warp direction, hence the name;

- The warp direction is also known as the wale, the same as weft knitting and also contains courses as the wale/warp direction yarns interloop down the length of the fabric to the neighbouring wale/warp directional yarn;

- Every knitting needle has its own individual yarn to form the loops vertically down the constructed knitted fabric;

- The warp and weft knitted structures have many similar inherent properties stretch, stretch recovery and drape;

- **Single** or **double** fabrics can be produced, double fabrics for seamless garments;

- Similar to the weave set-up, warp yarns are required to be planned and counted according to the requirements of the knitted structures, density and width.
Warp Knitting

Weft Knitting  Warp Knitting

Warp Knitting Machine
Knitted Structures

Controlled Stretch

Fully Fashioned
Preparation Processes

For Coloration, Chemical Treatment, Coating etc
Scale of Textile Processing

Batch Processing:
• Generally smaller quantities of textile materials are treated, and the processing time is limited to a few hours with small-scale machinery.

Continuous Processing:
• Larger quantities are treated, and the processing time extends to many hours using relatively larger expensive equipment;
• Typically process 10,000-100,000 metres (or more) of standard fabric with standard colours;

Generally the quality and uniformity of continuously processed fabric is better.

Wool fabrics are generally batch processed, while woven cotton/polyester fabric is continuously prepared.
Textile Fibre & Fabric Processing

Textile Wet & Dry Processing

- Preparation Processes
- Colouration Processes
- Finishing Processes

Natural Fibres – Most Necessary
Preparation Processes

Aims:
• To produce the textile material with the correct chemical and physical properties to ensure effective colouration and finishing.

Typical cotton processing include:
• Singeing, desizing, scouring, bleaching, mercerisation, setting, cropping, raising, calendering, enzyme treatments etc.

60-70% of downstream processing problems related to poor preparation of the textile material.
Preparation Processes for Cotton and Cotton/Polyester Woven Fabric

- Loomstate
- Inspection
- Singeing
- Desizing
- Scouring
- Bleaching
- Mercerisation
- White Fabric
- Colouration
- Finishing
Coloration Processes
Aims:

- Colouration is necessary for imparting aesthetic quality and functional performance (high visibility, Heat camouflage etc).

The pre-preparation processing needs to “deliver”:

- Fabric with uniform wettability and adsorption;
- Uniform whiteness;
- Fabric capable of level colouration;
- Good penetration of the colourant into the fabric.
Dye or Pigment?

Choice Depends on End-Product
Costs
Aesthetics
Durability Performance
General Comparison of Dyes and Pigments

Pigments:

- Relatively large;
- Insoluble in the application medium;
- High light fastness;
- Wash fastness is variable depending on pigment location;
- Rub fastness dependent on pigment location – surface or inside the fibre;
- Pigment/binder application can affect fabric handle;
- Pigment/binder surface application can affect fabric lustre.
- Inorganic or Organic molecules
Mass Pigmentation of Polyester

- Pigment is incorporated as a Melt Spinning additive.
- Extruded through spinneret to form filament and cooled.
- Pigment is uniformly distributed throughout the fibre interior.
- Needs to be Heat Stable!
Pigment Printing and Dyeing
Traditional or Digital


**Pigment Dyeing** – Application over Whole Fabric and all Fibre Surfaces. Consists of Pigment, Binder, Emulsifiers, Softeners and Crosslinkers. Simple Technology - Pad, Dry & Heat Cure.

**Rubbing & Washing Fastness** are the Key Performance Issues and are Controlled by Binder Hardness (Tg).
General Comparison of Dyes and Pigments

Dyes:

• Relatively small;
• Soluble in the application medium at some time;
• Variable light & wash fastness;
• Rub fastness generally very good as dye is located inside the fibre and surface abrasion has little effect;
• Modern dyeing procedures maintain fibre quality & handle by using short “gentle” processes;
• Little effect on the fabric lustre as dye is inside the fibre;
• Dyes can be applied to fibre, yarn, fabric or garments using a range of batch or continuous dyeing equipment.
Dyeing of Textiles
Natural Dyes or Synthetic Dyes?

Natural dyes:
- Variable Quality due to seasons and sources. Safe?
- Variable Colour Strength due to seasons and sources.
- Weak Tinctorial Strength relative to Synthetic Dyes.
- Generally Poor Washing Fastness – Metal salt mordants improve wash fastness & broad colour palette range;
- Light Fastness variable.

- **Use Synthetic Dyes** and use biobased “building blocks”
Dyes for Cotton

The dyes available for cellulosics are:
- Direct Dyes;
- Vat Dyes*;
- Sulphur Dyes*;
- Azoic Dyes;
- Reactive Dyes*.

The matching of dye to end-use may appear difficult but in reality is relatively simple.

Dyeing temperature from 30°C up to boil
Dyes for Polyester

• The dyes applied to polyester are:

• **Disperse Dyes** - Non-polar, low water solubility;

• Class A-D – Related to size and heat fastness/migration.

• Class A and B can be transfer printed or Thermosoled. Elevated dry heat causes solid dye to sublime and migrate as a gas into the polyester filament.

• **Dyeing temperature from 110°C up to 200°C**
Possible Dyeing Stages of Textiles

Natural Fibres
- Mass Pigmentation
- Gel Dyeing
- Tow Dyeing
- Loose Stock Dyeing
- Top Dyeing
- Yarn Dyeing x2
- Fabric Dyeing x5
- Garment Dyeing

Man-made Fibres

Aqueous Dyeing & Supercritical CO\textsubscript{2} Dyeing
Finishing Processes
Finishing – Why is it Important?

Good finishing can make a hessian blanket like silk!
Bad finishing can make a silk blanket like hessian!

In a sense it is the icing on the textile fabric “cake”
It is applying the final processing to the fabric or garment – finishing!
What the Consumer Expects?

Garment:
- Doesn’t shrink on washing and drying
- Is wash and light fast – Maintains colour design
- Is crease resistant & shedding - good appearance
- Offers environmentally friendly credentials
- Keeps you dry – Water resistant or proof
- Protects against fire and heat
- Manages garment/body microclimate
- Offer anti-microbial/healthcare benefits
- Platform for technology – Wearable Electronics
Natural Fibres Challenges

- Wool/Keratin fibres have unique surface structure – Felting Shrinkage problem
- Cotton fibres have swelling shrinkage and creasing problem
- Cotton has flammability problem
- Strength relative to synthetics
- Cost relative to synthetics
Finishing Processes

• Dimensional Stabilisation – Setting, Shrinkproofing, Sanforising (Preshrinking)

• Crease resist

• Softening

• Flame Retardancy

• Coating/Laminating

• Water Repellency & Water Proofing
Finished Fabric

• Integrated Wearable Electronics product based on polymer, fibre, yarn, fabric, finishes, dyes or pigments has to deliver performance

• Manufacturing Wearable Electronics with adequate end-use performance and durability challenging

• Wearable Electronic Manufacturing linked to cost effective Recycling is challenging
Thank You

Questions?