Nonwoven Filter Media: Fuel Filtration a Case Study

Dr. Umer Farooq
Sr. R&D Scientist
Overview

- What is a nonwoven?
- Applications and uses.
- Filtration Terminology.
- Fuel Filtration – a case study
What is a nonwoven fabric?

“A fabric made directly from a web of fibre (or filaments), without the yarn preparation necessary for weaving and knitting”.

Woven: interlaced

Knitted: intermeshed
What is a nonwoven?

A bonded fibrous assembly made of fibres or filaments with a complex architecture
- **Bonded Fibre Webs**
Web Forming

- Drylaid – carding, carding & lapping (cross or vertical), airlaying
- Wetlaid – derived from papermaking
- Spunmelt (polymer-laid) – filament extrusion, e.g. Spunlaid; Meltblown; Electrospun
Web Forming Production Methods (Europe: % tonnes)

<table>
<thead>
<tr>
<th>Process</th>
<th>2006</th>
<th>Δ %</th>
<th>2007</th>
<th>Δ %</th>
<th>2008</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spunmelt (1)</td>
<td>710.8</td>
<td>9.4</td>
<td>776.5</td>
<td>9.3</td>
<td>758.7</td>
<td>-2.3</td>
</tr>
<tr>
<td>Drylaid (2)</td>
<td>623.8</td>
<td>5.8</td>
<td>669.6</td>
<td>5.7</td>
<td>686.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Wetlaid</td>
<td>106.8</td>
<td>6.8</td>
<td>107.8</td>
<td>0.9</td>
<td>115.7</td>
<td>7.4</td>
</tr>
<tr>
<td>Airlaid</td>
<td>140.2</td>
<td>5.7</td>
<td>154.8</td>
<td>10.4</td>
<td>162.3</td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,681.4</strong></td>
<td><strong>7.6</strong></td>
<td><strong>1,598.7</strong></td>
<td><strong>7.4</strong></td>
<td><strong>1,722.4</strong></td>
<td><strong>1.4</strong></td>
</tr>
</tbody>
</table>

(1) Includes spunlaid and other polymer-based processes e.g. meltblown, flashspun by extension as well as composites of these fabrics (e.g. SMS...)

(2) Basically groups thermal and chemical bonding, plus needling or stitching only and hydroentangled webs. Does not include any airlaid products. The weight of adhesives, additives and similar chemicals has been taken into account in addition to binders.
Nonwovens are “Bonded” Webs

• In a nonwoven, the assembly of textile fibres is held together:

  • 1. by mechanical interlocking in a random web or batt,

  • 2. by melt-fusing the fibres in the case of thermoplastic fibres,

  • 3. by bonding with a cementing medium (natural or synthetic adhesive).

  Mechanical bonding
  Thermal bonding
  Chemical bonding
Web Bonding Production Methods (Europe: % tonnes)

<table>
<thead>
<tr>
<th>Process</th>
<th>2006</th>
<th>Δ %</th>
<th>2007</th>
<th>Δ %</th>
<th>2008</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermally-bonded</td>
<td>123.7</td>
<td>-4.5</td>
<td>127.5</td>
<td>3.1</td>
<td>126.2</td>
<td>-1.0</td>
</tr>
<tr>
<td>Chemically-bonded</td>
<td>150.9</td>
<td>5.1</td>
<td>157.8</td>
<td>4.6</td>
<td>149.5</td>
<td>-5.3</td>
</tr>
<tr>
<td>Needled</td>
<td>147.1</td>
<td>16.8</td>
<td>160.9</td>
<td>9.4</td>
<td>175.4</td>
<td>9.0</td>
</tr>
<tr>
<td>Hydroentangled</td>
<td>194.3</td>
<td>9.1</td>
<td>208.3</td>
<td>7.2</td>
<td>231.5</td>
<td>11.1</td>
</tr>
<tr>
<td>Composites</td>
<td>7.8</td>
<td>-35.8</td>
<td>5.1</td>
<td>-35.0</td>
<td>3.2</td>
<td>-37.9</td>
</tr>
<tr>
<td>Total Drylaid</td>
<td>623.8</td>
<td>5.8</td>
<td>659.6</td>
<td>5.7</td>
<td>685.7</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Convergence of 3 industries

Textiles
Plastics
Nonwovens
Paper

51% of total European production of nonwovens = 15 companies

Ahlstrom, Albis, Buckeye, Concert, DuPont, Fibertex, Fiberweb, Freudenberg, Glatfelter Schoeller, Johns Manville, PEGAS, Rex-Cell, Sandler, Tesalca/Texnovo, Union.
Polymer utilisation in nonwoven fabrics

Filament form (left) and Fibre form (right) - Tonnes

Confidential – Property of Parker/Racor
European Production of Nonwovens
(10^3 tonnes)

Total = 1.72 million tonnes
1.4% increase in 2008
Average fabric price = 3.19 Euro/kg
Overview

• What is a nonwoven?
• Applications and uses.
• Filtration Terminology
• Fuel Filtration – a case study
Product Life: Disposable vs Durable

**USE:**
- Wipes
- Tea bags
- Protective Clothing
- Fuel Filters
- Linings for clothing, Upholstery

**LIFE:**
- Seconds
- Minutes
- Hours
- Months
- Years

**DISPOSABLE** (short life) — **DURABLE** (long life)
Overview

• What is a nonwoven?
• Applications and uses.
• Filtration Terminology.
• Fuel Filtration – a case study
Filtration (of liquid, air, gas)

Air & gas filters (HEPA - 99.97%; ULPA-99.999%)

Liquid – oil / fuel, water, food and beverages….
Key Terms Defined…

- **Filtration** refers to the act of separating one or more distinct phases from another in a process which uses physical differences in the phases – such as particle size or density or electric charge.

- A *filter medium (or media)* is any material, that under the operating conditions of the filter, is permeable to one or more components of a mixture, solution or suspension and is impermeable to the remaining components.

- The operation of a filter usually needs a pressure differential across the filter medium, and this can be effected by means of fluid pressure upstream of the medium (*pressure filters*) or suction downstream (*vacuum filters*).
Filtration System and Process Parameters

**Process Parameters**
- Membranes
- Pressure ($\Delta P$), Temperature (feed)
- Recovery (%)
- Feed stream quality
- Flow rates (feed, concentrate)

**System performance**
- Permeate quality
- Throughput, filter fouling
- Specific energy (KWH/volume permeate)
- Filter service life, and cleaning cycles
- Downtime (maintenance)

**Symbols**
- $Q_f$: feed flow rate
- $Q_c$: concentrate flow rate
- $Q_p$: permeate flow rate
- $P_f$: upstream pressure (feed)
- $P_p$: downstream pressure (permeate)
- $\Delta P = P_f - P_p$: Differential pressure
- Recovery $= \frac{Q_p}{Q_f} \times 100$ (Percent)
2 Modes of Filtration

Dead-end flow:
- More fouling & flux decline
- But the feed stream is 100% filtered

Crossflow mode:
- Less fouling but the feed stream is not fully recovered in the permeate
Basic filtration mechanisms – Micro Level
Filtration Mechanism – Macro Level

Surface Straining

Depth Straining

Direction of Liquid Flow
Filtration Mechanism – Macro Level

Depth Filtration

Cake Filtration

Direction of the Fluid Flow

Particles

Filter Media

Direction of Liquid Flow
# Overview of Markets for Basic Type of Non-woven Media

<table>
<thead>
<tr>
<th>Market Segment</th>
<th>Needle felt</th>
<th>Dry laid</th>
<th>Wet laid</th>
<th>Spun Media</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Filters</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fabric Dust Filters</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea Bags</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Coffee Bags</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Milk</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Vacuum Cleaner Bags</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Edible Oil</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Face Masks</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food &amp; Beverages</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fuel &amp; oil</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Type of non-woven media**

**Bonded Media**

**Spun Media**

- Spunbonded
- Meltblown

From, BCCResearch.com
“Nonwoven Filter Media: Technologies and Global Markets” 2011
Overview

- What is a nonwoven?
- Applications and uses.
- Filtration Terminology.
- Fuel Filtration – a case study
Filters in Automotive Applications
– A Case Study on
Fuel Filters and Water Separators in Diesel Engines
BACKGROUND

• Ever tightening emission requirements - high pressure modern fuel systems with precise injection equipment
  • Injection volumes – microlitres;
  • Injection cycle timings – milliseconds;
  • Injection pressures in the order of 30,000 psi
• ... Precision injection systems require contamination free fuel
• WATER is a FUEL CONTAMINANT and can affect:
• Physical properties of the fuel by altering its filterability

• Accelerates fatigue wear in highly stressed parts of engine injectors, by:
  • promoting corrosion of steel components,
  • encouraging microbiological growth
  • reduces lubricity causing nozzle and pump plunger scoring

  .... FATAL FOR HIGH PRECISION DIESEL ENGINE INJECTORS – ENGINE MANUFACTURERS ARE NOW DEMANDING 100% WATER FREE FUEL

• Fuel filters and water separators are used to remove the contaminants before diesel enters the injectors
The efficiency of existing water separating media has recently been adversely affected by radical changes in the composition of the diesel fuel; namely:

- Introduction of Ultra Low Sulphur Diesel (ULSD) – which requires additives e.g. lubricity enhancers, rust inhibitors, and anti-wear agents
- Advent of Bio-diesels - European Legislation targets aim to increase content of the bio-fuels in EN590 (standard diesel) up to 20% by 2020!

All these additives belongs to the chemical category of SURFACTANTS...
Surfactants ...

- Surfactants are *amphiphilic* organic compounds i.e. they contain both hydrophobic groups (their *tails*) and hydrophilic groups (their *heads*) – soluble in both organic solvents and water.

![Surfactant Diagram](image)

**Assists Solubility in water**  
**Assists Solubility in diesel**
Surfactants ...

1. Surfactants change the nature of water in fuel.
   • Water drops in ULSD and biodiesel blends are smaller.
     • Surfactants lower interfacial tension between fuel and water, and enable smaller droplets to form.
   • Water drops in ULSD and biodiesel blends are more resistant to coalescence.
     • Surfactants associate with water drop surfaces, and create a barrier to drop coalescence. Coalescence is required for successful water separation.

2. Surfactants change the surface chemistry of water separation media.
   • Surfactants associate with media surfaces, and alter surface energies that are fundamental to successful separation.
Current Fuel Filters and Water Separators

The Hydrophobic Barrier Media

The Fibre-bed Coalescing Media
The Hydrophobic Barrier Type

*Barrier type* coalescers function through the use of hydrophobic (non-wettable) barrier to stop water droplets at the Upstream side.

Droplets smaller than the filter pore size may not be captured
Enhanced Water Separation Through Surface Modifications

Existing Parker melt-blown hydrophobic cellulose composite media was used. Alter the surface characteristics of the media by:

- Super hydrophobic treatments
- Hydrophilic treatments
- Deposition of electro-spun nano-fibres
- Hydrophobic / Oleophilic Treatments
Super Hydrophobic Treatments

- A combination of plasma and electro-spraying techniques were used to successfully create super-hydrophobic surfaces:
Hydrophilic Treatment

Electro-spraying technique was used to create Hydrophilic surfaces
Nano-fibre coatings

- Nano-fibres \((Dia \approx 100 – 300 \text{ nm})\) were sprayed on our existing barrier media using state-of-the-art electro spinning technique:
A typical coalescence bed filter
Development of samples


Outer Element: DCM I

Interior – Drainage Layer
Development of Samples

- Wet laid media
- Inner element
- Drainage layer on inner core
- Teflon mesh replaces inner element
- Samples made with MB samples made at NIRI
Thank you … questions, comments?