Technologies for production of 2D and 3D smart textiles

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TECHNOLOGIES FOR PRODUCTION OF 2D AND 3D SMART TEXTILES
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1. FUNCTIONAL AND TECHNOLOGICAL DESIGN OF TEXTILES USED FOR SMART APPLICATIONS
Textile value chain

Non smart Fibres → Functionalization → Smart Fibres

Non smart Yarns → Functionalization → Smart Yarns

Non smart Fabrics → Functionalization → Smart Fabrics

Spinning → Weaving (2D and 3D)
Knitting (2D and 3D)
Braiding (2D and 3D)
Non-woven technologies

Integration of non-textile components

Smart Products
Sewing
Embroidery
Welding

Conductive fibers
Piezo-electric fibers
Fiber-shaped actuators
Shape-memory fibers
Chromatic fibers
Thermoregulating fibers
Luminous fibers
Antibacterial fibers
.....
• Type of textile materials
• Integration of smart functions in a material/product?
• Available raw materials

Textile design for smart product

Properties of textile materials

Smart product functions

Functional design

Structure, structural parameters and shape

Technological design

Technological processes; textile machinery, technological parameters
2. TECHNOLOGIES FOR 1D TEXTILE STRUCTURES (YARNS)
Spinning technologies

Yarn manufacturing process

- Spun yarns
  - Ring spinning
  - Rotor spinning
  - Friction spinning
  - Air-jet spinning (Vortex)
  - Melt spinning
  - Wet spinning
  - Dry spinning
  - Electrospinning

- Filament yarns

Conventional ring spinning
- Modified ring spinning
- Sirospun
- Compact spinning
3. TECHNOLOGIES FOR 2D AND 3D TEXTILE STRUCTURES
Technologies for production of 2D and 3D smart textiles
3.1. 2D and 3D weaving
Weaving is a textile process in which two perpendicular sets of yarns (warp and weft) are interlaced to form a fabric.

- Large range of structures, with controlled properties
- Excellent dimensional stability, low deformability
- Good mechanical behaviour
- Large range of 3D shapes, with the possibility of extending the dimensions
- Possibility of using more yarn systems

Credit: David C Todd, source Wikimedia
https://commons.wikimedia.org/wiki/File:Twill_weave.png
Classification of weaving machines based on the picking mechanism

Weaving machines

Shuttle weaving
- With shuttle changer
- With pirn changer

Projectile weaving
- Single projectile
  - Multiple projectiles

Rapier weaving
- Rigid rapier
  - Flexible rapier
  - Telescopic rapier

Jet weaving
- Air jet
- Water jet

Shuttleless weaving
Woven fabrics

Simple fabrics, 2 yarn systems

2D fabrics
- Basic weaves
- Dobby structures
- Jacquard structures

2.5D and 3D fabrics
- Double warp and double weft structures
- Triple warp and triple weft structures

Compound fabrics, more yarn systems

2.5D and 3D fabrics
- Two-ply structures
- Multiply structures
- Warp interlock structures

Special structures

Partially connected

Completely connected

Pile, terry, leno and spacers

3D
3.1.1. 2D woven structures – basic weaves

Plain weave and derivatives

Plain weave

2/2 weft rib

2/2 warp rib

2/2 Basket weave
Twill weave and derivatives

- 3/3 Z twill
- 3/3 S twill
- 3/3 zigzag twill
- 4/4 broken twill

Satin weave and derivatives

- 8 harness weft satin
3.1.2. 3D woven fabrics

3D woven structures

- 3D solid
  - Flat surfaces
  - Combination of weaves
  - Moulding fabrics

- 3D hollow
  - Uneven surfaces
  - Discrete take-up

- 3D domes (shells)
Multilayer (or multi-ply) structures
✔ several warp and weft yarn systems,
✔ the warp yarns acting as binders from place to place, connecting the fabric layer to layer,
✔ when completely connected will generate solid shapes (flat or profiled) and when partially connected, generating hollow fabrics.

Dual shedding
✔ Warp yarns shed not only vertically, but also horizontally,
✔ Interlacing of the warp interlock structures at layer level.
The **warp interlock structures** → multiple systems of weft interlaced with multiple systems of warp. The fabric is connected through warp yarns called binder yarns.
Angle interlock, layer-to-layer connection

Orthogonal interlock, layer-to-layer connection

Angle interlock, through thickness connection

Ortho interlock, through thickness connection

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3.2. 2D and 3D knitting
Knitting is the textile process where yarns are sequentially looped to form stitches.

In weft knitting, the stitches are formed along the horizontal direction.

In warp knitting, the stitches are formed along the vertical direction, only one stitch in each row.

Front (a) and back (b) stitches for weft knitted fabrics.
Knitting technologies

- Weft knitting
  - Flat knitting machines
    - For shaped panels
    - Integral knitting
  - Circular knitting machines
    - Small diameter
      - One bed (cylinder)
      - Two beds
    - Large diameter
      - One bed (cylinder)
      - Two beds
      - Cylinder and dial
    - 2 cylinders

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3.2.1. 2D knitted fabrics

Weft knitted fabrics

Basic evolutions

Single jersey, Rib, Purl, Interlock

Feeding yarns with different characteristics

Stripes

Plated fabrics

Intarsia patterns

Jacquard patterns

Changing yarn geometry

Miss stitches, tuck stitches, lace patterns, cables, aran, racking patterns

Using weft inlay yarns, fleece yarns, plush/terry

Patterned fabrics
Single jersey

1x1 Rib (double jersey)

1x1 Purl

1x1 Interlock
Patterning possibilities suited for smart functionalities

- Single jersey plated
- Weft inlay in 1x1 rib structure
- Fleece pattern with 3x1 tucking repeat

Single jersey with intarsia pattern
Warp knitted fabrics

One needle bed
- Basic lappings
- Pillar, tricot, atlas
  - With 2, 3, 4 full sets of guide bars
- Partially threaded guide bars
- Weft/warp inlays
  - Open structures
  - Jacquard patterns
- Structures with inlay yarns
- Basic lappings
- Nets
- Simplex patterns
- Curtains
- Pile fabrics
- Laces
Warp knitted structures – basic lappings and derivatives

- Pillar lapping
- Tricot lapping
- 2x1 Tricot lapping
- 2x1 Atlas lapping
Patterning possibilities

Partially threaded guide bars

Yarn insertion - warp inlays (red) and weft inlays (blue)

Two full guide bars – locknit, reverse locknit, satin

Warp knitted meshes – rectangular, tulle
3.2.2. 3D knitted fabrics

- **Weft knitted**
  - Shell structures
  - Sandwich (spacer) structures

- **Warp knitted**
  - Multiaxial fabrics
  - Spacer fabrics

- **Regular shape**
- **Irregular shape**
- **Connected by yarns**
- **Connected by layers**
- With constant cross section
- With variable cross section
Multiaxial warp knitted fabrics

Weft knitted spacer fabric

Warp knitted spacer fabric

Weft spacer with connective double layers of constant length

Weft spacer with connective double layers of variable length
Principle of 3D fashioning line - flechage

Shell fabrics – box shaped, spherical
Summary

• This lesson discusses the principles of textile processes used to manufacture yarns, woven fabrics and knitted fabrics.

• First chapter: concepts of functional and technological design of textiles, options a material/product designer must make and the criteria these options are based on; the textile value chain and its possibilities for smart functionalization.

• Second chapter: yarns, types and technologies used to produce spun yarns and filament yarns.

• Third chapter: structural specificities and technologies for the manufacturing of woven and knitted fabrics. For 2D fabrics, the basic weaves are presented and exemplified, while 3D woven fabrics are discussed according to two main criteria – shape and manufacturing method. For knitted fabrics, the basic evolutions for 2D fabrics are presented for weft knitting and warp knitting. Other types of patterns suitable for smart functionalization are also considered. The 3 main types of fabrics with 3D architecture are presented.
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