Manufacturing Fabrics to Meet Performance Expectations

Karen K. Leonas & Hang Liu
Washington State University
Pullman

http://froggyfibers.com/blog/category/fiber/
http://www.spsj.or.jp/c5/pj/pj06/pj3811.htm
http://fronzonibedding.com/wool-the-wonder-fiber.html
• The term TEXTILES today is very encompassing

• Textiles are versatile and are in limitless end-uses
TEXTILES

• Textiles
  ▪ Latin term *texere* “to weave”

• Today
  ▪ Fibers
  ▪ Yarns
  ▪ Fabrics (woven, knit, nonwoven)
  ▪ Coloration
  ▪ Finishing
  ▪ End Products
Fibers
Raw materials

FIBERS

Natural

Man-made (includes synthetic)

Chemicals

NONWOVENS

YARNS

FABRICS

FINISHING

END PRODUCT FABRICATION
FIBERS

• Smallest Unit
  ▪ Characteristics to be suitable for textile fiber

• Classification
  ▪ Natural or Man-Made
  ▪ Chemical Class

• Length
  ▪ Staple (short – inches)
  ▪ Filament (long – miles)
Fiber Classifications

![Diagram of fiber classifications]

**Figure 2.1**

Major classifications of textile fibers.

### NATURAL FIBERS
- **CELLULOSE**
  - Seed Hair
    - cotton
    - kapok
  - Bast
    - linen
    - ramie
    - jute
    - hemp
    - kenaf
- **RUBBER**
  - Leaf and Other
    - agave
    - coir
    - henequen
    - sisal
    - yucca
    - pina
    - sacaton
- **MINERAL**
  - asbestos
- **PROTEIN**
  - Animal Hair
    - wool
    - cashmere
    - camel
    - mohair
    - qiviut
    - alpaca
    - llama
    - huarizo
    - misti
    - vicuña
    - guanaco
    - cashgora
  - Extruded silk

### MANUFACTURED FIBERS
- **REGENERATED**
- **INORGANIC**
  - glass
  - ceramic
  - metallic
- **SYNTHETIC**
  - nylon
  - vinyon
  - saran
  - olefin
  - modacrylic
  - acrylic
  - polyester
  - spandex
  - aramid
  - anidex
  - novoloid
  - sulfur
  - P.B.I.
  - carbon
  - nylril
  - vinal
  - fluoropolymer
  - elastomer
  - melamine
Fiber Chemical Structures

Natural Fibers

Cellulosic fibers

http://www.cottoninc.com/Nonwovens/CottonNonwovens/

[Diagram of Cellulose and Cellulose Acetate]

Modified Cellulosic

Protein Fiber

Kadolph, Textiles, 10th edition

[Diagram of Amino and Carboxyl Groups]
Synthetic Fibers

Nylon 6,6
http://www.eng.ku.ac.th/~mat/MatDB/MatDB/SOURCE/Struc/polymers/rub1/rub1.htm

Polyester
http://pslc.ws/macrogcss/pet.html

PLA

Degradable Polymer
FIBER PROPERTIES based on Fiber Structure

- External
  - Shape

- Internal
  - Amorphous
  - Crystalline
  - Oriented

- Molecular Weight
  - Degree of Polymerization

Collier, Understanding Textiles, 7th edition
Fiber Micrographs
Natural Fibers

- Cotton
- Cotton x-section
- Linen
- Linen x-section
- Wool
- Wool x-section

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Fiber Micrographs
Man-Made Fibers

Rayon

Rayon x-section (flat)

nylon

Nylon x-section (triangle)

Polyester

Acrylic

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Manufactured Fibers – Production

Steps

- Polymerization
- Liquidify
  - using heat or chemicals
- Extrusion
  - force through spinneret to form filaments
- Solidify
• Methods
  ▪ Wet Spinning
  ▪ Dry Spinning
  ▪ Melt Spinning
  ▪ Electro spinning
Electrospinning

Figure 1. Schematic of the Electrospinning setup.

http://www.che.vt.edu/Wilkes/electrospinning/electrospinning.html
Fiber Terminology

Monofilament - single filament of fiber used individually with a denier > 14

Microfiber - multifilament yarns of individual filaments have a denier < 1.
- typical one denier polyester fiber has a diameter of 10 microns.

Micron-Sized Fibers - fiber size is less the 0.3 denier
  
  size best defined in terms of diameter in microns

Nanofibers - fibers with diameters less than 0.5 microns.
  
  typical nanofibers have a diameter between 50 and 300 nm.

Denier Weight-per-unit-length measurement of a liner material defined as the number of grams per 9000 meters. Can refer to either individual filament or a bundle of filaments (yarn). Other terms used are micro-denier, sub-micron and superfine.
## Fiber Characteristic Comparison

<table>
<thead>
<tr>
<th>FIBERI.D. CONVENTIONAL PROCESSES</th>
<th>MFG.PROCESS</th>
<th>FIBER DESCRIPTION</th>
<th>FIBER SIZE (Microns)</th>
<th>FIBER SURF. AREA (Sq-nt/Gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conventional Staple or Spunbond</td>
<td>One denier fiber, Homopolymer</td>
<td>10.1</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>Conventional Meltblown</td>
<td>Two micron fiber, Homopolymer</td>
<td>2.0</td>
<td>1.4</td>
</tr>
<tr>
<td>3</td>
<td>Conventional Electrospun</td>
<td>Size/shape as best reported</td>
<td>0.3</td>
<td>9.5</td>
</tr>
</tbody>
</table>

### Other Comparisons of Interest
- Atom ~ 0.3 nm
- Blood Cell ~ 5000 nm
- Human Hair ~ 20,000 to 30,000 nm
Diameter of the electrospun fiber is approximately 300 nm, and that of the conventionally spun fiber is 10 microns.


A single human hair is usually around 50 ~150 microns.

http://www.engr.utk.edu/mse/pages/Textiles/Nanofiber%20Nonwovens.htm
Advantages of fabrics made of microfibers

• Lighter
• Comfortable as the small space between fibers prevents the loss of body heat but allow air to penetrate.
• Good drapeability
Yarns
FIBERS

YARNS

NONWOVENS

FABRICS

FINISHING

END PRODUCT FABRICATION

Spun Filament
YARNS

• Generic Term for a group of fibers or filaments “combined” together to form a long continuous strand

• Combined by
  ▪ Twist
  ▪ Adhesive
  ▪ Slit film
Terms used to describe yarns

- Staple/Filament
- Single/Ply/Cord
- Low twist/High twist
- Yarn Size
- Novelty/Simple
Yarns – Filament vs. staple

Filament vs. Staple Yarn

http://cte1401-01.sp00.fsu.edu/yarn.html

Filament vs. Staple Yarn
Textiles Professor

Kadolph, Textiles, 10th edition
Characteristics that Influence Yarn Performance

• Fiber Length (staple)

• Production method
  ▪ Open end spun
  ▪ Ring Spun

• Twist Influences
  ▪ Tenacity
  ▪ Stiffness/Flexibility
  ▪ Bulk
  ▪ Heat conductivity
  ▪ Hardness
  ▪ Abrasion Resistance
  ▪ Luster
  ▪ Smooth/Fuzzy
YARN SIZE

Direct Systems

*as number increases, size increases*

Denier – weight per 9000 meters
Tex – weight per 1000 meters

Indirect Systems *(used more for staple yarns)*

*As number decreases, size increases*

Cotton Count - # of 840 yd hanks/lb
Worsted Count - # of 560 yd hanks/lb
Woolen Count - # of 1600 yd hanks/lb
Linen Count - # 300 yd hanks/lb
Fabrics
Fabric Formation

• Woven
  ▪ Two or more sets of yarns *interlacing* at right angles

• Knit
  ▪ Series of *interlocking loops* (*from one or more yarns*)

• Nonwoven
  ▪ Directly from filament or fiber
WOVEN FABRICS & WEAVING

• WOVEN FABRICS:
  • The precise manner in which the warp & fill yarns interlace with each other determines the structure (interlacing sequence)

• Different interlacing sequences lead to different fabric structures
  ➢ Plain ➢ Twill ➢ Satin ➢ Jacquard
  Common Names: Chambray, Denim, Calico, Corduroy

• Sequence of interlacings have effect on fabric properties
Woven Fabric
Woven Fabrics
FABRIC COUNT Influences….

Fabric Count – Number of yarns per square inch

- Interlacings
- Yarn Mobility
- Tensile Strength
- Drapeability
- Flexibility
- Covering power
- Permeability
- Tear Strength
- Abrasion Resistance
KNITTING

• Fabric formed by a series of interlocking loops from 1 or more yarns

• 2nd most widely used method of fabric construction
Knit fabric descriptors & characteristics

• Stitch Type
• Gauge – number of loops per inch used in description

• In general, when compared with woven fabrics, knit fabrics
  ▪ Are more elastic
  ▪ Have higher porosity
  ▪ Have higher resiliency
  ▪ Have higher shrinkage potential
Nonwoven Fabrics

Typical End-Uses

- Industrial
- Apparel
- Interiors

End Properties controlled by

- fiber properties
- geometrical arrangement of fibers in web
- binder properties
Nonwoven Fabrics

FIBERS
fundamental unit of the structure
- strength
- absorbency
- tactile

Production
WEB FORMATION → BONDING = FINAL PRODUCT

- Fiber Orientation is critical to performance

- Distances between fibers are several times greater than the fiber diameter
Nonwoven Fabrics - Formation

I. Web Formation
- Carded
- Crosslaid
- Air Laid

II. Bonding
- Thermal
- Chemical
- Mechanical Entanglement
  - Needle punched
  - Hydroentangled
Comparison of Webs
(Air laid vs Carded)

Air Laid, Thermal bonded

Spunbonded, Nonwoven Fabric Selected for General Use Disposable Protective Apparel

- diamond shaped thermal-bonded area that flattens due to melting of fibers, giving the fabrics an embossed appearance

Note: The web is bonded in small diamond shaped spots that strengthen the web without drastically reducing the flexibility of the fabric.

Carded, Hydroentangled

Staple Fiber Web with Fibers Laid Parallel to the Fabric Length

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Specific Types of Nonwoven Systems

• Spunbonded*
• Meltblown*
• Spunlaced
• Needlepunched
• Dry laid
• Wet laid
Mechanical Entanglement

• Hydroentanglement
  “Spunlaced”

• Needle Punched
Specific Types of Nonwoven Systems

Spunbond

Meltblown

http://www.kasen.co.jp/english/product/line/work.html
Comparison of Spunbond & Meltblown Nonwoven Fabrics

Meltblown

- Random fiber web
  - Fibers are ‘fibrillated’
- Thermally bonded

Spunbond

- Random fiber web
- Thermally bonded

- Fibers in Meltblown webs are smaller in diameter than those in spunbonded webs
- Lighter web and better filtration efficiency
Composite fabric – Meltblown & Spunbond

250 nanometer average diameter meltblown on 20 micron diameter spunbond

http://www.hillsinc.net/nanomeltblownfabric.shtml
Composite Fabric
Spunbonded Meltblown Spunbonded

Top View of SMS

Cross section of SMS
Electrospun Fiber Webs

Electrospun nonwoven fiber web
http://web.mit.edu/rutledgegroup/projects/electrospinning.html

Electrospun blends of PLA and PGA
http://www.spsj.or.jp/c5/pj/pj06/pj3811.htm
Finishing

Methods of Classification:
- Chemical or Mechanical
- Functional or Aesthetic

*Finishing includes* dyeing, printing, durable press, flame retardant, napping.....

Dyeing

Functional finishing
Dyeing & Printing: Adding Color to Textiles

Purposes:
Aesthetic & Functional

Coloring Agents:
Dyes – applied to, or formed in textile substrate in molecularly dispersed form

\[ bonding \text{ mechanism between colorant and substrate } \]

Pigments – particulate which is insoluble in textile substrate

\[ attached \text{ with adhesive/binder/trapped } \]
• Colorfastness
  - Retaining initial color through use and care
    - Instable coloring agent
    - Poor fixation to substrate
    - Variety of exposure agents
      - light, laundering, perspiration, drycleaning…

• Colour Index (CI)
  - Reference Source for dyes/pigments
Colorant Classification

• CI Classifications – Name includes
  ▪ Class
    • Acid
    • Azoic
    • Basic
    • Direct
    • Disperse
    • Sulfur
    • Vat
    • Pigments
  ▪ Color category
  ▪ Specific number

• Other Classifications considerations
  ▪ Molecular Weight
  ▪ Source
  ▪ Chemical Groups
  ▪ End-use
Application of Colorants

• Applied at fiber, yarn of fabric stages
• For applications here
  ▪ Fiber – prior to extrusion
    • Dyes or pigments used
Functional Finishes

• Typical applications
  ▪ Incorporated into fiber prior to spinning
  ▪ Topical finish applied to substrate

• Functional Finishes
  ▪ Durable Press
  ▪ Flame Retardant
  ▪ Antimicrobial
  ▪ Anti-slip
  ▪ Anti-static
  ▪ Temperature Regulating
  ▪ Water Repellent
  ▪ Flame Resistant
  ▪ Moth Resistant
  ▪ Light Reflectant
  ▪ UV Stablization
Degradation of Textile Materials

- Physical/Mechanical forces
- Chemical breakdown of, or interaction with substrate
- Can be BOTH Physical/Mechanical and Chemical
- Sometimes synergistic impact
Factors that Impact Degradation - Summary

• Fiber
  ▪ Size
  ▪ Chemical structure
  ▪ Molecular weight
  ▪ Degree of Polymerization
  ▪ Crystallinity

• Yarn
  ▪ Size
  ▪ Twist
  ▪ Fiber length (if staple)
Factors that Impact Degradation - Summary

- **Fabric**
  - Woven – weight, thickness, yarn count, interlacing pattern
  - Knit – gauge, weight, thickness
  - Nonwoven – weight, thickness, bonding mechanism

- **Finish**
  - Block degrading agents
  - Chemical structure
  - Location within structure
  - Interaction with structure and environment
That’s all folks!

Thank you!

Questions?
• First person to market as advantage! Same in fashion industry

• Light transmission – measurement – impacted by pigmentation, yarns per inch, weight

• Color selective – different color mulch
• Difference in temperature

• Shade cloth

• Roll up sides-flexibility

• Permeability-porosity - Competing demands – allow for air circulation vs heat loss due to air flow
• Competing needs - air flow for circulation; retaining heat......

• Want degradation but not blow away.....

• Spectral use of plastics

• Solarization good in preventing/killing disease – what spectral distribution is effective – can design material to allow the wavelength of light to transmit?

• Use of LED lights to control spectral wavelength – this connects to degradation

• Control moisture – want to dissipate

• In cold regions do you need to be concerned with materials becoming brittle

• Wind resistance – is the a materials issue or a design issue
• Could plastic begin to degrade when spraying with microbial – this works with

• If degrades too fast can slow with hay on top and if so how much?

Weatherometer

• Laboratory acceleration spectral distribution dew cycles